ENERGY TECHNOLOGY AND GOVERNANCE PROGRAM
Electricity Market Initiative for Southeast Europe

Large-Scale RES Integration in Serbia: Impacts and Implications

– Final Report, July 2022 –

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ABBREVIATIONS

BRP – Balancing Responsible Party

CCGT -- Combine Cycle Gas Turbine

CCS – Carbon Capture and Storage

CD -- Common Dimensioning

EEX – European Energy Exchange

EKC – Electricity Coordinating Center

EMI – Electricity Market Initiative

EnCS – Energy Community Secretariat

EU – European Union

EU ETS – European Union Emissions Trading System

EXIST – Energy Exchange Istanbul

FRR -- Frequency Restoration Reserve (automated and manual)

IPEX – Italian Power Exchange

MAF – Mid-term Adequacy Forecast (Pan-European assessment of power system resource adequacy prepared every year by ENTSO-E)

MC – Market Coupling

MCP – Market Clearing Price

MO – Market Operator

NCV – Net Caloric Value

NRMSE - Normalized Root Mean Square Error

NMAE Normalized Mean Absolute Error

NTC – Net Transfer Capacity

OCGT – Open Cycle Gas Turbine

O&M – Operation and Maintenance

PEMDB	–	Pan-European Market Database (developed by ENTSO-E)
PMC	–	Partial Market Coupling
PSHPP	–	Pump Storage Hydro Power Plant
TANAP	–	Trans Anatolian Pipeline
TAP	–	Trans Anatolian Pipeline
RES	–	Renewable Energy Sources
ROR	–	Run-of-River
TSO	–	Transmission System Operator
TYNDP	–	Ten-year Network Development Plan (Europe's Network Development Plan prepared bi-annually by ENTSO-E)
USAID	–	United States Agency for International Development
USEA	–	United States Energy Association
WB6	–	Western Balkans Six
WG	–	Working Group

Market areas/regions:

SEE	–	Southeast Europe
AL	–	OST market area
BA	–	NOSBiH market area
BG	–	ESO EAD market area
GR	–	ADMIE/IPTO market area
HU	–	Hungarian market area
HR	–	HOPS market area
XK	–	KOSTT market area
ME	–	CGES market area
MK	–	MEPSO market area
RO	–	Transelectrica market area
RS	–	EMS market area
SI	–	ELES market area

EMI WG members:

ADMIE/IPTO – Independent Power Transmission Operator for Greece

Borzen – Slovenian Power Market Operator

CGES – Montenegrin Electric Transmission System

COTEE – Montenegro Electricity Market Operator

ELES – Electricity Transmission Company of Slovenia

EMS – Serbian Transmission System Operator

ESO EAD – Electricity System Operator of Bulgaria

HOPS – Croatian Transmission System Operator

HROTE – Croatian Energy Market Operator

KOSTT – Kosovo Transmission System and Market Operator

MEPSO – Electricity Transmission System Operator of Macedonia

NOSBiH – Independent System Operator in Bosnia and Herzegovina

OST – Albanian Transmission System Operator

Transelectrica – Romanian Transmission and System Operator

EXECUTIVE SUMMARY

This study investigated the impacts of different levels of RES capacities in Serbia on wholesale and balancing market operations, as well as the operation of the transmission network. Based on the results, we developed recommendations for improvements in EMS' business processes (and also recommendations for regulatory and legal improvements) that should enable more efficient RES integration, while preserving safe and secure system operation.

These proposals for potential improvements of procedures and mechanisms are related to all aspects of EMS' business connected with RES (i.e., the regulatory framework and RES support schemes, connection procedure and investments in necessary network reinforcement, system operation, and wholesale and balancing markets). They also take into account interdependency with the processes developed and implemented by the Serbian Government and Regulatory Agency.

In this process, we also assessed potential quantitative and qualitative benefits of the proposed improvements related to RES integration, as applicable.

Scenarios and Assumptions

To investigate the impacts of high levels of RES capacities in Serbia on the electricity markets, on balancing, and on network operation, we assessed a range of wind and solar capacities for the Expected and Ambitious scenarios in 2025 and 2030. There are about 400 MW of RES on line today.

Since operating circumstances are not significantly different between 2025 and 2030 (apart from RES capacities), we present the results of the analyzed Scenarios as a function of RES capacities, which are: 2.7 GW, 5.4 GW, 8.1 GW and 17 GW. The case with 17 GW in RES capacities is considered as a theoretical exercise to identify potential operational and transmission infrastructure development issues in an unlikely scenario.

	RES Development Scenarios for 2025 and 2030 [MW]			
Type	**2025**		**2030**	
	Expected (Referent)	**Ambitious (High)**	**Expected (Referent)**	**Ambitious (High)**
Wind	2461+0	4437+0	5400+1350	8000+2000
Solar	200+8.8	1010+0	1335+0	4123+3167
Total:	**2661+8.8**	**5447+0**	**6735+1350**	**9290+8000**
	2670	**5447**	**8085**	**17290**

*-connected to transmission + distribution grid

To measure the market impacts, we simulated the system operation in a regional context following the principles of day-ahead market, hydro-thermal optimization and economic dispatch with the Plexos software tool.

For all scenarios, we also investigated the impact of different CO2 emission costs. The referent CO2 analyses were based on CO2 prices of 23 and 27 EUR/t in 2025 and 2030, while the sensitivity analyses used CO2 prices of 53 and 56 EUR/tCO2. While these assumptions for CO2 prices may seem low, they were in line with the latest ENTSO-E considerations at the time of input data preparation (end of 2020).

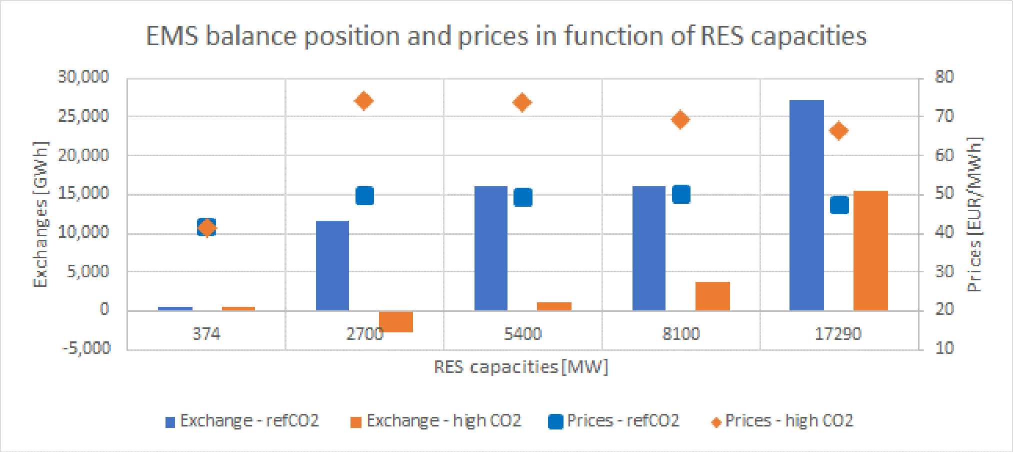
Regardless, the analysis of two different assumptions for CO2 prices (while lower than today's values) gives a relevant range of results related to generation mix and balance positions of countries or market zones, especially for the EMS market area. Using higher CO2 prices would have a similar impact on production costs in all regional market zones, and the resulting impact on the generation mix and balance position of the EMS market area would be small.

We note that this analysis did not limit lignite quality or lignite availability in the Serbian thermal generation fleet, and we simulated all thermal units with their projected parameters. Given that this analysis refers to a period in 2025 and beyond, we expect that by that time, the current problems with lignite supply will be resolved.

This study does not cover the power system's dynamic stability under high RES conditions, which is also key to determining the limits of RES integration, and to maintaining the integrity of the power system and its stable operation within acceptable limits. For that purpose, we recommend a study in the near future to assess the system's dynamic stability with a large share of RES. EMS AD, PE EPS and Elektrodistribucija Srbije d.o.o. would all benefit from this analysis.

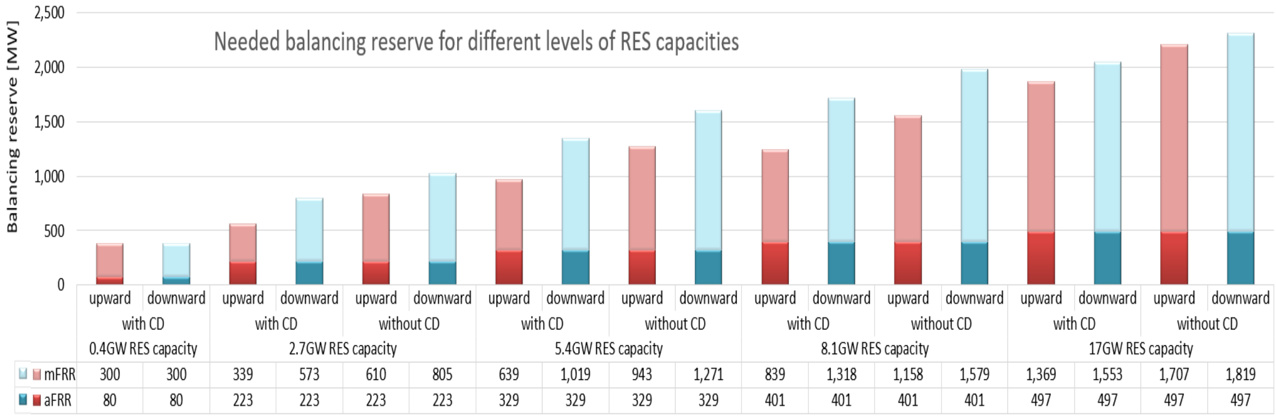
RES Impact on wholesale and balancing market

The impact of high RES on wholesale market operations shows that with more RES capacity in the Serbian power system, wholesale market prices will decrease, rather modestly (up to 11%), even with an additional 17 GW of RES capacity. By comparison, as shown in the figure below, changes in CO2 prices would bring higher changes in wholesale market prices. Also, generation from thermal units generally depends more on CO2 prices and their market position than on the level of RES, though when RES levels rise substantially, TPP generation also falls, even at lower CO2 price levels.



In addition, the increase in RES capacities causes an increase in the required balancing reserves (FRR-Frequency Restoration Reserve=aFRR+mFRR), as presented in the following diagram.

We have applied Common Dimensioning (CD) in EMS[1], and the balancing reserve for the case with 0.4 GW of RES capacity (2020) refers only to the case with CD, while for all other levels of RES, we present balancing reserves for both cases: with and without CD. Since we expect that EMS will become a full member of IGCC during 2022, the FRR values for higher RES capacities include the Imbalance Netting effect.



	0.4GW RES capacity		2.7GW RES capacity				5.4GW RES capacity				8.1GW RES capacity				17GW RES capacity			
	with CD		with CD		without CD		with CD		without CD		with CD		without CD		with CD		without CD	
	upward	downward	upward	downward	upward	downward	upward	downward	upward	downward	upward	downward	upward	downward	upward	downward	upward	downward
▨ ▨ mFRR	300	300	339	573	610	805	639	1,019	943	1,271	839	1,318	1,158	1,579	1,369	1,553	1,707	1,819
■ ■ aFRR	80	80	223	223	223	223	329	329	329	329	401	401	401	401	497	497	497	497

The increase in mFRR is significantly higher than the increase in aFRR, which is mainly driven by the long imbalance settlement period (1 hour). **These requirements can be meaningfully reduced by shortening the ISP to 15 minutes, which is one of our recommendations.**

Our analyses show that with these RES increases, required reserve capacities cannot be fully satisfied by conventional units inside the EMS market area.

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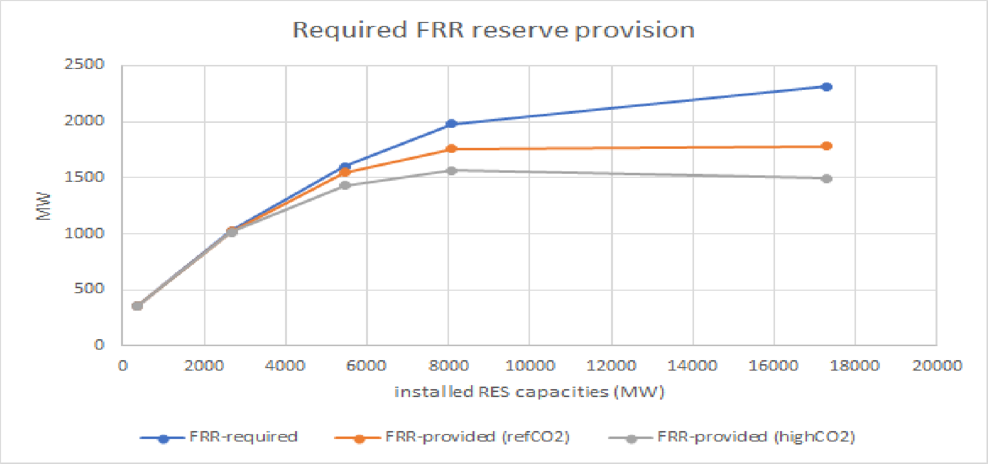
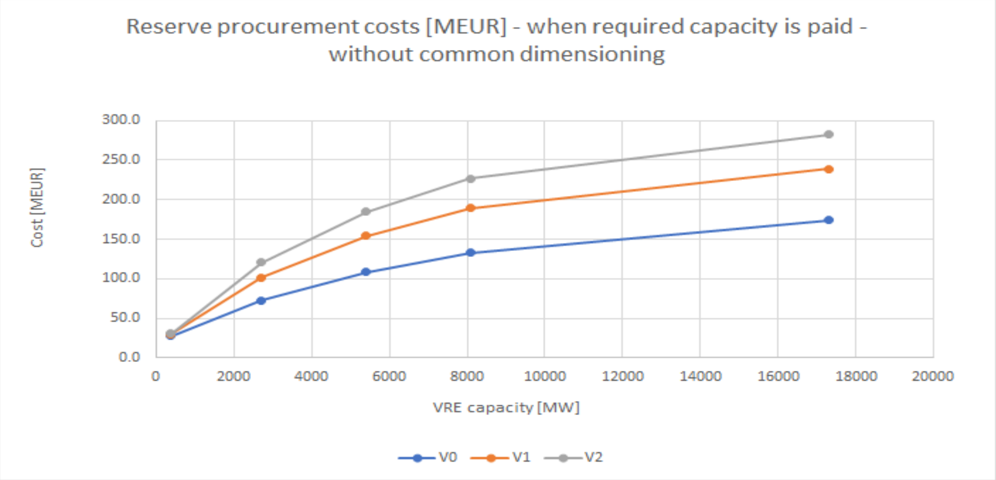
[1] These values are with Common Dimensioning within the SMM block (LFC area which include EMS, CGES and MEPSO). Within the SMM LFC block, the members set the distribution of FRR among them proportionally for both directions (positive and negative), based on the loss of the largest generation unit i.e., load unit within the individual LFC area.



In particular, the higher the balancing requirements, the lower the ability of the current system to satisfy them. **From a technical perspective, in 2025, EMS could integrate 2.7 GW of RES** and satisfy more than 90% of the system's balancing requirements. **However, for higher RES capacities,** the average provided FRR drops below 90% of requirements, and EMS would require **new flexibility sources (such as PSP Bistrica or other, battery storages, etc.) to ensure normal system operation, considering the existing balancing mechanism and compliance with ENTSO-E standards.**

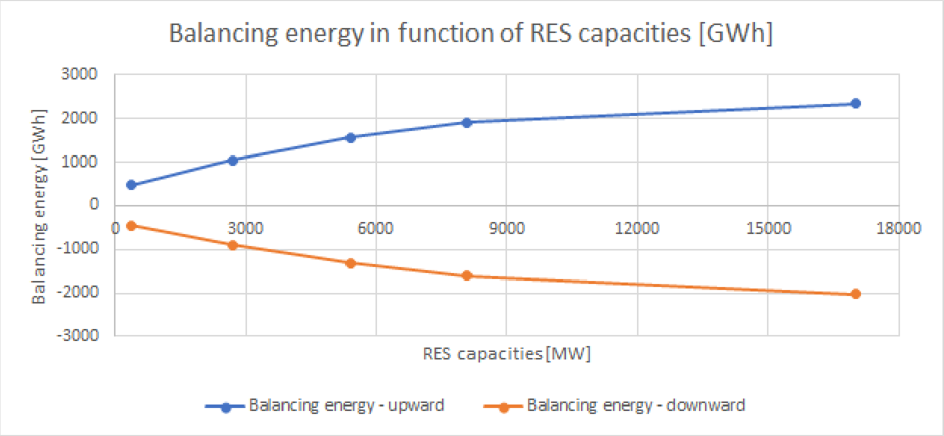
In addition, these balancing requirements have a cost impact, as with more RES, Serbia must procure more balancing reserves and activate more reserves to cover RES deviations. So, more RES will pose higher costs for both balancing reserves and for balancing energy, as shown in the figure below.

For the reserve procurement prices, we used prices regulated by the Serbian NRA (AERS) (aFRR=12.97 €/MW; upward mFRR=4.08 €/MW), and assumed downward mFFR prices in 3 variants (V0=0€/MW; V1=4.08€/MW; V2=6.28€/MW). The increase in costs for reserve procurement is driven by the increase in RES capacities, and ranges from 28 MEUR (0.4 GW in RES) to more than 250 MEUR (17 GW in RES). Even if the downward reserve procurement price remains zero (as it is currently), the increase to 2.7 GW of RES capacity in 2025 will lead to a tripling of the current reserve procurement costs. It should be noted that common dimensioning within the SMM block enables a savings in required reserves of 10 to 28 MEUR, depending on the variant and RES capacity level. **Since there is currently an agreement about such cross-border cooperation with CGES and MEPSO, these results point to the benefits of continuing this arrangement.**

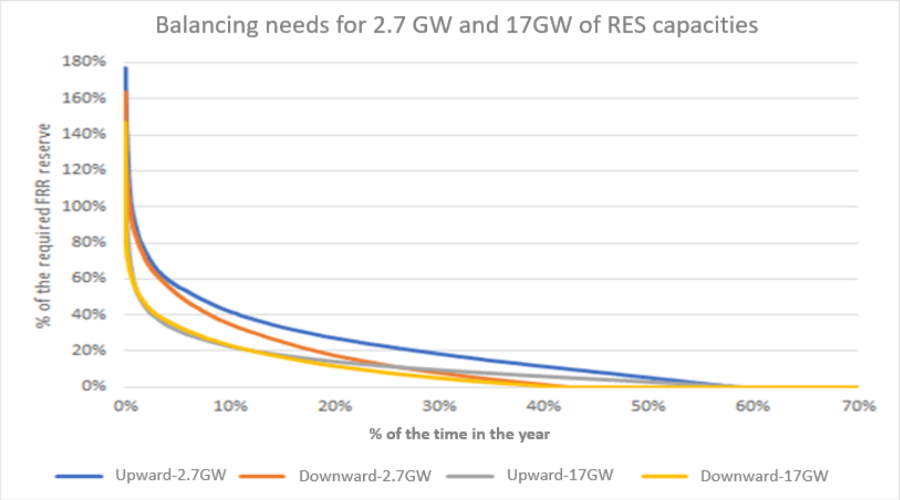


Balancing reserve activation may be necessary at any time to cover unexpected deviations in load or generation. To determine the level of balancing activation with rising RES, we considered EMS participation in imbalance netting schemes that would enable them to reduce balancing energy activation by 35% (both in the SMM block pre-netting and IGCC pan-European cooperation). When the market simulations showed that the Serbian balancing reserve was insufficient to cover the EMS control area imbalance (as obtained in market simulations), we considered balancing energy imports.

With these assumptions, the increase of RES capacities leads to a rise in annual balancing energy from 500 GWh to 2,200 GWh both upward and downward, as shown in the following figure. These values take into account a reduction of 350 GWh to 750 GWh in the balancing energy required based on EMS' participation in Imbalance Netting cooperation. **This points to the importance of EMS' accession to the scheme of Imbalance Netting cooperation in 2022 to facilitate higher RES integration in Serbia, which is one of our recommendations to EMS.**

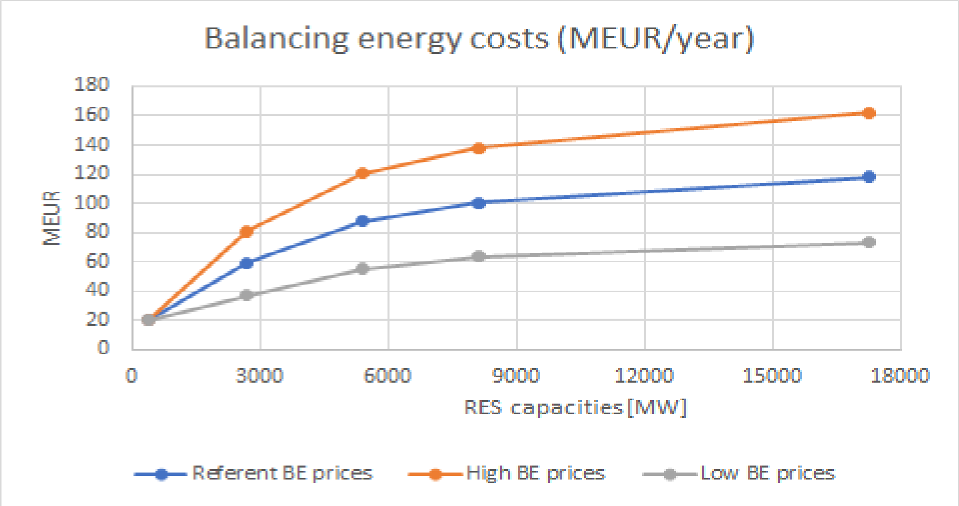


In general, for more than 90% of the time, only 40% of the FRR reserve is required to cover system imbalances, as the following figure shows. This indicates that shorter-term dynamic reserve dimensioning (month, week) in the context of annual dimensioning can be quite efficient, and so another **of our recommendations to EMS is to implement dynamic reserve dimensioning**.



We monetized balancing reserve activations using the forecasted price of balancing energy (EUR/MWh) calculated in relation to wholesale prices from our electricity market simulations. That is, we multiplied market prices using price coefficients for the upward and downward directions (upward - 1.39; downward - 0.36) based on the current coefficient in the EMS market area[2]. We also correlated the price of cross-border balancing energy activations with the wholesale price at a level of 1.82 (upward direction) and 0.2 (downward direction) for the neighboring markets (Hungary, Austria, and Slovenia) and applied these prices to calculate Serbia's balancing energy import costs.

Based on these assumptions and calculated balancing energy, balancing energy costs can increase from 20 MEUR (2020) to nearly 140 MEUR for the 8 GW case, and 160 MEUR for the 17 GW of RES capacity and high CO2 and BE prices.



When we include both balancing reserve procurement and balancing energy costs, we conclude that these costs can increase from 50 MEUR (2020) to 450 MEUR depending on many parameters (e.g., ref/high CO2 prices, low/ref/high balancing energy prices, and the status of balancing cooperation

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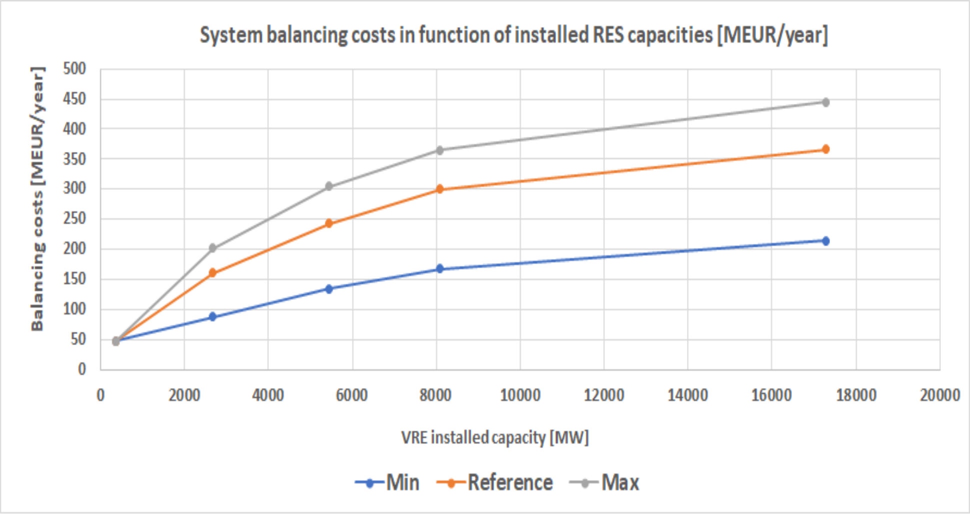
[2] In addition, sensitivity analysis were performed assuming:
- High prices: 30% higher prices in upward direction and 30% lower in downward direction
- Low prices: 30% lower prices in upward direction and 30% higher in downward direction

in the LFC block, etc.). Even in the lowest case (no costs for downward mFRR, low balancing energy costs, …), the balancing cost to increase RES capacities to 2.7 GW will almost double.



According to the current regulatory framework and balancing market design, the costs to procure balancing reserves are transferred to consumers via transmission tariffs, while the costs for balancing energy are paid by the Balancing Responsible Parties (BRP). The current guaranteed supplier (EPS - Public Enterprise Electric Power Industry of Serbia) is responsible for balancing RES producers, whether they are in or out of the market premium system, until the establishment of a liquid organized intraday electricity market. However, if the realized production from RES sources deviates more than the allowed percentage of imbalance in the settlement period, producers must bear the added balancing costs by paying a fixed fee for each kWh of deviation of their realized production from the plan reported to EPS, the guaranteed supplier.

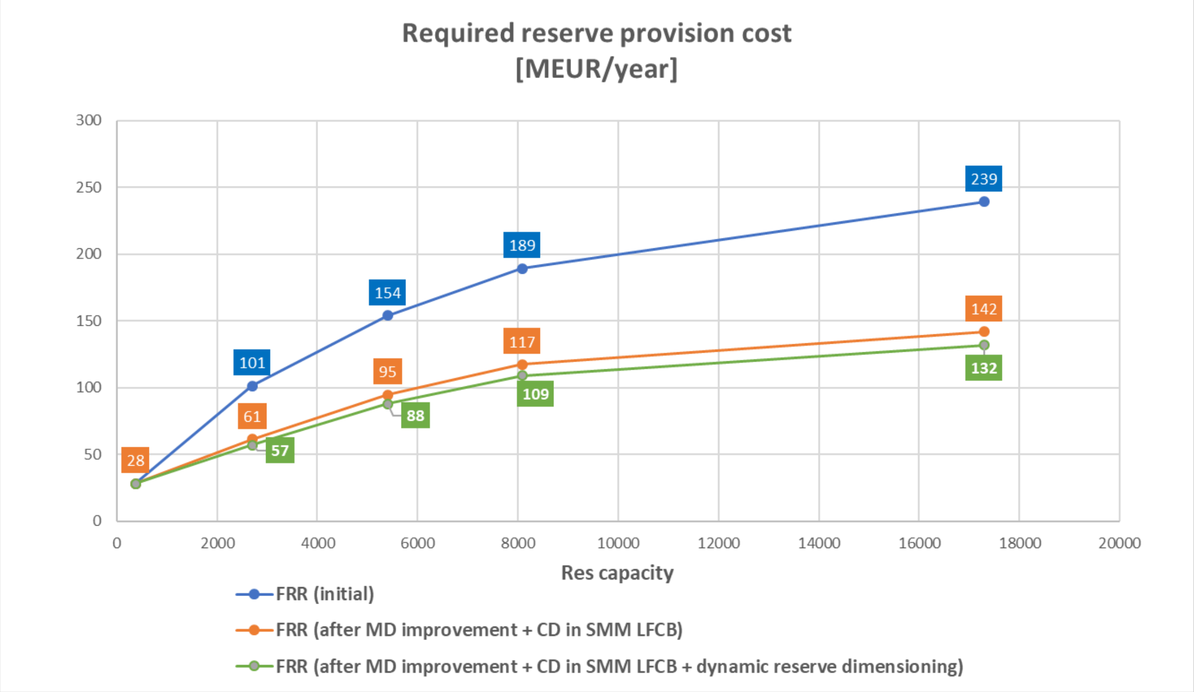
According to the Law, the Government shall regulate in more detail the allowed percentage of balance deviation, the determination method, and the fixed fee to the BRP for balance deviation outside the allowed percentage of balance deviation. They will also regulate the model of balance responsibility contract, the rights and obligations of renewable electricity producers/balance responsible party, and the criteria for determining the liquidity of the intraday market.

However, these types of RES incentive measures were abandoned in the rest of Europe in 2019, and can have a negative impact on the well functioning of the power system. They also affect the optimal inclusion of variable RES into the system, given the high balancing costs associated with integrating high levels of RES. Serbia can learn from others' experience.

To show the benefits of potential improvements in Serbia's procedures, legal and regulatory framework, we performed a preliminary quantitative impact assessment of some measures. Although such analysis only provides a tentative estimate, i.e., an order of magnitude for the potential benefits, the results demonstrate the importance of a proactive approach for decision makers (Government, Ministry, NRA, TSO), as well as the need to understand and implement decisions based on the lessons learned from more mature power systems and electricity markets with a high share of renewables. **The reforms should both aim to follow the best European practices, while also tailoring them to suit the Serbian energy sector and economy.**

This assessment included the impacts of common reserve dimensioning in the SMM block, and the recommended improvement of market design and dynamic reserve dimensioning presented in our final list of recommended improvements**.**

The results show that by adopting and implementing the proposed measures, the total FRR needs (in MW) could decrease by 46% on average across all scenarios. In economic terms, the savings would range from 44 MEUR/y to 107 MEUR/y, or 43% on average.



Impact on Transmission Network Development and Tariffs

The impact of high RES on the transmission network shows that reinforcements already planned for 2030 (in the latest EMS transmission network plan) are capable of providing satisfactory support to system operation. By contrast, the transmission network as planned in 2025 would not provide safe operation of the system in some operating regimes, including those with high exports that could overload the network. **This points to the importance of close synchronization of RES integration with network development in the next several years in particular.**

The results of the transmission network operation analyses (load-flow calculations, voltage profile and contingency n-1 analyses) in the presence of high RES capacities, showed that network reinforcements that include the planned project "North CSE Corridor", the "Pannonian Corridor" and reinforcements of the interconnections with Bosnia and Herzegovina and Montenegro (together with new 400 kV corridor to Bajina Basta), are necessary to provide secure system operation for the referent level of RES capacities in 2025 (even for only 2700 MW of RES capacities). **Thus, we consider these transmission projects to be priorities.**

We estimate the investment costs (CAPEX) for the added main network reinforcements mentioned above to be 367 MEUR, based on [15, 16]:

- Project North CSE Corridor with SS Belgrade 50: 83.5 MEUR [15]
- 400 kV interconnections Bajina Basta – Visegrad and Bajina Basta – Pljevlja, with 400 kV reinforcement from SS Obrenovac: 143 MEUR [16]
- New 400 kV line Pozarevac – Jagodina: 37.8 MEUR
- Pannonian Corridor: 103 MEUR

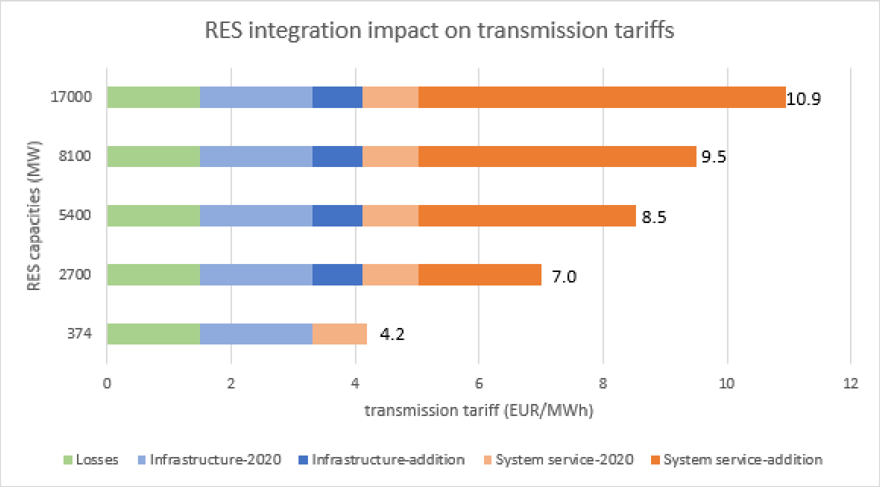
As additional support for RES integration, we recommend more implementation of elements for smart control of the transmission network, such as more widespread control of line temperature and Dynamic Line Rating (DLR). There are already examples of implementation of these projects in the EMS network, and they should be more numerous.

This study does not cover the dynamic stability of the power system under higher RES conditions, which is also key to determining the limits of RES integration to maintain the integrity of the power system and its stable operation within acceptable limits. For that purpose, we recommend a study in the near future to assess the system's dynamic stability with a larger share of RES. EMS AD, PE EPS and Elektrodistribucija Srbije d.o.o. would all benefit from this analysis.

Transmission tariffs are determined based on: (1) costs related to infrastructure; (2) costs related to system services; and (3) costs related to losses.

When we translate the above-recognized costs for balancing reserve procurement and transmission reinforcements into tariffs, we calculate that different levels of RES integration could lead to increases in transmission tariffs (from about 4 Eur/MWh today to as high as 11 Eur/MWh), mainly due to increases in the cost of system services. Such increases would amount to approximately 10% of historical retail prices.

Such costs for RES integration are common in North America and Western Europe, and are an issue that all countries in SEE will face as RES becomes a larger share of regional electricity supply. To lower these costs, best allocate risk, and accelerate RES development in Serbia, the report makes a number of recommendations, tailored to Serbia, taking into account best practices worldwide.



Since the impact of RES on transmission tariffs for system services is higher than the increase in infrastructure costs, and since there are real benefits from improvements in system balancing (30%),

we recommend that processes to improve system operation and balancing be high on the list of the processes on which EMS, with Government and the Regulatory Agency, should work.

Turning to Serbia's current regulatory documents and technical regulations, we identified certain notable elements related to RES integration in Serbia, which include:

1. Serbia introduced key changes to its support scheme for RES market integration by introducing the Feed-in Premium. The previous RES support scheme, the Feed-in Tariff, was quite commercially attractive, and there was a technical limit not to install more than 500 MW due to system balancing issues.
2. The future level of support or quota for RES will be organized through a tendering procedure. The auctions could be conducted for specific areas or on the country level, and for one or more types of renewable power plants.
3. The available RES quota is determined by the Serbian Government based on the Energy Law and other planning documents, international obligations, available data on existing capacities, planned needs or other data relevant to setting this quota.
4. RES producers are exempt from balancing responsibilities until the establishment of a liquid organized intraday electricity market, as long as such producers deviate less than the allowed imbalance percentage during the settlement period. The Government will determine the allowed imbalance percentage.
5. Until the establishment of a liquid organized intraday electricity market, the Guaranteed Supplier (Electric Power Utility of Serbia) is responsible for RES imbalances.
6. RES producers are treated equal to other power plants regarding their priority of connection i.e., connections are granted in the order of connection applications.
7. Serbia currently applies the same connection charges for conventional and RES generating plants, i.e., there is no financial support related to grid connection.
8. Regarding the access of RES electricity to the grid, all RES plants have priority dispatch. Therefore, the system uses the maximum amount of RES electricity, and power from RES producers is only curtailed as the last option in case of bottlenecks.
9. RES investors pay only for the transmission infrastructure necessary for connection, in accordance with the shallow connection charge scheme.
10. In the case of grid congestion due to the connection of a new applicant, the TSO can offer the applicant a reduced maximum installed capacity or a connection subject to operational restrictions (output curtailment up to 5% of total annual production), if such restriction is approved by the NRA.
11. A strategic energy development plan for Serbia to 2050 is currently underway in accordance with the new Energy Law, along with a corresponding national action plan to use RES.
12. Current (2020) RES deployment has no significant impact on power system operation.
13. Two innovative real-time system operation tools were recently deployed:
    a. Wind power generation forecasting, obtained currently from a single service provider
    b. Dynamic Line Rating, which aims to reduce congestion on power lines, optimize asset utilization and improve efficiency, and reduce costs
14. Wholesale market trades in Serbia are mainly conducted through bilateral trading.
15. Organized day-ahead trading is enabled on the power exchange, SEEPEX.

16. Power futures trading is enabled on the EEX.
17. There is no organized intraday market, but this is planned for the near future.
18. Serbia does not yet participate in European market coupling processes (e.g., day-ahead, intraday).
19. Prices for balancing services are regulated by the NRA. There is no remuneration for FCR and mFRR downward reserve.
20. There is one dominant incumbent balancing services provider (the state-owned power utility)
21. There is a balancing mechanism, with a number of regulated elements, and no balancing market competition is yet in place.
22. The greatest impact of RES integration in the transmission tariffs is related to system costs, so all recommendations that would lead to savings in system costs should have high priority.
23. There are bilateral contracts for balancing energy exchange with neighboring TSOs (CGES and NOSBiH).
24. EMS is not yet an operational member of the pan-European balancing processes and platforms (IGCC, PICASSO, MARI, TERRE), although EMS' accession to the IGCC process is expected in 2022.

Our comparison between the new Serbian Laws and EU good practice and legal framework related to RES integration shows that they are not fully harmonized, with these differences:

[1] In the EU, with the adoption of the new CEP-Clean Energy Package in 2019, the implicit incentives of priority dispatch and balance responsibility for variable solar and wind RES connected to the transmission system no longer exist.

Article 5 of EU Regulation 2019/943 provides for these incentives exclusively for power plants smaller than 400 kW, but does not for those above 400 kW.

[2] The Law on the Use of RES in Serbia from 2021 in the part concerning additional implicit incentives for RES introduces these implicit incentives (priority dispatch, balance responsibility, etc.), contrary to the current EU rules and practice in this field.

Also, the Law on the Use of RES from 2021 in Article 11 introduces a priority dispatch for all renewable energy sources, which is in direct conflict with EU practice and with the EU legal and regulatory framework (Article 12 of EU regulations 2019 / 943) where again the mentioned incentive is allowed only for power plants smaller than 400 kW.

These implicit incentives, abandoned in Europe in 2019, can affect the well functioning of the power system, as well the optimal inclusion of variable RES into the system.

Our analyses and recommendations take into account the current rules of the Serbian legal framework, and possible changes to harmonize with the EU's practices and legal framework, and which can benefit the TSO, customers and RES developers. Within these analyses, we qualified and quantified the impacts of changes in RES integration rules, and present the technical and economic basis for decision makers to consider potential changes to the current framework for RES integration.

Recommendations to Improve EMS' Core Business Processes for RES Integration

Based on our work, we summarize here the main recommendations for improvements in EMS' business processes. It is challenging to divide these measures between relevant parties, e.g., Government, the NRA and TSO, since in most cases there is a strong interdependency in developing and implementing each process. Nearly all EMS technical and organizational changes would also involve other parties.

We organize this summary in two main areas that would improve RES integration, while assuring safe and reliable power system operation:

A. Improvements in general RES integration processes and connection procedures
B. Improvements in market design and system operation control

A. Improvements in RES integration processes and connection procedures

Considering the complementarity between the phases of grid connection of RES and grid development, **the most challenging issue is how to share costs for large grid reinforcement and shorten times linked to building new lines.** To better coordinate grid operation, upgrades and RES development, we recommend that EMS consider:

- Regularly collecting data on RES development from public national registries and collection of reliable data on development targets
- Harmonizing and issuing grid code and connection procedures that would reduce lead times and simplify procedures
- Developing regulatory guidelines on the national level for power system development, to better align the pace of grid and RES development. This guideline should allow for better queue management and avoid "virtual grid saturation" in case EMS receives a large number of grid connection applications in a limited time before construction has begun. This guideline should further address these potential enhancements:
    - Adding deposit requirements for connection rights
    - Applying obligatory milestones to the RES application-realization process to maintain the pace of connection and prevent the blocking of connection points
    - Harmonizing the time for required construction licenses and energy permits during project development, with obligatory milestones for RES connection applicants
- Introducing a hybrid system, i.e., a system in which the Investor would pay for the connection and for part of the reinforcement works in case of a lack of grid capacity, while also respecting rules of non-discriminatory and transparent access.

In North America, such procedures have led to much shorter RES development timeframes.

B. Improvements in market design and system operation control

1. Change Market Design, Priority Dispatch and Balancing Responsibility Requirements

To further support RES integration into the power system, Serbia should further develop its wholesale and balancing markets.

The latest European Electricity Regulation (14/06/2019 - Regulation (EU) 2019/943) adopted under the Clean Energy Packages recognizes the importance of proper market design, which requires that all market participants be responsible for the system imbalances they cause. For RES producers active in the market, this means that they should bear the risk of incorrect predictions for production, (e.g., wind forecasts higher or lower than production in real time), just like other power plants.

The same Regulation, in Article 12 sets out the rules on power generation dispatch. Large new RES installations no longer benefit from priority dispatch, which means that all RES capacities commissioned after 4 July 2019 operate according to market-based dispatch.

Currently, the Serbian Energy Law and Law on the use of Renewable Sources provides priority dispatch for RES producers and does not require RES producers to be responsible for balancing. Balancing responsibility is expected to be introduced when a liquid intra-day market becomes operational in Serbia. Further, there is no time limit related to priority dispatch in the Laws.

As previously commented, **we recommend Serbia follow best European practice and introduce balancing responsibility for new RES generators.** This will provide an incentive for better RES forecasting, and decrease balancing reserve requirements and balancing costs.

For renewables, an organized intraday market will allow for an adjustment from the day ahead market to the intraday horizon in an efficient manner for RES generation. The cost of balancing energy activations would decrease, since a notable share of imbalances will trade on the ID market. The cost of balancing reserve procurement would also decrease, since imbalances traded on ID market will lead to smaller deviations in the balancing market, and a lower FRR requirement.

The key question from our perspective is <u>when</u> to introduce RES balancing responsibility without priority dispatch, and how to mitigate the financial risks for RES owners in Serbia. To do so, **we recommend further actions to improve market design, including**: **creating an intraday market; integrating markets across borders; and a shorter imbalance settlement period (ISP).** In these ways, Serbia's power system and market operations will be more efficient. While RES producers will bear financial responsibility for their own production deviations, they will also be able to proactively trade on the intraday market and update their forecasts closer to real time.

2. Reduce the ISP to 15 Minutes

We recommend that EMS implement a 15-minute ISP in two phases:

- Phase 1 – Implement a 15-minute imbalance settlement capability on a TSO-to-TSO, TSO-to-BRP and TSO-to-BSP business process level
- Phase 2 – Implement a 15-minute ISP on the distribution system operators' (DSOs') level

3. Develop Common Dimensioning in the SMM LFC Block

The SMM block now applies common dimensioning of balancing reserves, but this is currently a non-obligatory operational procedure. FRR common dimensioning is an opportunity for Serbia to lower the required reserve for the LFC block, also according to System Operation Guidelines, as stated in the Part IV, Load-Frequency Control and Reserves (Articles 119, 157, 160).

Since the SMM block members are all in the same time Bidding Zones (this is not so in the German Control Block, for example), **we recommend that the SMM LFC block recognize and make available the Cross Zonal Capacity required to apply common reserve needs.**

A positive element here is that EMS, together with CGES and MEPSO, is currently working to further improve their balancing cooperation in the SMM LFC block. This will lead to an operational agreement that will include technical conditions and methods that will satisfy these objectives:

- Development of a methodology to determine the total level of FRR on the LFC block level
- Analysis of available grid capacities for common FRR dimensioning in the SMM block
- Analysis of available cross-zonal capacities for FRR sharing with neighboring LFC blocks
- Work on a methodology to determine the minimum share of the aFRR in the total FRR
- Determination of the common technical requirements at the SMM block level for the availability and quality of system services
- Development of a methodology to allocate cross-zonal transmission capacities for the needs of joint reserve procurement
- Development of a methodology to allocate cross-zonal transmission capacities for the needs of regional cooperation with neighboring control blocks, and other areas regarding the sharing of FRR balance reserve
- Development of a mechanism to conduct auctions and activate joint reserve procurement

4. Cooperate on Cross-Border Balancing

Currently, EMS is an observer in the MARI project and does not participate in the PICASSO project. **We recommend that EMS join both projects.** In order to become an operational member of aFRR-platform and mFRR platforms (MARI and PICASSO), EMS would need to fulfill a series of conditions in the aFRR IF and mFRR IF, such as:

- Develop national terms and conditions related to balancing, according to article 18 of EBGL
- Pricing for balancing energy should be defined according to Article 30 of EBGL (e.g pay as cleared instead of pay as bid)
- Define the standard aFRR and mFRR products
- Set gate closure time to 25 minutes before the start of the validity period of aFRR/mFRR bid

5. Conduct Dynamic Reserve Dimensioning

To technically apply this approach, EMS should implement AI-based algorithms for dynamic reserve sizing, and conduct the additional regular input data collection for training using AI based algorithms.

We respectfully submit this analysis and recommendations for EMS to consider to support the adoption of substantial RES capacity and the transformation taking place in the Serbian and regional power systems on behalf of electricity customers in Serbia.

1 INTRODUCTION

The capacity and output of renewable energy systems (RES) are expected to grow rapidly in Serbia in the coming decade. To best meet the citizens' needs for power, all parties need to be fully prepared for the challenges of integrating such a substantial level of variable resources, in addition to other significant changes in the electricity system, at both the wholesale and retail levels.

In this light, this study by USEA's Electricity Market Initiative (EMI) is designed to support the Government of Serbia (Ministry of Energy), the National Regulatory Agency, the Transmission System Operator of Serbia (EMS AD), and other relevant entities in understanding the technical and economic implications of large-scale RES integration into the power system of Serbia, in 2025 and 2030. The Study analyzes and provides recommendations for changes in the future direction of grid development, and for changes in EMS' core business processes and mechanisms that would facilitate more efficient and larger RES integration, while maintaining system security and controllability.

In this project's Inception Report (finalized in June 2021 and approved by EMS), we presented the methodological approach, as well as summarized the input data sets, assumptions and proxies that we applied for the analyses.

EKC used the Plexos tool to prepare the market model as the basis for simulating future market operations in Serbia, and to evaluate the impacts of growing RES integration on factors such as power prices and the generation mix. High levels of RES also raise balancing concerns, so we also determined the required balancing reserves, and applied them in the market simulations. On the basis of our simulations, Chapter 3 presents the results of our analysis of market operation indicators.

Based on the market simulations results, we calculated the need to activate balancing reserves, and determined Serbia's balancing energy needs. Based on the available supply balancing reserves, and our calculation of the system's balancing needs in different scenarios, we calculated the costs to provide both balancing reserve capacities and balancing energy. Chapter 4 presents these considerations and results.

In Chapter 5, we describe the approach that we applied to propose indicative connections points for additional RES capacities and assess the needed transmission network reinforcement with the aim to support different levels of RES integration, and the corresponding costs.

In addition, it should be noted that EKC agreed with EMS on the locations and points of connection related to all additional RES capacities in this Report, based on proposals in the Interim report (finalized in December 2021 and approved by EMS). These connection points are unofficial proposals and do not present the official opinion or solutions of EMS. These proposals are developed only to anticipate the network's high-level needs for reinforcements and to assess the corresponding costs.

In Chapter 6, we assess the current regulatory and technical framework related to the integration of RES in Serbia, highlighting the following areas:

- Regulatory framework and RES support schemes
- Connection procedure and investments in necessary network reinforcement
- System operation
- Wholesale and balancing market design

This work provides proposals for improvements to existing EMS procedures and mechanisms, with the aim to enable easier, smoother and more secure integration of high levels of RES capacities.

IMPORTANT DISCLAIMER:

This EMI study covers the analysis of markets, regulatory reserves, balancing needs, and the need for new infrastructure given expected large scale RES integration in the Republic of Serbia in 2025 and 2030. This study does not cover the power system's dynamic stability under high RES conditions, which is also crucial to determining the limits of RES integration, and to maintain the integrity of the power system and its stable operation within acceptable limits. For that purpose, it will be important in the near future to conduct a detailed study of the system's dynamic stability with a large share of RES. EMS AD, PE EPS and Elektrodistribucija Srbije d.o.o. would all benefit from this analysis.

The work on the Study started at the end of 2020 and we defined all input data and assumptions before the energy crisis and war in Ukraine (April 2021). Thus, we made assumptions related to CO2 prices applied for the two different scenarios in line with ENTSO-E inputs at that time, which were rather low in comparison to the current values.

However, the use of two assumptions related to CO2 prices (although both rather low in comparison with today's values) gives a relevant range of possible results for the generation mix and balance positions of countries or market zones, especially for the EMS market area. Higher CO2 prices would have had a similar impact on production costs in all market zones (all will increase), and the resulting impact on the generation mix and balance position of the EMS market area would be small.

While the marginal (or wholesale market) prices presented in this Study can be considered low, even in the case with higher CO2, the impact of this discrepancy on the results of this study are limited. Only the balancing energy costs would be higher if higher CO2 prices were applied, so the balancing energy costs presented here can be considered at the lower portion of the possible range. Though wholesale market prices would be higher with higher CO2 prices, wholesale price levels were not the main focus of this study.

2 ANALYZED SCENARIOS

In light of the expected rapid expansion of RES in Serbia, at the transmission and distribution levels, the main task of this study is to analyze the impacts of such development on the Serbian:

- electricity market,
- provision of balancing services and
- network operation.

Therefore, our work evaluates these impacts with two levels of RES generation capacities in Serbia, in two horizon years, under operating circumstances that take into account different climatic and hydrological conditions, the availability of thermal power plants and different forecasts of fuel (gas, lignite, coal) and CO_2 emission prices. Throughout this Study, RES refers to wind and solar energy.

All our analyses (market, balancing and network) consider the status of the electricity markets and networks in SEE and distant regions in both horizon years – 2025 and 2030. For each market area other than EMS, we have modelled one referent level of RES and conventional power plants. To minimize uncertainties in this Study and assure a consistent approach, we took all input data for the market and network areas in SEE and the other regions from EMI studies in 2019 and 2020[3]. We presented these details in this Study's Inception Report.

We analyzed two scenarios in 2025 and 2030, with Expected (Referent) and Ambitious (High) scenarios that differ only with respect to the level of RES integration in Serbia at the transmission and distribution levels:

- The Expected (Referent) scenario examines the impact of moderate RES capacities, based on the current list of RES applicants until 2025 and 2030
- The Ambitious (High) scenario examines the consequences of more aggressive RES integration, considering the almost the full technical RES potential in Serbia through 2030

Generally, each country defines its referent level of RES integration in strategic documents, such as their national energy and climate plans (NECP[4]). The TSOs verify almost all large-scale RES projects through grid connection agreements, connection consents, and connection requests.

The process of RES integration and development over 10 years is a dynamic one in which there are many uncertainties, including the projects' location, stage of development, permitting and financial requirements, size and total installed capacity. We address the uncertainty related to the level of installed capacities through two substantially different scenarios (Expected and Ambitious), while we

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[3] 2019- USAID/USEA Study: Assessment of Benefits of Regional Electricity Market Integration in Southeast Europe
2020 – USAID/USEA Study: Assessment and Training on the Impact of Large-Scale RES Integration in Southeast Europe

[4] NCEP does not yet exist in Serbia, nor are regional targets yet set for the EnC region.

address the challenge of the projects' locations by taking into account current information on investment-attractive locations in Serbia, as well as the distribution of wind and solar potential [1].

To investigate the impacts of various levels of RES capacities in Serbia on the electricity markets, on balancing, and on network operation, we assessed a range of wind and solar capacities for the Expected and Ambitious scenarios in 2025 and 2030 (Table 2.1). There are about 400 MW of RES on line in Serbia today.

We determined our RES scenarios at the beginning of 2021, before the significant increases in requests for connection submitted to EMS, as presented in Table 2.3. So, Table 2.1 is updated with the newest information, while respecting the total level of RES capacities determined for different scenarios at the beginning of 2021.

Table 2.1: Expected and Ambitious Scenarios of RES development with shares in transmission and distribution networks

	RES Development Scenarios for 2025 and 2030 [MW]			
Type	**2025**		**2030**	
	Expected (Referent)	**Ambitious (High)**	**Expected (Referent)**	**Ambitious (High)**
Wind	2461+0[5]	4437+0	5400+1350	8000+2000
Solar	200+8.8[6]	1010+0	1335+0	4123+3167[7]
Total:	**2661+8.8**	**5447+0**	**6735+1350**	**9290+8000**
	2700	**5447**	**8085**	**17290**

*-connected to transmission + distribution grid

We developed these proposed RES scenarios based on information available at the beginning of 2021, in the following manner:

1. Because the year 2025 is rather close we propose somewhat conservative assumptions for the level of RES capacities in the Expected scenario compared to the requests from RES projects for connection in Table 2.2 below. Taking currently operating capacities into account, with higher certainty, we expect 2461 MW of wind by 2025. Similarly, we expect 200 MW in large-scale solar capacities in 2025 (around 50% of the current requests for connection), which includes only two projects from the list in Table 2.2.

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[5] Currently (April 2021) there are 431 MW in wind PPs in operation in Serbia. There are 2030 MW in new wind PPs planned for commissioning in 2025 that are currently in the design phase. See Table 2.2.

[6] The currently operating solar capacity (all at distribution level) is 8.8 MW

[7] According to the information EMS received from the Ministry, it might be possible to install 6 GW of rooftop solar capacities, but, having in mind received request for connection of 4123 MW to transmission network and total potential of 7290 MW, 3167 MW is expected to be connected to distribution network.

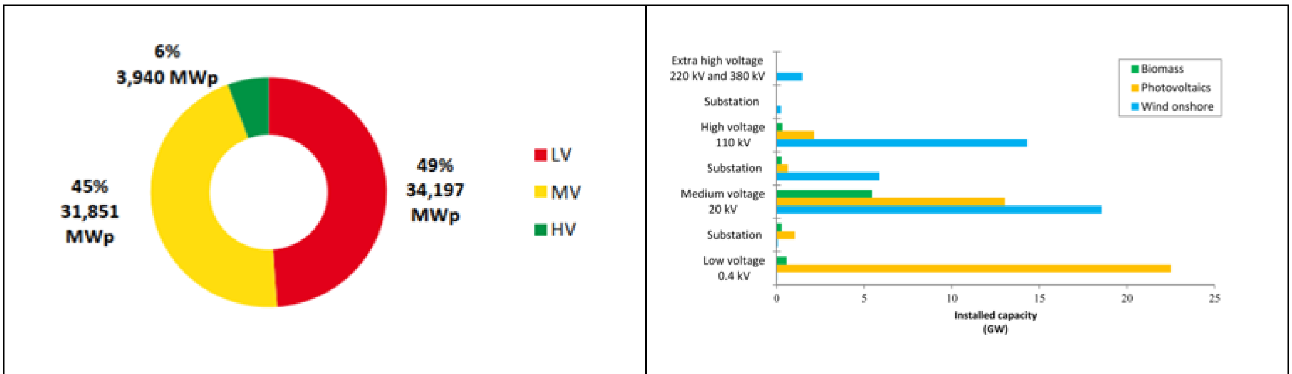
In the 2025 Ambitious (High) scenario, we assume that almost all RES projects for which EMS has received a request for connection (in Table 2.2[8]) will be realized. The only power plant that is excluded is the solar PP Navitacum, given the high uncertainty of its construction. In this case, a total of 5,447 MW of RES (focusing on wind and solar PPs) capacities will be connected to the transmission network.

Additional capacities can be connected to the distribution grid and they mainly include small solar projects (roof tops). However, due to large increase in requests to EMS to connect solar power plants at the end of 2021, we focused our analysis in 2025 on RES capacities connected to transmission network.

2. Because 2030 is more distant, we proposed to use very high levels of RES capacities in both the Expected and Ambitious scenarios to investigate their influence on market and network behavior. In the Ambitious scenario, we proposed levels close to the estimated RES potential in Serbia, while in the Expected scenario, RES capacities are between the Ambitious scenarios for 2025 and 2030. These scenarios include significant distributed RES capacities as well.

Important message: Our results should, in all cases, be understood as a function of installed RES capacities in the analyzed scenarios: approximately 2700 MW, 5400 MW, and 8100 MW. The last scenario with 17,000 MW in RES capacities should be understood as a theoretical exercise, to protect EMS in an unlikely scenario.

As noted, the proposed wind and solar capacities forecasted in the Expected and Ambitious scenarios in 2030 include capacities connected to the transmission (HV) network and the distribution (LV) network. Based on the wind and solar shares between the transmission and distribution grids in the EU and different European countries (Austria, Germany, Poland,…), there is no common pattern, and quite different shares exist. However, in almost all cases solar capacities are mainly connected to the distribution grid (more than 90%) as presented in Figure 2.1 [4]. The shares for wind capacities mainly depend on the general approach related to RES development in each country [7,8], while the case for Germany is presented in the figure below.



Solar capacities per voltage level – Europe - 2012

Wind capacities per voltage level – Germany - 2016

Figure 2.1: RES capacities connection to transmission and distribution grids

With this in mind, and considering the current wind and solar capacities in Serbia and the known development directions, we have applied an 80%/20% share (T/D) for wind capacity. In the case

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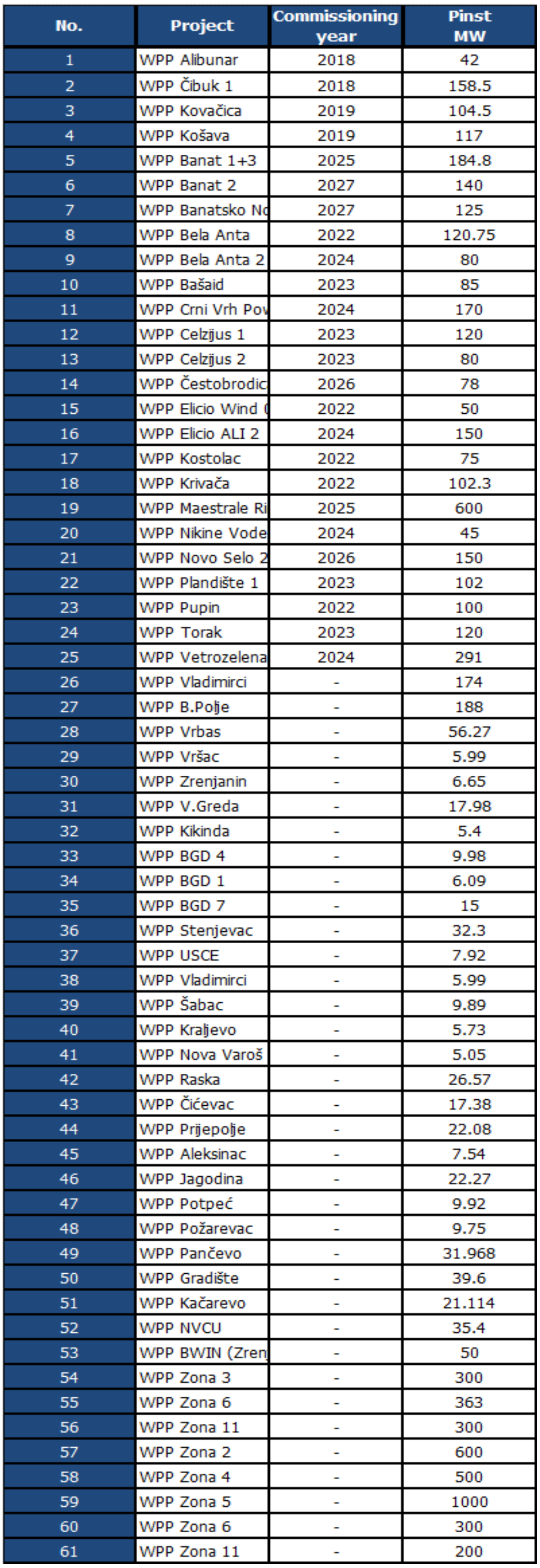
[8] In May 2021, EPS reported the construction of the new SPP Srednje Kostolacko Ostrvo but this project has not filed an official request for a connection study. Year of commissioning is 2024 and installed capacity is 100 MW. This additional large SPP is included in the list in Table 2.2.

of solar capacities, for large-scale solar capacities we considered applications to EMS for connection through the end of 2021. The rest of the solar potential will be developed on the distribution system (Table 2.1).

Table 2.2: RES Requests for Interconnection to EMS - status – beginning of 2021

No.	Project	Commissioning year	Pinst MW	In planning phase	In design phase	In construction phase
1	WPP Bela Anta	2022	120.75	YES	YES	
2	WPP Elicio Wind	2022	50	YES		
3	WPP Kostolac	2022	66	YES	YES	YES
4	WPP Krivača	2022	103.32	YES	YES	YES
5	WPP Pupin	2022	95.5	YES	YES	
6	WPP Bašaid	2023	85	YES	YES	
7	WPP Celzijus 1	2023	120	YES		
8	WPP Celzijus 2	2023	80	YES		
9	WPP Plandište 1	2023	102	YES	YES	
10	WPP Torak	2023	120	YES	YES	
11	WPP Alibunar 1	2024	99	YES	YES	YES
12	WPP Alibunar 2	2024	75	YES	YES	YES
13	WPP Bela Anta 2	2024	80	YES		
14	WPP Crni Vrh Po	2024	150	YES	YES	
15	WPP Elicio ALI 2	2024	150	YES		
16	WPP Košava	2024	68	YES	YES	
17	WPP Nikine Vode	2024	45	YES	YES	
18	WPP WPPtrozele	2024	300	YES	YES	
19	WPP Banat	2025	93	YES		
20	WPP Banat 3	2025	93	YES		
21	WPP GEH Wind 1	2025	238	YES		
22	WPP Maestrale Ri	2025	600	YES	YES	
23	WPP Čestobrodic	2026	238	YES		
24	WPP Novo Selo 2	2026	150	YES		
25	WPP Banat 2	2027	140	YES		
26	WPP Banatsko N	2027	125	YES		
27	WPP Čibuk 2	2027	300	YES		
28	WPP Uljma	2027	120	YES		
1	SPP Sjenica	2022	50	YES		
2	SPP Kima Solar	2024	50	YES		
3	SPP Pirot - Dobri	2024	75	YES		
4	SPP Solarina	2024	150	YES		
5	SPP Srednje Kost	2024	100			
6	SPP Power Plant	2027	80	YES		
7	SPP Navitacum	2030	785	YES		

Table 2.3: RES Requests for Interconnection to EMS - status – end of 2021



No.	Project	Commissioning year	Pinst MW
1	WPP Alibunar	2018	42
2	WPP Čibuk 1	2018	158.5
3	WPP Kovačica	2019	104.5
4	WPP Košava	2019	117
5	WPP Banat 1+3	2025	184.8
6	WPP Banat 2	2027	140
7	WPP Banatsko No	2027	125
8	WPP Bela Anta	2022	120.75
9	WPP Bela Anta 2	2024	80
10	WPP Bašaid	2023	85
11	WPP Crni Vrh Pov	2024	170
12	WPP Celzijus 1	2023	120
13	WPP Celzijus 2	2023	80
14	WPP Čestobrodic	2026	78
15	WPP Elicio Wind (	2022	50
16	WPP Elicio ALI 2	2024	150
17	WPP Kostolac	2022	75
18	WPP Krivača	2022	102.3
19	WPP Maestrale Ri	2025	600
20	WPP Nikine Vode	2024	45
21	WPP Novo Selo 2	2026	150
22	WPP Plandište 1	2023	102
23	WPP Pupin	2022	100
24	WPP Torak	2023	120
25	WPP Vetrozelena	2024	291
26	WPP Vladimirci	-	174
27	WPP B.Polje	-	188
28	WPP Vrbas	-	56.27
29	WPP Vršac	-	5.99
30	WPP Zrenjanin	-	6.65
31	WPP V.Greda	-	17.98
32	WPP Kikinda	-	5.4
33	WPP BGD 4	-	9.98
34	WPP BGD 1	-	6.09
35	WPP BGD 7	-	15
36	WPP Stenjevac	-	32.3
37	WPP USCE	-	7.92
38	WPP Vladimirci	-	5.99
39	WPP Šabac	-	9.89
40	WPP Kraljevo	-	5.73
41	WPP Nova Varoš	-	5.05
42	WPP Raska	-	26.57
43	WPP Čićevac	-	17.38
44	WPP Prijepolje	-	22.08
45	WPP Aleksinac	-	7.54
46	WPP Jagodina	-	22.27
47	WPP Potpeć	-	9.92
48	WPP Požarevac	-	9.75
49	WPP Pančevo	-	31.968
50	WPP Gradište	-	39.6
51	WPP Kačarevo	-	21.114
52	WPP NVCU	-	35.4
53	WPP BWIN (Zren	-	50
54	WPP Zona 3	-	300
55	WPP Zona 6	-	363
56	WPP Zona 11	-	300
57	WPP Zona 2	-	600
58	WPP Zona 4	-	500
59	WPP Zona 5	-	1000
60	WPP Zona 6	-	300
61	WPP Zona 11	-	200

No.	Project	Commissioning year	Pinst MW
1	SPP Sjenica	2022	80
2	SPP Kima Solar	2024	100
3	SPP Pirot - Dobri	2024	50
4	SPP Solarina	2024	75
5	SPP Srednje Kost	2024	50
6	SPP Power Plant	2027	150
7	SPP 1	before 2025	50
8	SPP 2	before 2025	76
9	SPP 3	before 2025	350
10	SPP 4	before 2025	80
11	SPP 5	before 2025	362
12	SPP 6	before 2025	71.5
13	SPP 7	before 2025	660
14	SPP 8	after 2025	90
15	SPP 9	before 2025	439
16	SPP 10	before 2025	80
17	SPP 11	before 2025	47.5
18	SPP 12	before 2025	70
19	SPP 13	before 2025	300
20	SPP 14	before 2025	67
21	SPP 15	before 2025	20
22	SPP 16	before 2025	70
23	SPP 17	after 2025	75
24	SPP 18	after 2025	80
25	SPP 19	after 2025	50
26	SPP 20	after 2025	50
27	SPP 22	after 2025	80
28	SPP 23	after 2025	90
29	SPP 26	after 2025	60
30	SPP 27	after 2025	300

EMS has reviewed and approved the proposed levels of RES capacities in Table 2.1. For the approved levels of RES capacities, we conducted market and balancing analyses, and prepared proposals for the locations and unofficial points of connection for RES capacities above those already known and given in EMS' network models.

For both RES scenarios, we investigated the impact of different CO2 emission costs to assess a wide range of possible effects. The referent CO2 analyses were based on a CO2 price of 23 and 27EUR/t in 2025 and 2030, while for the sensitivity analyses, we used a substantially higher CO2 price of 53 and 56 EUR/t. While the higher CO2 prices are closer to current ones, we also analyzed the referent one that now appears rather low, especially given prices in the Fall of 2021. When we defined the scenarios (Spring of 2021) these CO2 prices were not far from the ETS prices. These low CO2 prices have the benefit of enabling the investigation of EMS' and the regional market operation when TPPs in the EMS market area are in a better market position, in conjunction with significant RES capacity additions. More details about these sensitivity analyses are in the Inception Report (Chapter 3.3).

It is important to note that the robustness and dynamic stability of the power system are key in providing system security with high levels of variable RES generation, as well as during severe regimes and more extreme weather conditions. This Study did not analyze the dynamic, frequency and voltage simulations in this Study, so we recommend that EMS carry out more detailed analyses to assess the full impact of wind and solar capacities on power system operation.

3 THE IMPACTS OF RES INTEGRATION ON THE WHOLESALE POWER MARKET

3.1 Objective, Scope and Methodology

The Inception Report provided a detailed description of the methodology and input data sets as well as key assumptions, which we summarize here.

To measure the market impacts, we carried out hourly market simulations with hydro-thermal optimization and economic dispatch with the Plexos software tool. We conducted simulations for two target years, 2025 and 2030, and two scenarios, Expected and Ambitious, differentiated by alternative levels of RES development in Serbia, as explained in Chapter 2.

For both RES scenarios (focused on wind and solar), we also investigated the impact of different CO2 emission costs. The referent CO2 analyses were based on CO2 prices of 23 and 27 EUR/t in 2025 and 2030, while the sensitivity analyses used higher CO2 prices of 53 and 56 EUR/tCO2.

We assessed the Expected and Ambitious (Referent and High) RES scenarios, in Serbia and SEE, by quantifying their effects on these generation, environmental and other market indicators:

- Generation dispatch, energy mix and share of renewables
- Demand-supply balances
- CO2 emissions
- Generation adequacy and potential security of supply problems
- Curtailment of renewables
- Wholesale prices
- Cross border exchanges, congestion duration and costs

In addition to assessing these main market operation indicators, we used the results of the market simulations for our balancing and network analyses (Figure 3.1).

It should be noted that, within the market simulations, we included constraints imposed by different levels of required balancing reserves in different RES scenarios. We also assumed that aFRR and mFRR regulation services are provided by the units that EMS indicated (Table 4.6). Taking this into account, the hourly market and dispatch results provide the basis for determining the balancing reserves activations and corresponding costs, presented in Chapter 4. Within these analyses, the dispatch of conventional units in the RES scenarios, with CO2 price variations, generated different circumstances for balancing services.

Also, from the 8760 hourly results of the market simulation in one year, we selected six characteristic hours (as described in Chapter 5) and transferred the corresponding dispatch and loads to the network model to analyze network operation in selected operating regimes.

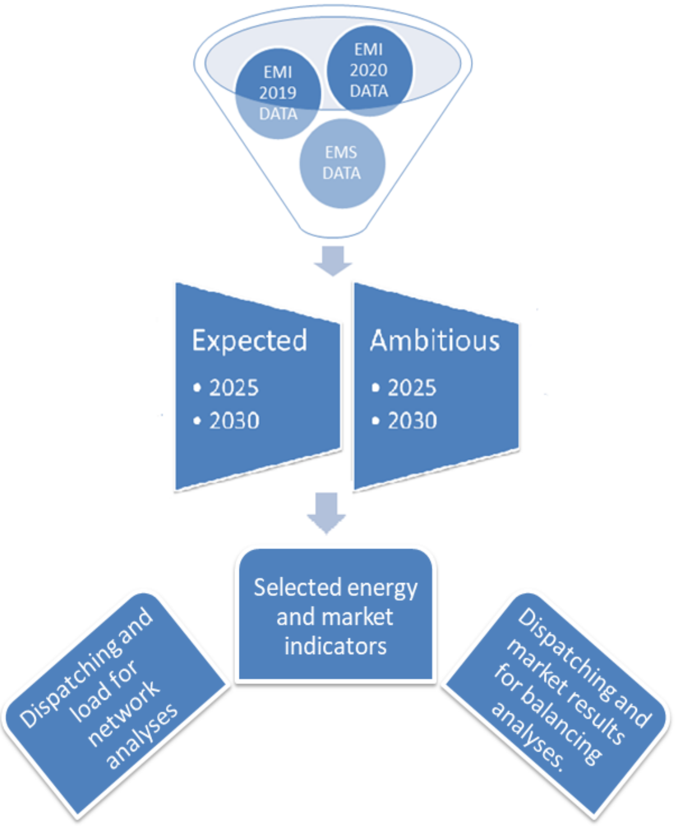


Figure 3.1: Market simulation workflow

3.2 Results at the Regional Level

The following two subchapters describe the market simulation results on the SEE regional level for both analyzed years (2025 and 2030), for each RES development scenario in Serbia (referent and high RES level), and for the referent and high CO2 emission tax.

We present and compare the main indicators between these years and scenarios in terms of:

- regional generation mix,
- total CO2 emissions,
- balances of market areas, and
- average annual prices.

We also assess how the high RES penetration level in Serbia would impact the changes in other market areas in the SEE region.

It should be noted that in all the analyzed scenarios, we implemented different RES levels only in the EMS market area, while in all other areas in the region, the RES levels refer to predetermined 2025 or 2030 levels (mainly in line with their NECPs).

3.2.1 Referent CO2 Tax (23 and 27 EUR/t CO2) Regional Results

We conclude that with referent CO2 prices, there are no significant differences between the referent and high RES scenarios, since the only difference is in installed capacities (wind and solar) in Serbia, while installed RES capacities in other market areas do not vary.

At the regional level, the largest changes in the generation mix from 2025 to 2030 are registered in TPP generation, which falls by 45 TWh in the referent case, and 53 TWh in the high case due to both regional RES development and the decommissioning of lignite generation throughout SEE. This drop is compensated for mainly by the increase in wind and solar, which together rise by over 37 TWh in the reference case, and 47 TWh in the high case.

In terms of the impact of RES generation in Serbia, the biggest impact arises from wind generation (about 3852 GWh more generation from WPPs in the high RES scenario in 2025, compared to the referent RES scenario, and 6337 GWh more generation in 2030). Solar generation in 2030 would also be about 8000 GWh higher in 2030 in the high RES case compared to the reference one. There are small regional differences in hydro, as more RES (in this case only in Serbia) leads to the increased engagement of pumped storage in the whole region.

Even with its significant decrease, fossil plants in 2025 are still a significant source of electricity - accounting for approximately 50% of the regional generation mix (including gas power plants). In 2030, this percentage falls to 33% under the High RES scenario, and 36% in the referent RES case. The vast majority of this reduction is in lignite generation. Generation from wind rises over 70% in 2030 compared to 2025, while generation from solar capacity more than doubles, as high RES provides about 13% of all generation in 2025, and 27% in 2030.

The increased level of RES capacity installed in the region, and the retirement of fossil plants are the main reasons for reduced regional fossil generation. Hydro generation is largely constant, i.e., 8% higher in 2030 than in 2025, and generation from nuclear power is unchanged.

Table 3.1 shows the total forecasted regional generation in the SEE region by technology. The corresponding regional generation mix is presented in Figure 3.2 for both 2025 and 2030 and the level of RES development in Serbia (referent and high RES case).

We conclude that with referent CO2 prices, there are no significant differences between the referent and high RES scenarios, since the only difference is in installed capacities (wind and solar) in Serbia, while installed RES capacities in other market areas do not vary.

At the regional level, the largest changes in the generation mix from 2025 to 2030 are registered in TPP generation, which falls by 45 TWh in the referent case, and 53 TWh in the high case due to both regional RES development and the decommissioning of lignite generation throughout SEE. This drop is compensated for mainly by the increase in wind and solar, which together rise by over 37 TWh in the reference case, and 47 TWh in the high case.

In terms of the impact of RES generation in Serbia, the biggest impact arises from wind generation (about 3852 GWh more generation from WPPs in the high RES scenario in 2025, compared to the referent RES scenario, and 6337 GWh more generation in 2030). Solar generation in 2030 would

also be about 8000 GWh higher in 2030 in the high RES case compared to the reference one. There are small regional differences in hydro, as more RES (in this case only in Serbia) leads to the increased engagement of pumped storage in the whole region.

Even with its significant decrease, fossil plants in 2025 are still a significant source of electricity - accounting for approximately 50% of the regional generation mix (including gas power plants). In 2030, this percentage falls to 33% under the High RES scenario, and 36% in the referent RES case. The vast majority of this reduction is in lignite generation. Generation from wind rises over 70% in 2030 compared to 2025, while generation from solar capacity more than doubles, as high RES provides about 13% of all generation in 2025, and 27% in 2030.

The increased level of RES capacity installed in the region, and the retirement of fossil plants are the main reasons for reduced regional fossil generation. Hydro generation is largely constant, i.e., 8% higher in 2030 than in 2025, and generation from nuclear power is unchanged.

Table 3.1: Annual generation (GWh) in the SEE region – referent CO2 scenario

Yearly generation - SEE region (GWh)	**2025-RefRES**	**2025-HighRES**	**2030-RefRES**	**2030-HighRES**
HPP	63,043	63,651	68,333	68,583
TPP lignite	130,728	129,563	86,188	79,726
TPP coal	1,728	1,721	1,684	1,683
TPP gas	33,661	32,252	31,787	29,560
Other	3,273	3,146	3,020	2,553
Nuclear	60,103	60,103	64,969	64,968
Solar	13,356	14,438	32,208	40,253
Wind	26,096	29,948	44,739	51,076
TOTAL	**331,987**	**334,824**	**332,928**	**338,402**

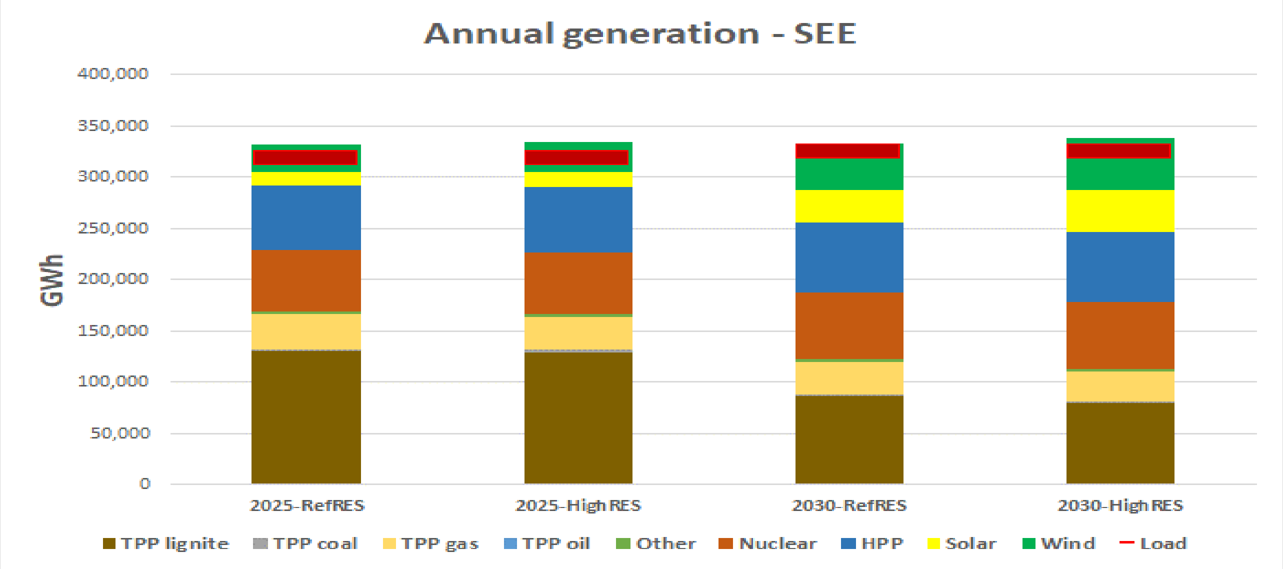


Figure 3.2: Regional generation mix – referent CO2 scenario

The following table (Table 3.2) shows the system operation indicators for the referent CO2 tax scenario. Annual load (including pumping) is a little higher in the high RES scenario, compared to the referent case, due to the increased use of pumped storage in the higher RES penetration scenario. On the other hand, total thermal generation is significantly lower (by about 28% in the referent case and 32% in the high RES case) in 2030 compared with 2025, especially for lignite plants, so total CO2 emissions fall around 50 M Tons, or 30%.

In 2025 and 2030, with assumed low CO2 prices, the SEE region, still rich in fossil plants, is a net electricity exporter. Increased RES capacities in the high RES scenarios increase total exports from the region. The increase in RES capacity decreases wholesale prices due to changes in the merit order curves. This decrease is not significant, and prices are at 50 EUR/MWh level in all scenarios we analyzed. In other words, the modest increase due to CO2 prices and the modest increase due to RES additions offset each other in terms of their impact on wholesale power prices in this case.

It should be noted that only in the case with high RES (17 GW) capacities in the EMS market area would curtailment/spillages occur, because there are hours during the year in which all the borders between the EMS market area and neighboring areas are congested. However, RES curtailment would only reach 100 GWh, just 0.3% of total RES generation. In all other cases, the system can use 100% of the RES generation from wind and solar generation to meet customer electricity needs.

Table 3.2: System totals in SEE region – referent CO2 scenario

System operation indicators (GWh)	**2025-RefRES**	**2025-HighRES**	**2030-RefRES**	**2030-HighRES**
Load (GWh)	317,593	318,357	324,480	324,859
Generation (GWh)	331,987	334,824	332,928	338,402
CO2 emission (000t)	150,480	148,579	103,208	95,134
Spillage / curtailment (GWh)	0	0	0	101
Net Interchange (GWh)	14,394	16,467	8,448	13,442
PRICES (EUR/MWh)	**50.6**	**50.2**	**51.3**	**50.0**

Figure 3.3 shows net exchanges by market area in the SEE region, for both analyzed years, and the RES penetration level in the EMS market area. The largest exporters of electricity in 2025 are the market areas of EMS and ESO EAD, each with more than 15 TWh, followed by the Transelectrica market area, with annual exports slightly below 10 TWh. Other market areas, such as IPTO, HOPS and Mavir are typical net electricity importers for both analyzed years and scenarios. We note that the ESO EAD market area, a typical net exporter in the SEE region, will significantly reduce its exports in 2030 (below 5 TWh). At the same time, the Transelectrica market area reduces its exports. Changes in the net position of these two market areas are due to the significant decommissioning

of old lignite-fired plants from 2025 to 2030. For the region as a whole, exports decrease from 2025 to 2030 in both RES development scenarios, particularly in the referent case (Table 3.2).

Figure 3.4 presents the average annual wholesale prices by market area. The results differ for 2025 and 2030. For instance, in 2025, for both RES scenarios, average annual prices for most of the market areas converge, while IPTO, HOPS and Mavir market areas become separate price zones, with relatively higher average annual prices. On the other hand, in 2030 the situation is different. While average annual prices converge for most of the market areas, the market areas of OST, ESO EAD, IPTO and MEPSO form separate price zones. The highest price is expected in the IPTO market area, while the lowest average annual price is expected in the EMS market area, in part due to the level of RES capacities assumed in the high RES scenario (17 GW).

We discuss the implications of this and other regional scenarios, along with the expected changes in Serbia, in the Chapters below.

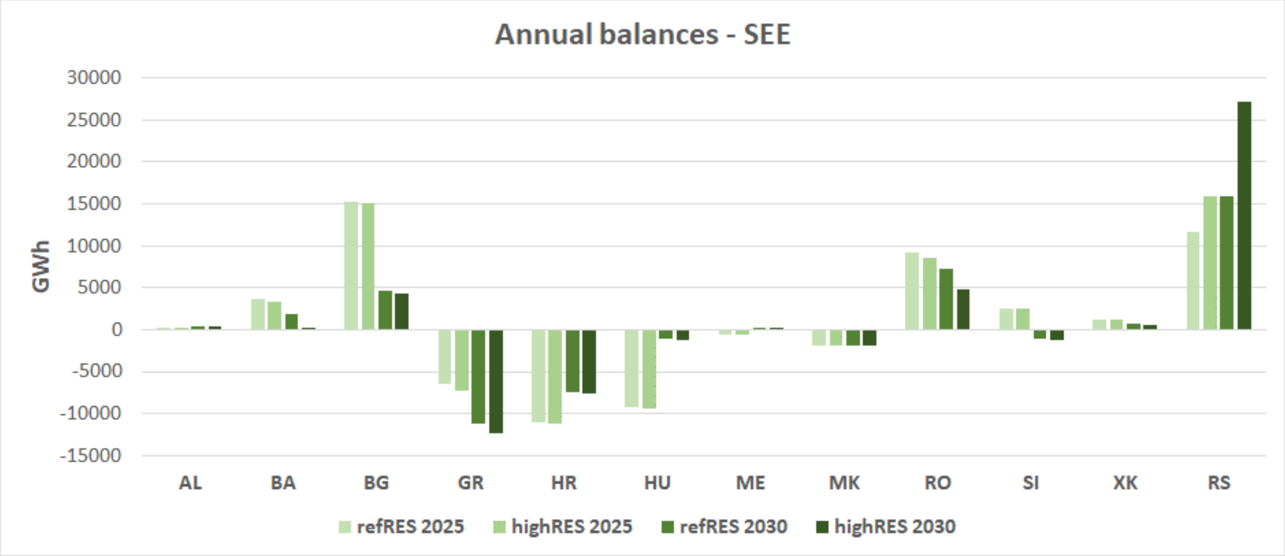


Figure 3.3: Annual balances in SEE region - referent CO2 scenario

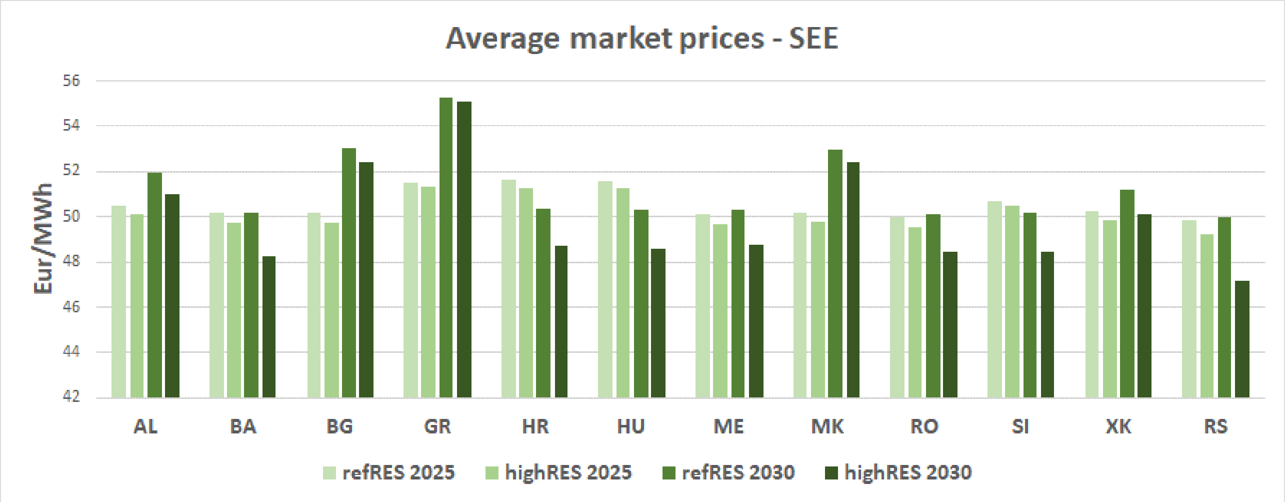


Figure 3.4: Average wholesale market prices in SEE region - referent CO2 scenario

3.2.2 High CO2 Tax (56 and 53 EUR/t CO2) Regional Results

Table 3.3 shows total regional generation in the SEE region by technology, and Figure 3.5 shows the corresponding generation mix for both analyzed years (2025 and 2030) and level of RES development in Serbia, assuming higher CO2 prices. The most significant changes in the regional generation mix between these two years compared to the referent CO2 tax case are the higher generation from RES capacities, and lower annual generation from thermal plants, especially lignite and gas. Also, generation from gas rises substantially compared to lignite, given its lower CO2 content. In the referent case overall, TPPs (lignite, coal and gas) fall from 47% to 34% of generation, and in the high RES case, from 45% to 30%, in 2025 and 2030.

Due to the higher CO2 tax, total thermal generation and regional exports also fall. Regional wholesale market prices are 36-48% higher in this case compared to the low CO2 scenario, rising from 50 Euros per MWh to a range of 68-74 Euros per MWh. In this case, the higher CO2 price more than offsets the decreasing impact of higher RES generation in Serbia on wholesale prices.

Table 3.4 shows that in 2025, the SEE region becomes an electricity importer. In 2030, the SEE region reverts to being a net exporter, due to increased RES capacities compared to 2025, but with significantly lower net exports than with referent (lower) CO2 prices. In the high CO2 price scenario, total spillage/curtailment from RES is reduced, since the total thermal generation is reduced.

Table 3.3: Annual generation in the SEE region – high CO2 scenario

Yearly generation SEE region (GWh)	2025-RefRES	2025-HighRES	2030-RefRES	2030-HighRES
HPP	62,693	63,259	67,775	68,066
TPP lignite	74,131	71,472	51,150	44,938
TPP coal	1,627	1,621	1,685	1,684
TPP gas	71,528	70,499	57,692	53,664
Other	6,245	6,242	6,178	6,020
Nuclear	60,103	60,103	64,969	64,969
Solar	13,356	14,438	32,208	40,253
Wind	26,096	29,948	44,739	51,076
TOTAL	**315,780**	**317,582**	**326,396**	**330,671**

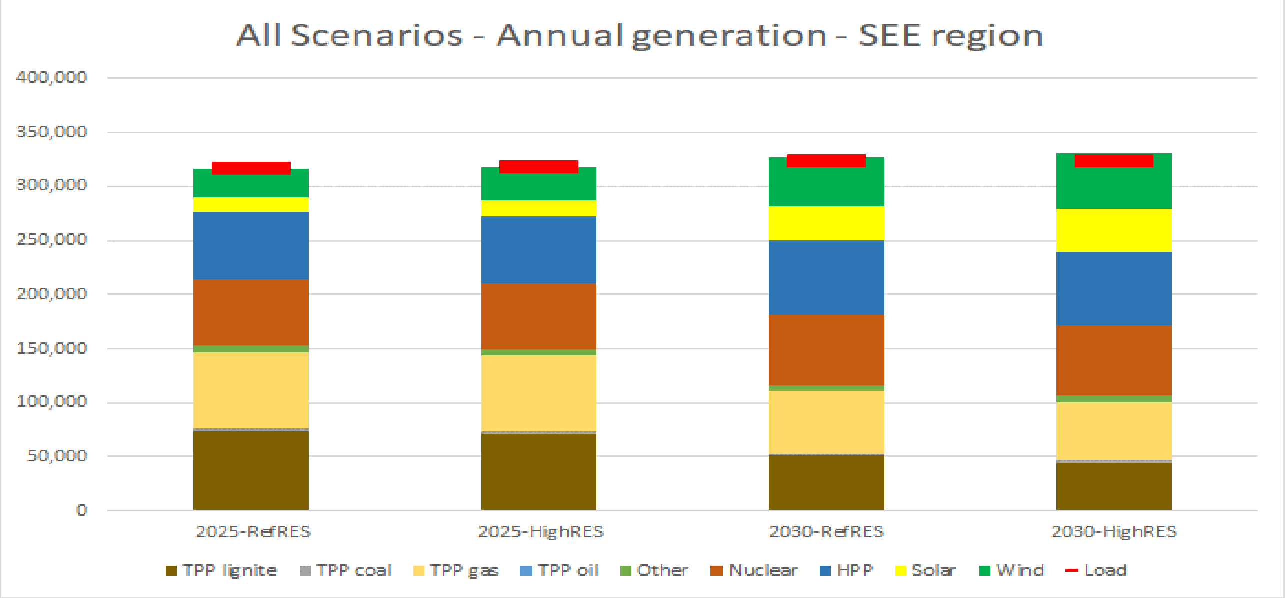


Figure 3.5: Regional generation mix – high CO2 scenario

We present the system totals for the high CO2 scenario at the regional level in Regional wholesale market prices are 36-48% higher in this case compared to the low CO2 scenario, rising from 50 Euros per MWh to a range of 68-74 Euros per MWh. In this case, the higher CO2 price more than offsets the decreasing impact of higher RES generation in Serbia on wholesale prices.

Table 3.4. Total CO2 emissions are lower in the high RES scenario, as well as between 2030 and 2025 (both reductions are around 30%). Total annual demand is again a little bit higher in the high RES scenario, due to the higher engagement of pumped storage.

Regional wholesale market prices are 36-48% higher in this case compared to the low CO2 scenario, rising from 50 Euros per MWh to a range of 68-74 Euros per MWh. In this case, the higher CO2 price more than offsets the decreasing impact of higher RES generation in Serbia on wholesale prices.

Table 3.4: System totals in SEE region – high CO2 scenario

System operation indicators (GWh)	2025-RefRES	2025-HighRES	2030-RefRES	2030-HighRES
Load (GWh)	317,136	317,876	323,757	324,157
Generation (GWh)	315,780	317,582	326,396	330,671
CO2 emission (000t)	102,147	98,944	73,800	65,816
Spillage / curtailment (GWh)	0	0	0	71
Net Interchange (GWh)	-1,357	-294	2,639	6,443
PRICES (EUR/MWh)	**74.0**	**73.6**	**69.4**	**67.8**

Figure 3.6 presents the annual generation balances for all SEE market areas. There are differences between importing/exporting status when comparing the results for 2025 and 2030. However, these differences are the most significant in the ESO EAD and EMS market areas. In 2025 the ESO EAD market area is the largest electricity exporter (despite higher CO2 taxes), but in 2030 the situation is completely different. Exports from this market area are significantly reduced, while the EMS market area becomes an electricity exporter.

In the High RES scenario, the reduction of exports from the ESO EAD market area is replaced by significant increases in net exports from the EMS market area. Here, electricity exports from the EMS market area rise from about 1 TWh to more than 15 TWh, while net exports from the ESO EAD market area decrease from about 16 TWh to about 3 TWh. The largest importers of electricity in the region are the HOPS, NOSBIH and MEPSO market areas. The Mavir market area is an electricity importer in 2025 and begins to export electricity in 2030. The IPTO market area is an electricity exporter for both years when higher CO2 prices are applied because thermal power plants from the IPTO market area become more competitive.

We present the average annual market prices by market areas in Figure 3.7. In the High RES scenario, the prices are more variable between market areas in 2025 and 2030. On the other hand, the market prices converge more in the referent RES scenario in 2030, with slightly higher values projected for the OST, ESO EAD and MEPSO market areas. In the region, EMS registered the lowest average annual price of approximately 66.5 EUR/MWh under the high RES scenario for 2030.

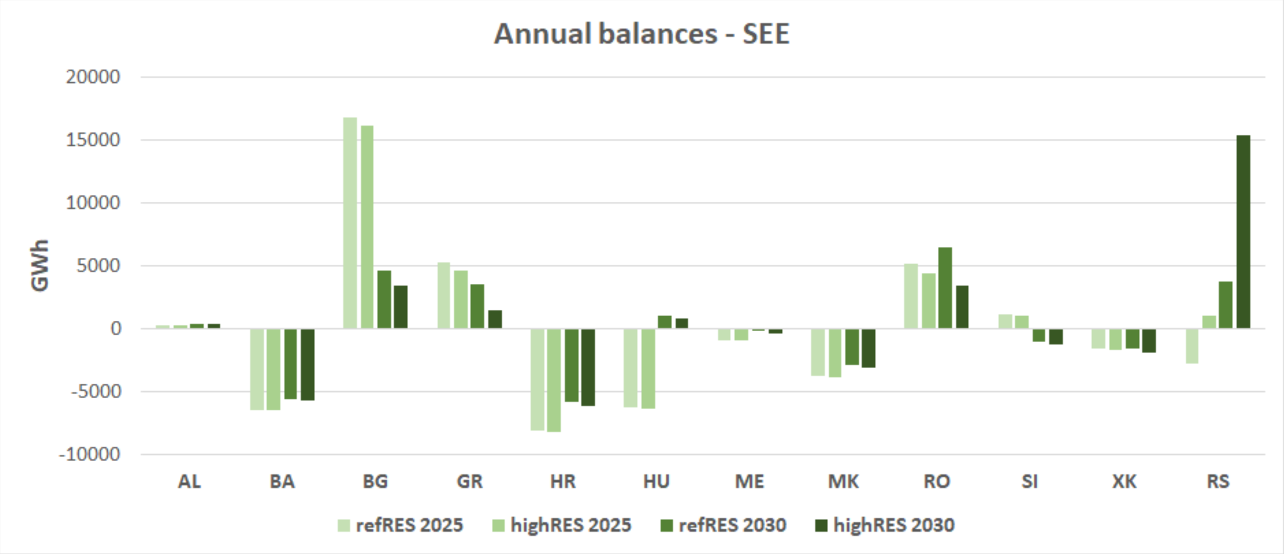


Figure 3.6: Annual balances in the SEE region - high CO2 scenario

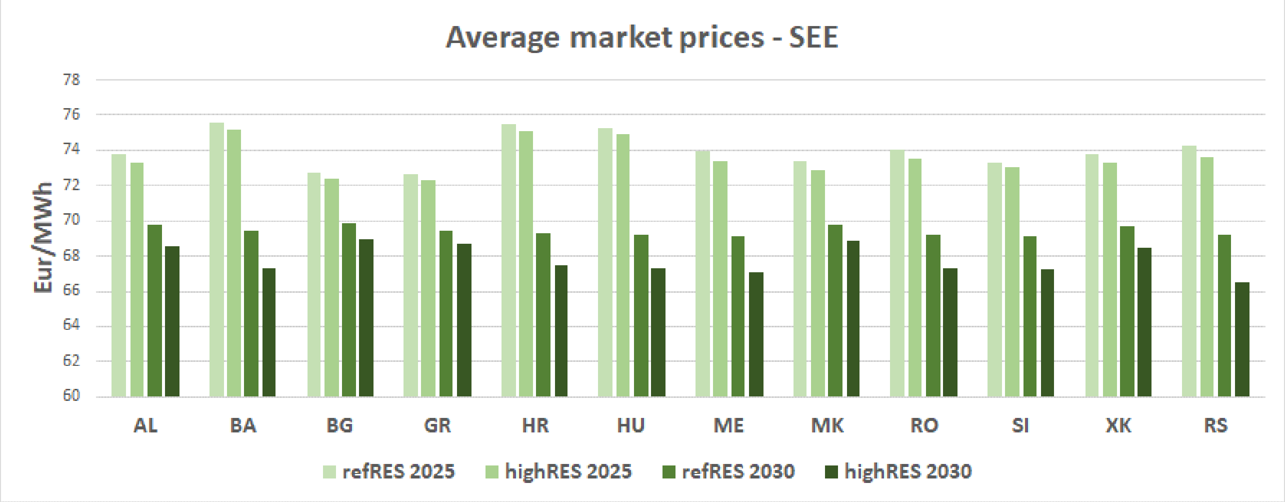


Figure 3.7: Average market prices in SEE region - high CO2 scenario

3.3 Results for the EMS Market Area

3.3.1 Characteristics of wind and solar generation in the EMS market area

In all of the analyzed scenarios, wind and solar generation is determined by hourly capacity factors. These factors represent possible hourly generation from RES capacities based on three representative climatic years (1982, 1984 and 2007) characterized by different wind speeds, insolation and ambient temperature.

The hourly capacity for wind and solar plants determine their hourly generation. Hourly generation forecasts were applied in our market simulations as a non-dispatchable generation. We present the annual solar and wind generation and installed capacities for our four scenarios in Table 3.5.

Table 3.5: Annual generation from wind and solar capacities – EMS market area

Wind & Solar	**2025-RefRES**	**2025-HighRES**	**2030-RefRES**	**2030-HighRES**
Wind installed capacity (MW)	2461	4437	6750	10000
PV installed capacity (MW)	209	1010	1335	7290
Wind generation (GWh)	**4798**	**8651**	**13161**	**19497**
Solar generatio (GWh)	**282**	**1365**	**1804**	**9849**
Total RES capacity (MW)	**2670**	**5447**	**8085**	**17290**
Total RES generation (GWh)	**5080**	**10016**	**14964**	**29347**
Annual capacity factor	**21.72%**	**20.99%**	**21.13%**	**19.38%**

With regard to annual RES capacity factors, higher values reflect better RES generation potential. Annual capacity factors around 20% such as we see in Table 3.5 are moderate, and characterize countries with significant but not the highest RES potential. Capacity factors vary due to different wind and solar shares in the mix of RES capacities per scenario.

We present the maximum hourly wind and solar generation for the scenarios in this study for the EMS market area in Table 3.6.

Table 3.6: Maximum hourly generation from wind and solar capacities – EMS market area

	2025-RefRES	2025-HighRES	2030-RefRES	2030-HighRES
Wind-installed capacity (MW)	2461	4437	6750	10000
Solar-installed capacity (MW)	208.8	1010	1335	7290
Total installed capacity (MW)	2670	5447	8085	17290
Max hourly generation (MW)	2388	4530	6821	12627
Percentage of the installed capacity (%)	89.4%	83.2%	84.4%	73.0%

The maximum hourly generation differs depending on the scenarios due to the shares of wind and solar capacities in total RES capacity. Depending on the level of RES capacity installed, the maximum hourly generation from RES capacities in 2025 and 2030 in the EMS market area can range from 2388 MW to 12627 MW, which is important input data for the network analyses.

The hourly characteristics of wind and solar generation determine its variability. The following figure demonstrates that an increase in RES capacities from 2.7 GW (2025-Referent RES scenario) to 17 GW (2030-High RES scenario) increases both absolute RES generation and variability. Higher installed RES capacity leads to higher absolute variabilities in RES generation.

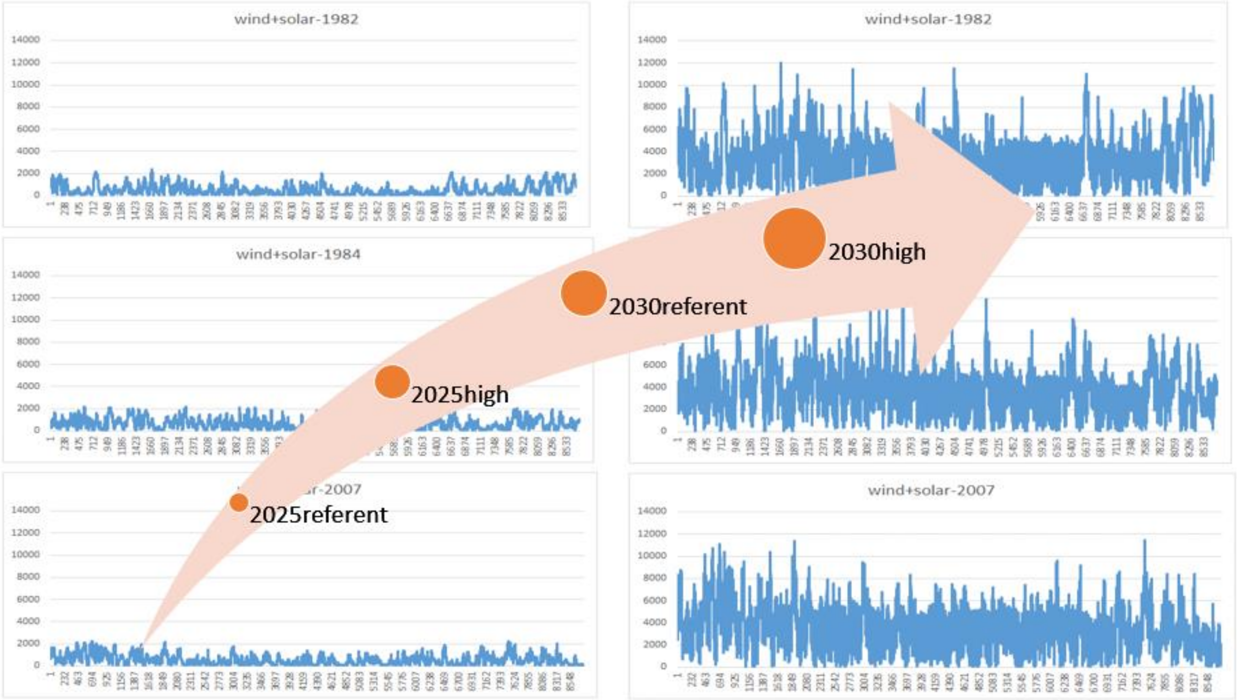


Figure 3.8: Hourly generation for 2.7 GW and 17 GW of RES capacities

The measure of wind and solar generation variability is called ramps, which is the hourly change in their generation as determined by capacity factors. We present ramp duration curves in Figure 3.9.

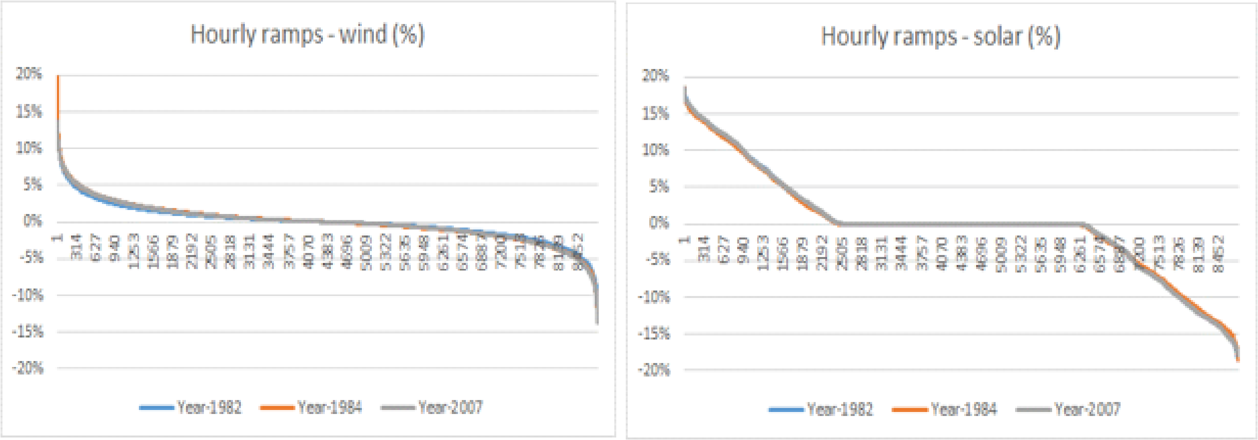


Figure 3.9: Hourly ramps of wind and solar generation

The natural variability of solar generation is higher than wind since more than 90% of all hourly changes in wind generation is within 5% of installed capacity. In the case of solar, natural variability is higher, but, as depicted in the following diagram, it is higher in all seasons except summer.

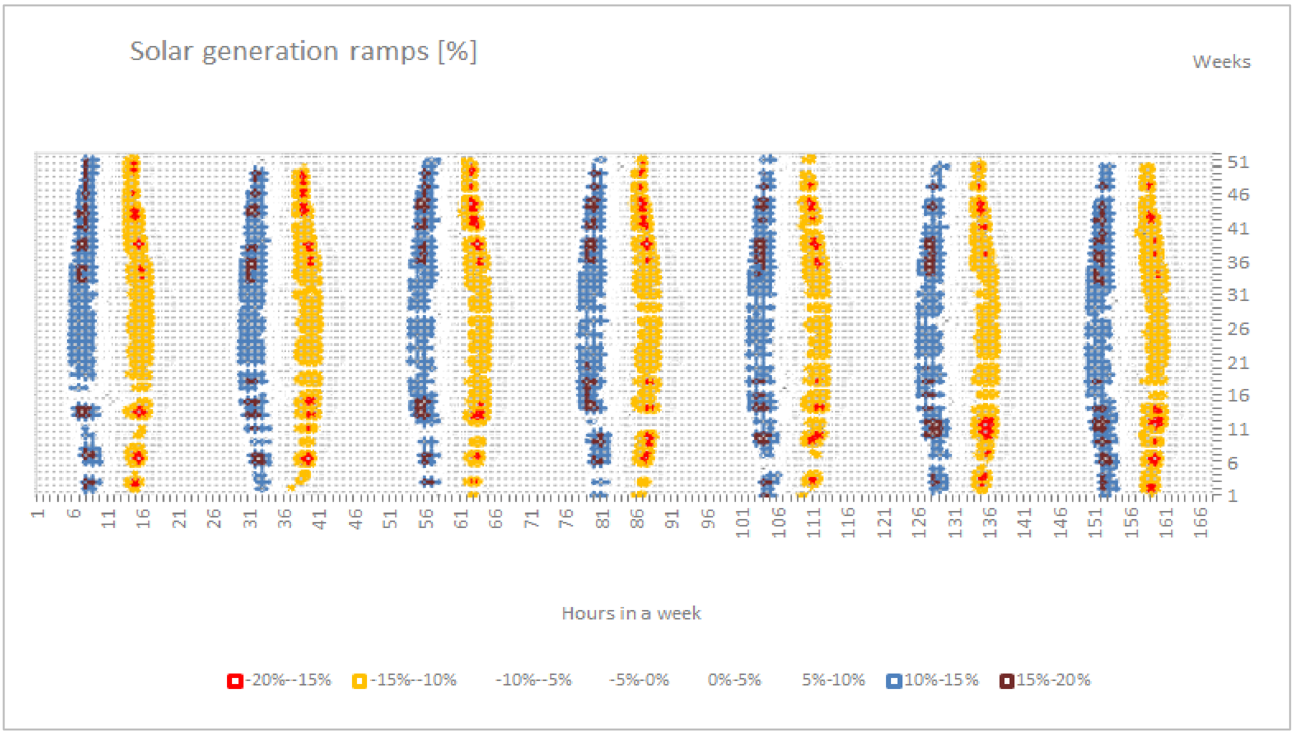


Figure 3.10: Hourly ramps of solar generation

Hourly changes in wind and solar generation create a need for flexible generation resources to compensate for their inherent variability.

In addition to flexibility requirements, errors in the load forecasts as well as forecasts of wind and solar generation, together with outages of power plants, generate the need for balancing reserves.

Figure 3.11 shows that wind generation deviations from the forecast are higher than natural variations. Deviations in a solar generation are smaller than natural variations because forecast errors for solar generation are rather low. Because of this, increased wind generation capacity may not drive the need for flexibility, but it might require high balancing reserves. High levels of solar capacity will generate the need for flexibility, rather than a need for higher balancing reserves.

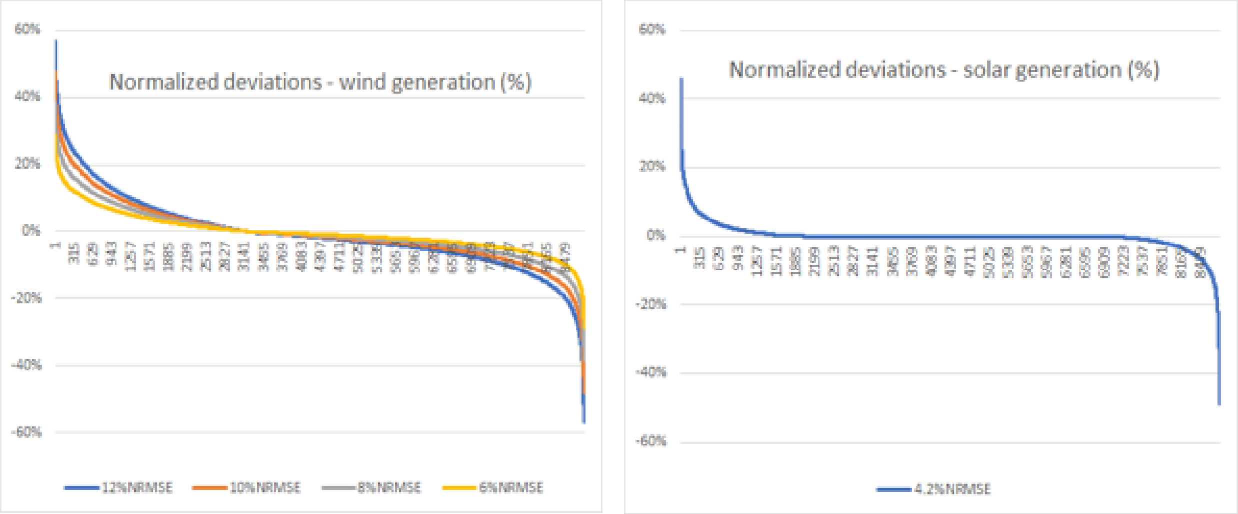


Figure 3.11: Normalized deviations of wind and solar generation forecasts

The following two subchapters describe the market simulation results for the EMS market area in 2025 and 2030 for the Referent and High RES development scenarios in combination with the referent and high CO2 emission tax.

The main indicators that are presented and compared between the years and scenarios are:

- generation mix,
- CO2 emission,
- net interchange of the EMS market area
- average annual prices
- export/import directions
- congestion on cross-border interconnections and potential congestion revenues.

3.3.2 Referent CO2 tax (23 and 27 EUR/t CO2) in the EMS market area

The following tables (Table 3.7 and Table 3.8) show total installed capacities and annual generation in the EMS market area by technology. The corresponding generation mix is presented in Figure 3.12 for both levels of RES development in Serbia (referent and high RES case) in 2025 and 2030.

These results lead to the following conclusions:

- HPP installed capacities in both years will be practically the same. The generation increase from 10.3 to almost 11 TWh will result from increased pumping and generation at the PSP Bajina Basta.

- Even though TPP installed capacities remain the same in both years and scenarios, TPP generation will decrease, especially in 2030 in comparison to 2025. TPP capacity will decrease from around 33 TWh in 2025 to 28.7 TWh in the 2030 referent scenario and 25.7 TWh in the high RES scenario. Most of the decrease will come from carbon-intensive lignite TPPs as a direct result of more RES generation in the EMS market area, but also due to more RES generation in the SEE region. Low CO2 prices in these scenarios enable TPPs in the EMS market area to be competitive and among the cheapest in the SEE region.

- An increase in WPP generation will directly follow an increase in WPP installed capacity, from 4.8 TWh in the 2025 referent scenario and 8.6 TWh in the 2025 high RES scenario to 13.2 TWh in the 2030 referent and 19.5 TWh in the 2030 high RES scenario.

- An increase of SPP generation will directly follow an increase in SPP installed capacities, from 0.3 TWh in the 2025 referent RES scenario and 1.4 TWh in the 2025 high RES scenario to 1.8 TWh in the 2030 referent case and 9.8 TWh in the 2030 high case.

- The total wind plus solar generation in the EMS market area is higher than the generation of TPPs only in the highest RES scenario, where there is 17 GW of RES capacities.

- Generation from other sources will remain at the same level (0.5 TWh) for each analyzed scenario and year because the installed capacities are envisaged to be the same.

- In total, generation in 2025 will be 49 TWh for the referent scenario. It will rise to 54 TWh for the high RES scenario. Most of this increase comes from an increase in RES installed capacities (predominantly wind). Notably, TPP generation decreases only 0.5 TWh.

- In total, generation in 2030 will be 55.1 TWh in the referent scenario. It will rise to 66.6 TWh for the high RES scenario. An increase in RES generation of 14.4 TWh (from 14.9 TWh to 29.3 TWh) will be partially offset by a decrease in TPP generation of 3 TWh (from 28.7 TWh to 25.7 TWh).

Table 3.7: Installed capacities in EMS market area per fuel type

Installed capacities [MW]	**2025**	**2030**
TPP	4829	4829
HPP	3035	3055
Wind (RefRes/HighRES)	2461/4437	6750/10000
Solar (RefRes/HighRES)	208.8/1010	1335/7290
Other[9]	135	135

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[9] These capacities refer to small HPPs, biogas, biomass, waste and other renewable technologies. Total capacity is based on data available at https://mre.gov.rs/sites/default/files/registri/registar_21.05.2021.html

Table 3.8: Annual generation in the EMS market area per fuel type – referent CO2 scenario

Yearly generation (GWh)	**2025-RefRES**	**2025-HighRES**	**2030-RefRES**	**2030-HighRES**
HPP	10,305	10,850	10,981	10,976
TPP lignite	31,583	31,115	27,535	24,617
TPP gas	1,530	1,486	1,165	1,072
Other	539	539	539	539
Solar	282	1,365	1,804	9,849
Wind	4,798	8,651	13,161	19,497
TOTAL	**49,038**	**54,006**	**55,185**	**66,551**

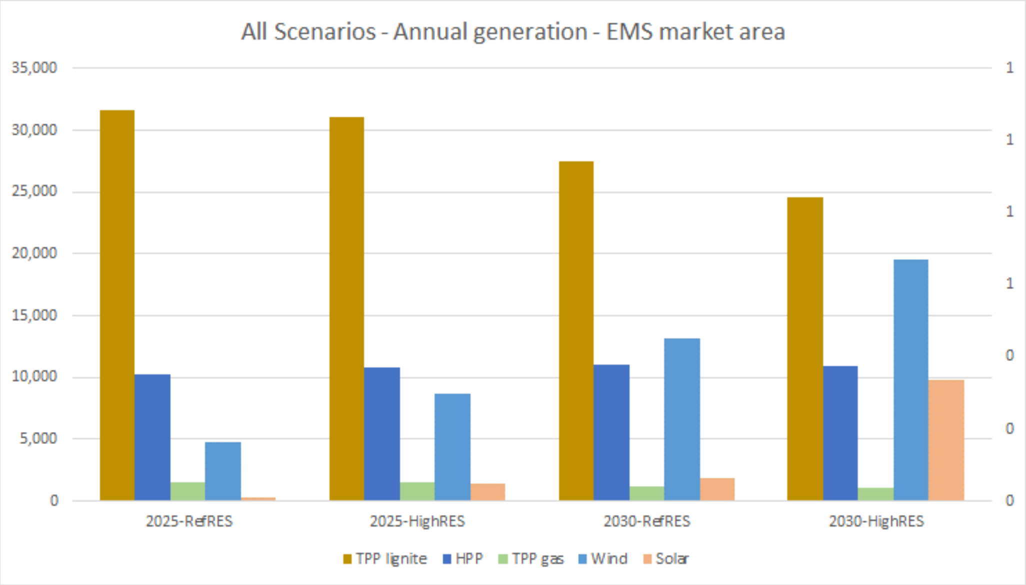

Figure 3.12: Generation mix for EMS market area – referent CO2 scenario

The following table (Table 3.9) shows system operation indicators for the referent CO2 tax scenario. It can be seen that annual load (including pumping) is a little higher in the high RES scenarios compared to the referent cases, which is a consequence of increased pumping in the case of higher RES penetration.

Table 3.9: System operation indicators for EMS market area – referent CO2 scenario

System operation indicators (GWh)	**2025-RefRES**	**2025-HighRES**	**2030-RefRES**	**2030-HighRES**
Load (GWh)	37,354	38,030	39,198	39,222
Generation (GWh)	49,038	54,006	55,185	66,551
CO2 emission (000t)	35,022	34,464	30,224	26,927
Spillage / curtailment (GWh)	0	0	0	101
Net Interchange (GWh)	11,684	15,976	15,987	27,228
PRICES (EUR/MWh)	**49.9**	**49.2**	**50.0**	**47.2**

Total CO2 emissions range from 35 M Tons in 2025 in the referent RES scenario to 26.9 M tons in the 2030 high RES scenario. The difference is due to a reduction in generation by the lignite TPPs.

Net exports range from 11.7 TWh in 2025 refRES to 27.2 TWh in 2030 high RES scenario. The EMS market area would experience the same level of export in the 2025 high RES and 2030 referent scenarios due to changes in the generation portfolio in the SEE region and a decline in the share of the TPP generation in the EMS market area.

In both years, an increase in RES generation leads to a decrease in wholesale prices (Figure 3.13). In 2025, an increase of RES capacities from 2700 MW to 5400 MW would decrease the wholesale prices by 0.7 €/MWh, or 1.5%, while an increase in RES capacities from 8085 MW to 17290 MW in 2030 would decrease wholesale prices by 2.8 €/MWh, or 5.6%. It should be noted that presented relative decrease of prices (in %) would be lower in case of higher CO2 prices.

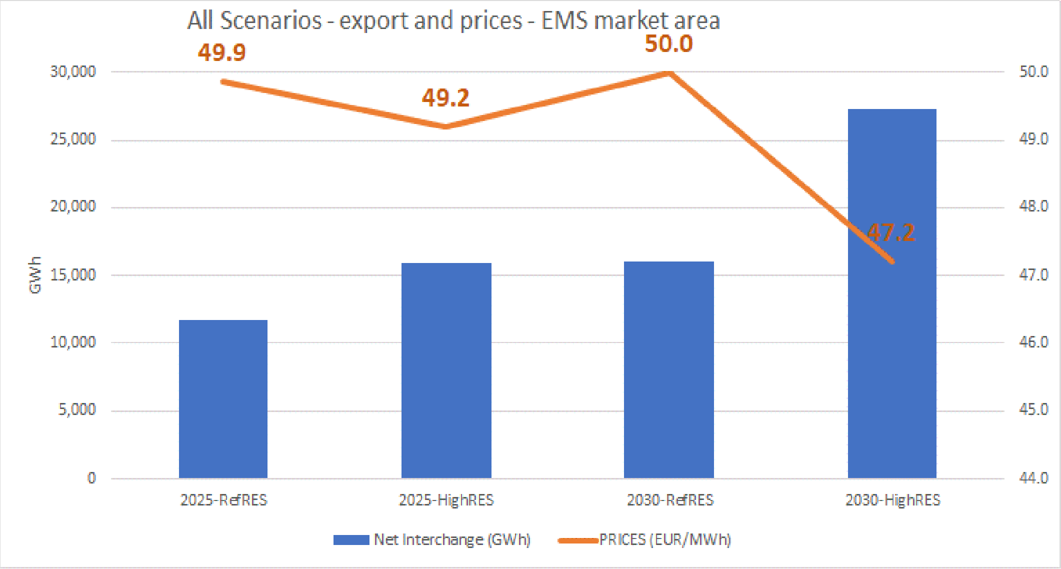

Figure 3.13: Annual prices and net export in EMS market area – referent CO2 scenario

We note that with 17 GW of RES capacity in the EMS market area, spillages/curtailment occurs (0.1TWh) and that there are hours during the year in which all borders between the EMS market area and neighboring areas are congested.

The total net interchange and congestion are presented in the following figures. Projected congestion revenue for EMS is in Table 3.10, and they range from 10 million to 43 million Euros per year. In 2025, most annual net interchanges are below 2 TWh, while in 2030 net interchanges are considerably higher in almost all directions, with more than half of the borders above 3 TWh. Net interchange is the highest on the border with the Transelectrica market area, and this energy is further exported to Ukraine and Moldova.

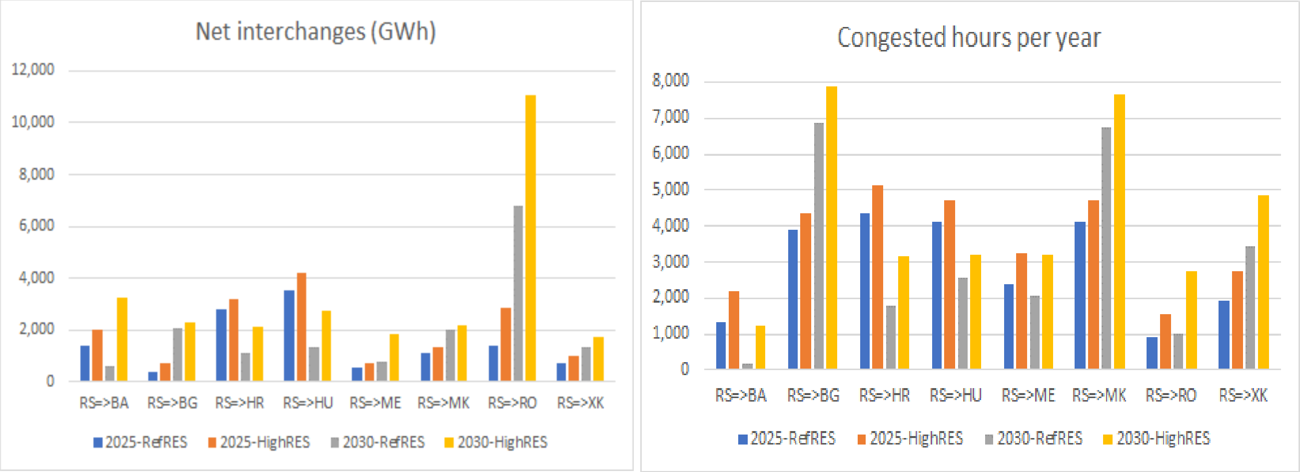

Figure 3.14: Annual net export and congestions in the EMS market area – referent CO2 scenario

Table 3.10: Congestion revenue for the EMS market area – referent CO2 scenario

	2025-RefRES	2025-HighRES	2030-RefRES	2030-HighRES
Congestion revenue (MEUR/year)	**10.2**	**14.5**	**12.3**	**43.13**

Congestion revenues increase with the rise in RES capacity since all excess energy is exported over interconnections of constant seasonal capacity without a significant decrease in wholesale prices.

It should be noted that congestion revenue has an impact on the total allowed revenue for EMS that determines transmission tariffs paid by consumers. Higher congestion revenues provide the potential for reduced transmission tariffs and lower costs for consumers.

As an illustration of the hourly net interchanges of the EMS market area, we present hourly net interchanges from the 2030 referent scenario in Figure 3.15.

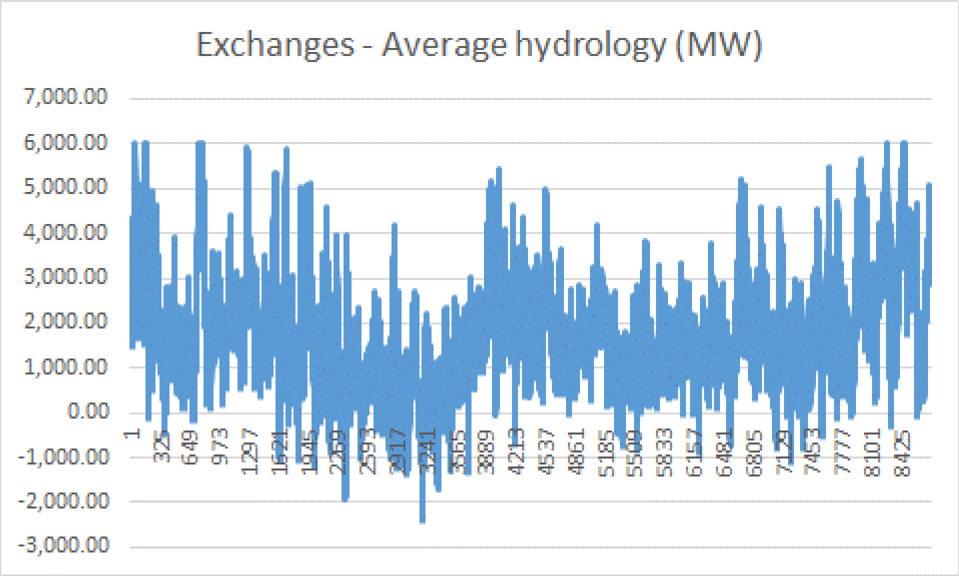

Figure 3.15: EMS net interchanges for the 2030 refRES scenario, referent CO2 scenario, one climatic year

Exchanges, mainly exports, are the highest in winter and the lowest in spring and summer, partially due to the maintenance period for TPPs and partially due to low hydro generation during the summer season. Although the total annual export, in this case, is around 16 TWh, there are hours during spring in which the EMS market area is an electricity importer, which brings additional benefits since regional prices are low.

3.3.3 High CO2 tax (56 and 53 EUR/t CO2)

Table 3.11 and Table 3.12 shows total installed capacities and annual generation in the EMS market area by technology. We present the corresponding generation mix in Figure 3.17 for both of the Serbian RES development scenarios in 2025 and 2030.

From these scenarios, we conclude the following:

- HPP installed capacities in both analyzed years are generally projected to be at the same level. As a result, hydropower generation will increase slightly from 10.2 to almost 11 TWh due to increased use of the Bajina Basta pumped storage station.

- Even though TPP installed capacities remain the same in both analyzed years and scenarios, TPP generation will decrease, especially in 2030 in comparison with 2025, from around 18 TWh in 2025 to 16.5 TWh in the 2030 referent scenario. In the High RES scenario, TPP generation would decline to 13.8 TWh. Most of the decrease will come from carbon-intensive lignite TPP as a direct result of RES integration and high CO2 taxes.

  The High CO2 price (56 and 53 EUR/tCO2) leads to a sharp decline in TPP generation in comparison with the referent CO2 tax (23 and 27 EUR/tCO2), as depicted in Figure 3.16. Due to higher CO2 prices, the decrease in TPP generation ranges from 11.8 TWh to 14.9 TWh, and is around 50% of the GWh for both of the two analyzed years and RES scenarios.

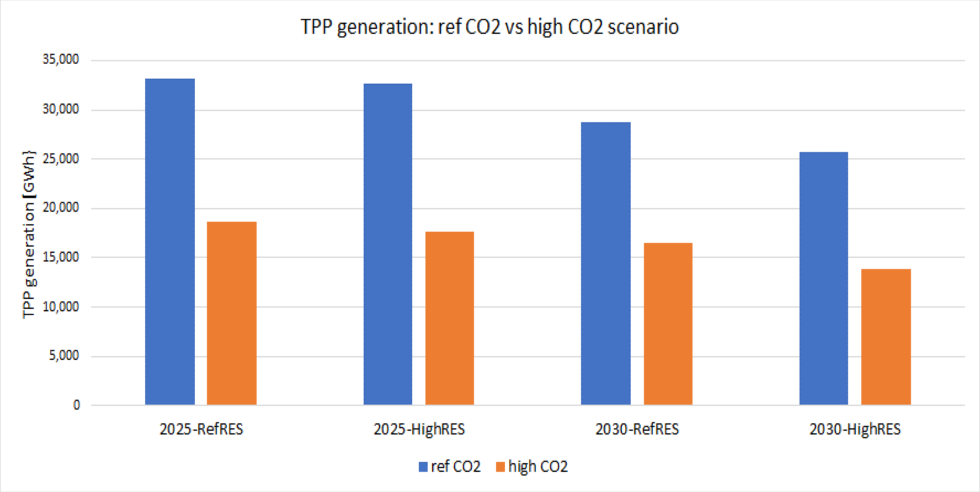

Figure 3.16: Comparison of TPP generation between referent and high CO2 tax scenario

- WPP generation follows the increase in WPP installed capacity, rising from 4.8 TWh in the 2025 referent scenario to 8.6 TWh in the 2025 high RES scenario. WPP production would reach 13.2 TWh in the 2030 referent scenario and 19.5 TWh in the 2030 high RES scenario.

- SPP generation follows the increase in SPP installed capacity, rising from 0.3 TWh in the 2025 referent scenario to 1.4 TWh in the 2025 high RES scenario. SPP production would reach 1.8 TWh in the 2030 referent scenario and 9.8 TWh in the 2030 high RES scenario.

- Total RES generation (wind plus solar) equals the same share of generation from TPPs in the 2030 referent scenario, when the installed RES capacity is projected to reach 8085 MW.

- Generation from other sources will remain at the same level (0.5 TWh) for all scenarios and years because there are no changes planned for this source of capacity.

- In the 2025 referent scenario, total generation will amount to 34.5 TWh. It will amount to 39 TWh in the high RES scenario. Most of this increase comes from an increase in RES installed capacities (predominantly wind). TPP generation decreases by 1 TWh.

- In the referent scenario, total generation will amount to 42.9 TWh, and in the high RES scenario, to 54.7 TWh. An increase in RES generation of 14.4 TWh (from 14.9 TWh to 29.3 TWh) will be partially offset by a decrease in TPPs of 2.6 TWh (from 16.5 TWh to 13.9 TWh).

Table 3.11: Installed capacities in EMS market area per fuel type

Installed capacities [MW]	2025	2030
TPP	4829	4829
HPP	3035	3055
Wind (RefRes/HighRES)	2461/4437	6750/10000
Solar (RefRes/HighRES)	208.8/1010	1335/7290
Other[10]	135	135

Table 3.12: Annual generation in EMS market area per fuel type – high CO2 scenario

Yearly generation (GWh)	**2025-RefRES**	**2025-HighRES**	**2030-RefRES**	**2030-HighRES**
HPP	10,251	10,794	10,919	10,947
TPP lignite	16,499	15,551	14,598	12,078
TPP gas	2,128	2,114	1,927	1,779
Other	539	539	539	539
Solar	282	1,365	1,804	9,849
Wind	4,798	8,651	13,161	19,497
TOTAL	**34,497**	**39,014**	**42,948**	**54,690**

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[10] These capacities refer to small HPPs, biogas, biomass, waste and other renewable technologies. Total capacity is based on data available at https://mre.gov.rs/sites/default/files/registri/registar_21.05.2021.html

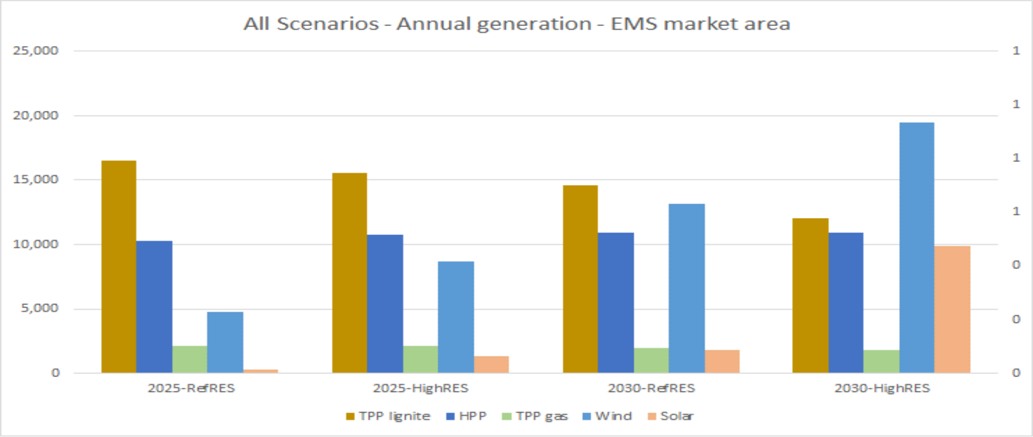


Figure 3.17: Generation mix for EMS market area – high CO2 scenario

Table 3.13 shows system operation indicators for the high CO2 tax scenario. The impact of RES capacities on the engagement of the PSP is similar to the impact in the referent CO2 scenario.

Total CO2 emissions range from 17.9 MTons in the 2025 referent scenario and 16.8 MTons in the 2025 high RES scenario to 15.8 MTons in the 2030 referent scenario and 13 MTons in the 2030 high RES scenario. This decrease results from the decline of lignite generation. In comparison with referent CO2 tax, CO2 emissions are reduced by half. When compared to the estimated CO2 emission based on 2020 data (23.1 MTon), the decrease in CO2 emissions can be almost 50% in the most ambitious case.

As a consequence of high RES penetration and a high CO2 tax (which drastically reduces TPP generation), the EMS market area net position will significantly change in comparison with the referent CO2 tax case. In the 2025 referent RES scenario, the EMS market area will be a net importer of electricity (-2.8 TWh), while in the high RES scenario the EMS market area will export around 1 TWh. Net exports will rise in the 2030 referent RES scenario to 3.8 TWh, and 15.4 TWh in the high RES scenario. This loss of exports in comparison to the referent CO2 tax scenario results from the decline in TPP generation (around 12- 15 TWh, depending on the analyzed year and RES scenario).

In both years, an increase in RES generation leads to a decrease in wholesale prices (Figure 3.18). In 2025 they will decrease from 74.3 €/MWh to 73.6 €/MWh, while in 2030 they will decrease from 69.2 €/MWh to 66.5 €/MWh.

Higher CO2 taxes cause market prices in the EMS market area to increase by approximately 24.4 €/MWh in 2025 and 19.2 €/MWh in 2030, which approaches and exceeds 40%, compared with the referent CO2 tax case (Figure 3.19).

When 17 GW of RES capacity is modelled in the EMS market area, spillages/curtailment amounts to 0.07 TWh because there are hours during the year in which all borders between the EMS market area and neighboring areas are congested.

Table 3.13: System operation indicators for EMS market area – high CO2 scenario

System operation indicators (GWh)	**2025-RefRES**	**2025-HighRES**	**2030-RefRES**	**2030-HighRES**
Load (GWh)	37,285	37,994	39,146	39,193
Generation (GWh)	34,497	39,014	42,948	54,690
CO2 emission (000t)	17,904	16,863	15,760	13,026
Spillage / curtailment (GWh)	0	0	0	71
Net Interchange (GWh)	-2,787	1,020	3,803	15,427
PRICES (EUR/MWh)	**74.3**	**73.6**	**69.2**	**66.5**

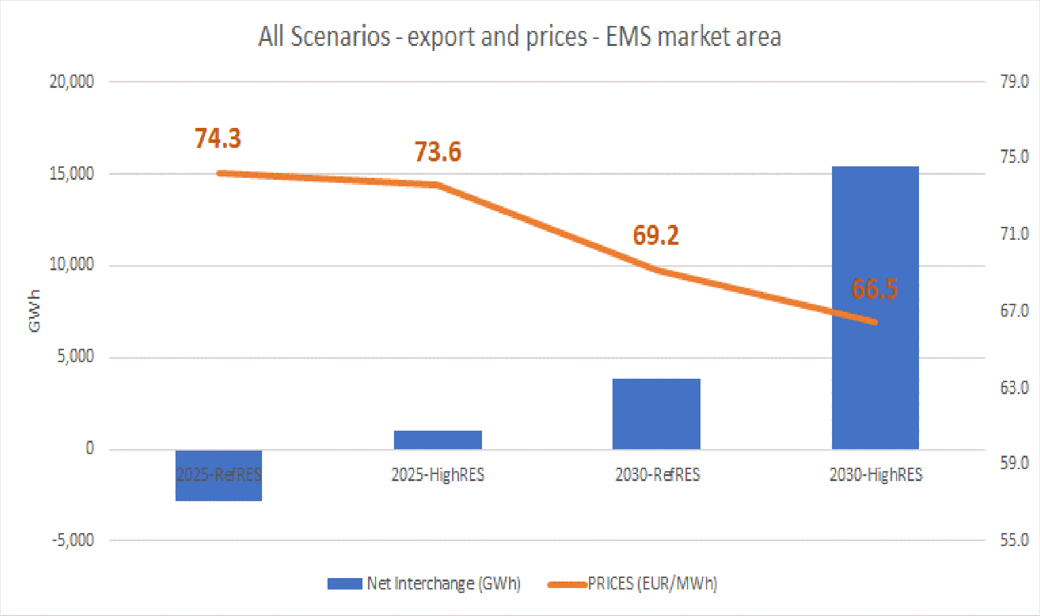


Figure 3.18: Annual prices and net export in EMS market area – high CO2 scenario

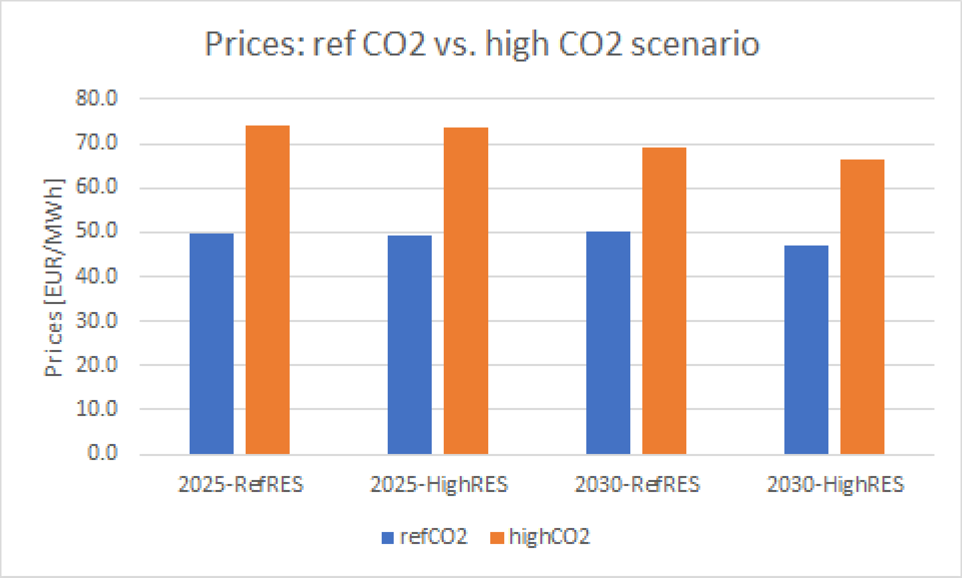


Figure 3.19: Comparison of prices in EMS market area between the referent and high CO2 tax scenarios

We present total net interchanges and congestion in the following figures, including congestion revenue in Table 3.14. In 2025, annual net interchanges are below 2 TWh and there are net exports and imports, while in 2030, net interchanges are higher in almost all directions. Similar to the referent CO2 case, the net interchange is the highest on the border with the Transelectrica market area. This energy is further exported to Ukraine and Moldova.

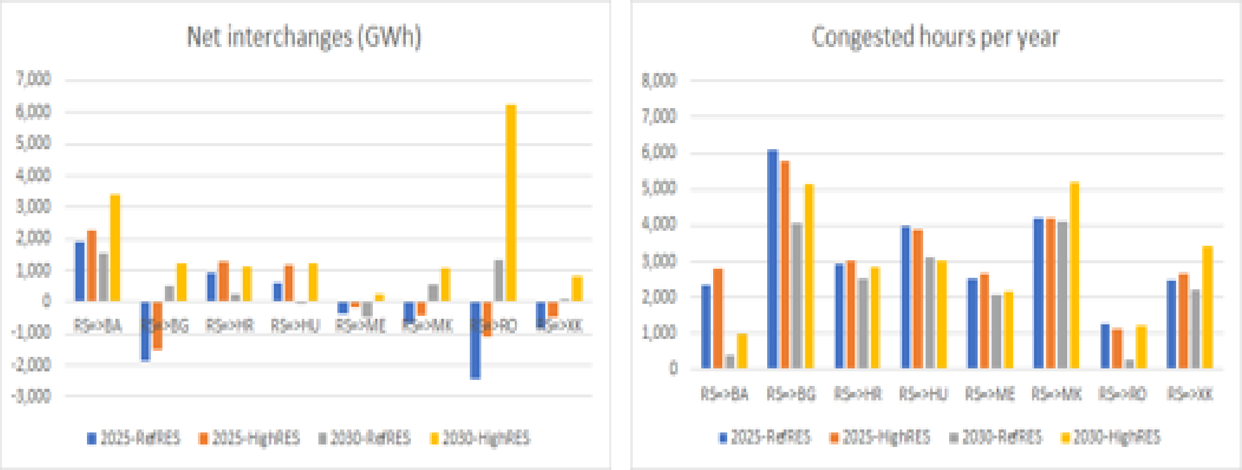


Figure 3.20: Annual net interchanges and congestions in the EMS market area – high CO2 scenario

Table 3.14: Congestion revenue for the EMS market area – high CO2 scenario

	2025-RefRES	2025-HighRES	2030-RefRES	2030-HighRES
Congestion revenue (MEUR/year)	**14.9**	**16.1**	**7**	**28.5**

In both years, congestion revenues increase with increases in RES capacities since all excess energy is exported over the interconnections modelled with constant seasonal capacity and since there is no significant decrease in wholesale prices. However, low congestion revenue in the 2030 refRES scenario is the consequence of not only low congestion but also smaller price differences between EMS and other market areas.

As an illustration of the hourly net interchanges of the EMS market area in the case of high CO2 prices, hourly net interchanges from the 2030 referent RES scenario are presented in Figure 3.21.

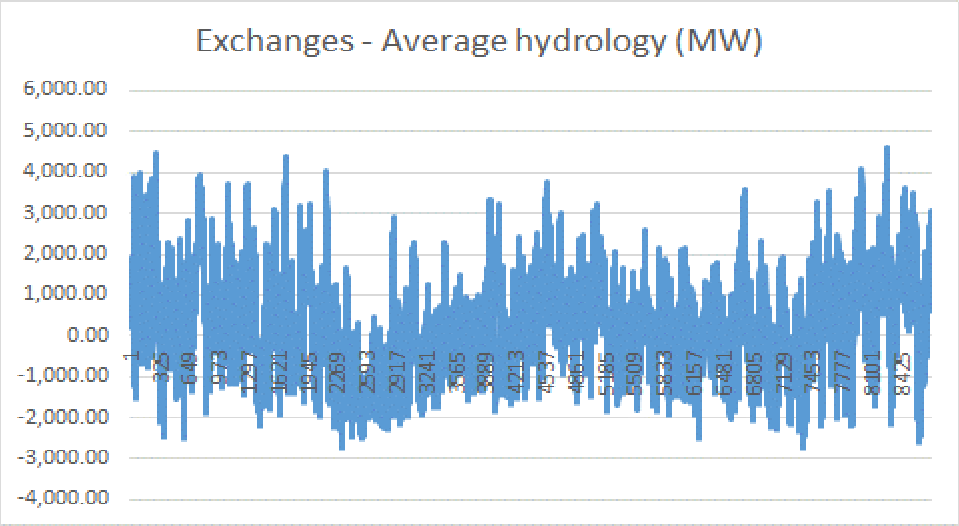


Figure 3.21: Net interchanges 2030 refRES scenario, high CO2 scenario

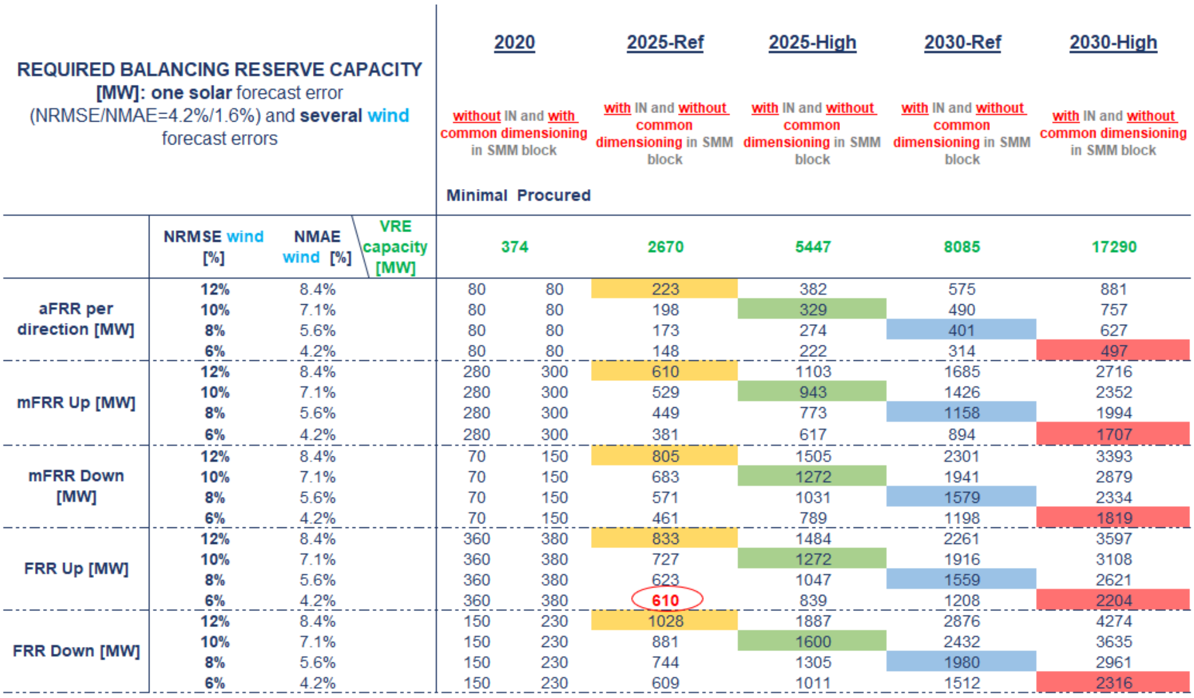
Similar to the referent CO2 tax scenario, exchanges generally come as exports, and are the highest in the winter, and lowest in spring and summer. However, the maximum exchange is lower, reaching only 4600 MW in the high CO2 tax scenario compared to 6031 MW in the referent CO2 case.

3.3.4 Provision of the balancing capacities

In addition to the technical and economic data for the EMS market area generation portfolio, we have taken into account information regarding the required levels of balancing reserve and generating units capable of providing it. The generation of the units providing balancing services is constrained by the reserve provision requirements.

In our market simulations, we applied different levels of the different types of reserves as determined in the balancing analyses presented in chapter 4. The required reserve capacities corresponding to the cases with imbalance netting (with IN) and without common dimension (without CD) were applied to simulate a more difficult and realistic case. These values are presented in Table 3.15 and they present the result of the reserve dimension process explained in details in chapter 4.

*Table 3.15: Required balancing reserve capacity in EMS control area with IN and **without** CD*

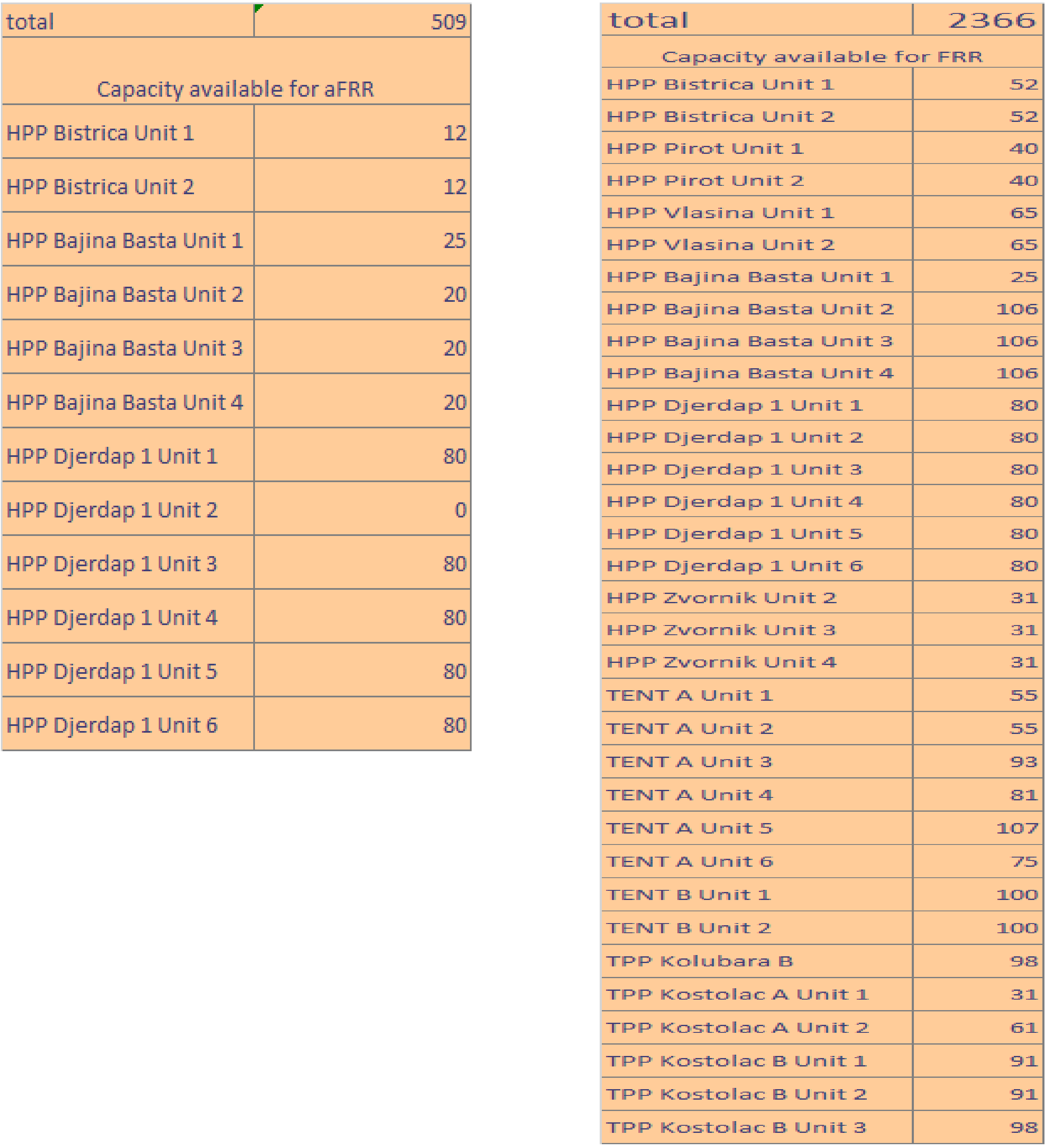


REQUIRED BALANCING RESERVE CAPACITY [MW]: one solar forecast error (NRMSE/NMAE=4.2%/1.6%) and **several** wind forecast errors			**2020**		**2025-Ref**	**2025-High**	**2030-Ref**	**2030-High**
			without IN and with common dimensioning in SMM block		with IN and without common dimensioning in SMM block	with IN and without common dimensioning in SMM block	with IN and without common dimensioning in SMM block	with IN and without common dimensioning in SMM block
			Minimal	Procured				
	NRMSE wind [%]	NMAE wind [%] \ VRE capacity [MW]	374		2670	5447	8085	17290
aFRR per direction [MW]	**12%**	8.4%	80	80	223	382	575	881
	10%	7.1%	80	80	198	329	490	757
	8%	5.6%	80	80	173	274	401	627
	6%	4.2%	80	80	148	222	314	497
mFRR Up [MW]	**12%**	8.4%	280	300	610	1103	1685	2716
	10%	7.1%	280	300	529	943	1426	2352
	8%	5.6%	280	300	449	773	1158	1994
	6%	4.2%	280	300	381	617	894	1707
mFRR Down [MW]	**12%**	8.4%	70	150	805	1505	2301	3393
	10%	7.1%	70	150	683	1272	1941	2879
	8%	5.6%	70	150	571	1031	1579	2334
	6%	4.2%	70	150	461	789	1198	1819
FRR Up [MW]	**12%**	8.4%	360	380	833	1484	2261	3597
	10%	7.1%	360	380	727	1272	1916	3108
	8%	5.6%	360	380	623	1047	1559	2621
	6%	4.2%	360	380	**610**	839	1208	2204
FRR Down [MW]	**12%**	8.4%	150	230	1028	1887	2876	4274
	10%	7.1%	150	230	881	1600	2432	3635
	8%	5.6%	150	230	744	1305	1980	2961
	6%	4.2%	150	230	609	1011	1512	2316

Generating units that participate in the provision of balancing services have been modelled with specific constraints depending on the type of balancing services the unit provides. For example, a group of hydropower plants were modelled with constraints related to the provision of aFRR at the level presented in Table 3.15. A group of hydro and thermal power plants were modelled with constraints related to the provision of mFRR. The PSP Bajina Basta was modelled as the plant that participates in the provision of all types of reserves.

The total capacity available for the provision of aFRR is presented in the following figure. The sum of the presented capacities are as follows:

- HPPs for aFRR: 509 MW + PSP Bajina Basta with 214 MW
- All for mFRR: 1857 MW + PSP Bajina Basta with 560/614 MW
- All for FRR: 2366 MW+ PSP Bajina Basta 560/614 MW



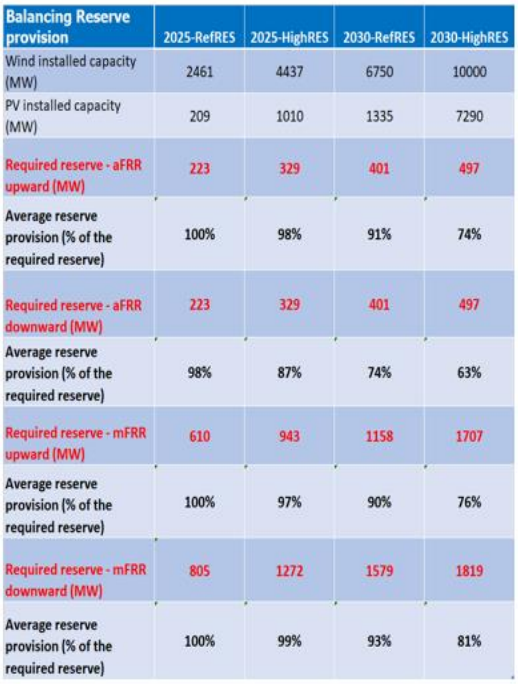
total	509
Capacity available for aFRR	
HPP Bistrica Unit 1	12
HPP Bistrica Unit 2	12
HPP Bajina Basta Unit 1	25
HPP Bajina Basta Unit 2	20
HPP Bajina Basta Unit 3	20
HPP Bajina Basta Unit 4	20
HPP Djerdap 1 Unit 1	80
HPP Djerdap 1 Unit 2	0
HPP Djerdap 1 Unit 3	80
HPP Djerdap 1 Unit 4	80
HPP Djerdap 1 Unit 5	80
HPP Djerdap 1 Unit 6	80

total	2366
Capacity available for FRR	
HPP Bistrica Unit 1	52
HPP Bistrica Unit 2	52
HPP Pirot Unit 1	40
HPP Pirot Unit 2	40
HPP Vlasina Unit 1	65
HPP Vlasina Unit 2	65
HPP Bajina Basta Unit 1	25
HPP Bajina Basta Unit 2	106
HPP Bajina Basta Unit 3	106
HPP Bajina Basta Unit 4	106
HPP Djerdap 1 Unit 1	80
HPP Djerdap 1 Unit 2	80
HPP Djerdap 1 Unit 3	80
HPP Djerdap 1 Unit 4	80
HPP Djerdap 1 Unit 5	80
HPP Djerdap 1 Unit 6	80
HPP Zvornik Unit 2	31
HPP Zvornik Unit 3	31
HPP Zvornik Unit 4	31
TENT A Unit 1	55
TENT A Unit 2	55
TENT A Unit 3	93
TENT A Unit 4	81
TENT A Unit 5	107
TENT A Unit 6	75
TENT B Unit 1	100
TENT B Unit 2	100
TPP Kolubara B	98
TPP Kostolac A Unit 1	31
TPP Kostolac A Unit 2	61
TPP Kostolac B Unit 1	91
TPP Kostolac B Unit 2	91
TPP Kostolac B Unit 3	98

Figure 3.22: Available capacities for different types of balancing reserve provision – EMS market area

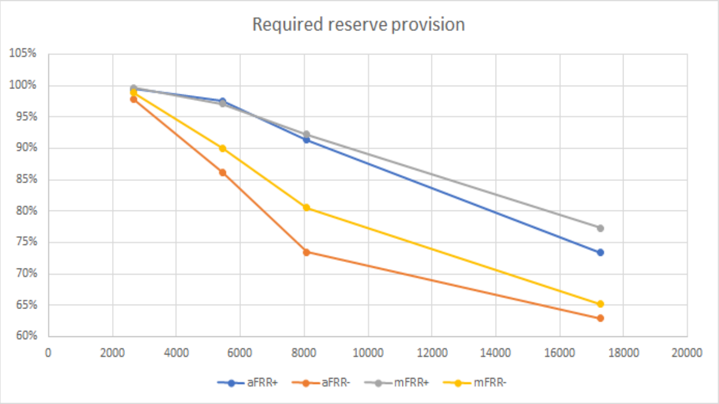
Although the market simulations attempted to satisfy the reserve requirements in each hour, the results show that in some hours during the year, the system is unable to provide the necessary reserves. The number of hours in which the reserve requirements are not satisfied increases with the level of RES and the level of required reserve capacities.

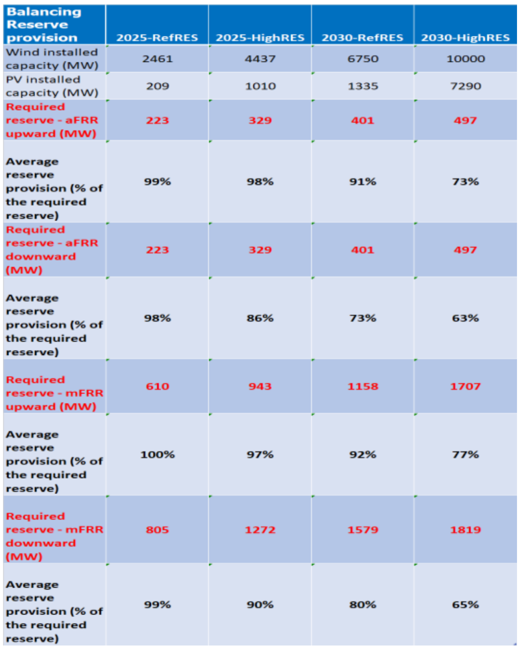
Figure 3.23 and Figure 3.24 demonstrate that the satisfaction of required reserves in the referent and high CO2 tax scenarios are similar but not satisfying at 100%. These results present the average values of provided reserves at the annual level calculated for nine Monte Carlo years.



Balancing Reserve provision	2025-RefRES	2025-HighRES	2030-RefRES	2030-HighRES
Wind installed capacity (MW)	2461	4437	6750	10000
PV installed capacity (MW)	209	1010	1335	7290
Required reserve - aFRR upward (MW)	223	329	401	497
Average reserve provision (% of the required reserve)	100%	98%	91%	74%
Required reserve - aFRR downward (MW)	223	329	401	497
Average reserve provision (% of the required reserve)	98%	87%	74%	63%
Required reserve - mFRR upward (MW)	610	943	1158	1707
Average reserve provision (% of the required reserve)	100%	97%	90%	76%
Required reserve - mFRR downward (MW)	805	1272	1579	1819
Average reserve provision (% of the required reserve)	100%	99%	93%	81%

Figure 3.23: Balancing reserves provision – EMS market area – referent CO2 case





Balancing Reserve provision	2025-RefRES	2025-HighRES	2030-RefRES	2030-HighRES
Wind installed capacity (MW)	2461	4437	6750	10000
PV installed capacity (MW)	209	1010	1335	7290
Required reserve - aFRR upward (MW)	223	329	401	497
Average reserve provision (% of the required reserve)	99%	98%	91%	73%
Required reserve - aFRR downward (MW)	223	329	401	497
Average reserve provision (% of the required reserve)	98%	86%	73%	63%
Required reserve - mFRR upward (MW)	610	943	1158	1707
Average reserve provision (% of the required reserve)	100%	97%	92%	77%
Required reserve - mFRR downward (MW)	805	1272	1579	1819
Average reserve provision (% of the required reserve)	99%	90%	80%	65%

Figure 3.24: Balancing reserves provision – EMS market area – high CO2 case

These results show that the provision of downward aFRR and mFRR is lower than upward reserve. This may be considered acceptable, since from technical perspective, the provision of this type of reserve is less important than upward reserve. In critical cases, the downward reserve can be satisfied through curtailment of RES generation. As a result, the provision of the upward reserve is more critical, since there is no easy solution if there is a lack of upward reserve.

Results for the provision of upward reserve presented in Figure 3.23 and Figure 3.24 show that required reserve can be provided for more than 90% of hours in a year for the installed capacities in wind and solar that are below 8,100 MW. In case of downward reserve this percentage is lower and reach 73% for the same 8,100 MW of RES capacity.

To provide a comprehensive reserve analysis, we analyzed the system capacity to provide hourly reserve in a wet hydrological case (sample 2 of nine Monte Carlo samples) because we considered it more critical from the perspective of upward reserve provision. The result of this analysis in the high CO2 case is presented in the following figure (Figure 3.25).

This shows that the increase of RES capacity reduces the time during which 100% of required reserves can be provided. The system's ability to provide downward reserves are lower than the ability to provide an upward reserve. An increase in RES capacities reduces the time with 100% reserve provision.

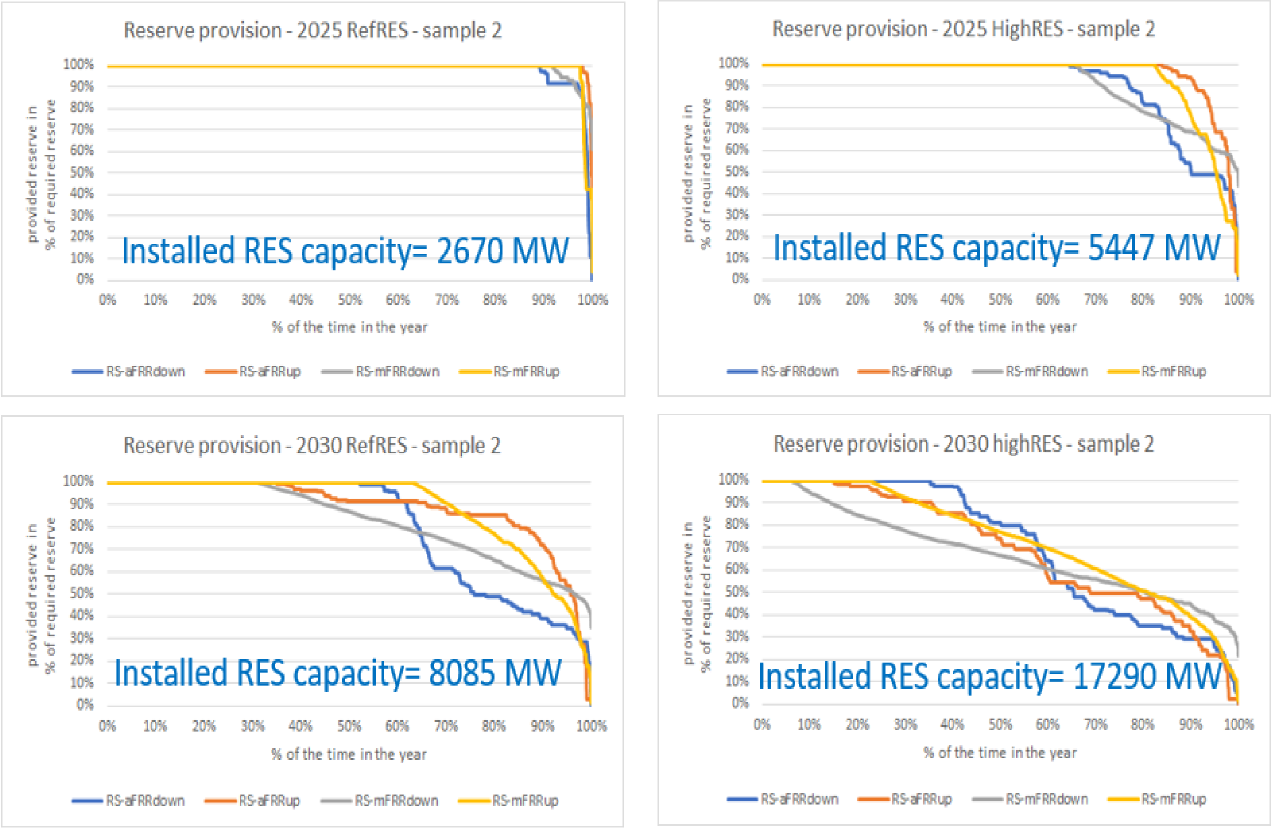


Figure 3.25: Provision of the reserve capacities for different levels of RES

We have used the results of these market simulations that respect the reserve requirements as the basis for the balancing energy calculations. In case of missing reserve capacities, we have assumed the import of balancing energy, as discussed in Chapter 4.2.

3.4 Summary of the impacts of RES integration on the wholesale market

Based on the results from the previous subchapters, we calculated the impact of RES capacity development on wholesale market operation:

The results were analyzed as a function of the four RES development scenarios: 2700 MW, 5400 MW, 8100 MW. The last scenario, where an ambitious 17,000 MW of installed RES capacity was modelled, should be understood as a theoretical exercise.

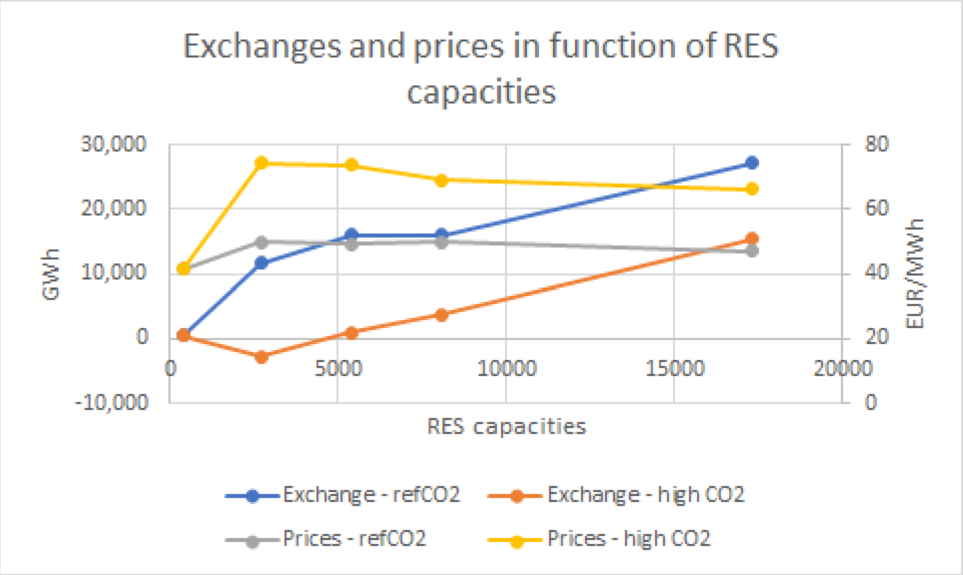


Figure 3.26: Exchanges and prices in EMS market area in function of RES capacities

The Figure 3.26 presents the level of exchanges and wholesale prices as a function of RES capacities. The first point corresponds to the exchanges and wholesale prices in 2020, when 374 MW of RES capacity was integrated into the system.

The main conclusions are:

- An increase in RES capacity increases exports from the SEE region as well as exports from the EMS market area

  More RES capacities lead to more exports from the EMS market area, but these exports are significantly different for the two different CO2 price levels. The starting point presents the data from 2020 when the EMS market area was almost balanced. It can be seen that more exports can be expected when TPP generation in the EMS market area is relatively cheap, and TPPs have a good market position (refCO2 case).

- An increase in RES capacity reduces wholesale market prices

More RES capacities provide more energy with zero wholesale cost, which reduces the wholesale market prices. The decrease in prices provoked by new 2.7 GW to 17 GW of RES capacities is not large – from 49.9 to 47.2 EUR/MWh, or 74.3 to 66.5 EUR/MWh - depending on the CO2 price. This can be compared with data from 2020, when the wholesale price in EMS market area was 41 EUR/MWh. Again, a substantially higher price difference is brought about by the CO2 price – an increase of 22 EUR/MWh on average.

- An increase in RES capacity decreases TPPs generation, although the capacity in TPPs in the period till 2030 increases. Still, the level of TPP generation differs in different CO2 price cases:
  - In the referent CO2 price case TPPs generation decreases from 33 TWh to 26 TWh
  - In the high CO2 price case, TPPs generation decreases from 18 TWh to 14 TWh

  In 2020, TPP generation in the EMS market area was 24 TWh. So, with lower CO2 prices, TPPs keeps their good market position and TPP generation rises to 33 TWh in 2030. Higher CO2 prices change this situation, and TPP generation does not reach the level from 2020.

- The increase in RES capacity decreases CO2 emissions:
  - In the referent CO2 case from 35 MTon to 26 MTon
  - In the high CO2 case from 17 MTon to 13 MTon

  CO2 emissions follows the change in TPPs generation, which is affected by both the level of RES generation and the level of CO2 tax.
- The impact of an increase in RES capacity on congestion revenue is not linear since changes in prices and in electricity exchanges with other market areas have different directions.

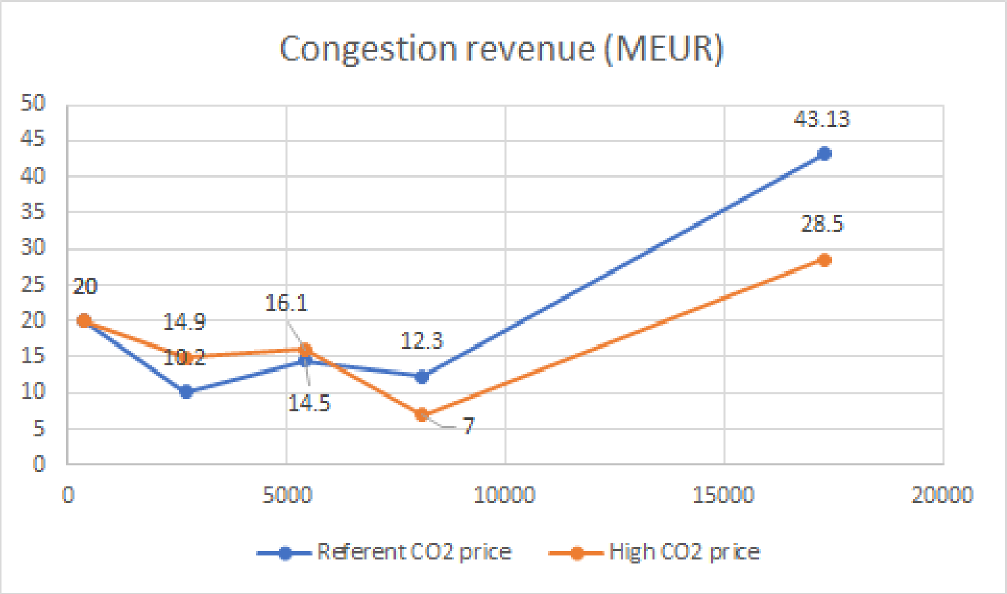


Figure 3.27: Congestion revenues in EMS market area in function of RES capacities

- Increased RES capacity provokes an increase in the required balancing reserves but also required balancing reserves cannot be satisfied in their full scope by the conventional generating units existing in 2025 and 2030.
  Figure 3.23 and Figure 3.24 demonstrate that the satisfaction of required reserves in the referent and high CO2 tax scenarios are similar but not satisfying at 100%. These results show that the provision of downward aFRR and mFRR is lower than upward reserve and this could be considered as acceptable, since, from technical perspective, provision of this type of reserve is less important than upward reserve.
  The following diagram (with downward reserve provision) shows that, in case of 2700MW of RES capacity, conventional units can provide required level of FRR in both CO2 cases. For higher RES capacities (>2700 MW), conventional units can better provide required level of reserve in case of refCO2 than high CO2 (since more TPPs are engaged in refCO2 case), but, in both CO2 cases, integration of more than 5,500 MW leads to the system operation in which conventional units cannot satisfy significant part of the required reserve levels (>90%).
  Further analyses with the addition of new sources of flexibility (batteries, PSP Bistrica, …) and the potential implementation of a capacity mechanism should be carried out with the aim to mitigate this situation.

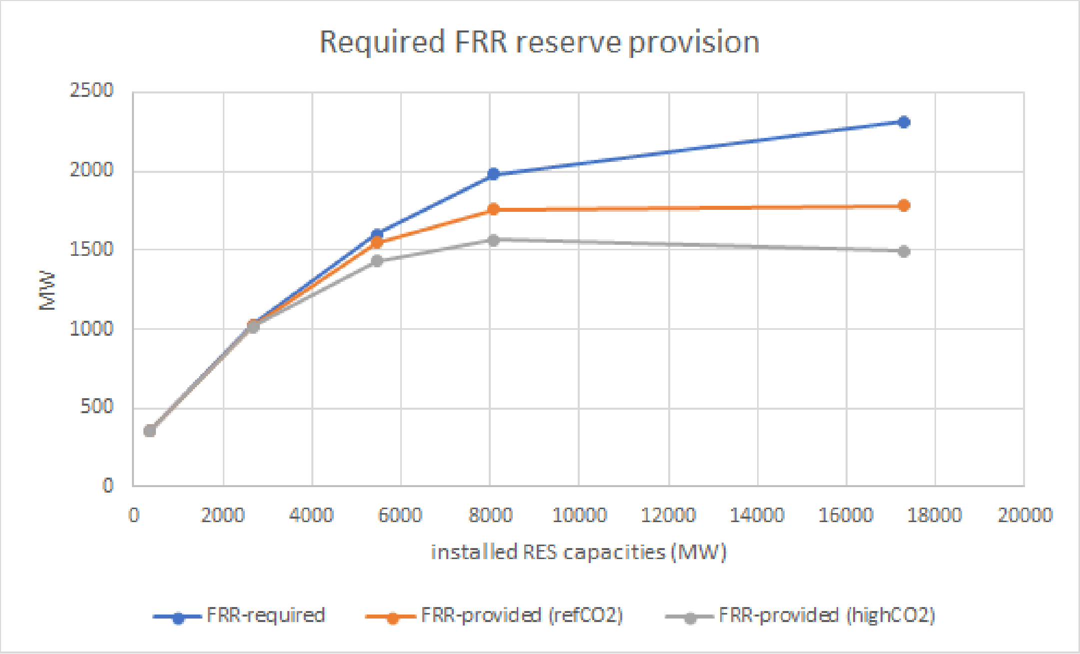


Figure 3.28: Required and provided FRR reserve provision (downward) in function of RES capacities

4 THE IMPACTS OF RES INTEGRATION ON POWER SYSTEM BALANCING

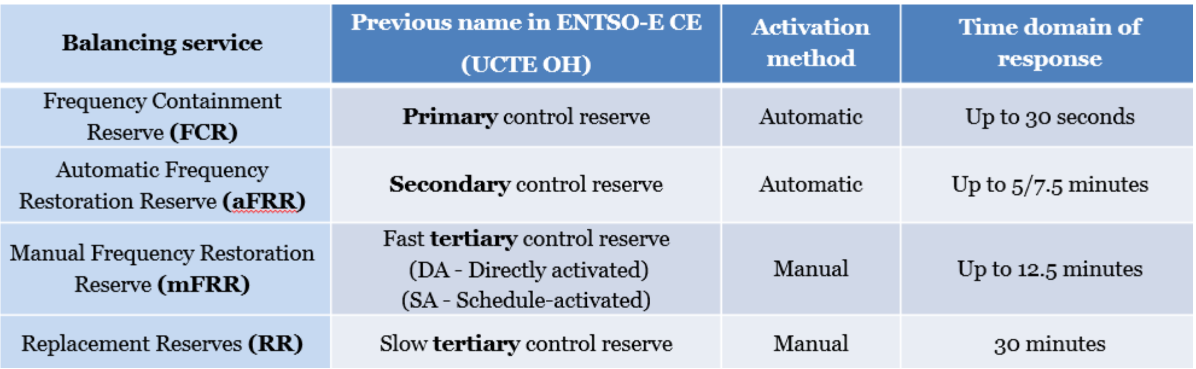
4.1 Balancing reserve dimensioning

4.1.1 Current status of aFRR and mFRR dimensioning in EMS control area

System imbalances can result from several issues, such as unexpected demand variations, unexpected variations of renewable generation (wind and solar), generation unit outages, particular network equipment outages, and unexpected variations of other non-RES sources (for example variation in TPP generation due to the lower quality of coal).

As the primary regulation reserve is defined deterministically on the level of a synchronous zone, this study is focused on setting up the methodology to determine the amounts of secondary (aFRR) and tertiary (mFRR) reserves in the EMS control area that would cover the system imbalances with higher shares of wind and solar generation planned for 2025 and 2030 in the Expected (Referent) and Ambitious (High) scenarios. This analysis determines whether the current levels of balancing reserves are sufficient and, if not, how much additional capacity is needed to ensure the secure and reliable operation of the system, taking regional cooperation into account.

Figure 4.1 shows the different types of balancing reserves required, and Figure 4.2 shows the reserve activation parameters for each type of balancing services.



Balancing service	**Previous name in ENTSO-E CE (UCTE OH)**	**Activation method**	**Time domain of response**
Frequency Containment Reserve **(FCR)**	**Primary** control reserve	Automatic	Up to 30 seconds
Automatic Frequency Restoration Reserve **(aFRR)**	**Secondary** control reserve	Automatic	Up to 5/7.5 minutes
Manual Frequency Restoration Reserve **(mFRR)**	Fast **tertiary** control reserve (DA - Directly activated) (SA - Schedule-activated)	Manual	Up to 12.5 minutes
Replacement Reserves **(RR)**	Slow **tertiary** control reserve	Manual	30 minutes

Figure 4.1: Types of balancing reserves

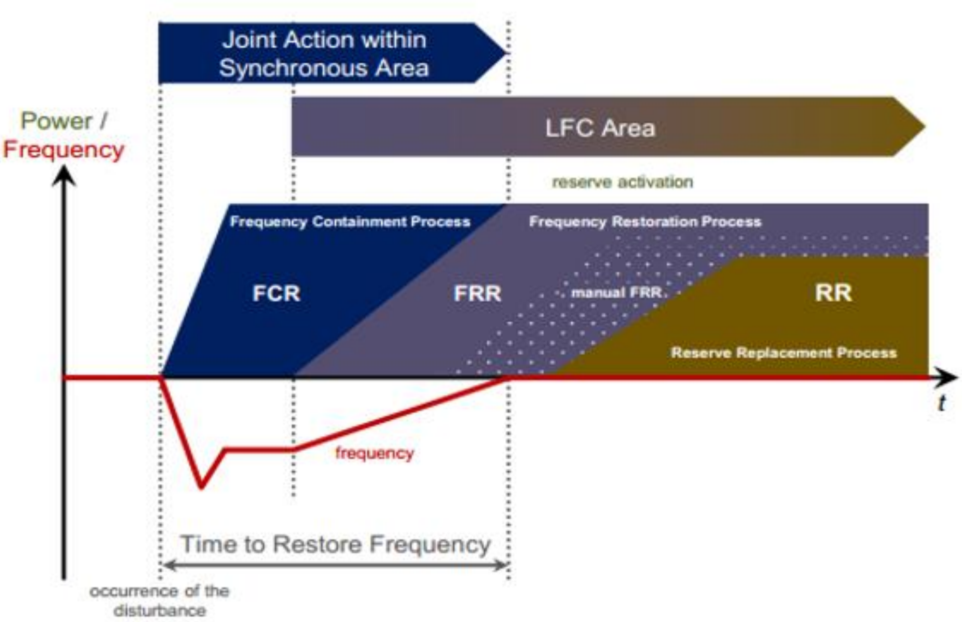


Figure 4.2: Reserve activation

According to the latest European regulatory framework, the total amount of aFRR and mFRR must cover 99% of the System Imbalance (15 min system error without activated regulation) recorded in the previous year, and cannot be lower than the power of the largest incident[11] in the system.

The currently established methodology for dimensioning FRR (secondary and tertiary reserve) in the EMS control area is in line with that approach. This implies the need for 600 MW in the upward direction, which is the capacity of the largest unit in the Serbian power system (TPP Nikola Tesla B), and in the downward direction, 300 MW as the outage of the largest load in the System.

Having in mind that the members of the SMM LFC block (EMS, CGES and MEPSO) apply FRR dimensioning rules for the SMM LFC block, as defined in their LFC block agreement, the positive dimensioning incident of the SMM LFC block amounts to the outage of the largest generating unit among these three systems (600 MW) and the negative one to the outage of the largest load (300 MW). The individual and common dimensioning of the reserves under the LFC Block are given in Figure 4.3, and the individual maximum FRR requirements for each LFC Area is in Table 4.1.

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[11] For upward direction, this incident is defined as outage of the largest unit in the system, while for downward direction this incident is defined as outage of the largest consumption in the system.

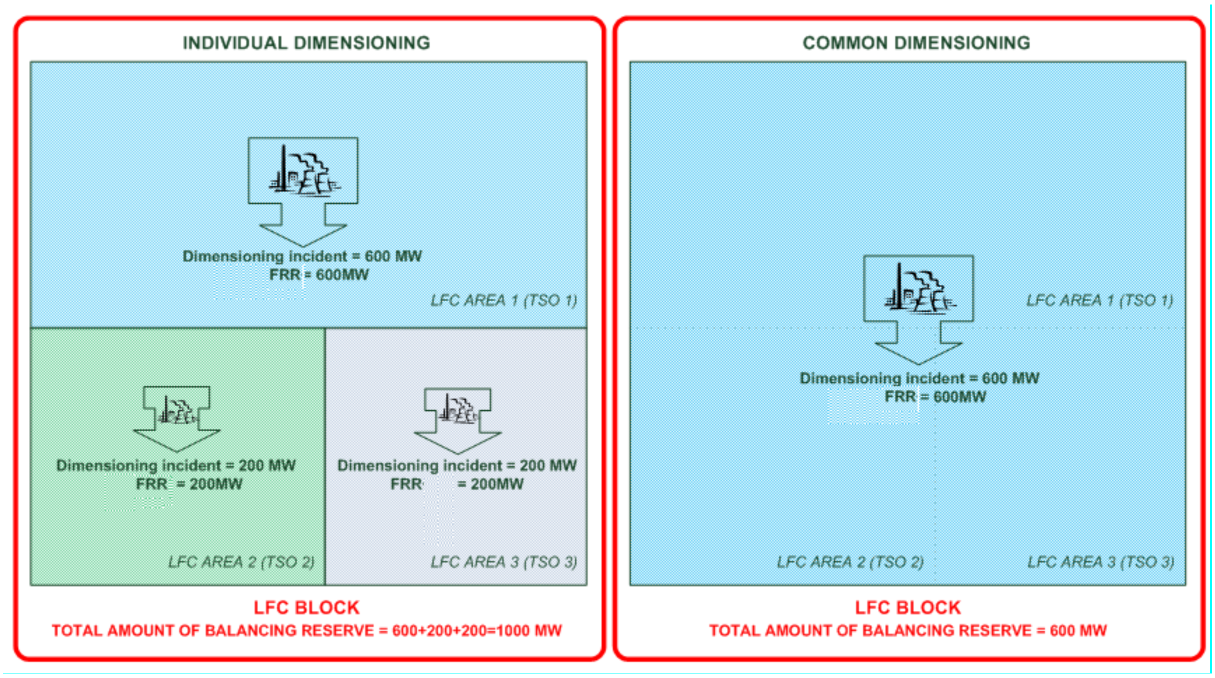

Figure 4.3: Concepts of individual and common dimensioning of the reserve under the LFC Block

Table 4.1: Individual Maximum FRR requirement per LFC Area

Individual Maximum FRR requirement per LFC Area	**EMS**	**MEPSO**	**CGES**
Generation unit [MW]	600	200	200
Load unit [MW]	300	100	200

Within the SMM LFC block, the members set the distribution of FRR among them proportionally for both directions (positive and negative), based on the loss of the largest generation unit i.e. load unit within individual LFC area, as follows:

Table 4.2: Minimum FRR share

Minimum FRR share	**EMS**	**MEPSO**	**CGES**	**Total**
Positive aFRR [MW]	360	120	120	600
Negative aFRR [MW]	150	50	100	300

In addition to the agreed shares related to FRR, the members agreed on the following Minimum requirements for aFRR distribution:

Table 4.3: Minimum aFRR share

Minimum aFRR share	**EMS**	**MEPSO**	**CGES**
Positive aFRR [MW]	80	40	20
Negative aFRR [MW]	80	40	20

When SMM LFC block members cover the Minimum requirement for aFRR, the requirements for mFRR are as follows:

Table 4.4: Minimum mFRR share

Minimum mFRR share	EMS	MEPSO	CGES
Positive mFRR [MW]	280	80	100
Negative mFRR [MW]	70	10	80

Currently, there is no reliable information on the impact of the probabilistic approach on reserve dimensioning in Montenegro and North Macedonia for 2025 and 2030, nor on their ability to provide higher levels of reserves in the future. After common dimensioning, the LFC block balancing reserve will be split among the participating TSOs, considering the cooperation within the SMM block.

Current participation ratios in the total reserve amount to:

- RS – 60% of total upward FRR, 50% of total downward FRR
- MK – 20% of total upward FRR, 17% of total downward FRR
- ME – 20% of total upward FRR, 33% of total downward FRR

Table 4.5: Contracted FRR capacity in the EMS control area for 2020

Contracted balancing reserve [MW]					
Month	2020				
	FCR	aFRR Up	aFRR down	mFRR up	mFRR down
January	±34	80	80	300	150
February	±34	80	80	300	150
March	±34	80	80	300	150
April	±34	80	80	300	150
May	±34	80	80	300	150
June	±34	80	80	300	150
July	±34	80	80	300	150
August	±34	80	80	300	150
September	±34	80	80	300	150
October	±34	80	80	300	150
November	±34	80	80	300	150
December	±34	80	80	300	150

Table 4.6 shows the reserve provision for each power plant in the EMS control area. All power plants participate in providing FCR, while only those with adequate technical characteristics (ramp rates) can provide aFRR – these are mainly hydro power plants and some thermal units such as units G3-G6 in TPP Nikola Tesla A.

Table 4.6: Power plants and reserve provision per type

Name	Location	Connection Node	Fuel	Number of units	Pmax [MW]	Pmin [MW]	Ramp Rate [MW/min]	FCR	aFRR	mFRR
HPP Djerdap 1	Kladovo	Djerdap 1 400 kV	Water	6	1140	0	10 (G3), 80 (G1-G2, G4-G6)	✓	✓	✓
HPP Djerdap 2	Kladovo	Djerdap 2 110 kV	Water	10	270	0	No data	✓		
HPP Bajina Basta	Bajina Basta	Bajina Basta 220 kV	Water	4	410	0	100	✓	✓	✓
RHPP Bajina Basta	Bajina Basta	Bajina Basta 220 kV	Water	2	614	0	160	✓	✓	✓
HPP Zvornik	Mali Zvornik	Mali Zvornik 110 kV	Water	4	125.6	0	31.45	✓		✓
HPP Bistrica	Nova Varoš	Knot Vardiste 220 kV	Water	2	104	0	25	✓	✓	✓
HPP Potpec	Pribojska Banja	Potpec 110 kV	Water	3	54	0	18	✓		✓
HPP Pirot	Pirot	Pirot 110 kV	Water	2	80	0	20	✓		✓
HPP Kokin Brod	Nova Varoš	Kokin Brod 110 kV	Water	2	22.5	0	6	✓		✓
HPP Uvac	Nova Varoš	Uvac 110 kV	Water	1	36	0	36	✓		✓
HPP Vrla 1	Surdulica	Vrla 1 110 kV	Water	4	51.4	0	2	✓		✓
HPP Vrla 2	Surdulica	Vrla 2 110 kV	Water	2	24	0	2	✓		✓
HPP Vrla 3	Surdulica	Vrla 3 110 kV	Water	2	29.37	0	2	✓		✓
HPP Vrla 4	Surdulica	Vrla 3 110 kV	Water	2	24.8	0	2	✓		✓
TPP Nikola Tesla A	Obrenovac	Obrenovac 220 kV	Lignite	6	1615	1135	2 (G1-G2) , 3 (G3-G6)	✓	✓ (G3-G6)	✓
TPP Nikola Tesla B	Obrenovac	Mladost 400 kV	Lignite	2	1220	1020	9	✓		✓
TPP Kostolac A	Kostolac	Kostolac A 110 kV	Lignite	2	280	203	4	✓		✓
TPP Kostolac B	Kostolac	Drmno 400 kV	Lignite	2	640	450	4	✓		✓
TPP Morava	Svilajnac	Morava 110 kV	Lignite	1	110	60	3	✓		✓
TPP Kolubara	Lazarevac	Kolubara 110 kV	Lignite	4	217	No data	3 (G1-G3) 4 (G5)	✓		✓
CHP Novi Sad	Novi Sad	Novi Sad 110 kV	Natural gas/mazut	2	208	120	1.5	✓		✓
CHP Zrenjanin	Zrenjanin	Zrenjanin 110 kV	Natural gas/mazut	1	70	45	3.6	✓		✓

4.1.2 The methodology applied for aFRR and mFRR dimensioning in the EMS control area with higher RES levels

The approach for reserve dimensioning applied in this study relies on a statistical method to determine the amount of balancing reserves required to integrate the projected level of RES development.

The method considers the historic imbalances of wind, solar, and demand, including planned integration of variable renewables (VRE[12]) in 2025 and 2030, described through the Expected

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[12] In the whole document VRE capacity (Variable Renewable Energy capacity) presents RES capacities that include only wind and solar capacities

(Referent) and Ambitious (High) scenarios. It also considers forced outages of generating units. The proposed methodology complies with the European System Operation Guidelines that authorizes the statistical approach for dimensioning upward and downward FRR.

As shown in Figure 4.4, the resulting imbalance of the system is forecasted by considering:

- Wind generation imbalance
- Solar generation imbalance
- Consumption imbalance
- Non-VRE generation imbalance:
    - Forced outage of units
    - Low quality of fuel

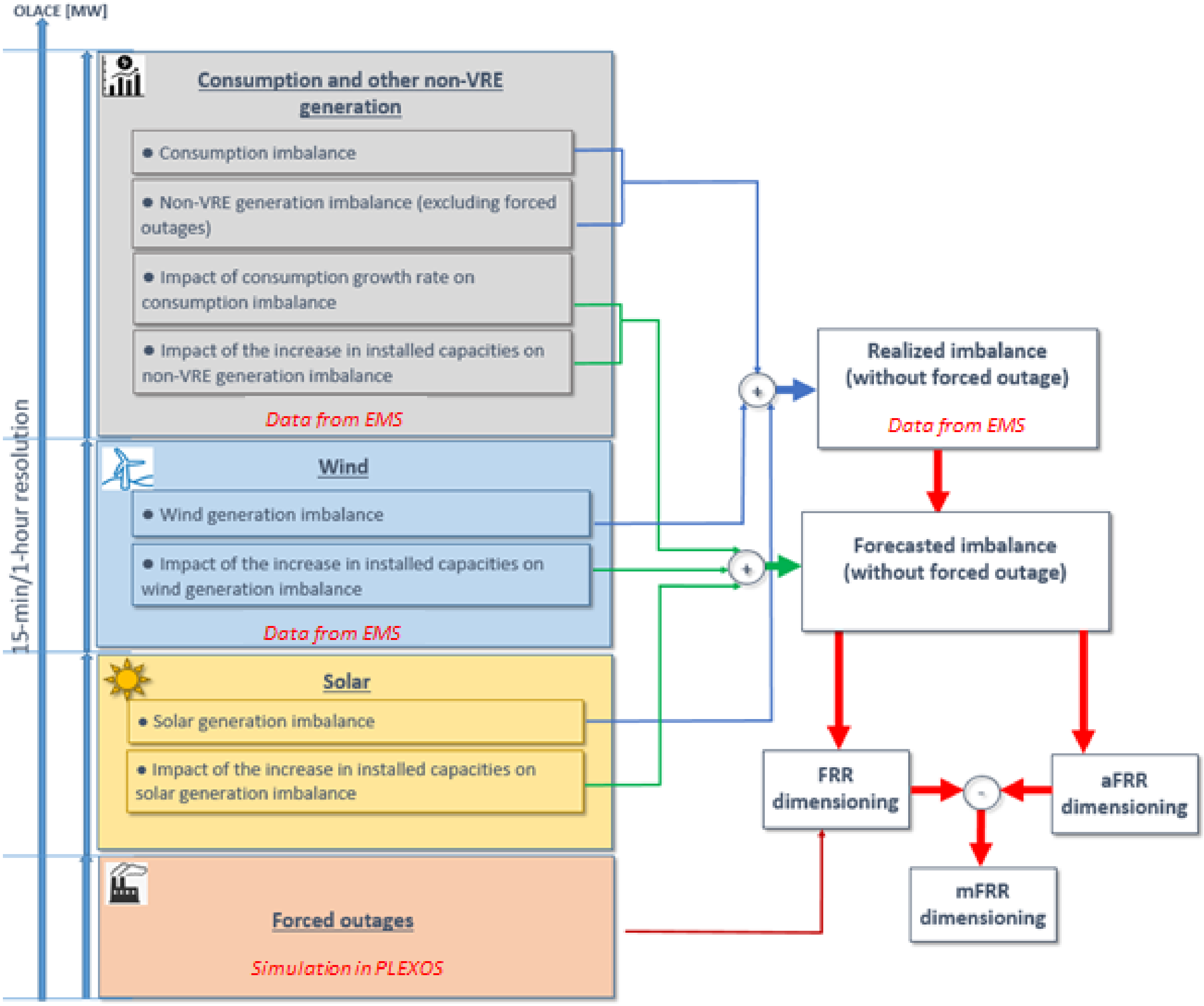

Figure 4.4: Methodology for dimensioning aFRR and mFRR capacity

The total amount of FRR dimensioning (aFRR+mFRR) considers the requirements of ENTSO-E System Operation Guidelines (SOGL), which defines the minimum value for FRR as a combination of deterministic and probabilistic assessments.

In the deterministic approach, FRR should not be smaller than the Dimensioning Incident separately for the positive and negative direction. The requirement for upward FRR capacity is determined by the size of the largest generation unit, while downward FRR is equal to the largest load in the system.

On the other hand, a probabilistic assessment requires FRR capacity, both positive and negative, to be sufficient to cover 99% of the imbalances based on the historical record (at least one full year).

The higher value obtained from the deterministic and probabilistic assessments is accepted as the required level of FRR reserve (Figure 4.4).

The dimensioning of symmetric aFRR is based on the level of variable RES integration, forecasted 15 min/hourly[13] wind and solar generation imbalance and imbalances in consumption and non-VRE generation. It does not consider the forced outages of generation units. According to the best European practice (Belgian and German TSOs), the symmetric aFRR should cover around 79% of such imbalances, which has been assumed for this analysis as well.

Upward mFRR is determined as the difference between previously described upward FRR and aFRR, while for downward mFRR it is the difference between downward FRR and aFRR.

We based the forecast of the wind generation imbalance in the target years and scenarios on the historic error (normalized historic imbalance shape) for the wind generation portfolio in Serbia, and the expected wind levels in the target years and scenarios (Table 2.1). The calculated 15-minute wind deviations are based on hourly wind deviations transformed into a 15-minute forecast for the day ahead and the realization with a 15-minute resolution.

In this way, the day-ahead wind forecast error of 11.9% is obtained for the EMS control area. The Normalized Root Mean Square Error (NRMSE) of wind depends on several factors including the quality of the forecast, the stochastics of the wind at a certain location, the level of the netting effect, i.e., the location of wind farms, whether they are grouped only in one zone of the country within the same or a similar microclimate or are distributed throughout the country (To account for these factors, we performed a sensitivity analysis with lower levels of wind forecast errors (NRMSE).

Because there is little solar generation in Serbia at the moment, we lack information on the solar generation imbalances. To cope with this issue, we used relevant data from neighbouring countries similar to Serbia in terms of terrain, geographical longitude and latitude.

We generated the solar generation imbalance for the target years based on the normalized historic imbalance shape with a 15-minute resolution for one of the neighbouring countries and fitted according to the expected level of forecast error from the literature/relevant sources.

We derived the generating units’ forced outages from the Monte Carlo simulation performed in the PLEXOS software tool.

We measure the impact of variable RES integration on balancing reserve for all of the scenarios by comparing the:

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[13] Since EMS provided data related to wind forecast with both (15min and hourly) time resolutions, reserve dimension will take them both into account.

- Expected RES development scenario (Reference scenario) versus the current status
- Ambitious RES development scenario (High scenario) versus the current status

We quantified the related increase of balancing costs due to the higher reserve procurement using the most recent balancing reserve prices in Serbia (2021), i.e., 12.97 EUR/MW for aFRR capacity and 4.08 EUR/MW for mFRR capacity in the upward direction. Currently, the downward reserve in Serbia is not remunerated.

4.1.3 Balancing reserves dimensioning results

For balancing reserve dimensioning based on statistical modelling which includes regression analyses, a general way of measuring the deviation of the realized value from the predicted value is the RMSE (Root Mean Square Error), given by the following formula:

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n}(y_i - \hat{y})^2}{n}}$$

Where:

- ŷ is the predicted value
- y is realization
- n represents the total number of the observed intervals

If the predicted values are very close to the realized ones, the RMSE is small. A case with zero value would indicate a perfect prediction. On the other hand, if the predicted and realized values differ substantially – not for all intervals but at least for some - the RMSE will be significant. It requires only several intervals with very high differences between the prediction and realization to result in higher RMSE and high reserve requirements.

The Normalized RMSE (NRMSE) in terms of wind and solar is independent of the installed capacity and therefore is applicable for determining imbalances for future years and scenarios.

Within this Study, balancing reserve dimensioning is performed for one solar forecast error obtained for the normalized historic imbalance shape with a 15-minutes resolution of a European country with a similar climate and geography (NRMSE of 4.2%). For wind, balancing reserve dimensioning is performed using four different wind forecast errors (NRMSE of 12%, 10%, 8% and 6%), having in mind that installed wind capacity is more dominant in the RES generation portfolio in the EMS control area and its forecast errors will have a greater impact on imbalances and reserve dimensioning.

The necessary FRR, aFRR and mFRR capacities per direction, target year and scenario are provided as a function of different wind NRMSE values ranging from 12% to 6%. In addition to the NRMSE, there is also the NMAE, an additional measure to describe uniformly distributed errors, frequently used in variable renewable energy (VRE) integration-related studies.

Wind power forecasting literature reports an NRMSE of around 8-12% (NMAE of around 6-10%) for the day-ahead production. For solar power forecasting (SPF), the NRMSE is around 4.3-4.9% for the day ahead. Sensitivity analyses for the balancing reserve dimensioning are consistent with these ranges. [9]

Two matrices are provided in the Report – one without common dimensioning (Table 4.8) and the other with common dimensioning (CD) in the SMM LFC block (Table 4.9). Common dimensioning decreases the total FRR upward/downward capacity required but has no impact on aFRR. On the other hand, the imbalance netting mechanism decreases aFRR requirements, without any impact on FRR dimensioning. Both matrices consider the imbalance netting mechanism applied to all target years and scenarios.

Table 4.7: The impact of imbalance netting and common dimensioning on balancing reserves

	FRR	aFRR	mFRR
Imbalance netting (IN)	×	↓	↑
Common dimensioning (CD)	↓	×	↓

This analysis focuses on the reserve values corresponding to one NRMSE for wind per year and scenario. We assume that beginning with the Reference scenario in 2025 and ending with the High scenario in 2030, the NRMSE for wind will gradually decrease with more accurate forecasting and higher netting effect. For this reason, we dimensioned the reserves by decreasing NRMSE as follows:

- Reference scenario in 2025 – NRMSE for wind is 12% (marked in yellow)
- High scenario in 2025 - NRMSE for wind is 10% (marked in green)
- Reference scenario in 2030 - NRMSE for wind is 8% (marked in blue)
- High scenario in 2030 - NRMSE for wind is 6% (marked in red)

We selected the maximum FRR value (per direction) obtained from the probabilistic and deterministic approaches for the FRR upward/downward requirement. The aFRR requirement is calculated as the value covering 79% of the positive and negative 15-minutes imbalances within a single year, excluding forced outages of generating units. For this analysis, we used the 15-minutes imbalances from the year 2020. We present the results in the following diagrams.

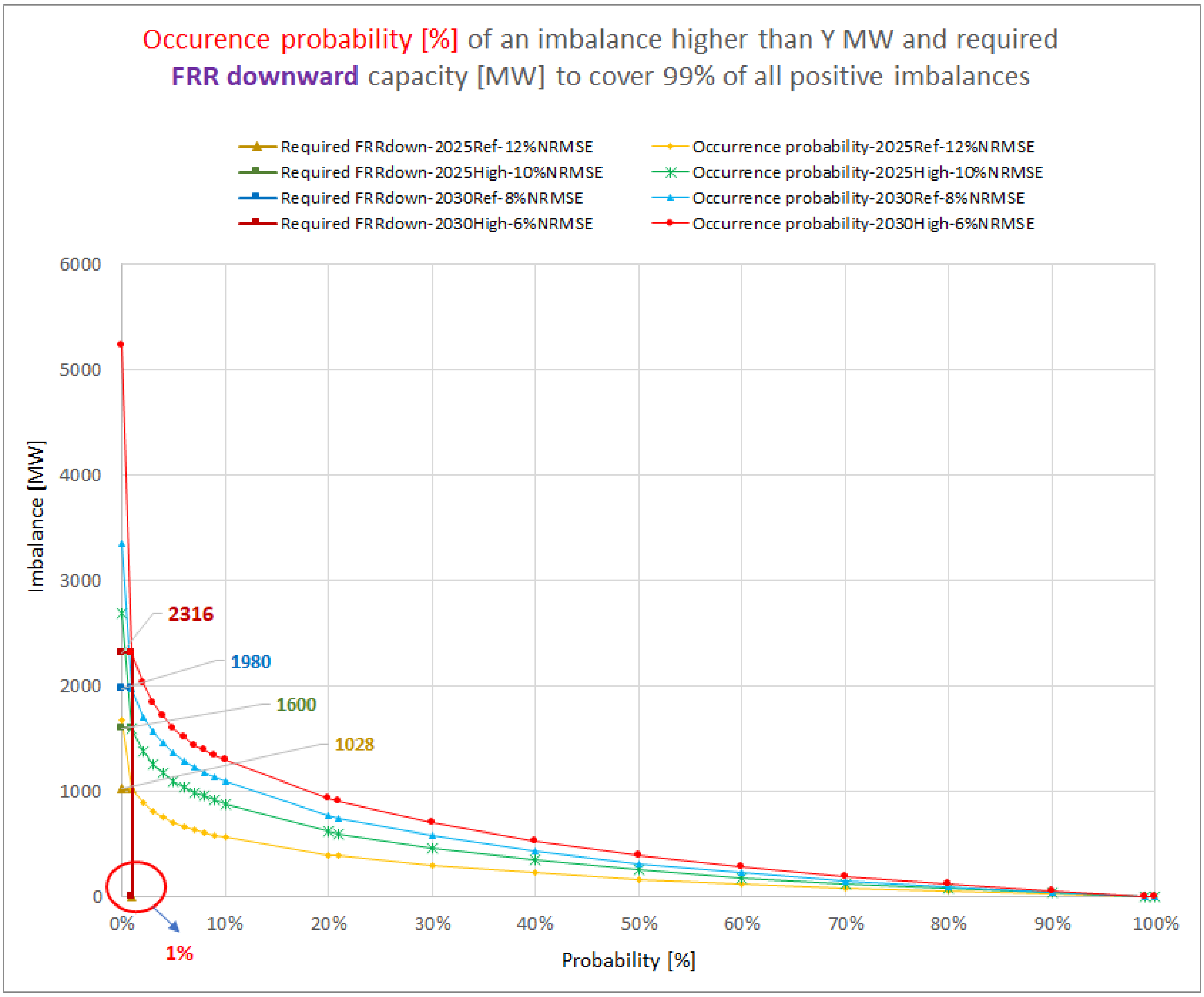


Figure 4.5: The occurrence probability of positive imbalances and required FRR downward capacity

Figure 4.5 provides the results of using the probabilistic methodology for downward FRR dimensioning. It shows the probability of all positive imbalances throughout a year for each scenario and the selected wind NRMSE. It also provides the related required downward capacity. The figure demonstrates that 99% of the projected imbalances will be covered if indicated level of balancing reserve is kept.

Using the common dimensioning approach in the SMM, the values are even lower to:

- 2050 MW in the High scenario in 2030, with NRMSE for wind of 6%, instead of 2316 MW
- 1719 MW in the Reference scenario in 2030, with NRMSE for wind of 8%, instead of 1980 MW
- 1348 MW in the High scenario in 2025, with NRMSE for wind of 10%, instead of 1600 MW
- 796 MW in the Reference scenario in 2025, with NRMSE for wind of 12%, instead of 1028 MW

Common dimensioning in the SMM block reduces the level of required downward FRR capacity by 250 MW.

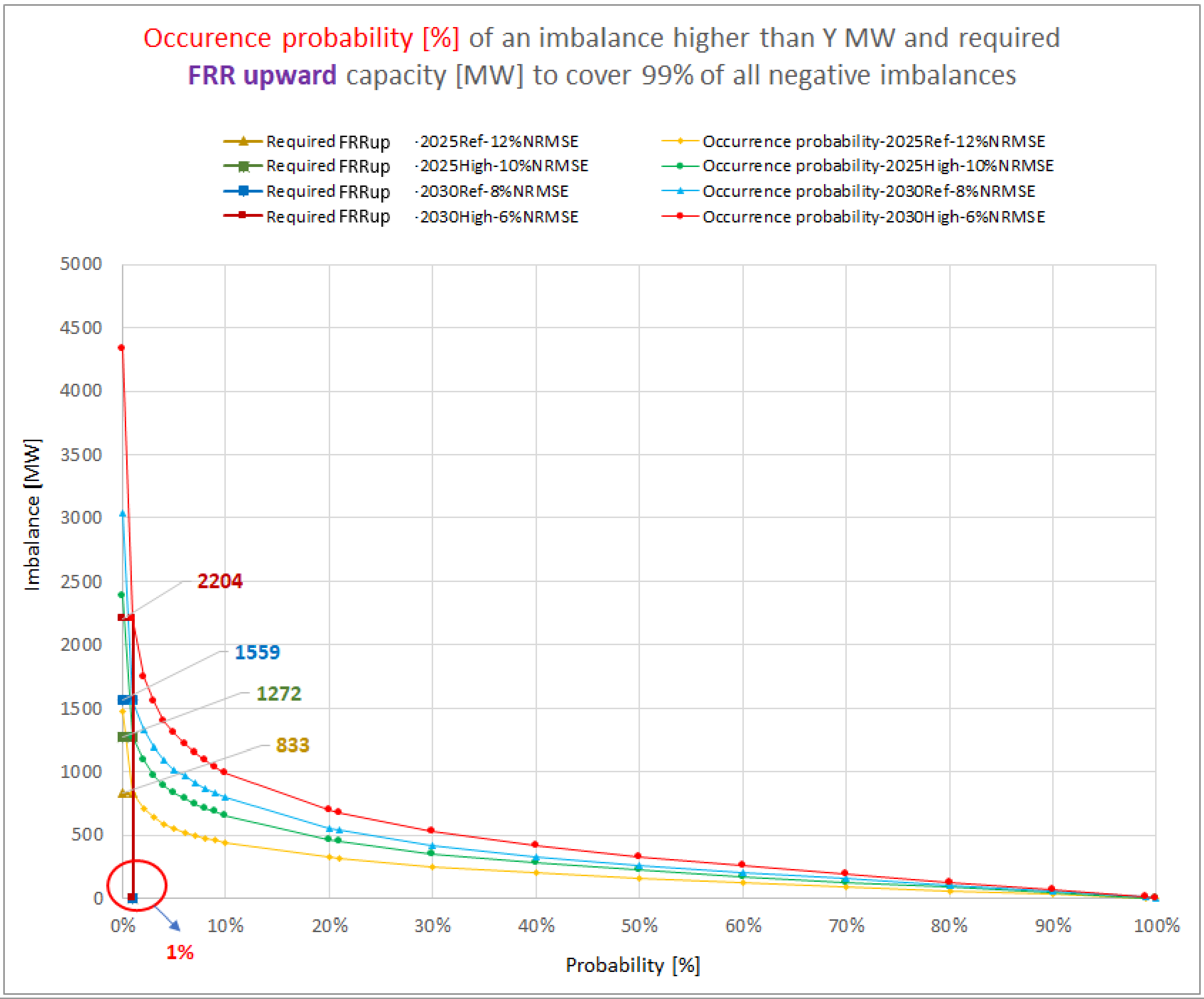


Figure 4.6: The occurrence probability of negative imbalances and required FRR upward capacity

Figure 4.6 illustrates the results obtained using a probabilistic methodology to calculate upward FRR dimensioning. It shows the probability of all negative imbalances throughout a year for each scenario and selected NRMSE for wind. It also shows the related upward capacity requirements. This figure demonstrates 99% of imbalances will be covered if indicated level of balancing reserve is kept.

With common dimensioning in SMM block these values are as follows:

- 1866 MW in the High scenario in 2030, with NRMSE for wind of 6%, instead of 2204 MW
- 1240 MW in the Reference scenario in 2030, with NRMSE for wind of 8%, instead of 1559 MW
- 968 MW in the High scenario in 2025, with NRMSE for wind of 10% instead of 1272 MW
- 563 MW in the Reference scenario in 2025, with NRMSE for wind of 12%, instead of 833 MW

On average, common dimensioning in the SMM block reduces the level of required upward FRR capacity by 308 MW.

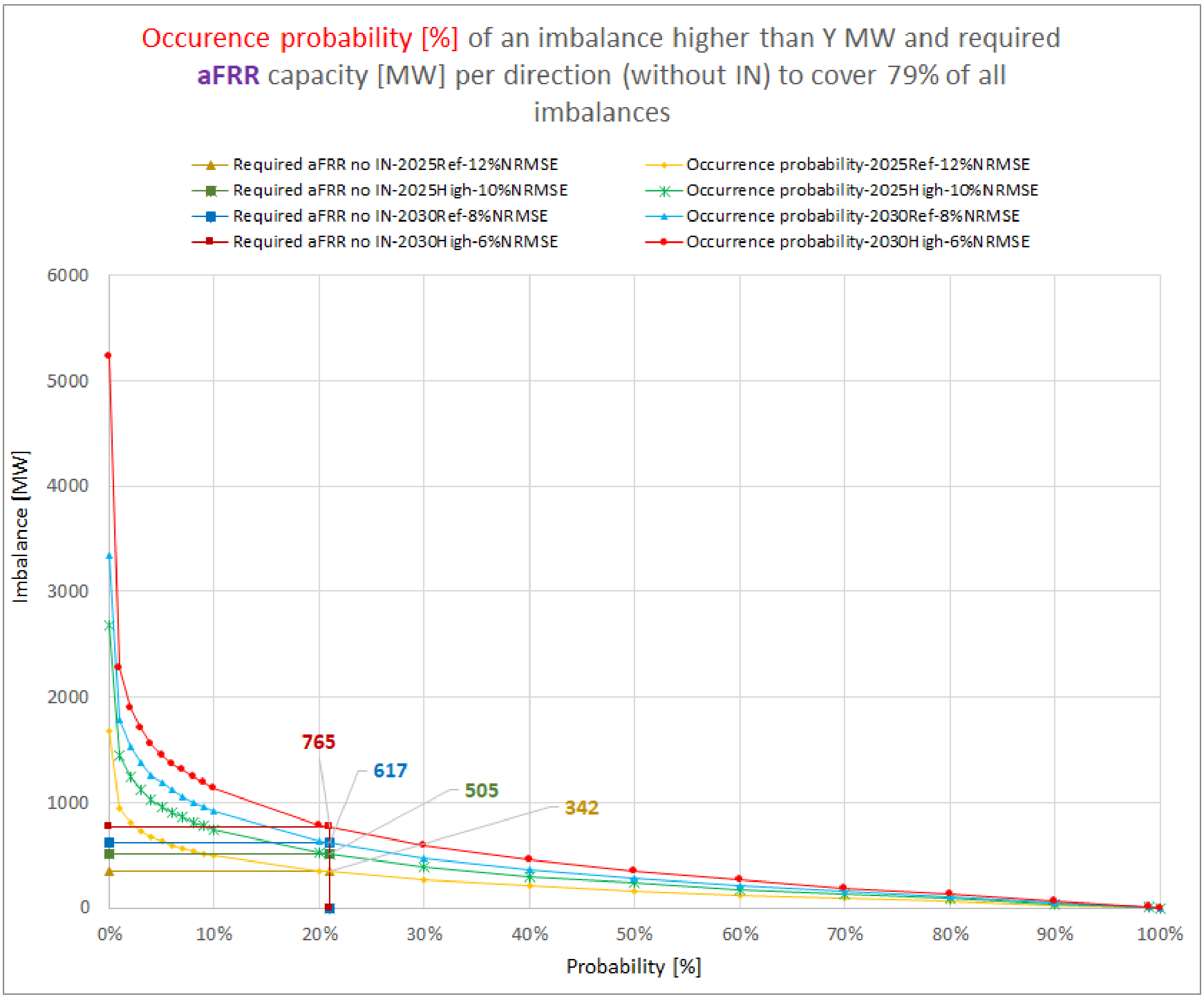


Figure 4.7: The occurrence probability of all imbalances and required aFRR capacity per direction without IN

Figure 4.7 represents aFRR requirements per direction and the occurrence probability of all imbalances (excluding forced outages of generating units) throughout a year depending on the scenario and related NRMSE for wind. The values given in the diagram correspond to the required aFRR capacity per direction which can cover 79% of all presented imbalances when imbalance netting is not applied.

Figure 4.8 shows the probability of all imbalances (excluding forced outages of generating units) throughout a year with previously applied imbalance netting, and the required aFRR capacity per direction. The level of imbalance netting within IGCC cooperation is assumed to be 35%.

Comparing these figures reveals that the aFRR is reduced through imbalance netting:

- From 765 MW to 497 MW in the High scenario in 2030, with NRMSE for wind of 6%
- From 617 MW to 401 MW in the Reference scenario in 2030. with NRMSE for wind of 8%
- From 505 MW to 329 MW in the High scenario in 2025, with NRMSE for wind of 10%
- From 342 MW to 223 MW in the Reference scenario in 2025, with NRMSE for wind of 12%

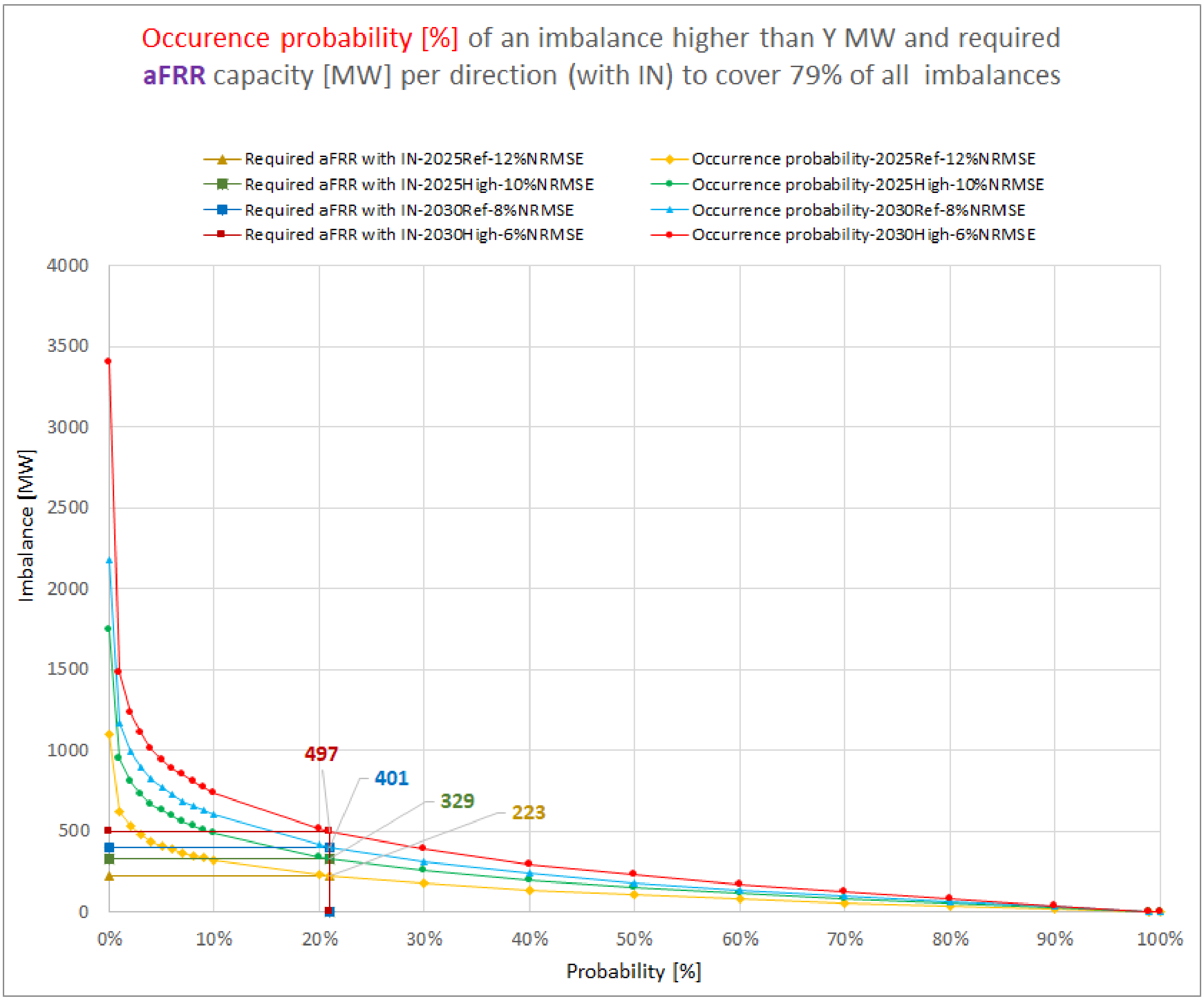
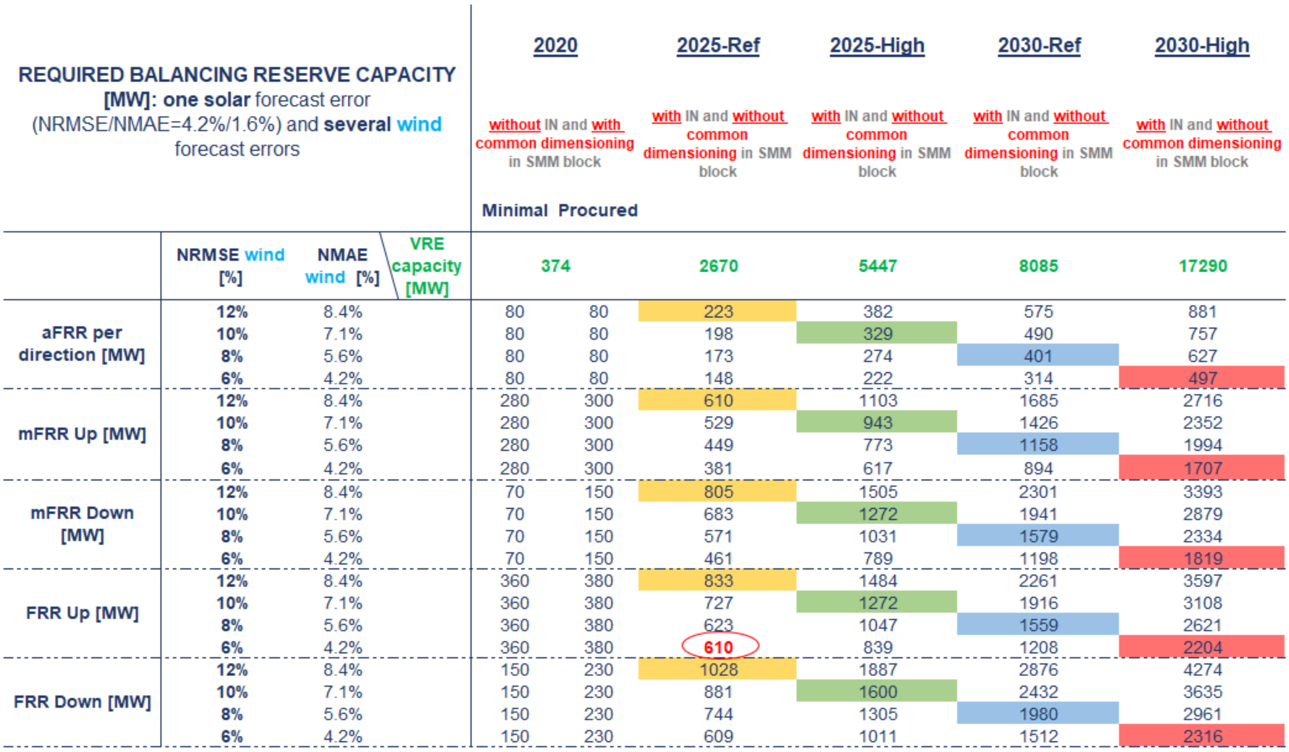


Figure 4.8: The occurrence probability of all imbalances and required aFRR capacity per direction with IN

The summary of the approach applied above is provided in the following tables.

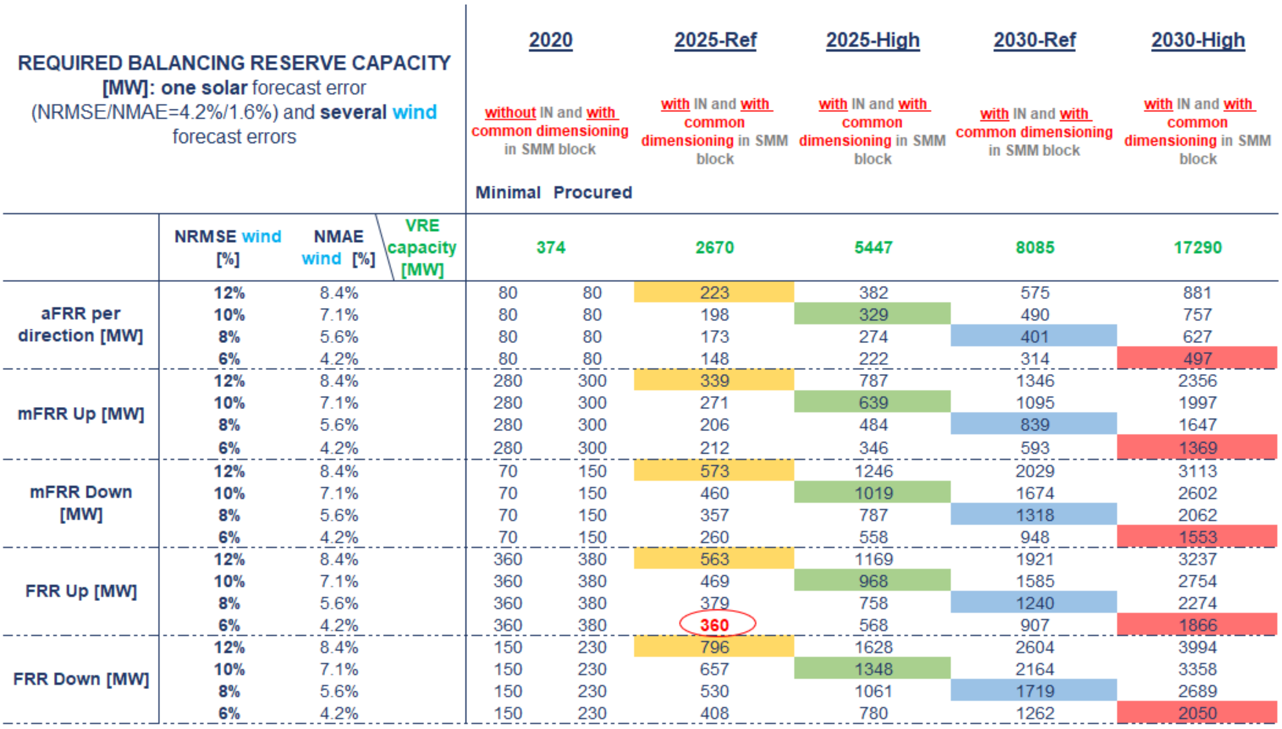
Table 4.8: Required balancing reserve capacity in EMS control area with IN and ***without*** *CD*



REQUIRED BALANCING RESERVE CAPACITY [MW]: one solar forecast error (NRMSE/NMAE=4.2%/1.6%) and **several wind** forecast errors			**2020**		**2025-Ref**	**2025-High**	**2030-Ref**	**2030-High**
			without IN and with common dimensioning in SMM block		with IN and without common dimensioning in SMM block	with IN and without common dimensioning in SMM block	with IN and without common dimensioning in SMM block	with IN and without common dimensioning in SMM block
			Minimal	**Procured**				
	NRMSE wind [%]	**NMAE wind [%]** / **VRE capacity [MW]**	**374**		**2670**	**5447**	**8085**	**17290**
aFRR per direction [MW]	**12%**	8.4%	80	80	223	382	575	881
	10%	7.1%	80	80	198	329	490	757
	8%	5.6%	80	80	173	274	401	627
	6%	4.2%	80	80	148	222	314	497
mFRR Up [MW]	**12%**	8.4%	280	300	610	1103	1685	2716
	10%	7.1%	280	300	529	943	1426	2352
	8%	5.6%	280	300	449	773	1158	1994
	6%	4.2%	280	300	381	617	894	1707
mFRR Down [MW]	**12%**	8.4%	70	150	805	1505	2301	3393
	10%	7.1%	70	150	683	1272	1941	2879
	8%	5.6%	70	150	571	1031	1579	2334
	6%	4.2%	70	150	461	789	1198	1819
FRR Up [MW]	**12%**	8.4%	360	380	833	1484	2261	3597
	10%	7.1%	360	380	727	1272	1916	3108
	8%	5.6%	360	380	623	1047	1559	2621
	6%	4.2%	360	380	**610**	839	1208	2204
FRR Down [MW]	**12%**	8.4%	150	230	1028	1887	2876	4274
	10%	7.1%	150	230	881	1600	2432	3635
	8%	5.6%	150	230	744	1305	1980	2961
	6%	4.2%	150	230	609	1011	1512	2316

In almost all cases when the FRR capacity (without common dimensioning presented in Table 4.8) is determined by probabilistic analysis, the requirements are higher compared with those obtained from a deterministic approach. The exception is the case with NRMSE for the wind of 6% in the 2025 Reference scenario. Here, tripping of the largest generating unit (610 MW) in the EMS control area is a worse dimensioning incident in comparison to 99% of all negative imbalances driven primarily by wind (529 MW).

Table 4.9: Required balancing reserve capacity in EMS control with IN and with CD



REQUIRED BALANCING RESERVE CAPACITY [MW]: one solar forecast error (NRMSE/NMAE=4.2%/1.6%) and **several wind** forecast errors			**2020**		**2025-Ref**	**2025-High**	**2030-Ref**	**2030-High**
			without IN and with common dimensioning in SMM block		with IN and with common dimensioning in SMM block	with IN and with common dimensioning in SMM block	with IN and with common dimensioning in SMM block	with IN and with common dimensioning in SMM block
			Minimal	**Procured**				
	NRMSE wind [%]	**NMAE wind [%]** \ **VRE capacity [MW]**	**374**		**2670**	**5447**	**8085**	**17290**
aFRR per direction [MW]	**12%**	8.4%	80	80	223	382	575	881
	10%	7.1%	80	80	198	329	490	757
	8%	5.6%	80	80	173	274	401	627
	6%	4.2%	80	80	148	222	314	497
mFRR Up [MW]	**12%**	8.4%	280	300	339	787	1346	2356
	10%	7.1%	280	300	271	639	1095	1997
	8%	5.6%	280	300	206	484	839	1647
	6%	4.2%	280	300	212	346	593	1369
mFRR Down [MW]	**12%**	8.4%	70	150	573	1246	2029	3113
	10%	7.1%	70	150	460	1019	1674	2602
	8%	5.6%	70	150	357	787	1318	2062
	6%	4.2%	70	150	260	558	948	1553
FRR Up [MW]	**12%**	8.4%	360	380	563	1169	1921	3237
	10%	7.1%	360	380	469	968	1585	2754
	8%	5.6%	360	380	379	758	1240	2274
	6%	4.2%	360	380	**360**	568	907	1866
FRR Down [MW]	**12%**	8.4%	150	230	796	1628	2604	3994
	10%	7.1%	150	230	657	1348	2164	3358
	8%	5.6%	150	230	530	1061	1719	2689
	6%	4.2%	150	230	408	780	1262	2050

With common dimensioning (Table 4.9), the exception is the 6% NRMSE case in the 2025 Reference scenario. Here, the EMS control area's share in the SMM LFC block of 360 MW is higher than the capacity required to cover 99% of all negative imbalances driven by wind (301 MW).

In both tables, the required aFRR levels are the same. With imbalance netting included, the requirements range from 223 MW in the 2025 Reference scenario (assuming 2670 MW of VRE capacity) to 497 MW in the 2030 High scenario with 17290 MW of VRE capacity.

Tables 4.8 and 4.9 provide the minimal required and procured reserves per type in 2020. They demonstrate that the increase in the required reserve capacity is correlated to the growth of variable renewable energy capacity.

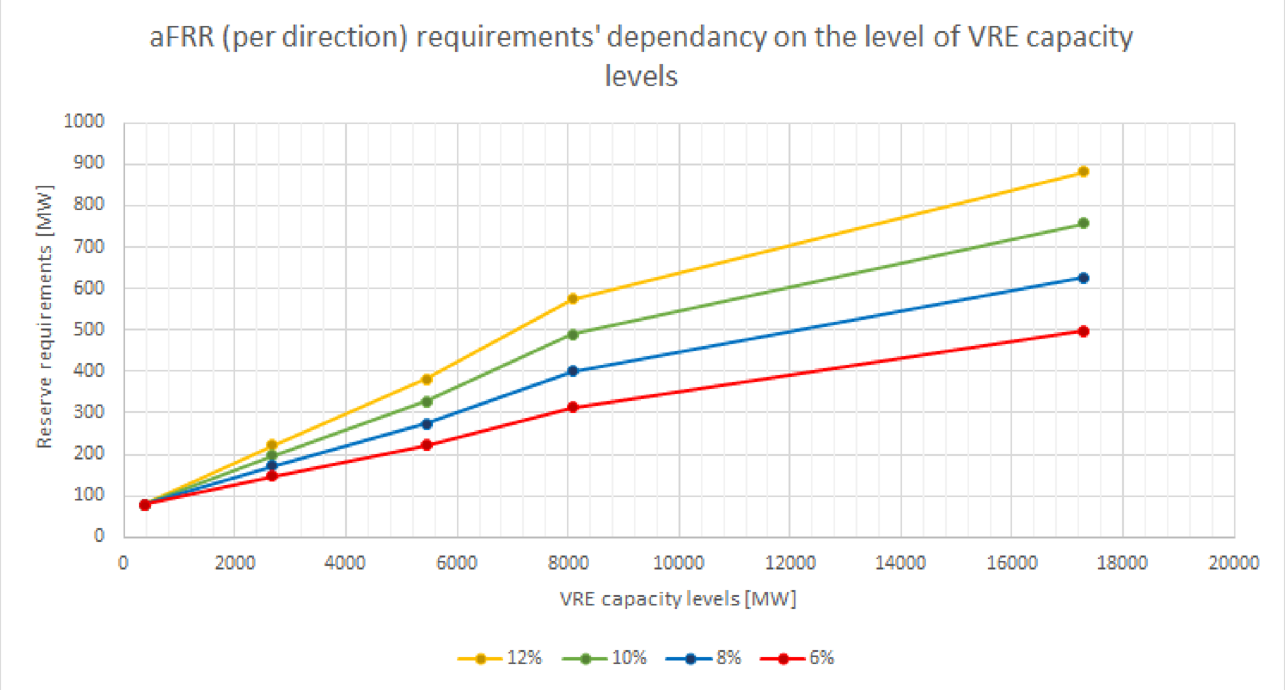


Figure 4.9: aFRR (per direction) requirements' dependency on the level of VRE

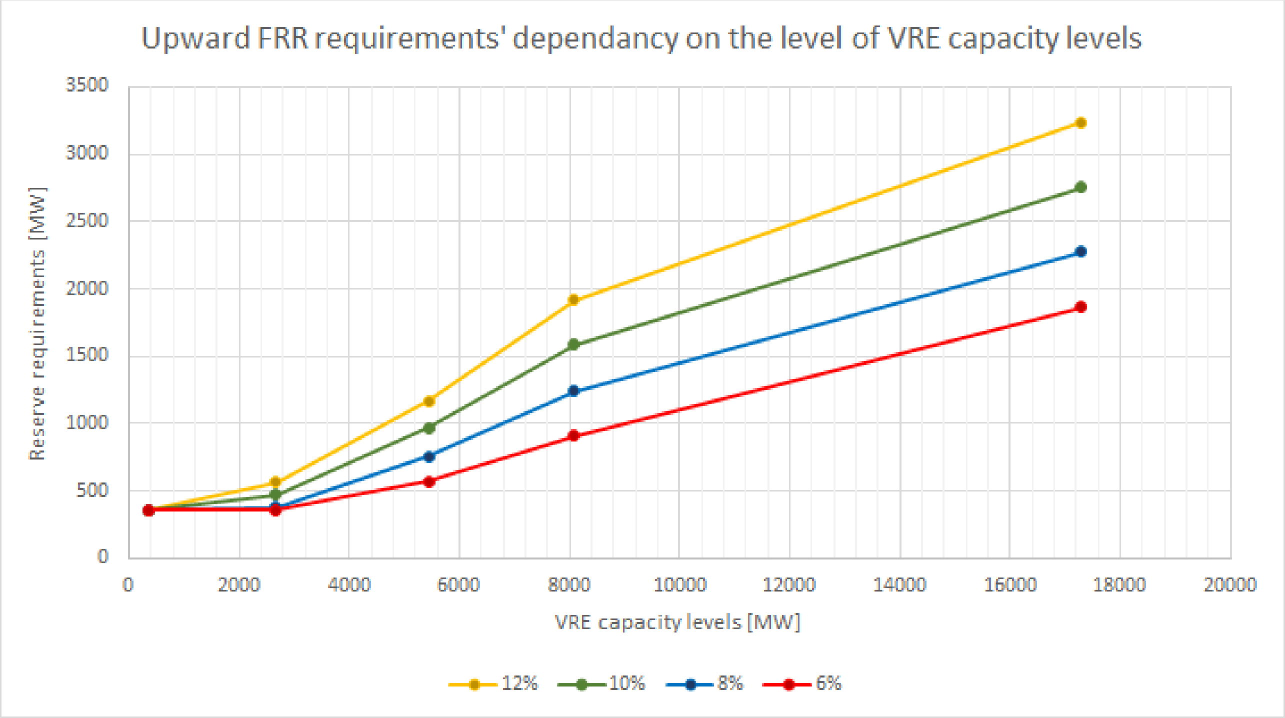


Figure 4.10: Upward FRR requirements' dependency on the level of VRE (with common dimensioning in SMM LFC block)

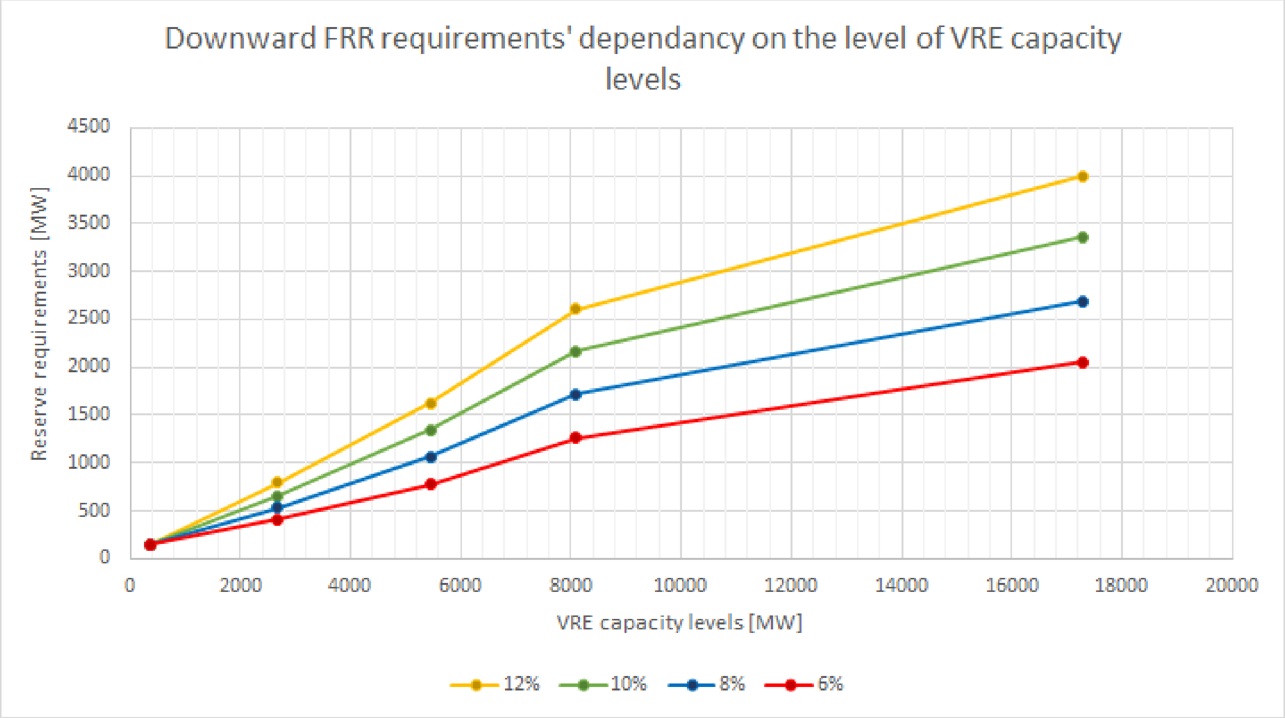


Figure 4.11: Downward FRR requirements' dependency on the level of VRE (with common dimensioning in SMM LFC block)

4.1.4 Balancing reserve capacities costs

We calculate the costs for the required reserve provision based on the results of the reserve dimensioning and the current prices for the symmetric aFRR and upward mFRR products. We used the following reserve procurement prices[14] (regulated by NRA):

- For aFRR capacity - 12.97 €/MW
- For upward mFRR capacity - 4.08 €/MW

Although the provision of downward mFRR capacity is currently not remunerated, we analyzed two additional cases with different downward mFRR reserve provision prices:

- V0 - 0€/MW
- V1 – 4.08€/MW
- V2 – 6.28€/MW

The first case (V0) corresponds to the current situation wherein all target years and scenarios for downward mFRR capacity provision are not remunerated.

In the second case (V1) the downward mFRR capacity price equals the upward mFRR price in the EMS control area.

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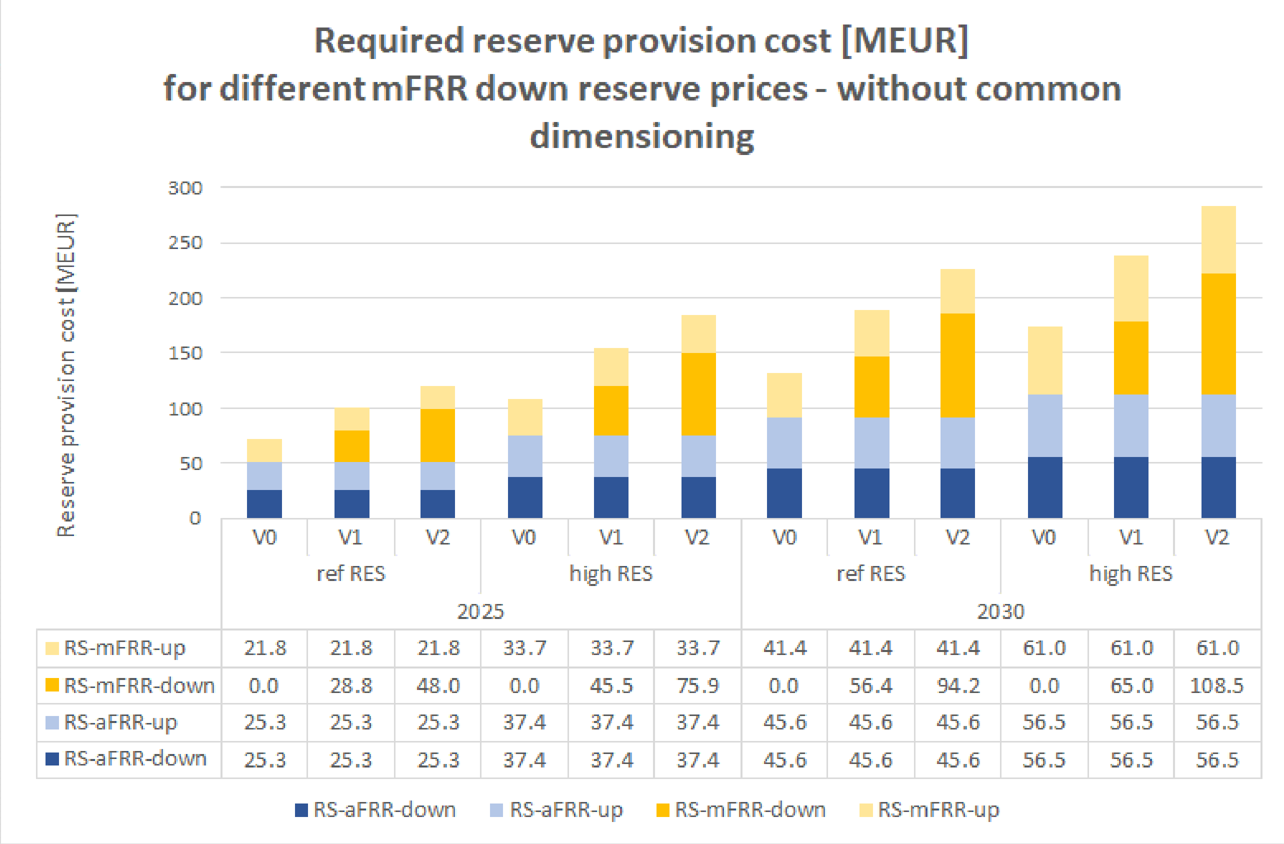
[14] https://www.aers.rs/FILES/Odluke/OCenama/Sistemske%20usluge/2021-01-21%20Odluka%20o%20ceni%20sistemskih%20usluga%20za%202021.pdf

In the third case (V2) the downward mFRR capacity price equals the average downward mFRR provision price in the region.



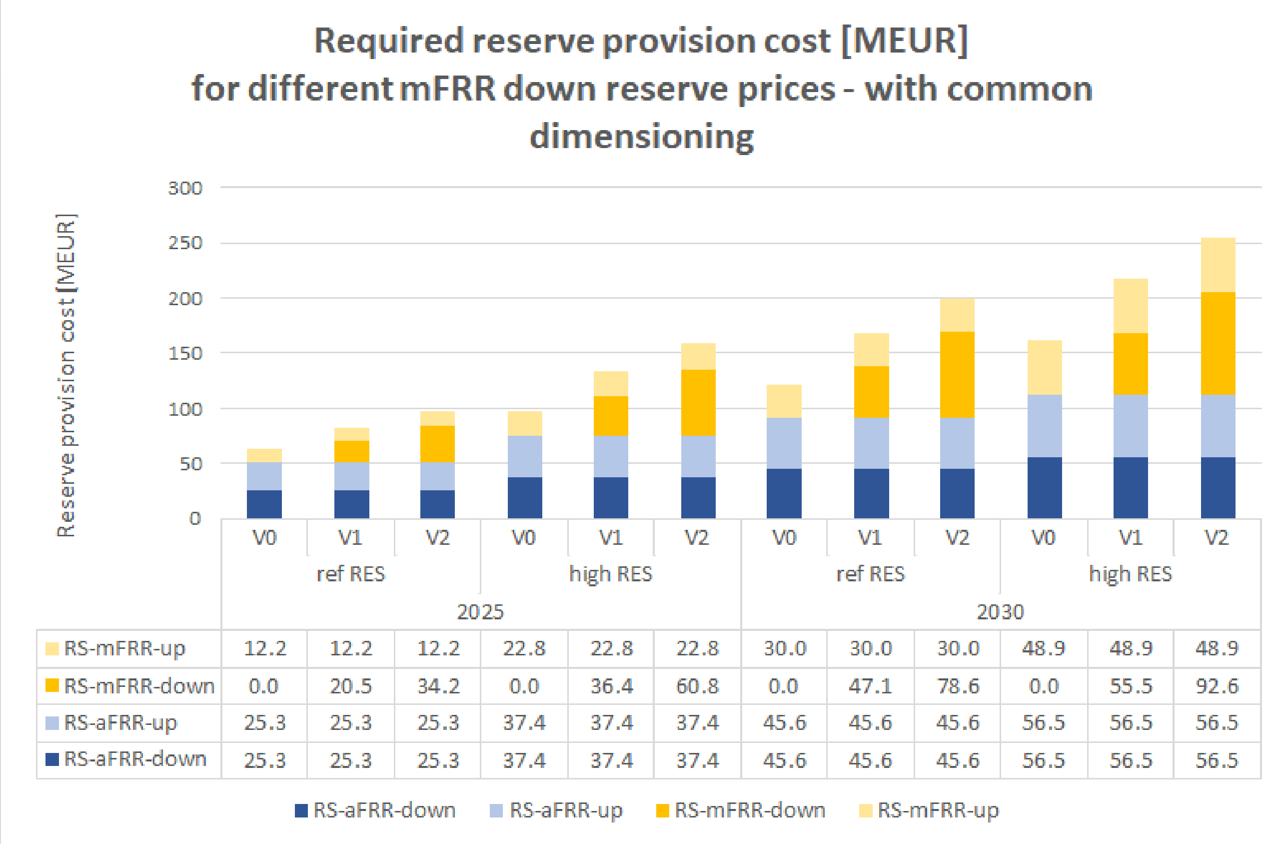
	2025						2030					
	ref RES			high RES			ref RES			high RES		
	V0	V1	V2	V0	V1	V2	V0	V1	V2	V0	V1	V2
RS-mFRR-up	21.8	21.8	21.8	33.7	33.7	33.7	41.4	41.4	41.4	61.0	61.0	61.0
RS-mFRR-down	0.0	28.8	48.0	0.0	45.5	75.9	0.0	56.4	94.2	0.0	65.0	108.5
RS-aFRR-up	25.3	25.3	25.3	37.4	37.4	37.4	45.6	45.6	45.6	56.5	56.5	56.5
RS-aFRR-down	25.3	25.3	25.3	37.4	37.4	37.4	45.6	45.6	45.6	56.5	56.5	56.5

Figure 4.12: Required reserve provision costs in the function of different downward mFRR reserve prices without common dimensioning in SMM LFC block

We calculated the following costs of meeting the reserve requirements for the 2025 and 2030 reference and high scenarios without common dimensioning:

- 72.5 – 120.5 MEUR in the Reference scenario in 2025
- 108.5 – 184.3 MEUR in the High scenario in 2025
- 132.5 – 226.7 MEUR in the Reference scenario in 2030
- 173.9 – 282.5 MEUR in the High scenario in 2030

The distribution of these costs per reserve type is given in Figure 4.12.



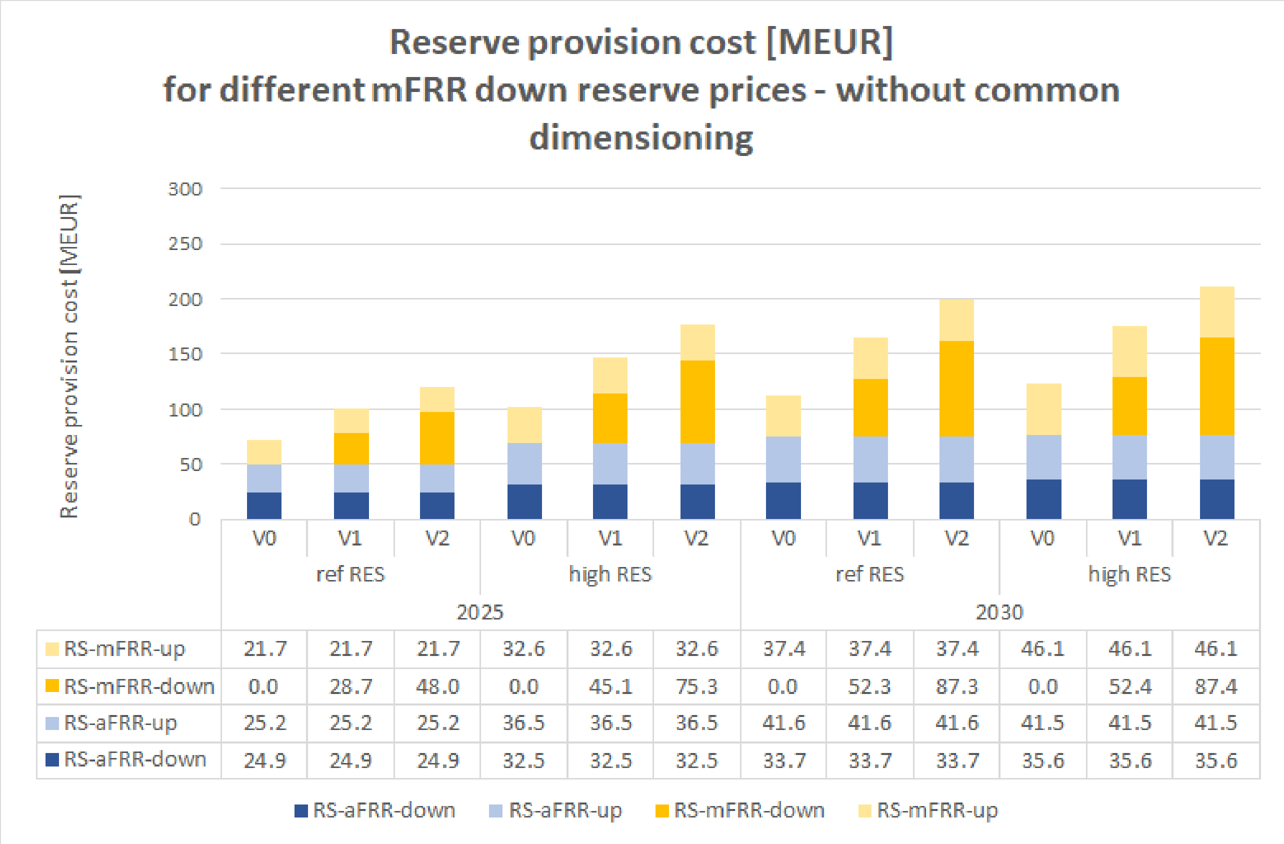
	V0	V1	V2	V0	V1	V2	V0	V1	V2	V0	V1	V2
	ref RES			high RES			ref RES			high RES		
	2025						2030					
■ RS-mFRR-up	12.2	12.2	12.2	22.8	22.8	22.8	30.0	30.0	30.0	48.9	48.9	48.9
■ RS-mFRR-down	0.0	20.5	34.2	0.0	36.4	60.8	0.0	47.1	78.6	0.0	55.5	92.6
■ RS-aFRR-up	25.3	25.3	25.3	37.4	37.4	37.4	45.6	45.6	45.6	56.5	56.5	56.5
■ RS-aFRR-down	25.3	25.3	25.3	37.4	37.4	37.4	45.6	45.6	45.6	56.5	56.5	56.5

Figure 4.13: Reserve provision costs in the function of different downward mFRR reserve prices with common dimensioning in SMM LFC block

With common dimensioning (Figure 4.13) the costs are lower, and range between:

- 62.8 – 97 MEUR in the Reference scenario in 2025
- 97.6 – 158.4 MEUR in the High scenario in 2025
- 121.1 – 199.7 MEUR in the Reference scenario in 2030
- 161.9 – 254.5 MEUR in the High scenario in 2030

These results indicate that the use of common dimensioning reduces the cost of reserves by 10 to 28 MEUR, depending on the case and scenario.



	V0	V1	V2	V0	V1	V2	V0	V1	V2	V0	V1	V2
	ref RES			high RES			ref RES			high RES		
	2025						2030					
RS-mFRR-up	21.7	21.7	21.7	32.6	32.6	32.6	37.4	37.4	37.4	46.1	46.1	46.1
RS-mFRR-down	0.0	28.7	48.0	0.0	45.1	75.3	0.0	52.3	87.3	0.0	52.4	87.4
RS-aFRR-up	25.2	25.2	25.2	36.5	36.5	36.5	41.6	41.6	41.6	41.5	41.5	41.5
RS-aFRR-down	24.9	24.9	24.9	32.5	32.5	32.5	33.7	33.7	33.7	35.6	35.6	35.6

Figure 4.14: Reserve provision costs in the function of different downward mFRR reserve prices without common dimensioning in SMM LFC block

The costs of the procured reserve are calculated based on the reserve provision levels obtained from market simulations and the reserve procurement prices per reserve type as defined by NRA for 2020 given at the beginning of this chapter. As expected, these costs are slightly lower compared to those when the required reserve capacity is fully procured in 100% of the time. Depending on the scenario and the case, the total reserve provision costs (Figure 4.14) range between:

- 71.8 – 119.8 MEUR in the Reference scenario in 2025
- 101.6 – 177 MEUR in the High scenario in 2025
- 112.8 – 200.1 MEUR in the Reference scenario in 2030
- 123.3 – 210.7 MEUR in the High scenario in 2030

Reserve procurement cost in the function of VRE installed capacity when only available capacity is paid (Figure 4.15) has a higher growth rate for VRE levels up to 8000 MW. For greater VRE levels, this cost shows much lower sensitivity, which indicates that the required reserve fulfilment significantly drops after VRE levels reach 8000 MW.

When required reserve capacity is paid, these costs growth shows a similar pattern as the increase of VRE levels (Figure 4.16 and Figure 4.17).

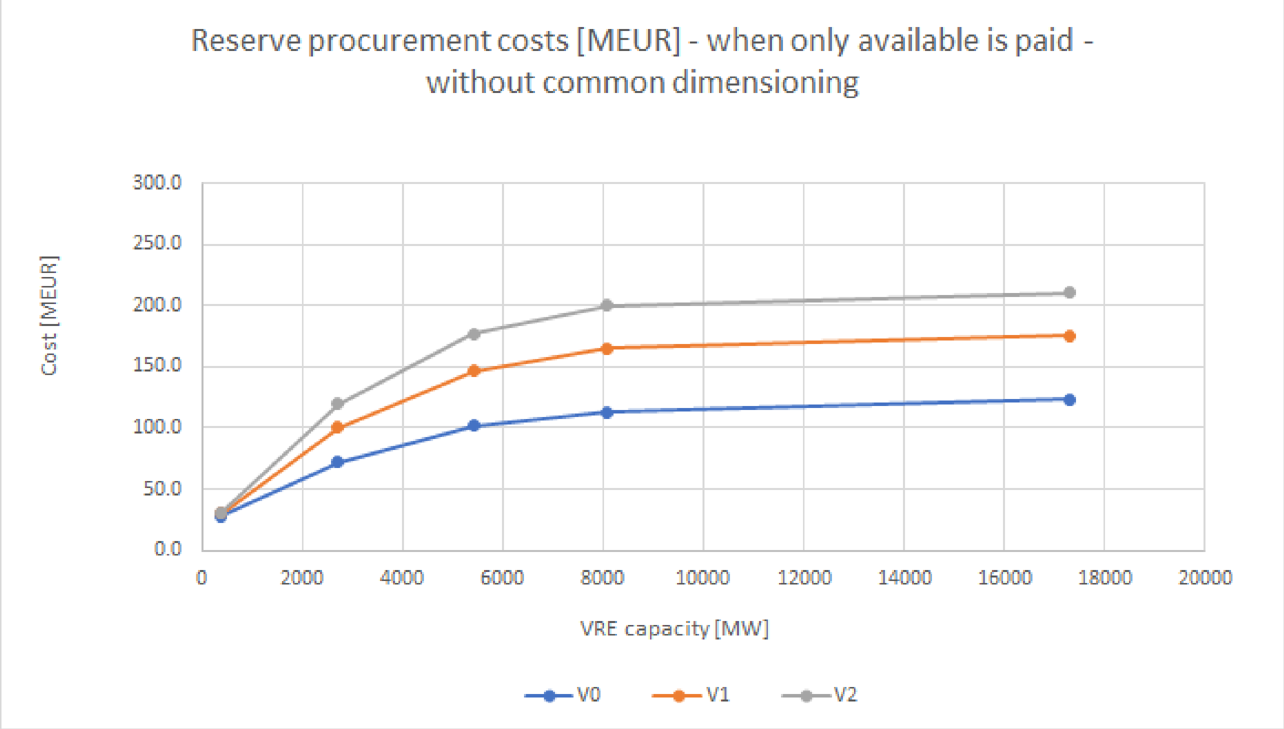


Figure 4.15: Reserve procurement costs in the function of VRE capacities without common dimensioning in SMM LFC block

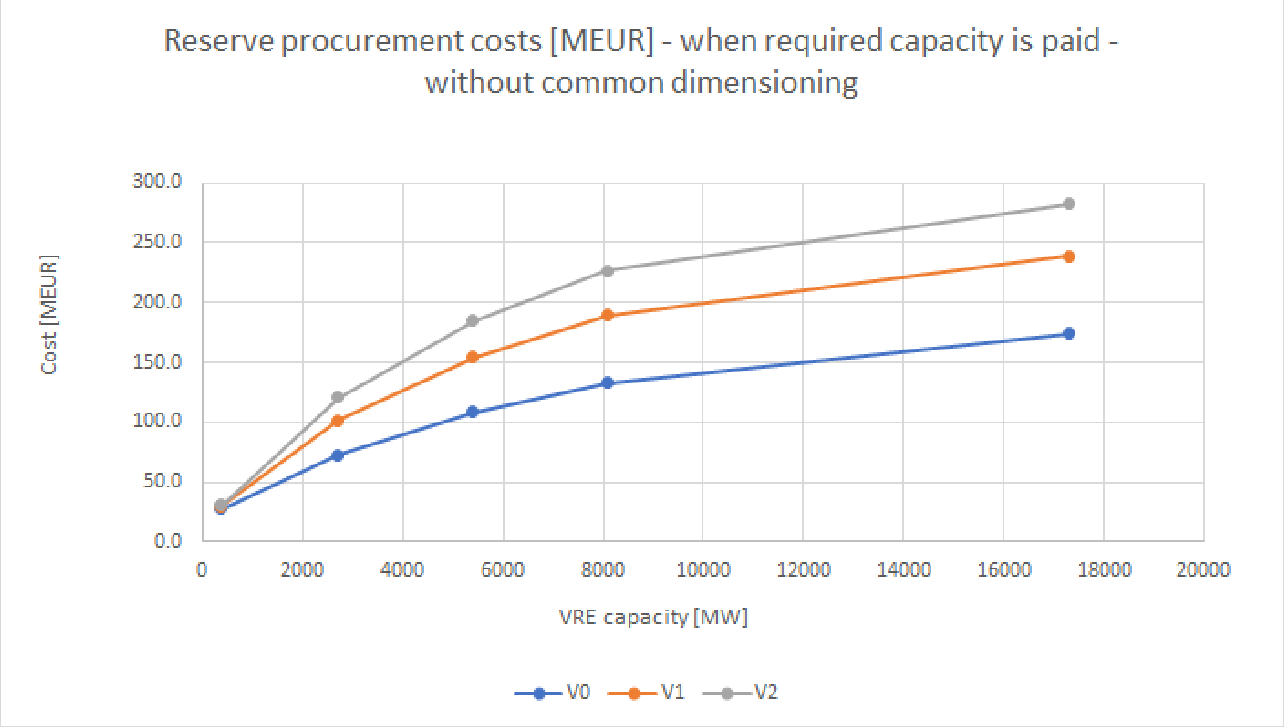


Figure 4.16: Required reserve procurement costs in the function of VRE capacities without common dimensioning in SMM LFC block

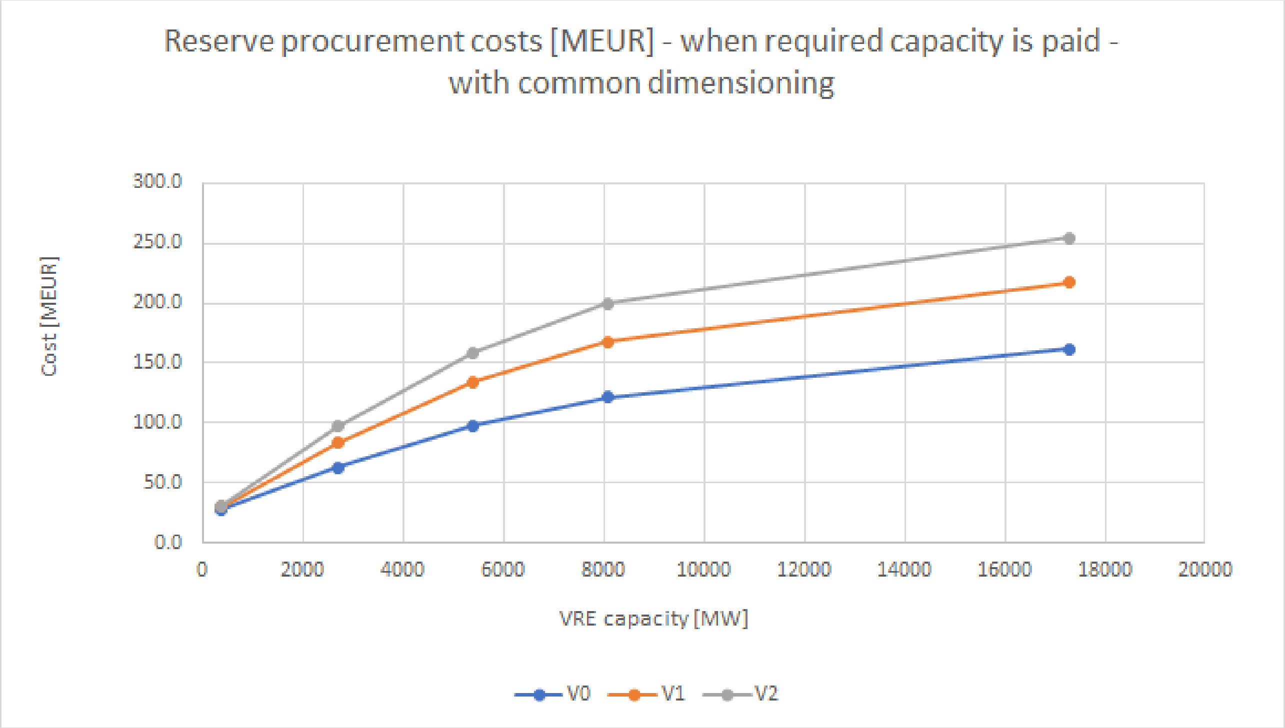


Figure 4.17: Required reserve procurement costs in the function of VRE capacities with common dimensioning in SMM LFC block

To summarize the analysis in this chapter:

- The maximum aFRR requirements in the case with the highest projected VRE levels (17290 MW) and NRMSE for a wind of 6% reach:
    - 765 MW without imbalance netting
    - 497 MW with imbalance netting applied (35% as the assumed level of imbalance netting)
- The maximum upward FRR requirements in the case with the highest projected VRE levels (17290 MW) and NRMSE for a wind of 6% reach:
    - 2204 MW without common dimensioning in the SMM LFC block
    - 1866 MW with common dimensioning in the SMM LFC block
- The maximum downward FRR requirements in such case are expected to reach:
    - 2316 MW without common dimensioning in the SMM LFC block
    - 2050 MW with common dimensioning in the SMM LFC block
- On average, common dimensioning in the SMM block decreases the level of the required:
    - upward FRR capacity by 308 MW
    - downward FRR capacity by 250 MW
- The impact of imbalance netting in terms of decreasing the required aFRR capacity can be expected in the range of 120-260 MW.
- The maximum related costs when required reserve capacity is provided, without common dimensioning applied ranges between 72.5 – 282.5 MEUR depending on the scenario and the downward mFRR procurement price case.
- Common dimensioning enables required reserve provision cost savings of 10 to 28 MEUR, depending on the case and scenario.

- To facilitate greater RES penetration in the future, with the highest impact of VRE sources on imbalances, and to decrease the required balancing reserve and related costs, this Study recommends EMS participation in cross border balancing cooperation processes such as common dimensioning in the SMM LFC block and imbalance netting within the IGCC.

4.2 Variable RES integration impact on balancing energy activations

4.2.1 Methodology

The imbalance assessment analysis described in the previous chapter provided forecasted imbalances as a function of analyzed RES integration scenarios for 2025 and 2030. On the basis of forecasted system imbalance, we quantified the expected balancing energy activations in both directions. The difference between forecasted system imbalances under different scenarios serve as a measure of additional balancing energy needs associated with further RES development. Therefore, we only forecasted and assessed physical imbalances, and did not account for potential gaming and arbitrage opportunities to exploit the balancing market rules in this analysis.

The impact of RES integration on balancing energy needs and their costs were each measured by comparing:

- Expected (Referent) RES development scenario versus the current RES state
- Ambitious (High) RES development scenario versus the current RES state

The cost of balancing energy was monetized using the forecasted price of balancing energy (EUR/MWh). Considering the current correlation between balancing energy prices and wholesale electricity market prices (Figure 4.18 and Figure 4.19), we determined the balancing prices in 2025 and 2030 in relation to wholesale prices from our electricity market simulation, and adjusted them with a balancing price correlation coefficient. We calculated the balancing price coefficient separately for the upward and downward directions, as the ratio between average balancing energy prices and wholesale prices in recent years in the EMS control area:

- k_{Upward} = 1.39
- $k_{Downward}$ =0.36

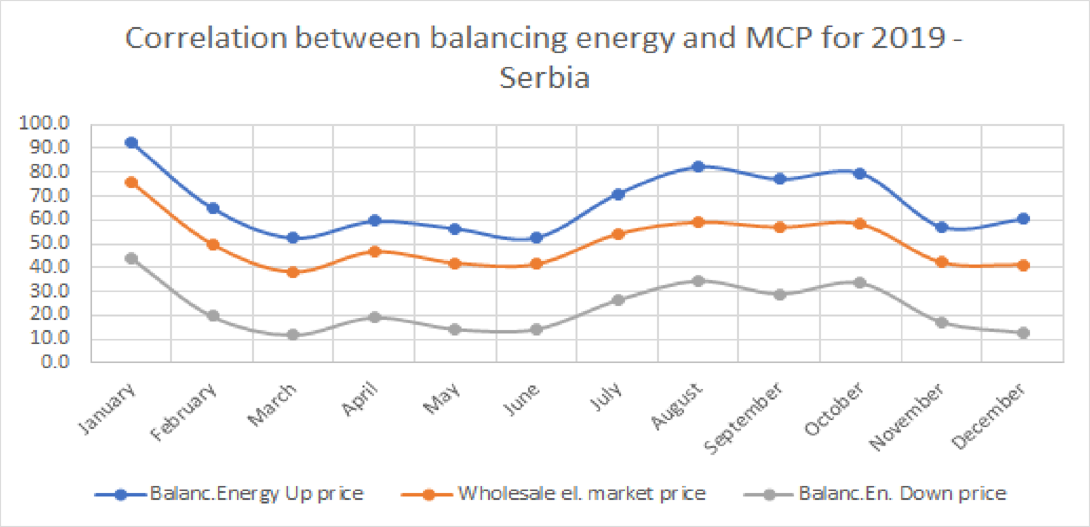


Figure 4.18: Correlation between balancing energy prices and MCP [€/MWh] - 2019

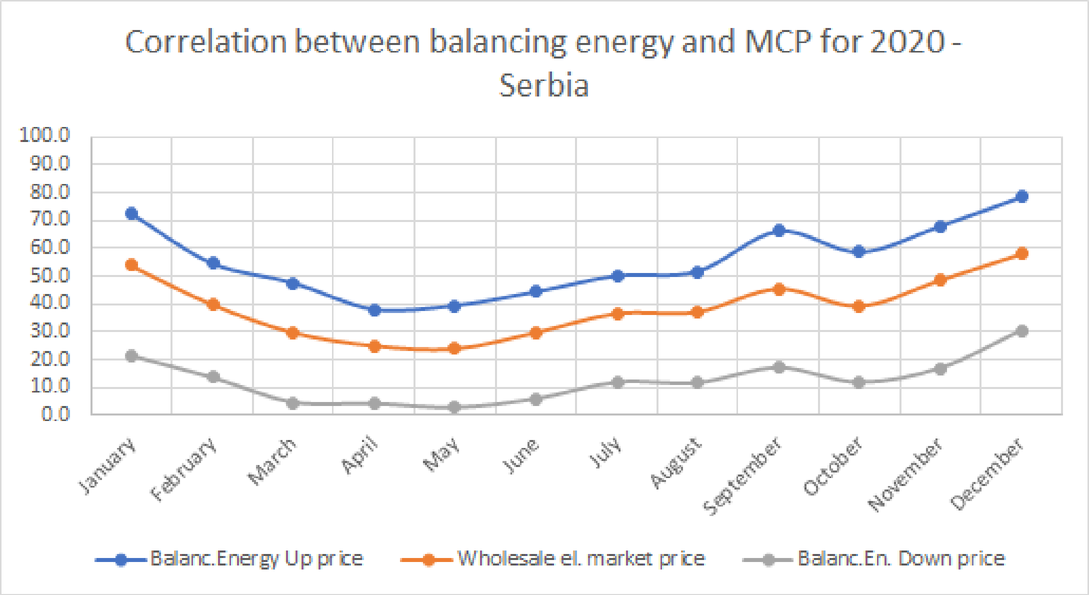


Figure 4.19: Correlation between balancing energy prices and MCP [€/MWh] - 2020

In addition, we performed a sensitivity analysis assuming:

- High prices: the price of balancing energy in the upward direction is 30% higher, while the price for balancing energy in the downward direction is 30% lower in comparison to the baseline assumptions.
- Low prices: the price of balancing energy in the upward direction is 30% lower, while the price for downward balancing is 30% higher in comparison to the baseline assumptions.

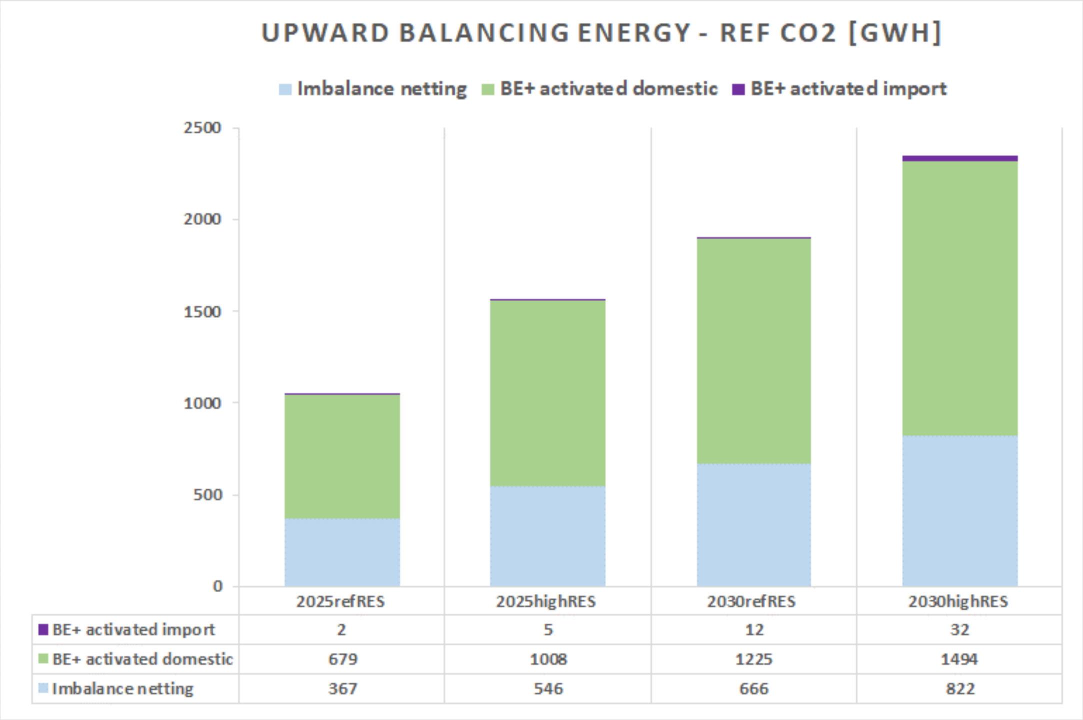
During the periods when the Serbian balancing reserve (obtained in market simulations) was insufficient to cover the EMS control area imbalance, we considered balancing energy imports. We correlated the price of cross-border balancing energy activations with the wholesale price at a level of 1.82 (upward direction) and 0.2 (downward direction), based on the average price correlation on the relevant regional markets (Hungary, Austria, and Slovenia).

To determine the balancing activation, we considered the participation of EMS in an imbalance netting scheme.

The assumed imbalance netting effects on avoided balancing energy activation was considered at the level of 35% for EMS participation in the SMM block pre-netting and IGCC pan-European cooperation. This estimate was based on the average historic imbalance netting effect observed for operational IGCC member countries reported by ACER. We assumed the payment for provided and consumed electricity through IGCC[15] as the average of above-stated coefficients of balancing energy prices versus wholesale prices (i.e. 0.94 of the wholesale price).

4.2.2 Balancing energy needs and costs

Figures 4.20, 4.21, 4.22 and 4.23 illustrate the balancing energy needs in 2025 and 2030 under different RES integration scenarios.



	2025refRES	2025highRES	2030refRES	2030highRES
■ BE+ activated import	2	5	12	32
■ BE+ activated domestic	679	1008	1225	1494
■ Imbalance netting	367	546	666	822

Figure 4.20: Balancing energy needs in the upward direction under the CO2 reference case

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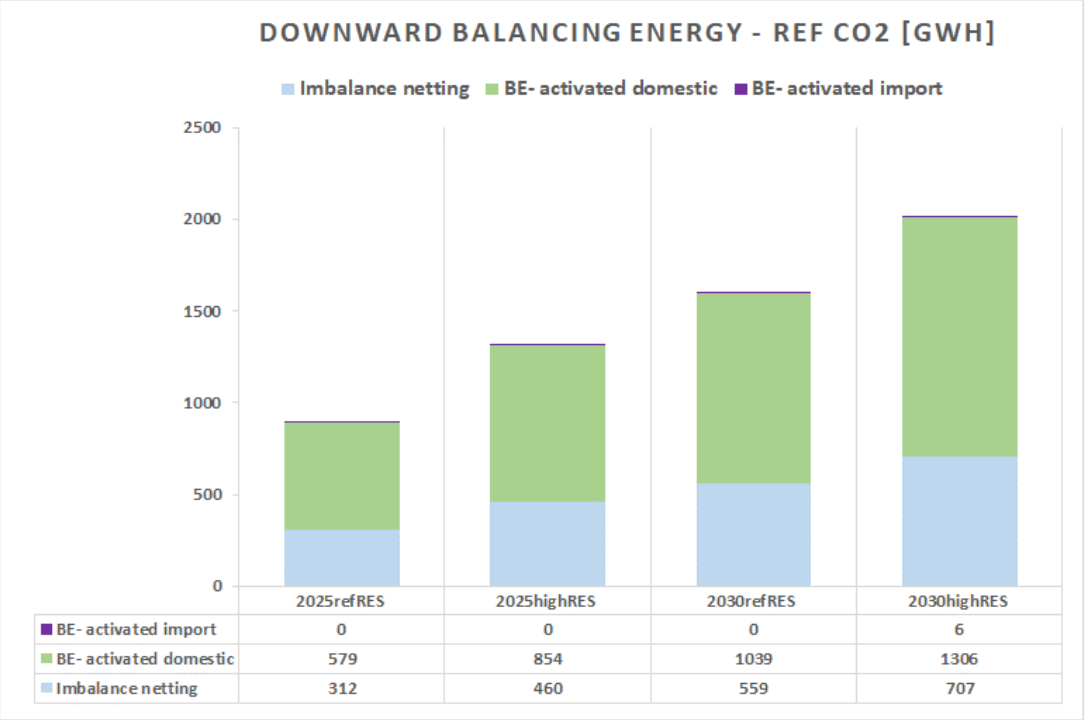
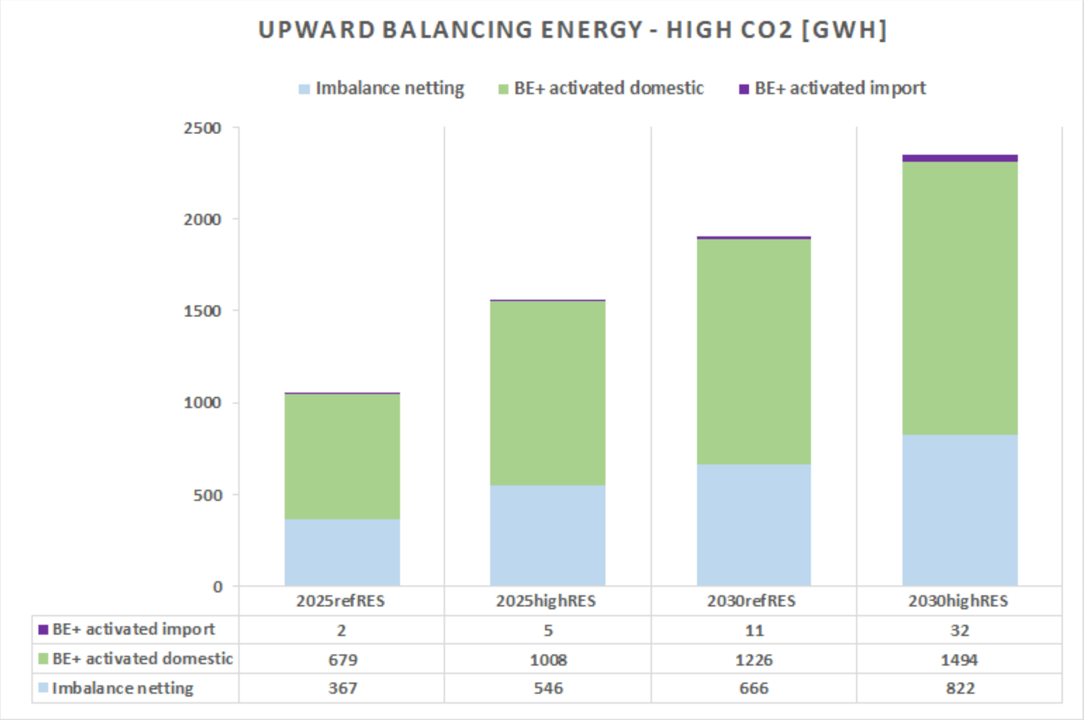
[15] The actual figure shall be determined on the basis of the positions and avoided costs of all parties (TSOs) participating in the IGCC. Since such figure cannot be obtained without simulating whole European imbalance netting process, the estimation based on IGCC settlement principles was made.



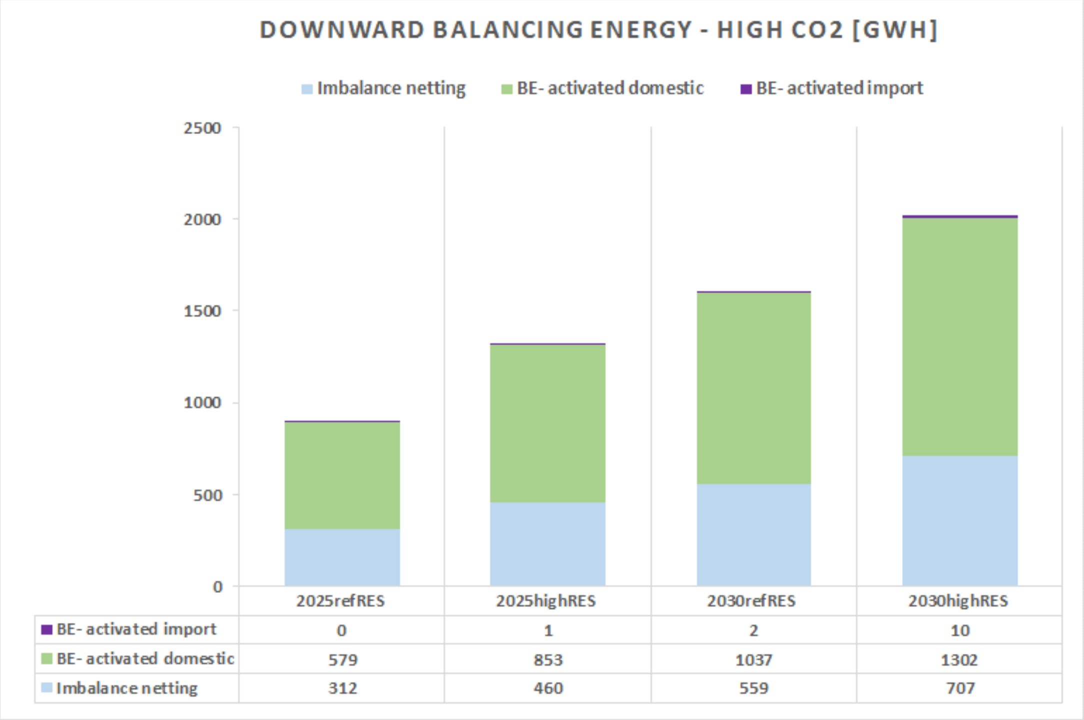
	2025refRES	2025highRES	2030refRES	2030highRES
BE- activated import	0	0	0	6
BE- activated domestic	579	854	1039	1306
Imbalance netting	312	460	559	707

Figure 4.21: Balancing energy needs in downward direction under CO2 reference case



	2025refRES	2025highRES	2030refRES	2030highRES
BE+ activated import	2	5	11	32
BE+ activated domestic	679	1008	1226	1494
Imbalance netting	367	546	666	822

Figure 4.22: Balancing energy needs in downward direction under high CO2 case



	2025refRES	2025highRES	2030refRES	2030highRES
BE- activated import	0	1	2	10
BE- activated domestic	579	853	1037	1302
Imbalance netting	312	460	559	707

Figure 4.23: Balancing energy needs in downward direction under high CO2 case

The following diagram presents a duration curve of the balancing energy needs as a percentage of required balancing reserve (FRR) for the 2025 referent scenario and the 2030 High RES scenario.

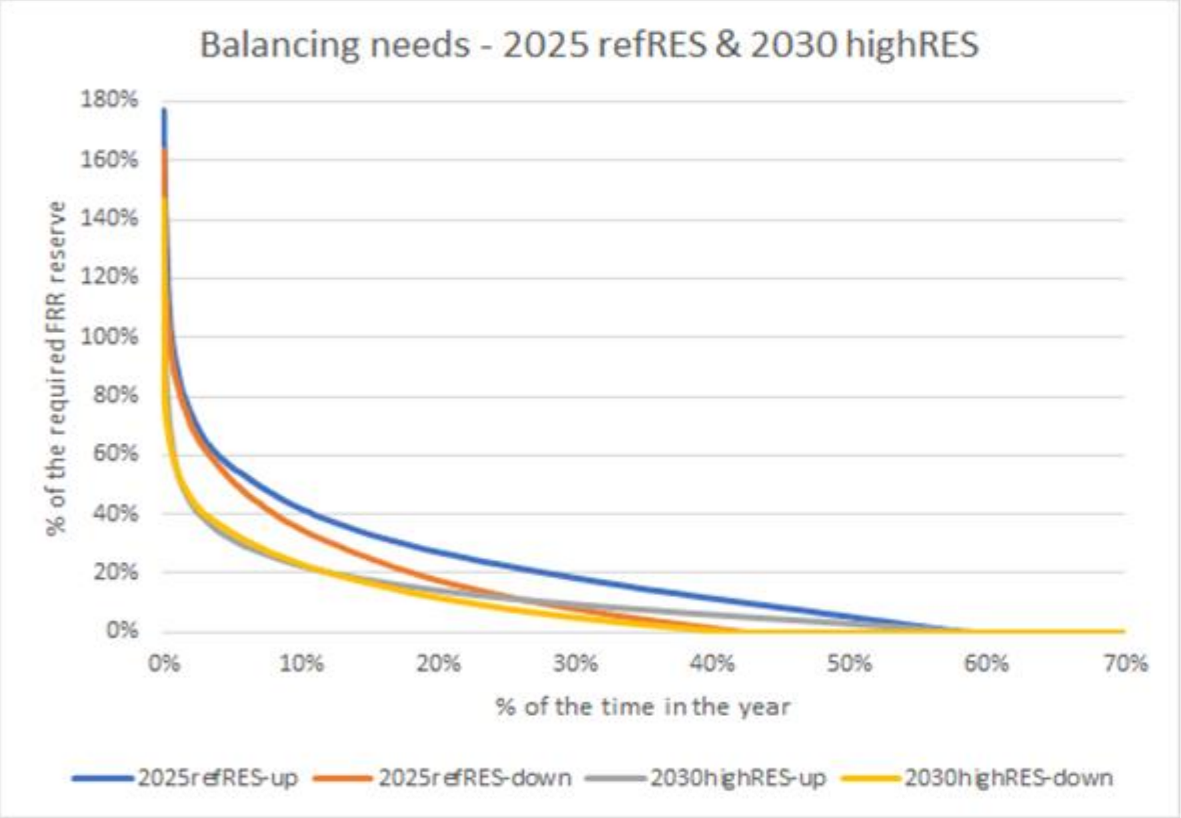


Figure 4.24: Balancing energy needs and duration

The performed analysis shows that:

- The overall balancing energy needs under the assessed VRE forecast errors range from 1.9 TWh (2025 refRES scenario) to 4.4 TWh (2030 highRES scenario).
- The EMS participation in Imbalance Netting cooperation can provide a strong boost to power system balancing by preventing balancing energy activations in the range of 0.7 TWh – 1.5 TWh. **Accession of EMS to the Imbalance Netting cooperation in 2022 is an important milestone in facilitating higher RES integration in Serbia.**
- The imported balancing energy account could rise to as much as 42 GWh/year in the most challenging 2030 high RES scenario. However, **without Imbalance Netting, the need for balancing energy imports would reach 220 GWh/year in the 2030 highRES scenario.**
- In general, more than 90% of the time, less than 40% of FRR reserve is required to cover system imbalances. This indicates that shorter-term dynamic reserve dimensioning (month, week) in the context of annual dimensioning can be efficient.

The corresponding balancing energy costs in 2025 and 2030 under different RES integration scenarios are provided in Figure 4.25 and Figure 4.26. These costs are calculated for the balancing needs that takes Imbalance Netting into account.

We also conducted a sensitivity assessment for or a +/-30% range of balancing prices.

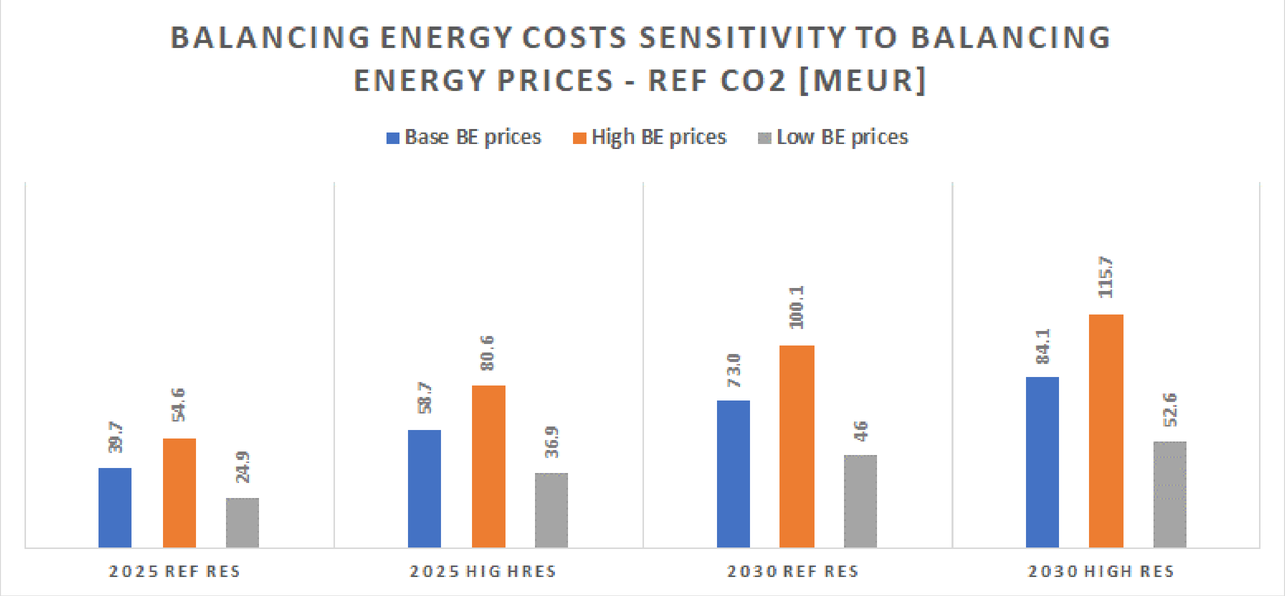


Figure 4.25: Balancing energy costs under CO2 reference case

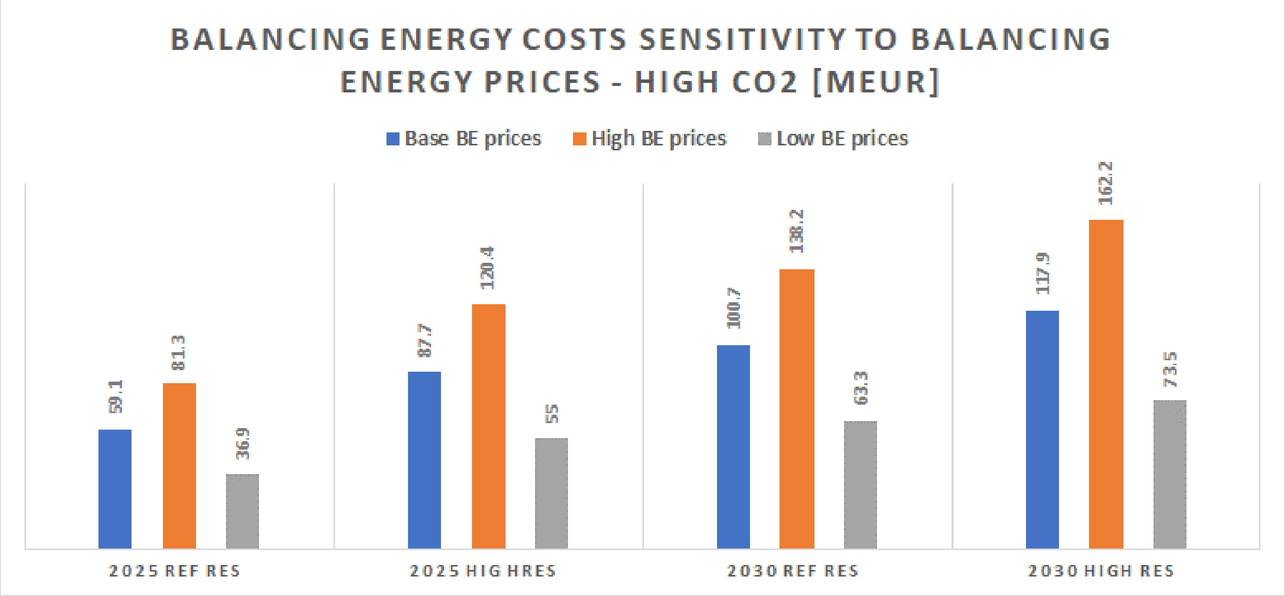


Figure 4.26: Balancing energy costs under high CO2 case

The analysis shows that annual balancing energy costs range from 24.9 MEUR (2025refRES scenario / low balancing prices assumption) to 162.2 MEUR (2030highRES scenario / high balancing prices assumption).

Comparing the growth of balancing energy costs in the different RES scenarios, we conclude that **for baseline balancing energy prices, each installed 1 MW of RES increases the annual balancing cost by 3036 EUR.** If we divide this annual increase by the amount of electricity generated by renewable sources, we estimate that **each 1 MWh produced from RES increases balancing costs by less than 2 EUR (i.e., <2EUR/MWh)**.

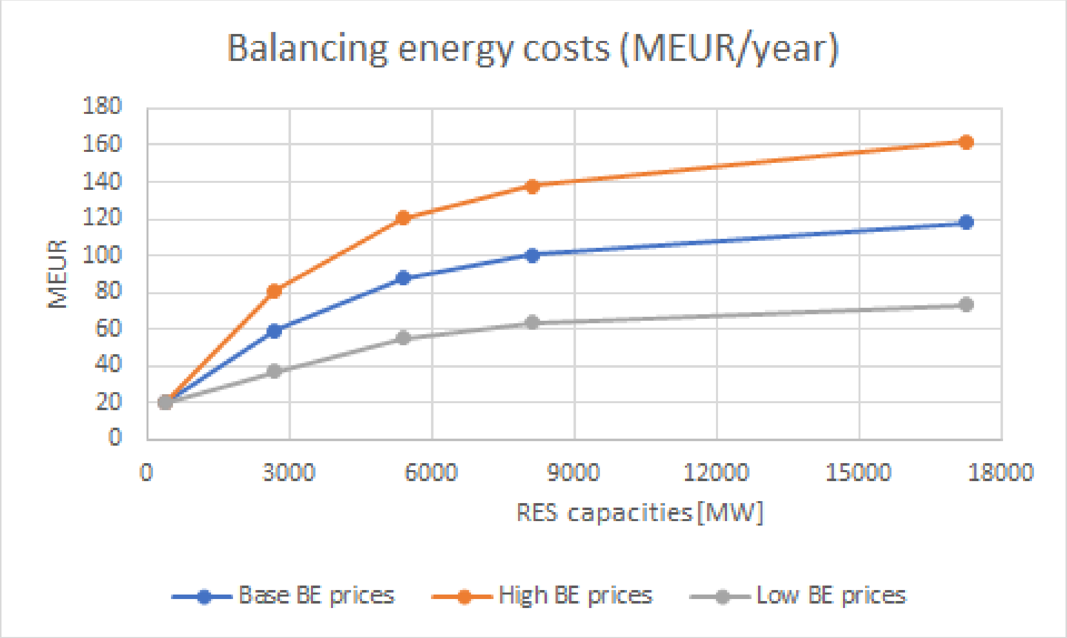


Figure 4.27: Balancing energy costs in function of installed RES capacities (highCO2 case)

4.3 Summary of the impact of RES integration on the balancing of the EMS power system

We provide an overview of the forecasted balancing conditions for the development of the EMS control block under the analyzed RES integration scenarios in *Table 4.10* and Table 4.11.

The assumed imbalance netting effects on avoided balancing energy activation was considered at the level of 35% for EMS participation in the SMM block pre-netting and IGCC pan-European cooperation. This estimate was based on the average historic imbalance netting effect observed for operational IGCC member countries reported by ACER. We also assumed the payment for provided and consumed electricity through IGCC[16] to be the average of the applied coefficients of balancing energy prices versus wholesale prices (i.e. 0.94 of the wholesale price).

Table 4.10: Summary of EMS' balancing reserve needs under alternative RES development scenarios

Scenario	**Without common dimensioning [MW]**				**With common dimensioning [MW]**			
	aFRR+	aFRR-	mFRR+	mFRR-	aFRR+	aFRR-	mFRR+	mFRR-
2025refRES **2700 MW RES**	**223**	**223**	**610**	**805**	223	223	339	573
2025highRES **5400 MW RES**	**329**	**329**	**943**	**1272**	329	329	639	1019
2030refRES **8085 MW RES**	**401**	**401**	**1158**	**1579**	401	401	839	1318
2030highRES **17290 MW RES**	**497**	**497**	**1707**	**1819**	497	497	1369	1553

Table 4.11: Summary of EMS' balancing energy needs under alternative RES development scenarios

Scenario	**Upward balancing energy needs [GWh]**			**Downward balancing energy needs [GWh]**		
	Imbalance Netting	Domestic activation	Imported energy	Imbalance Netting	Domestic activation	Imported energy
2025refRES **2700 MW RES**	**367**	**679**	**2**	**312**	**579**	**0**
2025highRES **5400 MW RES**	**546**	**1008**	**5**	**460**	**854**	**0**
2030refRES **8085 MW RES**	**666**	**1225**	**12**	**559**	**1039**	**0**
2030highRES **17290 MW RES**	**822**	**1494**	**32**	**707**	**1306**	**6**

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[16] The actual figure shall be determined on the basis of the positions and avoided costs of all parties (TSOs) participating in the IGCC. Since such figure cannot be obtained without simulating the whole European imbalance netting process, we made this estimation based on IGCC settlement principles.

Figure 4.28 shows the correlation between the costs of balancing the system (costs for reserve and balancing energy) and the amount of installed RES capacity. This figure provides a wide range of potential costs accounting for many sensitivities, including ref/high CO2 prices, low/ref/high balancing energy prices, the status of balancing cooperation in the LFC block, etc.

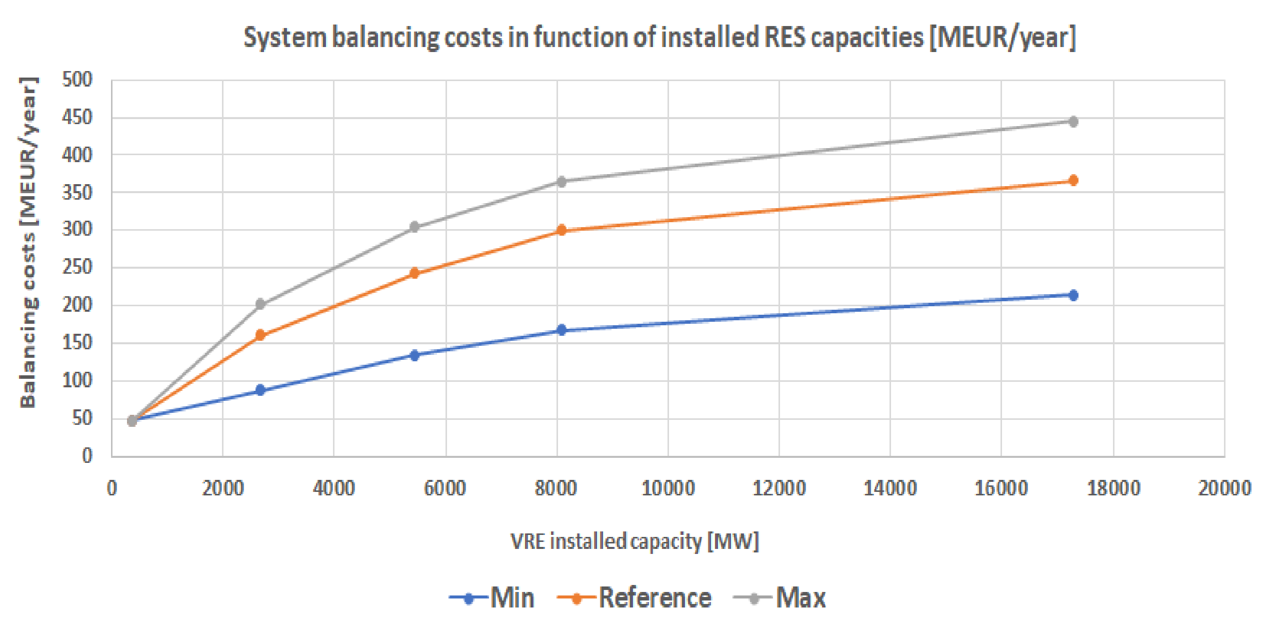


Figure 4.28: Balancing costs as a function of installed RES capacities

We draw the following key recommendations from this analysis:

- It is technically plausible to integrate 2670 MW (2025refRES) and satisfy the balancing requirements of the system.

- **There are considerable costs to balance the system.** They range from 88 MEUR/year to 202 MEUR/year depending on the market conditions (compared to the current level of around 50 MEUR/year). Though the direct cost of RES integration (i.e. LCOE of new RES plants) are currently market competitive, the indirect costs (system costs of RES integration) can amount to the same order of magnitude as the direct costs.

  We also note that these levels of balancing costs are based on assessed wholesale market prices in 2025 and 2030 (chapter 3) that include CO2 prices significantly lower than the current CO2 prices. With this in mind, the presented level of balancing costs can be considered at the lower end of the possible range.

- **For the larger RES portfolios in the 2025 highRES (5.5GW) and 2030 refRES (8.1GW) and 2030 highRES (17.3GW), we identified a shortage of reserves**. **This condition could lead to deterioration of frequency regulation and quality**, putting the SMM LFC Block at risk of failing to comply with frequency regulation standards defined by the ENTSO-E Continental Europe Synchronous Area Framework Agreement.

- **EMS should consider the addition of new flexible sources** (such as PSPs, batteries, etc.) as a very important step toward ensuring the normal power system operation and compliance with ENTSO-E standards.

- **EMS should prioritize participation in cross border balancing cooperation to facilitate greater RES penetration**.

- For more than 90% of the time, less than 40% of the available FRR reserve is needed to cover system imbalances. **In this light, we would recommend shorter-term dynamic reserve dimensioning (month, week) versus annual dimensioning.**

- **Common dimensioning within the SMM LFC block provides a notable decrease in total reserve requirements and costs** (10 – 28 MEUR/year).

  Participation in the International Grid Control Cooperation (IGCC), i.e. pan-European imbalance netting platform, is expected to reduce the balancing energy activations by at least one-third of the total system imbalance. As a member of the SMM LFC block, Serbia can exercise both pre-netting with other block members (CGES, MEPSO) and later participate in imbalance netting with other European LFC blocks that are members of the IGCC cooperation. Further, Serbia could increase its netting potential by joining the PICASSO project and thus exercising additional pre-netting envisaged in the first step of pan-European aFRR cooperation.

The Study inputs were based on the day-ahead forecast errors for the current portfolio of RES generation. Because RES generators have no financial balancing responsibility, there is no incentive for them to commit to better forecasting or recalculate forecasts for intraday adjustments.

The following preconditions could lead to lower balancing needs compared to the one quantified in this study, hence producing significant economic savings:

- **The introduction of balancing responsibility for new RES generators** (i.e. incentive for better forecasting)

- **The creation of an organized intraday market** (i.e. the possibility to adjust the market position from the day ahead to the intraday horizon)

- **The greater netting effect of forecast errors** with the growth of RES installed capacities.

5 THE IMPACTS OF RES INTEGRATION ON THE TRANSMISSION NETWORK

The main goal of this task is to analyze the necessary investments in the transmission system to increase network capacity (with new substations, line upgrades, and new lines) and to enable safe evacuation of the energy produced from RES sources based on the study scenarios.

The scope of work for this task consists of load flows and voltage profile calculations to assess the impact on the transmission network of renewable energy development envisaged under the Expected and Ambitious scenarios till 2025 and 2030.

For these analyses, in the First step, we created regional transmission network models. These models include the Winter Peak, Summer Peak and Summer Off-Peak regimes for 2025 and 2030. The national models for each regime and target were collected from EMS. To model the rest of Southeast Europe, we utilized the SECI models for 2025 and EMI models for 2030 as the starting point. We then merged the national models from EMS with the regional models that we prepared to create the regional models for the base case in this Study.

During the Second step, we finalized the network models by adding new RES projects at specific locations, including their network connections. When project locations were unknown we determined them based on our network loading analysis, which included generation from the RES projects where connection points are known. The Results of these analyses have been presented in the Interim report and discussed and agreed with EMS. This preliminary connection solutions have been applied for network analyses.

It should be noted that all additional locations and points of connection proposed in this Report are unofficial, and should not be understood as the official opinion or solutions of EMS. We developed these proposals to analyze the high-level needs for network reinforcements and to assess the corresponding costs.

5.1 Proposed locations for the additional RES capacities

The network model for the year 2030 received from EMS included locations and connection points for almost all of the wind capacity corresponding to our 2025 Ambitious (High) scenario (4400 MW). It included only 180 MW of solar capacity for the same scenario.

This model was used as the basis for developing proposals related to locations and points of connection for additional wind and solar capacities.

Considering the data from Table 2.1, we needed to propose the locations for:

- An additional 1000 MW in wind capacities, to reach 5400 MW modelled in the 2030 Referent scenario
- An additional 1155 MW in solar capacities, to reach 1335 MW modelled in the 2030 Referent scenario

With these additions, the locations and points of connection were determined for all large scale wind and solar capacity in the 2030 Referent scenario.

We also developed proposals to identify the locations and points for connection for large scale wind and solar capacities for the 2030 High RES scenario:

- An additional 2600 MW in wind capacity, to reach the 8000 MW modelled in the 2030 High RES scenario
- An additional 2788 MW in solar capacity, to reach the 4123 MW modelled in the 2030 High RES scenario

We determined the proposed locations for the additional RES capacities based on the network loading in the initial EMS models for 2030. We previously had divided the EMS transmission network into Zones, based on their wind and solar potentials, as explained in the following chapter.

5.1.1 Indication of the zones in EMS transmission network

Considering the objectives of the study, this analysis started by selecting potential zones in the EMS transmission network consistent with the wind and solar potential areas, as shown in [1].

Figure 5.1 presents the zones in the EMS transmission network that are consistent with the wind and solar potential areas presented above. We provide the list of proposed zones in the EMS transmission network below:

1. Zone 1 – Pančevo region
2. Zone 2 – Požarevac region
3. Zone 3 – Zrenjanin region
4. Zone 4 – Belgrade region
5. Zone 5 – Smederevo region
6. Zone 6 – Bor region
7. Zone 7 – Subotica region
8. Zone 8 – Šabac region
9. Zone 9 – Kragujevac region
10. Zone 10 – Bajina Bašta region
11. Zone 11 – Niš region
12. Zone 12 – Vranje region

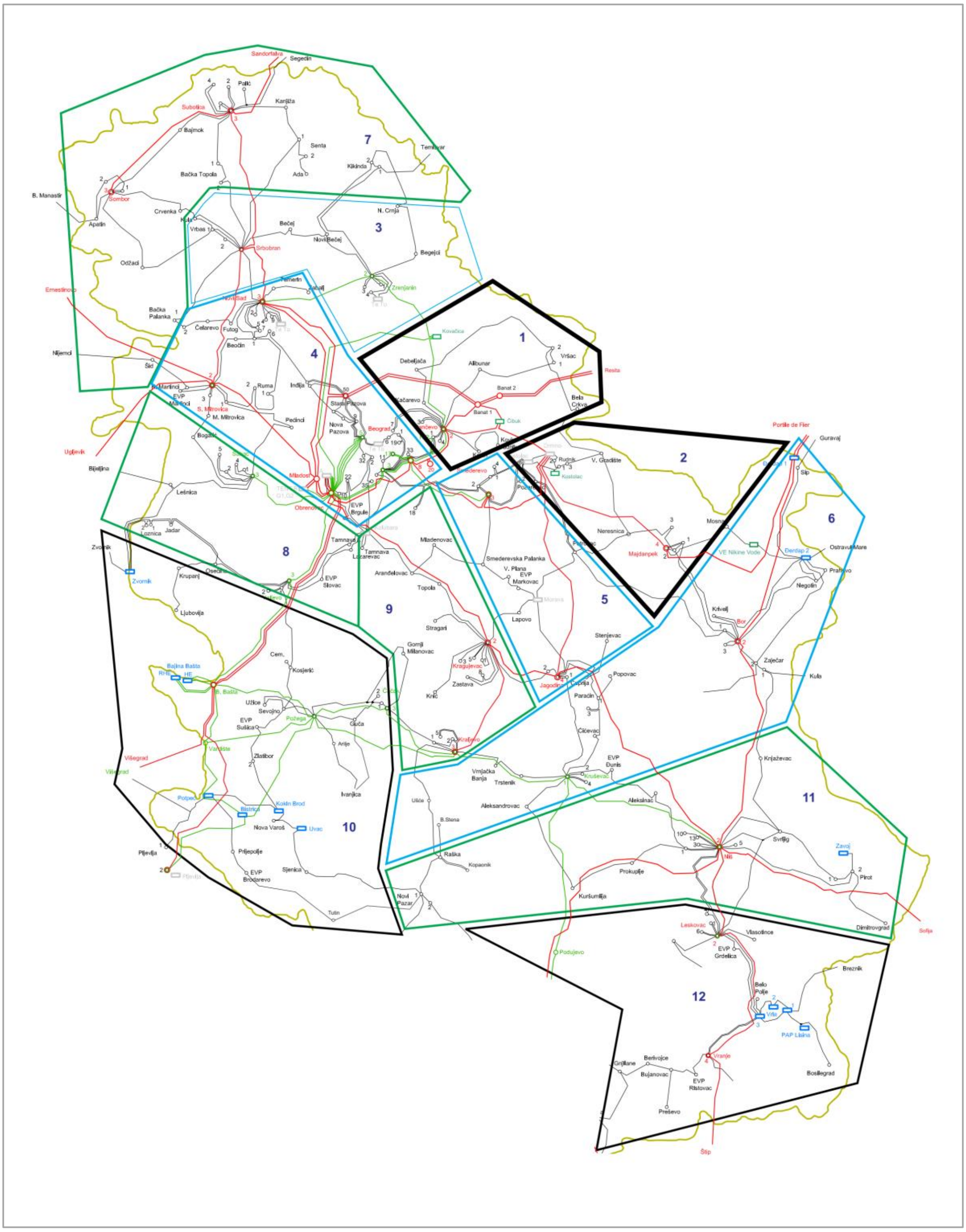


Figure 5.1: Proposed zones in EMS transmission network in line with the wind and solar potential zones, transmission network topology for 2030

The zones with dark black borders (zones 1 and 2) have the most wind potential. The green-bordered zones have the second most wind potential (zones 3-6). The blue zones are the third best (zones 7-9 and 11), and the zones with light black borders are the least favorable (zones 10 and 12).

We summarize the current RES capacities in the 2030 model, their distribution per indicated zones and the ratio to loads in specific regimes in Table 5.1.

Table 5.1: RES capacities in the EMS system in the 2030 model

		4236.7	180			
		WPP Installed	**SPP Installed**	**WPP/Load Wmax**	**WPP/Load Smax**	**WPP/Load Smin**
1	**ZONA 1 - PA**	2554.602	0	9.4	11.7	20.7
2	**ZONA 2 - PO**	226.65	100	1.1	1.4	1.7
3	**ZONA 3 - ZR**	112.92	0	0.4	0.6	1.2
4	**ZONA 4 - BG**	31.07	80	0.0	0.0	0.0
5	**ZONA 5 - SD**	54.57	0	0.1	0.2	0.3
6	**ZONA 6 - BOR**	361.24	0	0.6	0.7	1.0
7	**ZONA 7 - SU**	810.4	0	2.0	2.9	8.2
8	**ZONA 8 - SA**	15.88	0	0.0	0.0	0.1
9	**ZONA 9 - KG**	5.73	0	0.0	0.0	0.1
10	**ZONA 10 - BB**	37.05	0	0.1	0.2	0.3
11	**ZONA 11- NIS**	26.57	0	0.1	0.1	0.3
12	**ZONA 12- VR**	0	0	0.0	0.0	0.0

In addition to the level of potential, we used the ratios between the installed capacity and load in specific regimes to select the zones where additional large scale RES capacities could be located. We did not analyze Zones 8, 9, 10 and 12 for additional wind capacity, and did not analyze zones 3, 5, 7, 8, and 9 for additional solar capacities. And, due to the already high level of wind capacity in zone 1 (as presented in the above table), we did not use zone 1 to analyze locations for potential additional wind capacity.

In addition to considering the wind and solar potential, loads and existing RES capacity in each potential zone, we also accounted for the loading of the lines in different zones to determine proposed locations and points of connection for additional large scale RES capacities.

5.1.1.1 Loading of the lines in the initial model for 2030

Analyses of the lines loading in the initial EMS model for 2030, revealed that the focus should be on Summer Max and Min regimes, since the loading in the Winter Max regime is lower.

We present the results of the initial OHLs loading for 2030 in Table 5.2.

Table 5.2: Overhead lines loadings in initial model for 2030

		400 kV	**220 kV**	**110 kV**	**Total**
Total number of lines	**Wmax**	90	67	644	**801**
	Smax	90	67	644	**801**
	Smin	90	67	644	**801**
Number of lines loaded >50%	**Wmax**	0	0	13	**13**
	Smax	2	10	47	**59**
	Smin	4	8	29	**41**
Number of lines loaded >50%	**Wmax**	0.0%	0.0%	2.0%	**2.0%**
	Smax	2.2%	14.9%	7.3%	**24.4%**
	Smin	4.4%	11.9%	4.5%	**20.9%**

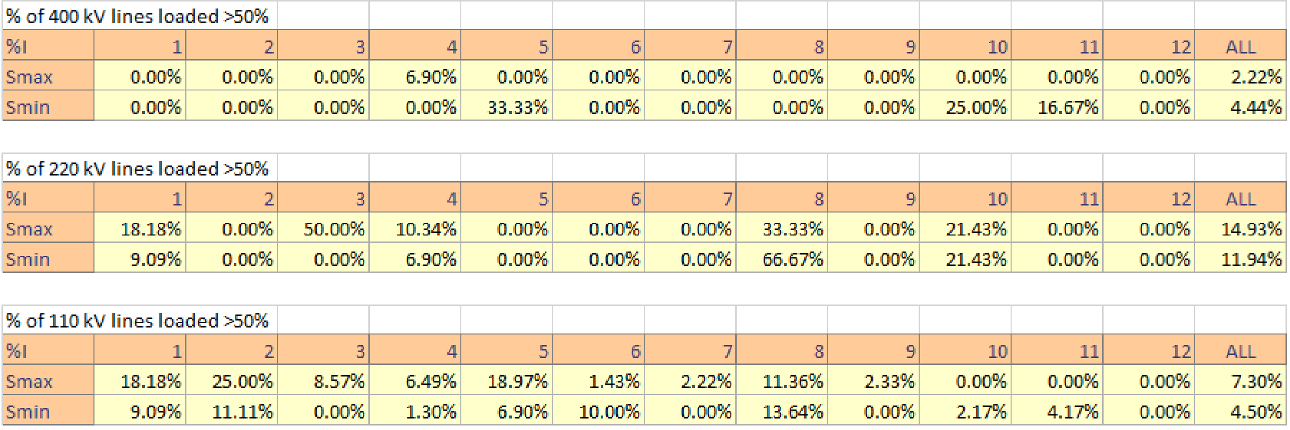
5.1.1.2 Loading of the lines per indicated zones

We present the line loading per indicated zones in the initial EMS model for 2030 summer regimes in Table 5.3.

In determination of the potential connection points for the additional RES capacities not already defined in the network models obtained from EMS, less loaded parts of the network have been considered as good candidates and 50% loading has been considered as a reasonable threshold. The analyses reveal that there are just a few 400 kV overhead lines loaded above 50% in the Summer Max and Min regimes, while in the 220 kV part of the network, there are more lines loaded over 50%, primarily in the regions where the 400 kV network does not exist, including zones 8 and 10. Connecting additional RES capacity in these zones should have the lowest priority.

Based on the 110 kV network loading, we conclude that zones 1, 2 and 5 should have the lowest priority to connect new RES capacity.

Table 5.3: Overhead lines loading per indicated zones for the 400 kV, 220 kV and 110 kV networks



% of 400 kV lines loaded >50%

%I	1	2	3	4	5	6	7	8	9	10	11	12	ALL
Smax	0.00%	0.00%	0.00%	6.90%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	2.22%
Smin	0.00%	0.00%	0.00%	0.00%	33.33%	0.00%	0.00%	0.00%	0.00%	25.00%	16.67%	0.00%	4.44%

% of 220 kV lines loaded >50%

%I	1	2	3	4	5	6	7	8	9	10	11	12	ALL
Smax	18.18%	0.00%	50.00%	10.34%	0.00%	0.00%	0.00%	33.33%	0.00%	21.43%	0.00%	0.00%	14.93%
Smin	9.09%	0.00%	0.00%	6.90%	0.00%	0.00%	0.00%	66.67%	0.00%	21.43%	0.00%	0.00%	11.94%

% of 110 kV lines loaded >50%

%I	1	2	3	4	5	6	7	8	9	10	11	12	ALL
Smax	18.18%	25.00%	8.57%	6.49%	18.97%	1.43%	2.22%	11.36%	2.33%	0.00%	0.00%	0.00%	7.30%
Smin	9.09%	11.11%	0.00%	1.30%	6.90%	10.00%	0.00%	13.64%	0.00%	2.17%	4.17%	0.00%	4.50%

5.1.2 Locations and connections of additional RES

We provide the indicative locations and connections to the transmission network for additional RES capacities not present in the 2030 model in the following sub-chapters.

5.1.2.1 Wind locations and connections

Considering the potential of the zones and their OHL loadings, we distributed additional capacities of wind power capacity as follows:

In the 2030 Referent RES scenario, we added 1000 MW in:

- zone 3 (ZR) - 300 MW
- zone 6 (BO) - 363 MW
- zone 11 (NI) - 300 MW

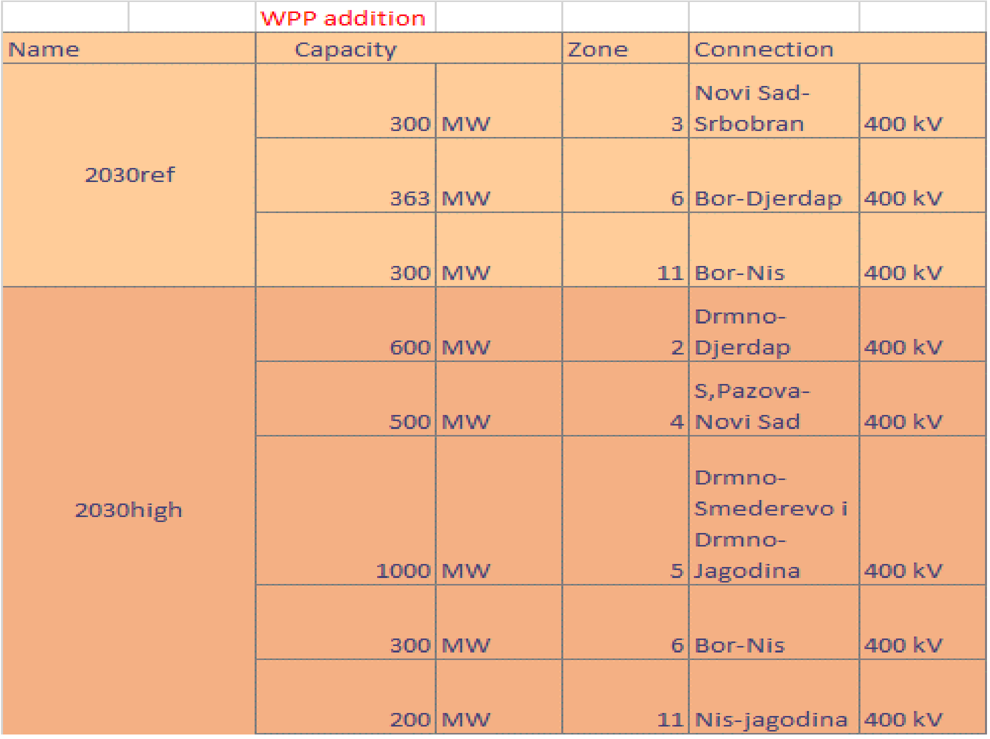
In the 2030 High RES scenario, we added 2600 MW (in addition to the MWs in the 2030 Referent scenario) in:

- zone 2 (PO) - 600 MW

- zone 4 (BG) - 500 MW
- zone 5 (SD) - 1000 MW
- zone 6 (BO) - 300 MW
- zone 11 (NI) - 200 MW

Table 5.4 presents the additional WPP capacity connected directly to the transmission network for the 2030 Referent and High scenarios.

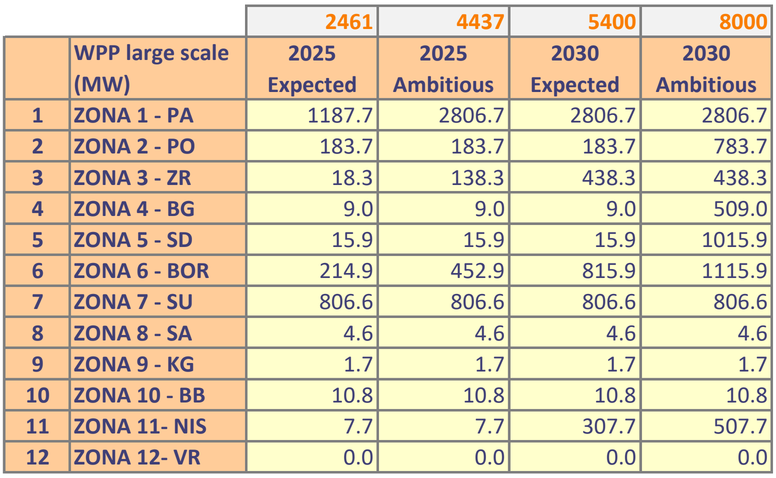
Table 5.4: Proposed additional WPPs directly connected to the transmission network, for the 2030 Expected and Ambitious scenarios



		WPP addition				
Name		Capacity		Zone	Connection	
2030ref		300	MW	3	Novi Sad-Srbobran	400 kV
		363	MW	6	Bor-Djerdap	400 kV
		300	MW	11	Bor-Nis	400 kV
2030high		600	MW	2	Drmno-Djerdap	400 kV
		500	MW	4	S,Pazova-Novi Sad	400 kV
		1000	MW	5	Drmno-Smederevo i Drmno-Jagodina	400 kV
		300	MW	6	Bor-Nis	400 kV
		200	MW	11	Nis-jagodina	400 kV

Table 5.5 provides a summary of all the large scale WPPs connected directly to the transmission network in the Referent and High scenarios for 2025 and 2030 for each zone.

Table 5.5: Large scale WPP installed capacity for 2025 and 2030, in the Referent and High scenarios



		2461	4437	5400	8000
	WPP large scale (MW)	**2025 Expected**	**2025 Ambitious**	**2030 Expected**	**2030 Ambitious**
1	**ZONA 1 - PA**	1187.7	2806.7	2806.7	2806.7
2	**ZONA 2 - PO**	183.7	183.7	183.7	783.7
3	**ZONA 3 - ZR**	18.3	138.3	438.3	438.3
4	**ZONA 4 - BG**	9.0	9.0	9.0	509.0
5	**ZONA 5 - SD**	15.9	15.9	15.9	1015.9
6	**ZONA 6 - BOR**	214.9	452.9	815.9	1115.9
7	**ZONA 7 - SU**	806.6	806.6	806.6	806.6
8	**ZONA 8 - SA**	4.6	4.6	4.6	4.6
9	**ZONA 9 - KG**	1.7	1.7	1.7	1.7
10	**ZONA 10 - BB**	10.8	10.8	10.8	10.8
11	**ZONA 11- NIS**	7.7	7.7	307.7	507.7
12	**ZONA 12- VR**	0.0	0.0	0.0	0.0

Zone 1 remains the zone with the highest wind capacity since the majority of the requirements for connection already received by EMS are in this zone, close to Pancevo and Vrsac.

Additional wind capacities are mainly envisaged as wind farms of high capacity (>300 MW), located in zones 2, 5 and 6, and connections are only proposed at 400 KV level having in mind lower loading as presented in Table 5.3. We will present the analysis of the network operation with these proposals embedded in the network model in the next phase of this report.

5.1.2.2 Solar locations and connections

Similar to wind capacity, the locations and connection to the transmission network for large scale SPPs are determined in this section.

Almost all of the installed capacity and connection points are already known for the large scale SPPs contained in the current EMS 2030 planning model. A summary of the location and connection points for large scale solar projects is presented in Table 5.6.

Table 5.6: Installed capacity of SPP in 2030

SPP in the model 2030

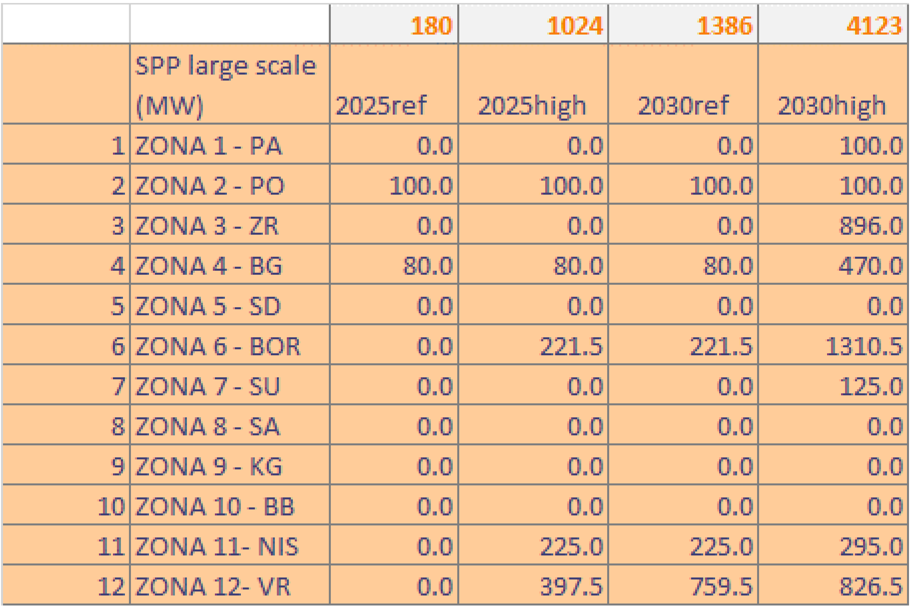
Name	Location	Capacity		Zone	Connection	
	Zabalj 110 kV	80	MW	4	SS	110 kV
	Kostolac-Drmno 110 kV	100	MW	2	SS	110 kV

SPP addition

Name	Location	Capacity		Zone	Connection	
SE Kima Solar	Sjenica	50	MW	10	Sjenica-N.Pazar	110 kV
SE Pirot Dobri Do	Pirot	75	MW	11	Pirot-Bpala	110 kV
SE Sjenica	Sjenica	50	MW	10	Sjenica-N.Pazar	110 kV
SE Solarina	Zajecar	150	MW	6	SS Bor	110 KV side
SE Navitacum		785	MW	12	Leskovac-Vranje	400 kV

We present the values of large SPPs directly connected to the transmission network for the 2025 and 2030 Referent and High scenarios for each zone in Table 5.7.

Table 5.7: Total installed capacity of large SPP per zones for 2025 and 2030, in the Referent and High scenarios



		180	1024	1386	4123
	SPP large scale (MW)	2025ref	2025high	2030ref	2030high
1	ZONA 1 - PA	0.0	0.0	0.0	100.0
2	ZONA 2 - PO	100.0	100.0	100.0	100.0
3	ZONA 3 - ZR	0.0	0.0	0.0	896.0
4	ZONA 4 - BG	80.0	80.0	80.0	470.0
5	ZONA 5 - SD	0.0	0.0	0.0	0.0
6	ZONA 6 - BOR	0.0	221.5	221.5	1310.5
7	ZONA 7 - SU	0.0	0.0	0.0	125.0
8	ZONA 8 - SA	0.0	0.0	0.0	0.0
9	ZONA 9 - KG	0.0	0.0	0.0	0.0
10	ZONA 10 - BB	0.0	0.0	0.0	0.0
11	ZONA 11- NIS	0.0	225.0	225.0	295.0
12	ZONA 12- VR	0.0	397.5	759.5	826.5

5.1.2.3 Wind - distributed

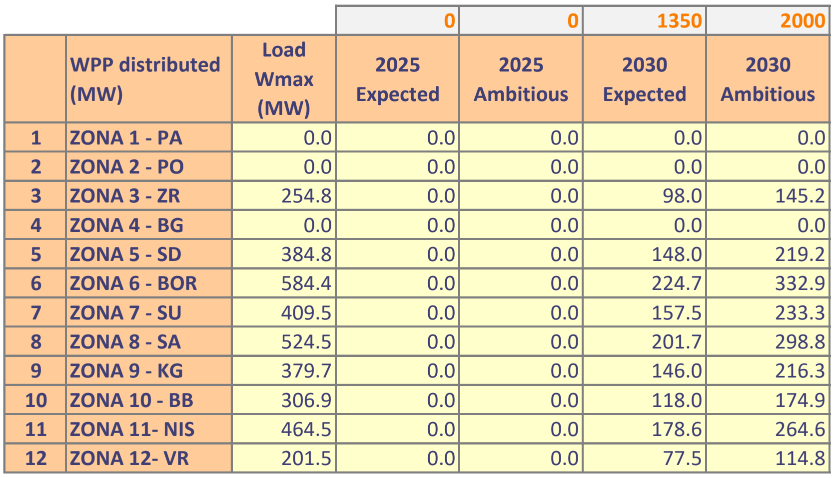
The renewable capacity that will be connected to the distribution network must be distributed on transmission network nodes. We propose the following approach.

We assume that additional small wind farms connected to the distribution network will be located in rural areas. For this reason, we did not include small wind capacity in zones 1, 2 and 4.

We distributed small wind power capacity in proportion to the load in the Winter Max regime in all zones except zones 1 (PA), 2 (PO) and 4 (BG).

Table 5.8 presents the total distributed capacity and total load for each zone for the 2025 and 2030 Referent and High scenarios.

Table 5.8: Installed capacity of distributed WPPs per zones for 2025 and 2030, in the Referent and High scenarios



			0	0	1350	2000
	WPP distributed (MW)	Load Wmax (MW)	2025 Expected	2025 Ambitious	2030 Expected	2030 Ambitious
1	ZONA 1 - PA	0.0	0.0	0.0	0.0	0.0
2	ZONA 2 - PO	0.0	0.0	0.0	0.0	0.0
3	ZONA 3 - ZR	254.8	0.0	0.0	98.0	145.2
4	ZONA 4 - BG	0.0	0.0	0.0	0.0	0.0
5	ZONA 5 - SD	384.8	0.0	0.0	148.0	219.2
6	ZONA 6 - BOR	584.4	0.0	0.0	224.7	332.9
7	ZONA 7 - SU	409.5	0.0	0.0	157.5	233.3
8	ZONA 8 - SA	524.5	0.0	0.0	201.7	298.8
9	ZONA 9 - KG	379.7	0.0	0.0	146.0	216.3
10	ZONA 10 - BB	306.9	0.0	0.0	118.0	174.9
11	ZONA 11- NIS	464.5	0.0	0.0	178.6	264.6
12	ZONA 12- VR	201.5	0.0	0.0	77.5	114.8

Table 5.9 provides a summary of the large scale and distributed WPPs and WPP/Load in the Summer Max regime ratios.

Table 5.9: Total WPP capacity and WPP/Load ratios per zones for 2025 and 2030, in the Referent and High scenarios

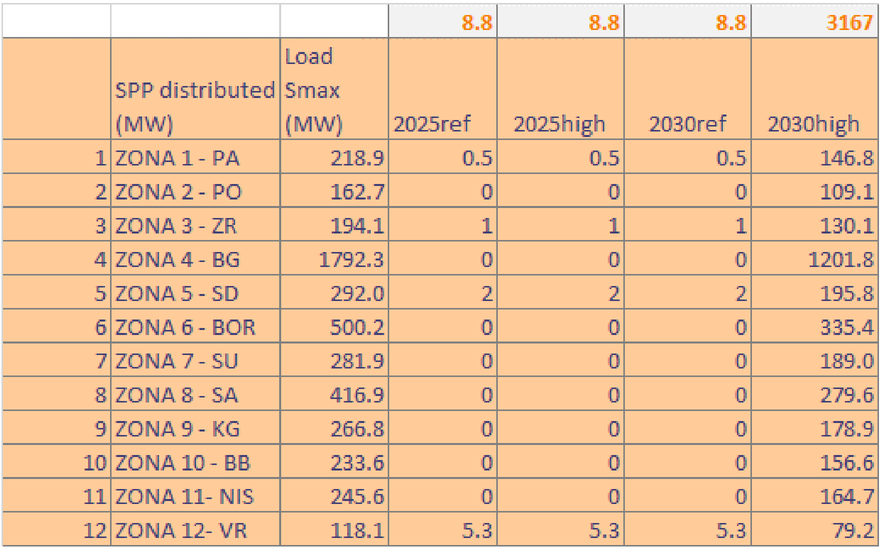
		2461	4437	6750	10000	WPP/Load Smax			
	WPP total (MW)	**2025 Expected**	**2025 Ambitious**	**2030 Expected**	**2030 Ambitious**	**2025 Expected**	**2025 Ambitious**	**2030 Expected**	**2030 Ambitious**
1	**ZONA 1 - PA**	1187.7	2806.7	2806.7	2806.7	5.4	12.8	12.8	12.8
2	**ZONA 2 - PO**	183.7	183.7	183.7	783.7	1.1	1.1	1.1	4.8
3	**ZONA 3 - ZR**	18.3	138.3	536.3	583.5	0.1	0.7	2.8	3.0
4	**ZONA 4 - BG**	9.0	9.0	9.0	509.0	0.0	0.0	0.0	0.3
5	**ZONA 5 - SD**	15.9	15.9	163.9	1235.1	0.1	0.1	0.6	4.2
6	**ZONA 6 - BOR**	214.9	452.9	1040.6	1448.8	0.4	0.9	2.1	2.9
7	**ZONA 7 - SU**	806.6	806.6	964.0	1039.9	2.9	2.9	3.4	3.7
8	**ZONA 8 - SA**	4.6	4.6	206.3	303.4	0.0	0.0	0.5	0.7
9	**ZONA 9 - KG**	1.7	1.7	147.7	218.0	0.0	0.0	0.6	0.8
10	**ZONA 10 - BB**	10.8	10.8	128.8	185.6	0.0	0.0	0.6	0.8
11	**ZONA 11- NIS**	7.7	7.7	486.4	772.4	0.0	0.0	2.0	3.1
12	**ZONA 12- VR**	0.0	0.0	77.5	114.8	0.0	0.0	0.7	1.0

5.1.2.4 Solar - distributed

We assumed solar production connected to the distribution network will be located mainly in urban areas with higher load, as rooftop photovoltaic panels.

We distributed these small solar generators in proportion to the load in the Summer Max regime in all of the zones. The results of this distribution are presented in Table 5.10.

Table 5.10: Installed capacity of distributed SPPs per zones for 2025 and 2030, in the Referent and High scenarios



			8.8	8.8	8.8	3167
	SPP distributed (MW)	Load Smax (MW)	2025ref	2025high	2030ref	2030high
1	ZONA 1 - PA	218.9	0.5	0.5	0.5	146.8
2	ZONA 2 - PO	162.7	0	0	0	109.1
3	ZONA 3 - ZR	194.1	1	1	1	130.1
4	ZONA 4 - BG	1792.3	0	0	0	1201.8
5	ZONA 5 - SD	292.0	2	2	2	195.8
6	ZONA 6 - BOR	500.2	0	0	0	335.4
7	ZONA 7 - SU	281.9	0	0	0	189.0
8	ZONA 8 - SA	416.9	0	0	0	279.6
9	ZONA 9 - KG	266.8	0	0	0	178.9
10	ZONA 10 - BB	233.6	0	0	0	156.6
11	ZONA 11- NIS	245.6	0	0	0	164.7
12	ZONA 12- VR	118.1	5.3	5.3	5.3	79.2

A summary of the large scale and distributed SPPs and SPP/Load in the Summer Max regime ratios are presented in Table 5.11.

Table 5.11: Total SPP capacity and SPP/Load ratios per zones for 2025 and 2030, in Referent and High scenario

			189	1033	1395	7290	SPP/Load Smax			
	SPP total (MW)	Load Smax (MW)	2025ref	2025high	2030ref	2030high	2025ref	2025high	2030ref	2030high
1	ZONA 1 - PA	218.9	0.5	0.5	0.5	246.8	0.0	0.0	0.0	1.1
2	ZONA 2 - PO	162.7	100.0	100.0	100.0	209.1	0.6	0.6	0.6	1.3
3	ZONA 3 - ZR	194.1	1.0	1.0	1.0	1026.1	0.0	0.0	0.0	5.3
4	ZONA 4 - BG	1792.3	80.0	80.0	80.0	1671.8	0.0	0.0	0.0	0.9
5	ZONA 5 - SD	292.0	2.0	2.0	2.0	195.8	0.0	0.0	0.0	0.7
6	ZONA 6 - BOR	500.2	0.0	221.5	221.5	1645.9	0.0	0.4	0.4	3.3
7	ZONA 7 - SU	281.9	0.0	0.0	0.0	314.0	0.0	0.0	0.0	1.1
8	ZONA 8 - SA	416.9	0.0	0.0	0.0	279.6	0.0	0.0	0.0	0.7
9	ZONA 9 - KG	266.8	0.0	0.0	0.0	178.9	0.0	0.0	0.0	0.7
10	ZONA 10 - BB	233.6	0.0	0.0	0.0	156.6	0.0	0.0	0.0	0.7
11	ZONA 11- NIS	245.6	0.0	225.0	225.0	459.7	0.0	0.9	0.9	1.9
12	ZONA 12- VR	118.1	5.3	402.8	764.8	905.7	0.0	3.4	6.5	7.7

We concluded that the biggest share of wind capacity will be installed in zone 1, around Pancevo and Vrsac. Solar capacity will be distributed more evenly, with the biggest absolute share in zones 4 and 6, around Belgrade and Bor.

5.2 Steps applied in identification of the impacts of RES integration on the transmission

The input for the load flow and voltage profile calculations are the transmission network models for the existing network state and for the future perspective states (2025 and 2030) that were prepared and approved by EMS.

These models have been updated with respect to new RES projects and their connection at specific locations. In addition, we incorporated the results of the market analysis of hourly generation dispatch, loads and balances into these network models. We conducted detailed network simulations for specific hours suggested by the market results that we believe are critical regimes for network security and reliability.

To effectively combine the network and market analysis, we extracted hourly load and dispatch data from the Plexos model, and convert it to PSS/E format, and then executed the precise network simulation using the detailed AC network model.

Based on results from the market analysis, we created regional models for six regimes:

- Winter Peak
- Summer Off-Peak
- Operating regime with the highest wind+solar generation in EMS market area
- Summer regime with the highest generation in EMS market area
- Operating regime with the highest export from EMS market area
- Operating regime with the highest import to EMS market area

Each of these regimes has four variants related to RES integration in 2025 and 2030 in the Referent and High scenario for one CO2 price.

Within this activity, we analyzed the characteristics and behavior of the transmission network for the EMS control area and identify weak points and constraints. This included:

- Steady state AC load flow analyses with complete modelling of the Serbian electricity grid 400, 220 and 110 kV for 2025 and 2030.
- Security (n-1) assessment.
- Voltage profile analysis.
- Identification of potential weak points in the network and possible problems in the network operation, assessment of potential solutions and corresponding costs.

Depending on the results of the analyses performed for the Referent and High scenarios, we identified possible violations of operational security limits and weak points of the network. Proposed reinforcements in the network are identified and corresponding costs have been assessed.

The costs for necessary reinforcement in the network due to a high level of RES integration have been assessed using standard operational expenditures (OPEX) and capital expenditures (CAPEX) components based on available information and EMS databases for the projects of this type and scope. Additional analysis should include the aspects/costs of compensation for reactive energy as consequence of the developed network, in the case when wind plants do not operate.

The estimated specific investment costs (in Euros per kilometer and Euros per pcs) for new elements are presented in the tables below.

Table 5.12: Overhead line estimated specific investment costs

Single line 400 kV, ACSR 2x490/65	
OHL route characteristics	**Price €/km**
Plain undeveloped terrain	220,000
Hilly mountainous terrain, difficult to access	25,000
Built, inhabited, suburban or urban area	28,000

Double line 400 kV, ACSR 2x490/65	
OHL route characteristics	**Price €/km**
Plain undeveloped terrain	350,000
Hilly mountainous terrain, difficult to access	370,000
Built, inhabited, suburban or urban area	420,000

Single line 220 kV, ACSR 490/65	
OHL route characteristics	**Price €/km**
Plain undeveloped terrain	140,000
Hilly mountainous terrain, difficult to access	170,000
Built, inhabited, suburban or urban area	200,000

Double line 220 kV, ACSR 490/65	
OHL route characteristics	**Price €/km**
Plain undeveloped terrain	220,000
Hilly mountainous terrain, difficult to access	245,000
Built, inhabited, suburban or urban area	280,000

Single line 110 kV, ACSR 240/40	
OHL route characteristics	**Price €/km**
Plain undeveloped terrain	90,000
Hilly mountainous terrain, difficult to access	110,000
Built, inhabited, suburban or urban area	140,000

Double line 110 kV, ACSR 240/40	
OHL route characteristics	**Price €/km**
Plain undeveloped terrain	135,000
Hilly mountainous terrain, difficult to access	150,000
Built, inhabited, suburban or urban area	180,000

Table 5.13: High voltage bay estimated specific investment costs

High Voltage Bays					
		Voltage level, Price in €			
Type	**pcs.**	**35 kV**	**110 kV**	**220 kV**	**400 kV**
Line bay		90,000	330,000	400,000	700,000
Transformer bay		100,000	300,000	380,000	650,000
Coupler bay		65,000	200,000	350,000	500,000
Uneqipped bay		27,000	66,200	84,000	205,000

Table 5.14: Power transformer estimated specific investment costs

Power Transformers			
No.	**Type**	**Price in €**	**Price €/MVA**
1	31.5 MVA, 123 kV, 110/35 kV	551,250	17,500
2	63 MVA, 123 kV, 110/35 kV	756,000	12,000
3	100 MVA, 123 kV, 110/35 kV	1,100,000	11,000
4	150 MVA, 245 kV, 220/110 kV	1,500,000	10,000
5	250 MVA, 245 kV, 220/110 kV	2,250,000	9,000
6	300 MVA, 420 kV, 400/110 kV	2,550,000	8,500
7	400 MVA, 420 kV, 400/220 kV	3,000,000	7,500

5.3 RES integration impacts on the transmission network

This Chapter provides the results of detailed power network analyses. It is focused on the impact of high RES integration on the main power network operation indicators such as:

1. Load flows
2. Voltage profiles on transmission network nodes
3. Security analyses (N-1) and the detection of network bottlenecks at 110 kV and above

Below, we present the relevant network results for each scenario in the following way:

1. EMS control area summary list, with total generation, consumption and losses;
2. Geographic map, with cross-border exchanges (MW) and directions
3. Heavily loaded branches (>80%) on the 400 kV and 220 kV levels (base case)
4. Voltage profiles on the 400 kV, 220 kV and 110 kV levels
5. Critical network outages and consequent overloadings (n-1 analysis)

The focus of these analyses are on the regimes that could present a significant challenge for secure operation of the transmission network with possible overloading of the network elements.

With the aim to analyze more stressed situation for the EMS transmission network, we selected results from the market simulations carried out with referent CO2 tax (at rather low level of 23 and 27 EUR/t) have been selected. In this case, the high thermal generation and high exports from the EMS market area is expected to place more stress for the network.

The market simulation results for the higher CO2 prices (56 and 53 EUR/t) gives significantly lower generation from thermal units in Serbia, and they are almost balanced with small amounts of export or import from the EMS market area, which leads to a lower loading of the network. Differences in the balance positions in all analyzed regimes and scenarios are shown in Figure 5.2.

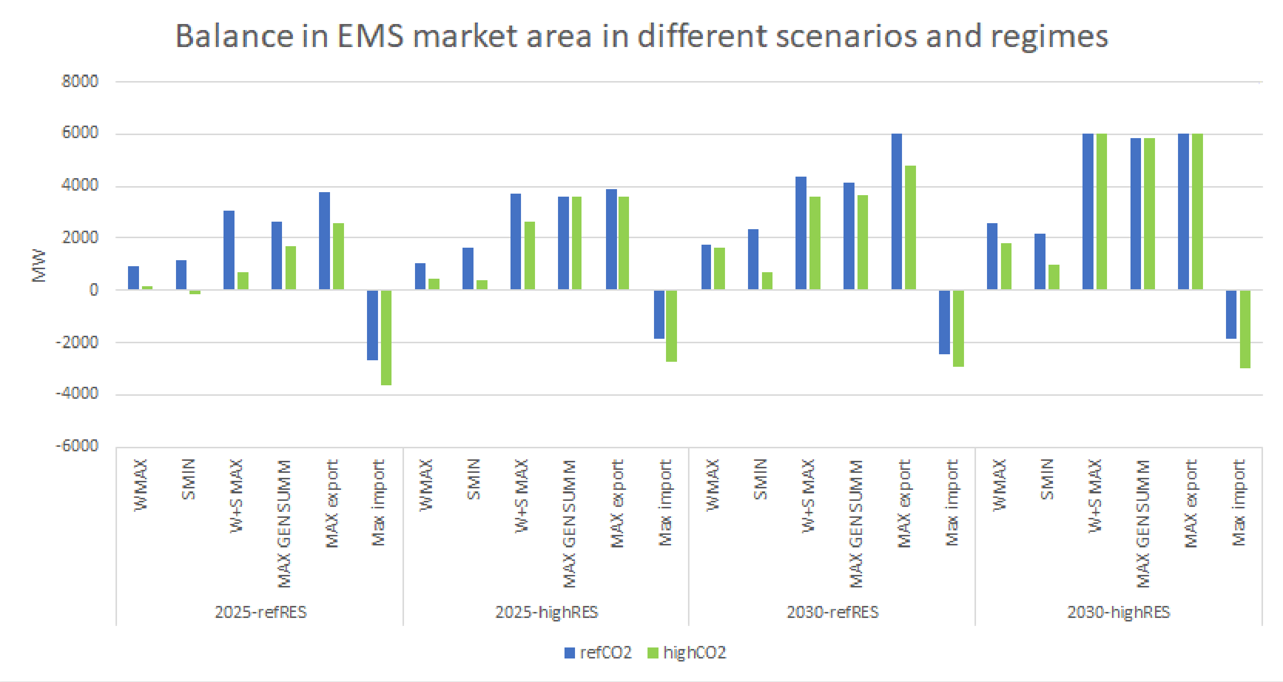


Figure 5.2: Differences in balances in EMS market area between market results for referent and high CO2 price

We present the analyzed regimes in Table 5.15 and Table 5.16. As mentioned, for all regimes we take the hourly dispatch from the market simulations with referent CO2 tax (23 and 27 EUR/t).

While the presented load does not include losses in the transmission network, it does take into account the appropriate levels of distributed RES generation in each scenario in 2030.

Table 5.15: List of analysed regimes in 2025

Scenario	Characteristic hour	Load in EMS market area (MW)	Balance of EMS market area (MW)
2025-RefRES RES=2670MW	Winter Peak January 17 at hour 20	6080	957
	Summer off-peak July 18 at hour 04	2471	1173
	Operating regime with the highest wind+solar generation in EMS market area March 12 at hour 12	4906	3071
	Summer regime with the highest generation in EMS market area April 30 at hour 09	4720	2627
	Operating regime with the highest export from EMS market area February 01 at hour 08	4907	3747
	Operating regime with the highest import to EMS market area April 08 at hour 13	3602	-2677
2025-HighRES RES=5400MW	Winter Peak January 17 at hour 20	6087	1054
	Summer off-peak July 18 at hour 04	2486	1657
	Operating regime with the highest wind+solar generation in EMS market area March 12 at hour 12	4913	3723
	Summer regime with the highest generation in EMS market area April 30 at hour 09	4735	3612
	Operating regime with the highest export from EMS market area February 01 at hour 08	4914	3891
	Operating regime with the highest import to EMS market area April 08 at hour 13	3618	-1877

The selected regimes include different levels of generation from wind and solar capacities with minimum at the level of 11% of installed capacities in summer off-peak regime and maximum that reaches 85% of installed capacities.

Concerning export from EMS market area, it should be noted that, values of 3723 MW and 3891 MW present the sum of all cross-border capacities available for commercial exchanges (the sum of NTCs) in summer and winter season, and exports are limited within these values.

Based on market results for the Referent RES Scenario, export reached these maximum values in only 2 hours (of 8760 hours) in this Scenario.

In the High RES Scenario, these values are reached in the highest export and summer regime with the highest generation in EMS area. Annually, exports are limited in 59 hours during the summer and 144 hours in winter. However, no RES curtailment is noted in these regimes.

Table 5.16: List of analysed regimes in 2030

Scenario	**Characteristic hour**	**Load in EMS market area (MW)**[17]	**Balance of EMS market area (MW)**
2030-RefRES RES=8100MW	Winter Peak January 17 at hour 20	5865	1782
	Summer off-peak July 18 at hour 04	2218	2356
	Operating regime with the highest wind+solar generation in EMS market area March 12 at hour 12	3832	4354
	Summer regime with the highest generation in EMS market area April 29 at hour 20	4039	4145
	Operating regime with the highest export from EMS market area January 02 at hour 16	3755	6031
	Operating regime with the highest import to EMS market area April 15 at hour 11	4370	-2443
2030-HighRES RES=17000MW	Winter Peak January 17 at hour 20	5761	2563
	Summer off-peak July 18 at hour 04	2235	2176
	Operating regime with the highest wind+solar generation in EMS market area January 07 at hour 11	2634	6025
	Summer regime with the highest generation in EMS market area April 30 at hour 09	3587	5705
	Operating regime with the highest export from EMS market area January 02 at hour 16	3337	6031
	Operating regime with the highest import to EMS market area April 06 at hour 21	4287	-1870

In the Scenario with 8100 MW in RES (referent RES scenario), minimum generation in wind and solar capacities at the level of 11% of installed capacities is noted in summer off-peak regime. Maximum reaches 85% of installed capacities, similar as in cases with 2700 MW and 5400 MW. In Scenario with 17000 MW, with more solar generation than in previous scenarios, these ratios drops: minimum drops to 8% of total installed capacity (in the same summer off-peak regime) and maximum drops to 70% of installed capacity.

Concerning exports from the EMS market area, it should be noted that maximum value of 5863 MW and 6031 MW are the sum of all cross-border capacities available for commercial exchanges (sum of NTCs) in the summer and winter seasons, respectively.

---

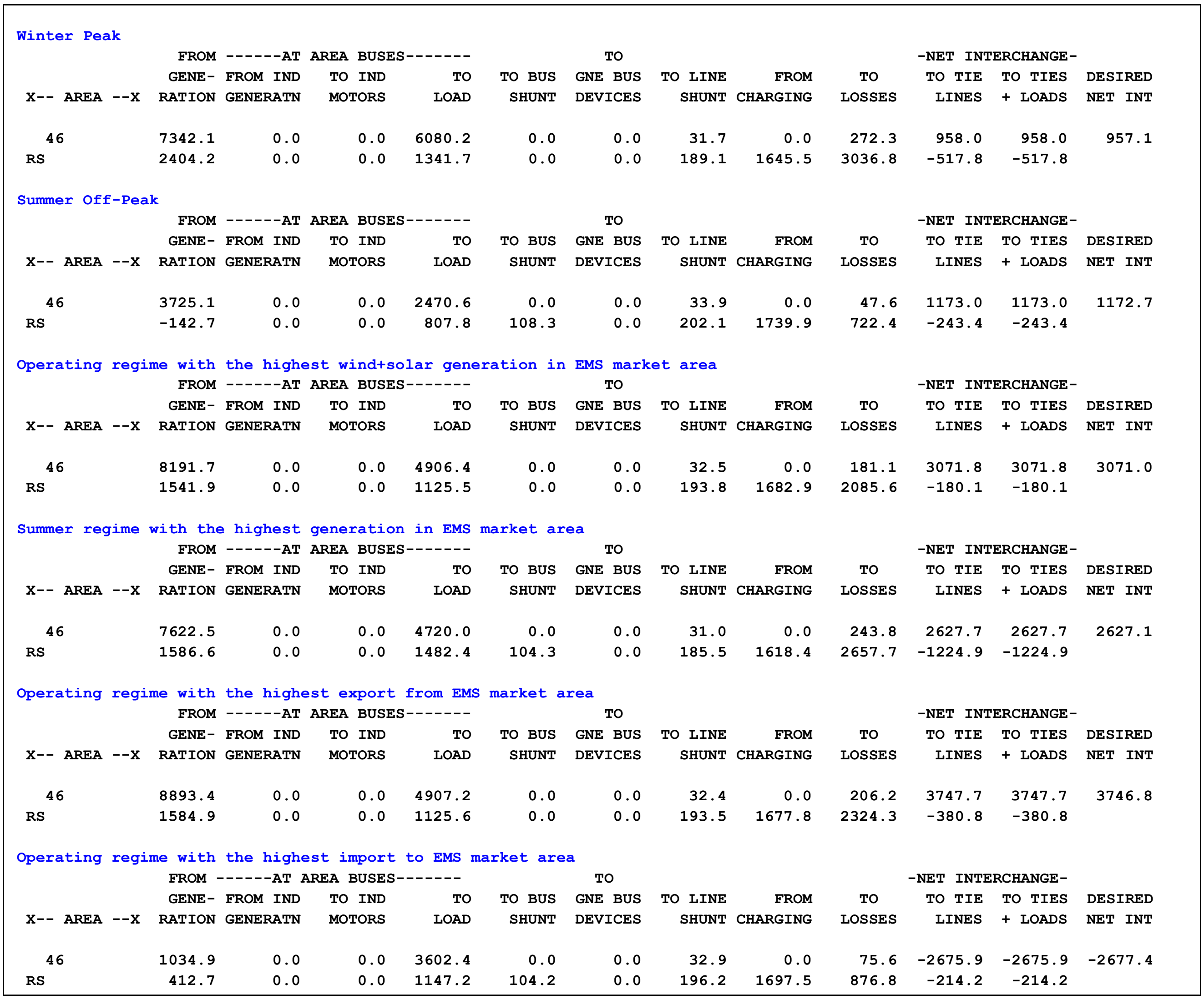
[17] Load takes into account appropriate levels of distributed RES generation in each scenario in 2030

In the Referent RES Scenario, these values are reached in the regime with the highest export. At an annual level, export is limited in only 10 hours during winter, without any RES curtailments.

In the high RES Scenario, with 17 GW of RES installed capacities, these values are reached in the regime with the highest exports, but on an annual level, exports are limited in 126 hours during the summer and in 292 hours during winter. In this case, there are 135 hours and regimes in which part of RES generation is curtailed, reaching a maximum of curtailed power of 3100 MW. Total annual RES curtailment in this Scenario (and this selected climatic year) is 99.5 GWh, which is still rather low in comparison with total RES generation of 29,347 GWh (only 0.34%).

5.3.1 Year 2025-refRES, RES=2700 MW

We first provide the summary report, with data only for the EMS market area. We present the area summary for the analyzed six network regimes as follows:



```
Winter Peak
                 FROM ------AT AREA BUSES-------              TO                              -NET INTERCHANGE-
                GENE- FROM IND   TO IND        TO   TO BUS  GNE BUS  TO LINE     FROM       TO    TO TIE  TO TIES  DESIRED
 X-- AREA --X  RATION GENERATN   MOTORS      LOAD    SHUNT  DEVICES    SHUNT CHARGING   LOSSES     LINES  + LOADS  NET INT

   46          7342.1      0.0      0.0    6080.2      0.0      0.0     31.7      0.0    272.3     958.0    958.0    957.1
 RS            2404.2      0.0      0.0    1341.7      0.0      0.0    189.1   1645.5   3036.8    -517.8   -517.8

Summer Off-Peak
                 FROM ------AT AREA BUSES-------              TO                              -NET INTERCHANGE-
                GENE- FROM IND   TO IND        TO   TO BUS  GNE BUS  TO LINE     FROM       TO    TO TIE  TO TIES  DESIRED
 X-- AREA --X  RATION GENERATN   MOTORS      LOAD    SHUNT  DEVICES    SHUNT CHARGING   LOSSES     LINES  + LOADS  NET INT

   46          3725.1      0.0      0.0    2470.6      0.0      0.0     33.9      0.0     47.6    1173.0   1173.0   1172.7
 RS            -142.7      0.0      0.0     807.8    108.3      0.0    202.1   1739.9    722.4    -243.4   -243.4

Operating regime with the highest wind+solar generation in EMS market area
                 FROM ------AT AREA BUSES-------              TO                              -NET INTERCHANGE-
                GENE- FROM IND   TO IND        TO   TO BUS  GNE BUS  TO LINE     FROM       TO    TO TIE  TO TIES  DESIRED
 X-- AREA --X  RATION GENERATN   MOTORS      LOAD    SHUNT  DEVICES    SHUNT CHARGING   LOSSES     LINES  + LOADS  NET INT

   46          8191.7      0.0      0.0    4906.4      0.0      0.0     32.5      0.0    181.1    3071.8   3071.8   3071.0
 RS            1541.9      0.0      0.0    1125.5      0.0      0.0    193.8   1682.9   2085.6    -180.1   -180.1

Summer regime with the highest generation in EMS market area
                 FROM ------AT AREA BUSES-------              TO                              -NET INTERCHANGE-
                GENE- FROM IND   TO IND        TO   TO BUS  GNE BUS  TO LINE     FROM       TO    TO TIE  TO TIES  DESIRED
 X-- AREA --X  RATION GENERATN   MOTORS      LOAD    SHUNT  DEVICES    SHUNT CHARGING   LOSSES     LINES  + LOADS  NET INT

   46          7622.5      0.0      0.0    4720.0      0.0      0.0     31.0      0.0    243.8    2627.7   2627.7   2627.1
 RS            1586.6      0.0      0.0    1482.4    104.3      0.0    185.5   1618.4   2657.7   -1224.9  -1224.9

Operating regime with the highest export from EMS market area
                 FROM ------AT AREA BUSES-------              TO                              -NET INTERCHANGE-
                GENE- FROM IND   TO IND        TO   TO BUS  GNE BUS  TO LINE     FROM       TO    TO TIE  TO TIES  DESIRED
 X-- AREA --X  RATION GENERATN   MOTORS      LOAD    SHUNT  DEVICES    SHUNT CHARGING   LOSSES     LINES  + LOADS  NET INT

   46          8893.4      0.0      0.0    4907.2      0.0      0.0     32.4      0.0    206.2    3747.7   3747.7   3746.8
 RS            1584.9      0.0      0.0    1125.6      0.0      0.0    193.5   1677.8   2324.3    -380.8   -380.8

Operating regime with the highest import to EMS market area
                FROM ------AT AREA BUSES-------              TO                              -NET INTERCHANGE-
                GENE- FROM IND   TO IND        TO   TO BUS  GNE BUS  TO LINE     FROM       TO    TO TIE  TO TIES  DESIRED
 X-- AREA --X  RATION GENERATN   MOTORS      LOAD    SHUNT  DEVICES    SHUNT CHARGING   LOSSES     LINES  + LOADS  NET INT

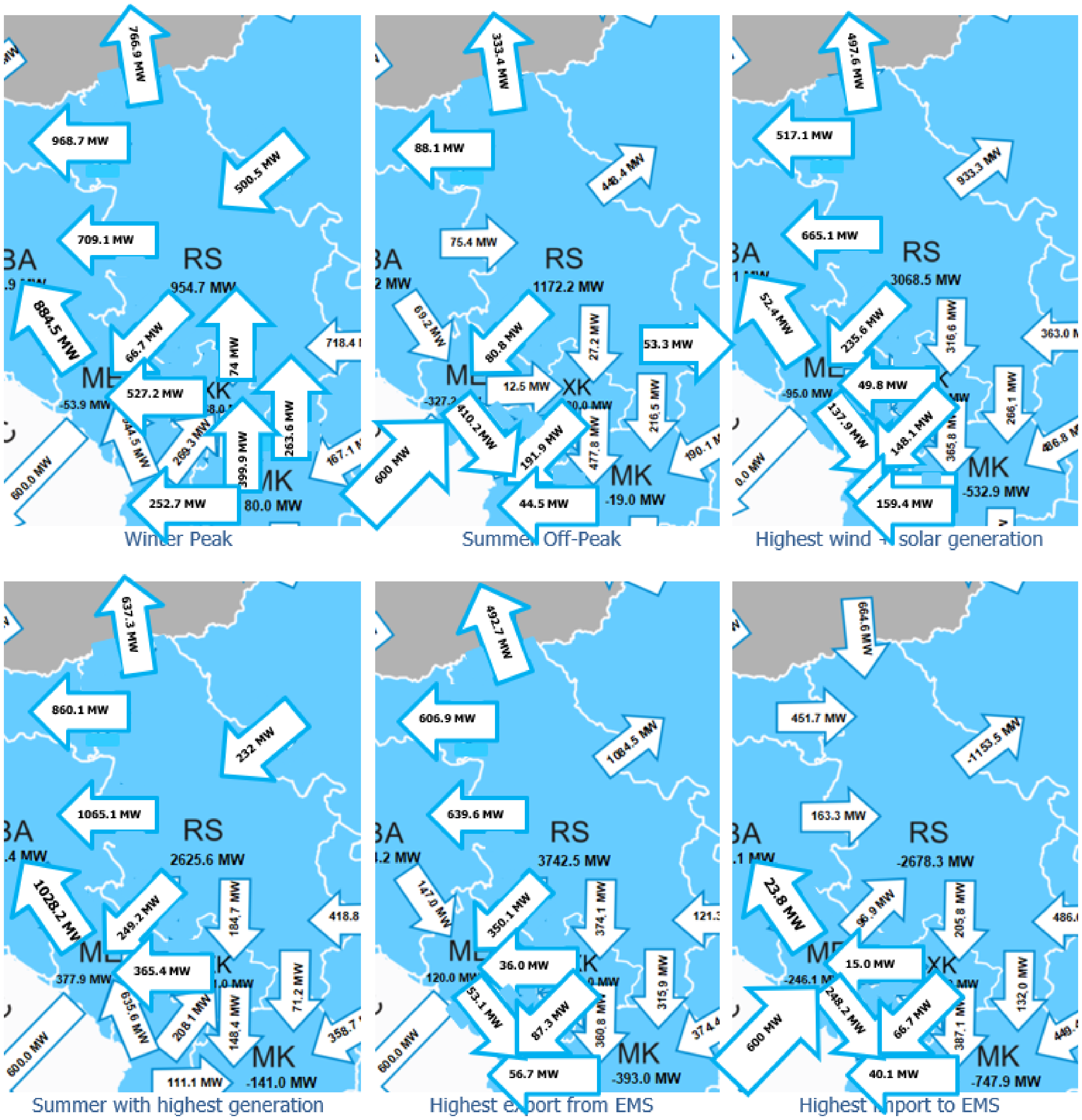
   46          1034.9      0.0      0.0    3602.4      0.0      0.0     32.9      0.0     75.6   -2675.9  -2675.9  -2677.4
 RS             412.7      0.0      0.0    1147.2    104.2      0.0    196.2   1697.5    876.8    -214.2   -214.2
```

Figure 5.3: Area summary report for 2025 analysed regimes (referent RES, referent CO2)

Based on the above area summary report, results for EMS market area are the following:

- Winter Peak regime:
    - The total EMS system load is 6080 MW and 1342 MVar
    - Generation is 7342 MW and EMS exports 957 MW
- Summer Off-Peak regime:
    - The total EMS system load is 2471 MW and 808 MVar
    - Generation is 3725 MW and EMS exports 1173 MW
- Highest wind+solar generation regime:
    - The total EMS system load is 4906 MW and 1125 MVar
    - Generation is 8192 MW and EMS exports 3071 MW
- Summer with highest generation regime:
    - The total EMS system load is 4720 MW and 1482 MVar
    - Generation is 7622 MW and EMS exports 2627 MW
- Highest export from EMS regime:
    - The total EMS system load is 4907 MW and 1125 MVar
    - Generation is 8893 MW and EMS exports 3747 MW
- Highest import to EMS regime:
    - The total EMS system load is 3602 MW and 1147 MVar
    - Generation is 1035 MW and EMS imports 2677 MW

The following figures show the cross-border power exchange map for all six analysed regimes for year 2025 referent RES.



Winter Peak — Summer Off-Peak — Highest wind + solar generation

Summer with highest generation — Highest export from EMS — Highest import to EMS

Figure 5.4: Cross-border exchanges (MW) and directions between the countries in year 2025 and Referent RES scenario

The following three figures show the 400 kV, 220 kV and 110 kV voltage profiles with maximum, minimum and average values in EMS transmission network for all six analysed regimes. The voltage profiles in the 400 kV and 220 kV networks are within limits for all analysed regimes.

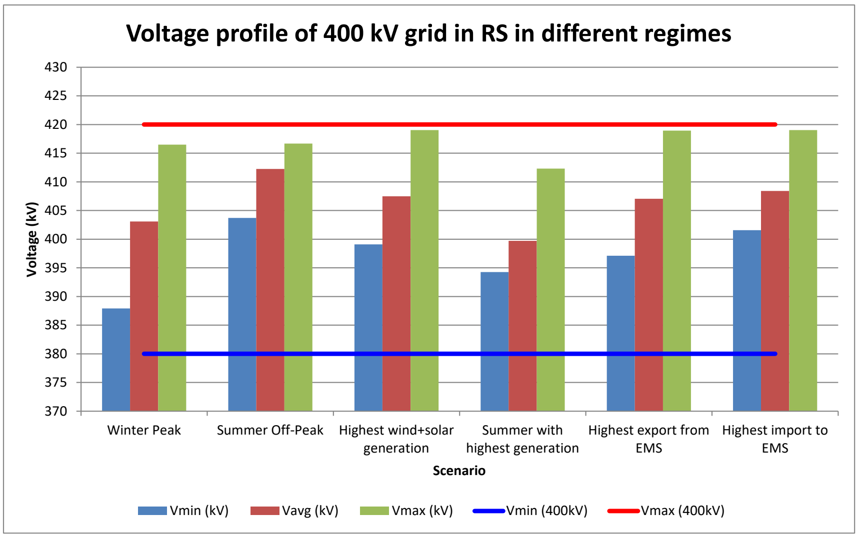


Figure 5.5: 400 kV voltage profiles (minimum, maximum and average) for 2025 analysed regimes (referent RES, referent CO2)

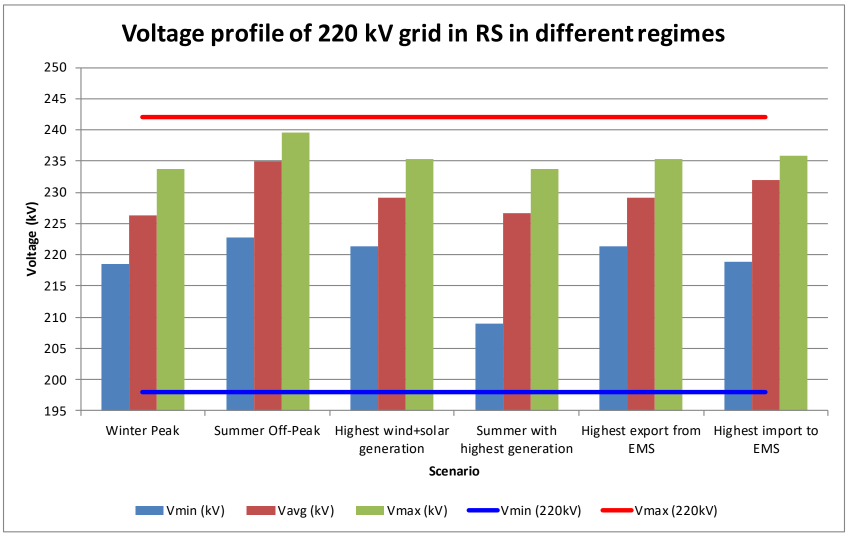


Figure 5.6: 220 kV voltage profiles (minimum, maximum and average) for 2025 analysed regimes (referent RES, referent CO2)

In case of 110 kV network, in some nodes voltages above acceptable limits are observed. These problems can be considered as local and can be controlled by fine tunning of the voltage profiles at higher network levels.

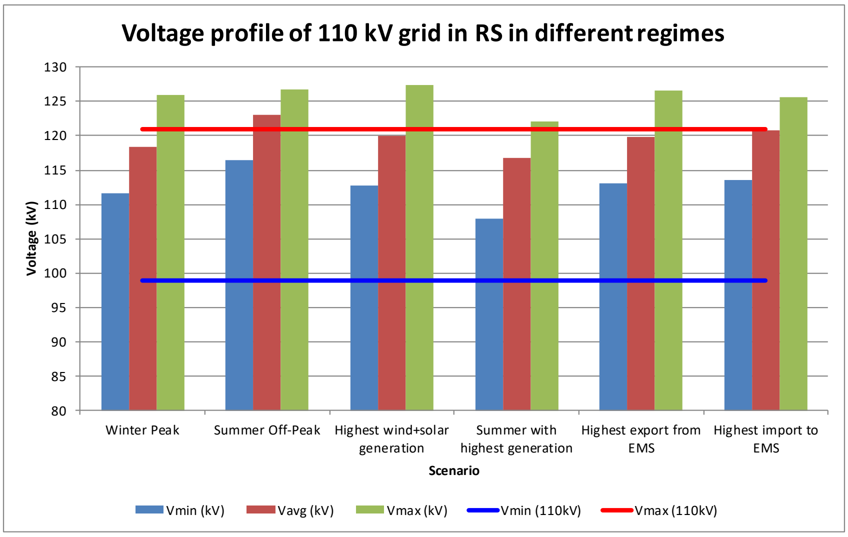


Figure 5.7: 110 kV voltage profiles (minimum, maximum and average) for 2025 analysed regimes (referent RES, referent CO2)

The 400 kV and 220 kV elements that are loaded more than 80% are as follows:

```
Winter Peak
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
 460090 JRPMLA12    400.00*   46 460095 JSMIT211    400.00    46  1   1427.4  1330.2   107.3
 461145 JSABA321    220.00*   46 3WNDTR T1           WND 1    46  1    124.1   150.0    82.7

Summer Off-Peak
/
Operating regime with the highest wind+solar generation in EMS market area
/
Summer regime with the highest generation in EMS market area
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
 460070 JPANC211    400.00*   46 460151 JBGD2012    400.00    46  A     952.0   935.3   101.8
 460090 JRPMLA12    400.00*   46 460095 JSMIT211    400.00    46  1   1540.5  1205.5   127.8
  13231 XVI_VA21    220.00    99 461130 JPOZEG21    220.00*   46  1    221.9   274.4    80.9
 461145 JSABA321    220.00*   46 3WNDTR T1           WND 1    46  1    125.0   150.0    83.3

Operating regime with the highest export from EMS market area
/
Operating regime with the highest import to EMS market area
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
 461000 JBBAST21    220.00*   46 461135 JRHBBA21    220.00    46  1    269.3   331.5    81.2
```

Figure 5.8: List of 400 and 220 kV elements loaded more than 80% for 2025 analysed regimes (referent RES, referent CO2)

The most critical regimes are the ones with high export towards West and North-West which has the values between 346 MW and 2445 MW (Figure 5.4). The maximum export in these directions are in winter peak regime (2445 MW) and summer regime with maximum generation in EMS area (2330 MW). The second regime is even more critical since the operating constraints in the network are higher due to different seasonal settings.

The overloaded lines SS Mladost – SS Sremska Mitrovica and SS Pančevo 2 – Belgrade 20 points to the potential problems with evacuation of the high amounts of power towards West (and North-West), disregarding what is the source of excess of generation: conventional units or RES. With respect to this problem, plans for network reinforcement that EMS already has (projects "North CSE corridor", interconnection with BA and ME and „Pannonian Corridor" present a solution for these situations. It should only be noted that, these reinforcements are not only provoked by additional RES in Serbian power system but also by other system security requirements.

Concerning 110 kV network, situation is somewhat different having in mind that in many cases overloading of this part of the network is directly provoked by expected additional RES capacities or additional industrial load. These issues are taken into account within preparation of the connection solutions for each RES or large industrial complex and do not present a general obstacle for integration of the proposed level of RES capacities.

The 110 kV elements that are loaded more than 80% are as follows:

```
Winter Peak
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
  46031 XNP_LE51    110.00*   99 462830 JNPAZ25     110.00    46  1     91.1   110.5    82.4
 462825 JNPAZ151    110.00    46 462830 JNPAZ25     110.00*   46  1     88.9   110.5    80.4

Summer Off-Peak
/
Operating regime with the highest wind+solar generation in EMS market area
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
462170 JBGD3 52    110.00    46 462935 JPANC151    110.00*   46  1     95.1   110.5    86.0

Summer regime with the highest generation in EMS market area
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
  13531 XBI_LE51    110.00    99 462710 JLESNI5     110.00*   46  1     87.4   106.7    82.0
  13533 XZV_BI51    110.00    99 462480 JHZVOR51    110.00*   46  1    119.0   106.7   111.6
 462165 JBGD3 51    110.00    46 462180 JBGD335     110.00*   46  1     84.9    78.1   108.7
 462170 JBGD3 52    110.00    46 462935 JPANC151    110.00*   46  1    105.9    78.1   135.6
 462180 JBGD335     110.00    46 462940 JPANC152    110.00*   46  1     93.7    78.1   120.0
 462575 JKOLUB52    110.00    46 463285 JTAMNZ5     110.00*   46  1     70.8    78.1    90.7
 462710 JLESNI5     110.00    46 463100 JSABA352    110.00*   46  1     95.6    78.1   122.4
 462721 JRTINT51    110.00    46 463390 JVALJ351    110.00*   46  1     77.6    78.1    99.4
 462915 JOSECI5     110.00    46 463395 JVALJ352    110.00*   46  2    109.8    78.1   140.5
 462935 JPANC151    110.00    46 462950 JPANC252    110.00*   46  2    112.4   106.7   105.4
 462940 JPANC152    110.00    46 462960 JPANC451    110.00*   46  2     95.6    78.1   122.5
 462945 JPANC251    110.00*   46 462960 JPANC451    110.00    46  1    113.4   106.7   106.3

Operating regime with the highest export from EMS market area
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
462825 JNPAZ151    110.00    46 462830 JNPAZ25     110.00*   46  1     91.9   110.5    83.2

Operating regime with the highest import to EMS market area
/
```

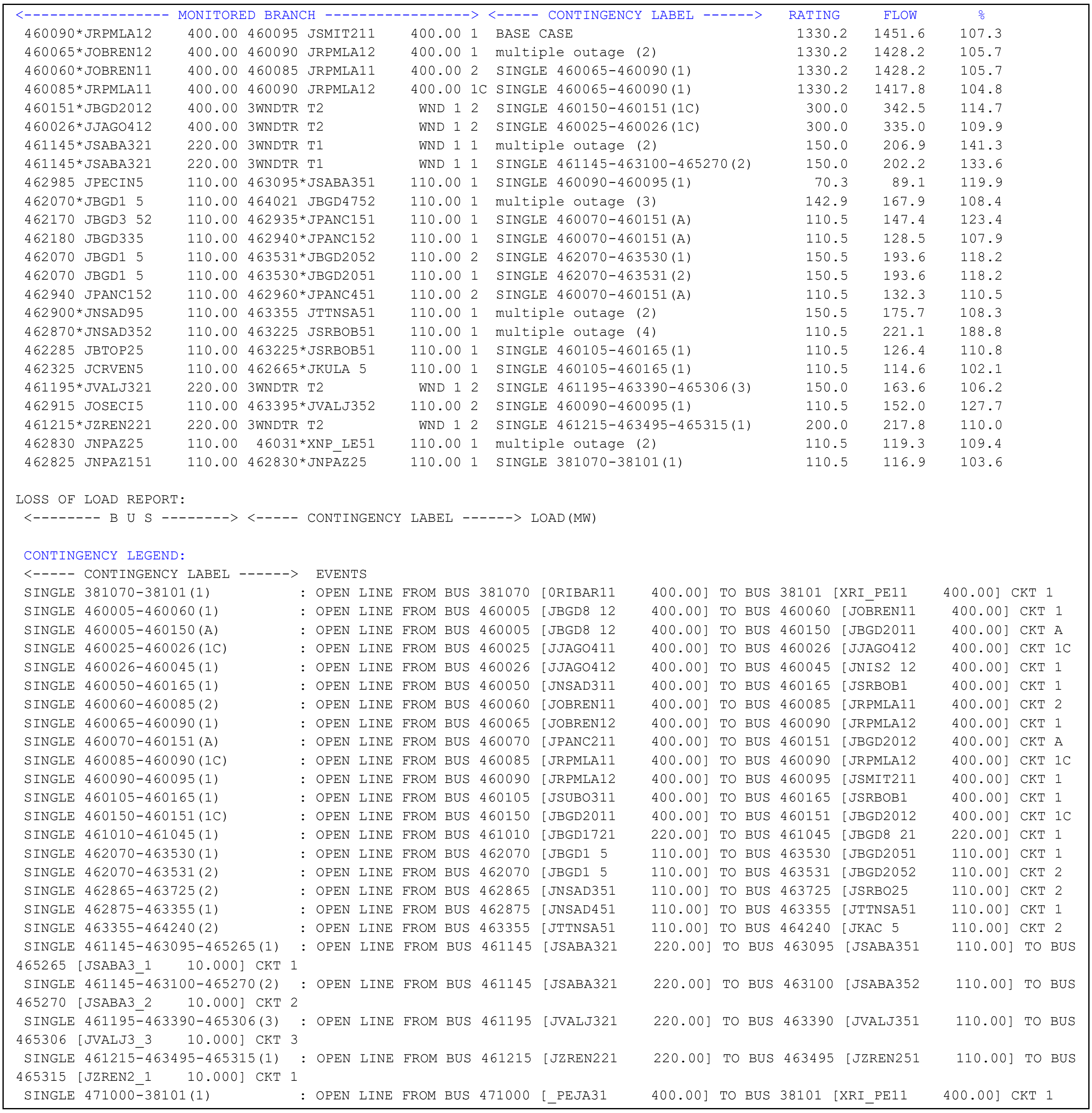
Figure 5.9: List of 110 kV elements loaded more than 80% for 2025 analysed regimes (referent RES, referent CO2)

The complete contingency n-1 analysis reports for 2025 Ref RES analysed regimes are given in Appendix, while the edited shorten reports are presented below. These results just confirm the above stated needs for reinforcement of the network around Belgrade and at the border with BA and ME.

As it can be concluded from the results bellow, the overloading of transformers in 400/110kV SS Belgrade 20 and 220/110kV SS Zrenjanin 2 are directly resolved with reinforcement of 400kV network around Belgrade (development of North CSE Corridor), while the overloading of 400/110kV TR Jagodina 4 with construction of new 400kV OHL Pozarevac - Jagodina.

On the other side, the overloading of transformers in 220/110kV SS Sabas 3 is a topology problem, these overloadings are not resolved with proposed development projects. Transformers are radially connecting 220kV and 110kV transmission network, supplying two 110kV interconnection lines to BiH (Bijeljina and Zvornik). It is recommended that these transformers should be upgraded with additional capacity in the future.

New development project do not have influence on the overloading of 400/110kV TR Bor 2, this overloading is below 10%.

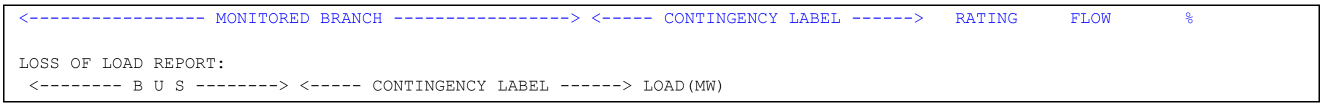


```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW       %
 460090*JRPMLA12    400.00 460095 JSMIT211    400.00 1  BASE CASE                          1330.2   1451.6    107.3
 460065*JOBREN12    400.00 460090 JRPMLA12    400.00 1  multiple outage (2)                1330.2   1428.2    105.7
 460060*JOBREN11    400.00 460085 JRPMLA11    400.00 2  SINGLE 460065-460090(1)            1330.2   1428.2    105.7
 460085*JRPMLA11    400.00 460090 JRPMLA12    400.00 1C SINGLE 460065-460090(1)            1330.2   1417.8    104.8
 460151*JBGD2012    400.00 3WNDTR T2           WND 1 2  SINGLE 460150-460151(1C)            300.0    342.5    114.7
 460026*JJAGO412    400.00 3WNDTR T2           WND 1 2  SINGLE 460025-460026(1C)            300.0    335.0    109.9
 461145*JSABA321    220.00 3WNDTR T1           WND 1 1  multiple outage (2)                 150.0    206.9    141.3
 461145*JSABA321    220.00 3WNDTR T1           WND 1 1  SINGLE 461145-463100-465270(2)      150.0    202.2    133.6
 462985 JPECIN5     110.00 463095*JSABA351    110.00 1  SINGLE 460090-460095(1)              70.3     89.1    119.9
 462070*JBGD1 5     110.00 464021 JBGD4752    110.00 1  multiple outage (3)                 142.9    167.9    108.4
 462170 JBGD3 52    110.00 462935*JPANC151    110.00 1  SINGLE 460070-460151(A)             110.5    147.4    123.4
 462180 JBGD335     110.00 462940*JPANC152    110.00 1  SINGLE 460070-460151(A)             110.5    128.5    107.9
 462070 JBGD1 5     110.00 463531*JBGD2052    110.00 2  SINGLE 462070-463530(1)             150.5    193.6    118.2
 462070 JBGD1 5     110.00 463530*JBGD2051    110.00 1  SINGLE 462070-463531(2)             150.5    193.6    118.2
 462940 JPANC152    110.00 462960*JPANC451    110.00 2  SINGLE 460070-460151(A)             110.5    132.3    110.5
 462900*JNSAD95     110.00 463355 JTTNSA51    110.00 1  multiple outage (2)                 150.5    175.7    108.3
 462870*JNSAD352    110.00 463225 JSRBOB51    110.00 1  multiple outage (4)                 110.5    221.1    188.8
 462285 JBTOP25     110.00 463225*JSRBOB51    110.00 1  SINGLE 460105-460165(1)             110.5    126.4    110.8
 462325 JCRVEN5     110.00 462665*JKULA 5     110.00 1  SINGLE 460105-460165(1)             110.5    114.6    102.1
 461195*JVALJ321    220.00 3WNDTR T2           WND 1 2  SINGLE 461195-463390-465306(3)      150.0    163.6    106.2
 462915 JOSECI5     110.00 463395*JVALJ352    110.00 2  SINGLE 460090-460095(1)             110.5    152.0    127.7
 461215*JZREN221    220.00 3WNDTR T2           WND 1 2  SINGLE 461215-463495-465315(1)      200.0    217.8    110.0
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  multiple outage (2)                 110.5    119.3    109.4
 462825 JNPAZ151    110.00 462830*JNPAZ25     110.00 1  SINGLE 381070-38101(1)              110.5    116.9    103.6

LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 381070-38101(1)          : OPEN LINE FROM BUS 381070 [0RIBAR11    400.00] TO BUS 38101 [XRI_PE11    400.00] CKT 1
 SINGLE 460005-460060(1)         : OPEN LINE FROM BUS 460005 [JBGD8 12    400.00] TO BUS 460060 [JOBREN11    400.00] CKT 1
 SINGLE 460005-460150(A)         : OPEN LINE FROM BUS 460005 [JBGD8 12    400.00] TO BUS 460150 [JBGD2011    400.00] CKT A
 SINGLE 460025-460026(1C)        : OPEN LINE FROM BUS 460025 [JJAGO411    400.00] TO BUS 460026 [JJAGO412    400.00] CKT 1C
 SINGLE 460026-460045(1)         : OPEN LINE FROM BUS 460026 [JJAGO412    400.00] TO BUS 460045 [JNIS2 12    400.00] CKT 1
 SINGLE 460050-460165(1)         : OPEN LINE FROM BUS 460050 [JNSAD311    400.00] TO BUS 460165 [JSRBOB1     400.00] CKT 1
 SINGLE 460060-460085(2)         : OPEN LINE FROM BUS 460060 [JOBREN11    400.00] TO BUS 460085 [JRPMLA11    400.00] CKT 2
 SINGLE 460065-460090(1)         : OPEN LINE FROM BUS 460065 [JOBREN12    400.00] TO BUS 460090 [JRPMLA12    400.00] CKT 1
 SINGLE 460070-460151(A)         : OPEN LINE FROM BUS 460070 [JPANC211    400.00] TO BUS 460151 [JBGD2012    400.00] CKT A
 SINGLE 460085-460090(1C)        : OPEN LINE FROM BUS 460085 [JRPMLA11    400.00] TO BUS 460090 [JRPMLA12    400.00] CKT 1C
 SINGLE 460090-460095(1)         : OPEN LINE FROM BUS 460090 [JRPMLA12    400.00] TO BUS 460095 [JSMIT211    400.00] CKT 1
 SINGLE 460105-460165(1)         : OPEN LINE FROM BUS 460105 [JSUBO311    400.00] TO BUS 460165 [JSRBOB1     400.00] CKT 1
 SINGLE 460150-460151(1C)        : OPEN LINE FROM BUS 460150 [JBGD2011    400.00] TO BUS 460151 [JBGD2012    400.00] CKT 1C
 SINGLE 461010-461045(1)         : OPEN LINE FROM BUS 461010 [JBGD1721    220.00] TO BUS 461045 [JBGD8 21    220.00] CKT 1
 SINGLE 462070-463530(1)         : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463530 [JBGD2051    110.00] CKT 1
 SINGLE 462070-463531(2)         : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463531 [JBGD2052    110.00] CKT 2
 SINGLE 462865-463725(2)         : OPEN LINE FROM BUS 462865 [JNSAD351    110.00] TO BUS 463725 [JSRBO25     110.00] CKT 2
 SINGLE 462875-463355(1)         : OPEN LINE FROM BUS 462875 [JNSAD451    110.00] TO BUS 463355 [JTTNSA51    110.00] CKT 1
 SINGLE 463355-464240(2)         : OPEN LINE FROM BUS 463355 [JTTNSA51    110.00] TO BUS 464240 [JKAC 5      110.00] CKT 2
 SINGLE 461145-463095-465265(1)  : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463095 [JSABA351    110.00] TO BUS
465265 [JSABA3_1    10.000] CKT 1
 SINGLE 461145-463100-465270(2)  : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463100 [JSABA352    110.00] TO BUS
465270 [JSABA3_2    10.000] CKT 2
 SINGLE 461195-463390-465306(3)  : OPEN LINE FROM BUS 461195 [JVALJ321    220.00] TO BUS 463390 [JVALJ351    110.00] TO BUS
465306 [JVALJ3_3    10.000] CKT 3
 SINGLE 461215-463495-465315(1)  : OPEN LINE FROM BUS 461215 [JZREN221    220.00] TO BUS 463495 [JZREN251    110.00] TO BUS
465315 [JZREN2_1    10.000] CKT 1
 SINGLE 471000-38101(1)          : OPEN LINE FROM BUS 471000 [_PEJA31     400.00] TO BUS 38101 [XRI_PE11    400.00] CKT 1
```

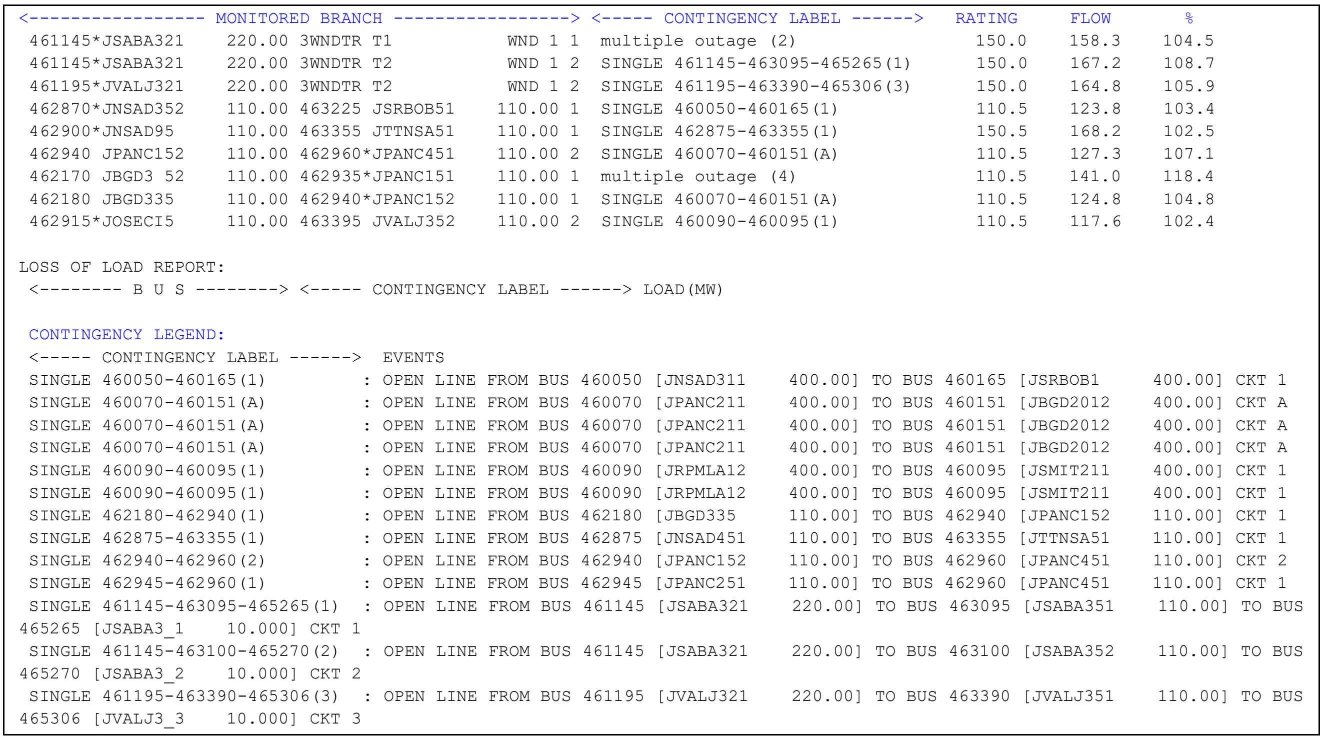
Figure 5.10: Contingency (n-1) analysis report for Winter Peak regime 2025 (referent RES, referent CO2)



```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>  RATING     FLOW       %

LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)
```

Figure 5.11: Contingency (n-1) analysis report for Summer Off-Peak regime 2025 (referent RES, referent CO2)

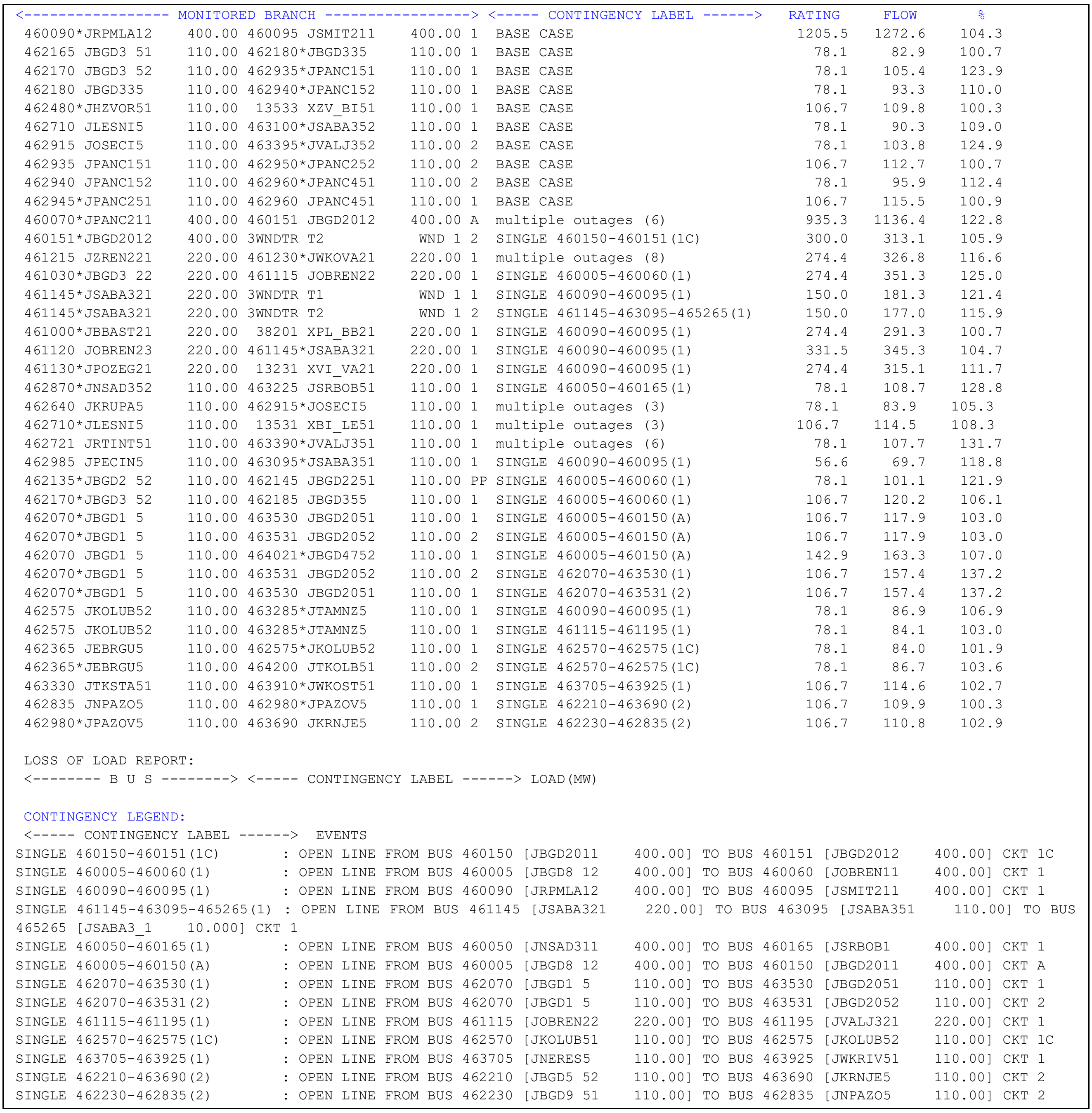


```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>  RATING     FLOW       %
 461145*JSABA321    220.00 3WNDTR T1           WND 1 1  multiple outage (2)               150.0    158.3    104.5
 461145*JSABA321    220.00 3WNDTR T2           WND 1 2  SINGLE 461145-463095-465265(1)    150.0    167.2    108.7
 461195*JVALJ321    220.00 3WNDTR T2           WND 1 2  SINGLE 461195-463390-465306(3)    150.0    164.8    105.9
 462870*JNSAD352    110.00 463225 JSRBOB51    110.00 1  SINGLE 460050-460165(1)           110.5    123.8    103.4
 462900*JNSAD95     110.00 463355 JTTNSA51    110.00 1  SINGLE 462875-463355(1)           150.5    168.2    102.5
 462940 JPANC152    110.00 462960*JPANC451    110.00 2  SINGLE 460070-460151(A)           110.5    127.3    107.1
 462170 JBGD3 52    110.00 462935*JPANC151    110.00 1  multiple outage (4)               110.5    141.0    118.4
 462180 JBGD335     110.00 462940*JPANC152    110.00 1  SINGLE 460070-460151(A)           110.5    124.8    104.8
 462915*JOSECI5     110.00 463395 JVALJ352    110.00 2  SINGLE 460090-460095(1)           110.5    117.6    102.4

LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 460050-460165(1)         : OPEN LINE FROM BUS 460050 [JNSAD311    400.00] TO BUS 460165 [JSRBOB1     400.00] CKT 1
 SINGLE 460070-460151(A)         : OPEN LINE FROM BUS 460070 [JPANC211    400.00] TO BUS 460151 [JBGD2012    400.00] CKT A
 SINGLE 460070-460151(A)         : OPEN LINE FROM BUS 460070 [JPANC211    400.00] TO BUS 460151 [JBGD2012    400.00] CKT A
 SINGLE 460070-460151(A)         : OPEN LINE FROM BUS 460070 [JPANC211    400.00] TO BUS 460151 [JBGD2012    400.00] CKT A
 SINGLE 460090-460095(1)         : OPEN LINE FROM BUS 460090 [JRPMLA12    400.00] TO BUS 460095 [JSMIT211    400.00] CKT 1
 SINGLE 460090-460095(1)         : OPEN LINE FROM BUS 460090 [JRPMLA12    400.00] TO BUS 460095 [JSMIT211    400.00] CKT 1
 SINGLE 462180-462940(1)         : OPEN LINE FROM BUS 462180 [JBGD335     110.00] TO BUS 462940 [JPANC152    110.00] CKT 1
 SINGLE 462875-463355(1)         : OPEN LINE FROM BUS 462875 [JNSAD451    110.00] TO BUS 463355 [JTTNSA51    110.00] CKT 1
 SINGLE 462940-462960(2)         : OPEN LINE FROM BUS 462940 [JPANC152    110.00] TO BUS 462960 [JPANC451    110.00] CKT 2
 SINGLE 462945-462960(1)         : OPEN LINE FROM BUS 462945 [JPANC251    110.00] TO BUS 462960 [JPANC451    110.00] CKT 1
 SINGLE 461145-463095-465265(1)  : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463095 [JSABA351    110.00] TO BUS
465265 [JSABA3_1    10.000] CKT 1
 SINGLE 461145-463100-465270(2)  : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463100 [JSABA352    110.00] TO BUS
465270 [JSABA3_2    10.000] CKT 2
 SINGLE 461195-463390-465306(3)  : OPEN LINE FROM BUS 461195 [JVALJ321    220.00] TO BUS 463390 [JVALJ351    110.00] TO BUS
465306 [JVALJ3_3    10.000] CKT 3
```

Figure 5.12: Contingency (n-1) analysis report for Highest wind+solar generation regime 2025 (referent RES, referent CO2)



```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW        %
 460090*JRPMLA12    400.00 460095 JSMIT211    400.00 1  BASE CASE                        1205.5   1272.6    104.3
 462165 JBGD3 51    110.00 462180*JBGD335     110.00 1  BASE CASE                          78.1     82.9    100.7
 462170 JBGD3 52    110.00 462935*JPANC151    110.00 1  BASE CASE                          78.1    105.4    123.9
 462180 JBGD335     110.00 462940*JPANC152    110.00 1  BASE CASE                          78.1     93.3    110.0
 462480*JHZVOR51    110.00  13533 XZV_BI51    110.00 1  BASE CASE                         106.7    109.8    100.3
 462710 JLESNI5     110.00 463100*JSABA352    110.00 1  BASE CASE                          78.1     90.3    109.0
 462915 JOSECI5     110.00 463395*JVALJ352    110.00 2  BASE CASE                          78.1    103.8    124.9
 462935 JPANC151    110.00 462950*JPANC252    110.00 2  BASE CASE                         106.7    112.7    100.7
 462940 JPANC152    110.00 462960*JPANC451    110.00 2  BASE CASE                          78.1     95.9    112.4
 462945*JPANC251    110.00 462960 JPANC451    110.00 1  BASE CASE                         106.7    115.5    100.9
 460070*JPANC211    400.00 460151 JBGD2012    400.00 A  multiple outages (6)              935.3   1136.4    122.8
 460151*JBGD2012    400.00 3WNDTR T2           WND 1 2  SINGLE 460150-460151(1C)          300.0    313.1    105.9
 461215 JZREN221    220.00 461230*JWKOVA21    220.00 1  multiple outages (8)              274.4    326.8    116.6
 461030*JBGD3 22    220.00 461115 JOBREN22    220.00 1  SINGLE 460005-460060(1)           274.4    351.3    125.0
 461145*JSABA321    220.00 3WNDTR T1           WND 1 1  SINGLE 460090-460095(1)           150.0    181.3    121.4
 461145*JSABA321    220.00 3WNDTR T2           WND 1 2  SINGLE 461145-463095-465265(1)    150.0    177.0    115.9
 461000*JBBAST21    220.00  38201 XPL_BB21    220.00 1  SINGLE 460090-460095(1)           274.4    291.3    100.7
 461120 JOBREN23    220.00 461145*JSABA321    220.00 1  SINGLE 460090-460095(1)           331.5    345.3    104.7
 461130*JPOZEG21    220.00  13231 XVI_VA21    220.00 1  SINGLE 460090-460095(1)           274.4    315.1    111.7
 462870*JNSAD352    110.00 463225 JSRBOB51    110.00 1  SINGLE 460050-460165(1)            78.1    108.7    128.8
 462640 JKRUPA5     110.00 462915*JOSECI5     110.00 1  multiple outages (3)             78.1     83.9    105.3
 462710*JLESNI5     110.00  13531 XBI_LE51    110.00 1  multiple outages (3)            106.7    114.5    108.3
 462721 JRTINT51    110.00 463390*JVALJ351    110.00 1  multiple outages (6)               78.1    107.7    131.7
 462985 JPECIN5     110.00 463095*JSABA351    110.00 1  SINGLE 460090-460095(1)            56.6     69.7    118.8
 462135*JBGD2 52    110.00 462145 JBGD2251    110.00 PP SINGLE 460005-460060(1)            78.1    101.1    121.9
 462170*JBGD3 52    110.00 462185 JBGD355     110.00 1  SINGLE 460005-460060(1)           106.7    120.2    106.1
 462070*JBGD1 5     110.00 463530 JBGD2051    110.00 1  SINGLE 460005-460150(A)           106.7    117.9    103.0
 462070*JBGD1 5     110.00 463531 JBGD2052    110.00 2  SINGLE 460005-460150(A)           106.7    117.9    103.0
 462070 JBGD1 5     110.00 464021*JBGD4752    110.00 1  SINGLE 460005-460150(A)           142.9    163.3    107.0
 462070*JBGD1 5     110.00 463531 JBGD2052    110.00 2  SINGLE 462070-463530(1)           106.7    157.4    137.2
 462070*JBGD1 5     110.00 463530 JBGD2051    110.00 1  SINGLE 462070-463531(2)           106.7    157.4    137.2
 462575 JKOLUB52    110.00 463285*JTAMNZ5     110.00 1  SINGLE 460090-460095(1)            78.1     86.9    106.9
 462575 JKOLUB52    110.00 463285*JTAMNZ5     110.00 1  SINGLE 461115-461195(1)            78.1     84.1    103.0
 462365 JEBRGU5     110.00 462575*JKOLUB52    110.00 1  SINGLE 462570-462575(1C)           78.1     84.0    101.9
 462365*JEBRGU5     110.00 464200 JTKOLB51    110.00 2  SINGLE 462570-462575(1C)           78.1     86.7    103.6
 463330 JTKSTA51    110.00 463910*JWKOST51    110.00 1  SINGLE 463705-463925(1)           106.7    114.6    102.7
 462835 JNPAZO5     110.00 462980*JPAZOV5     110.00 1  SINGLE 462210-463690(2)           106.7    109.9    100.3
 462980*JPAZOV5     110.00 463690 JKRNJE5     110.00 2  SINGLE 462230-462835(2)           106.7    110.8    102.9

 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
SINGLE 460150-460151(1C)       : OPEN LINE FROM BUS 460150 [JBGD2011    400.00] TO BUS 460151 [JBGD2012    400.00] CKT 1C
SINGLE 460005-460060(1)        : OPEN LINE FROM BUS 460005 [JBGD8 12    400.00] TO BUS 460060 [JOBREN11    400.00] CKT 1
SINGLE 460090-460095(1)        : OPEN LINE FROM BUS 460090 [JRPMLA12    400.00] TO BUS 460095 [JSMIT211    400.00] CKT 1
SINGLE 461145-463095-465265(1) : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463095 [JSABA351    110.00] TO BUS
465265 [JSABA3_1    10.000] CKT 1
SINGLE 460050-460165(1)        : OPEN LINE FROM BUS 460050 [JNSAD311    400.00] TO BUS 460165 [JSRBOB1     400.00] CKT 1
SINGLE 460005-460150(A)        : OPEN LINE FROM BUS 460005 [JBGD8 12    400.00] TO BUS 460150 [JBGD2011    400.00] CKT A
SINGLE 462070-463530(1)        : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463530 [JBGD2051    110.00] CKT 1
SINGLE 462070-463531(2)        : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463531 [JBGD2052    110.00] CKT 2
SINGLE 461115-461195(1)        : OPEN LINE FROM BUS 461115 [JOBREN22    220.00] TO BUS 461195 [JVALJ321    220.00] CKT 1
SINGLE 462570-462575(1C)       : OPEN LINE FROM BUS 462570 [JKOLUB51    110.00] TO BUS 462575 [JKOLUB52    110.00] CKT 1C
SINGLE 463705-463925(1)        : OPEN LINE FROM BUS 463705 [JNERES5     110.00] TO BUS 463925 [JWKRIV51    110.00] CKT 1
SINGLE 462210-463690(2)        : OPEN LINE FROM BUS 462210 [JBGD5 52    110.00] TO BUS 463690 [JKRNJE5     110.00] CKT 2
SINGLE 462230-462835(2)        : OPEN LINE FROM BUS 462230 [JBGD9 51    110.00] TO BUS 462835 [JNPAZO5     110.00] CKT 2
```

Figure 5.13: Contingency (n-1) analysis report for Summer regime with the highest generation 2025 (referent RES, referent CO2)

```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW       %
 462870*JNSAD352    110.00 463225 JSRBOB51    110.00 1  SINGLE 460050-460165(1)            110.5     128.7     107.5
 462170 JBGD3 52    110.00 462935*JPANC151    110.00 1  SINGLE 460070-460151(A)            110.5     128.5     107.5
 462915*JOSECI5     110.00 463395 JVALJ352    110.00 2  SINGLE 460090-460095(1)            110.5     117.1     101.3
 462900*JNSAD95     110.00 463355 JTTNSA51    110.00 1  SINGLE 462875-463355(1)            150.5     168.1     102.4
 461145*JSABA321    220.00 3WNDTR T1           WND 1 1  multiple outage (2)                150.0     175.9     114.3
 461145*JSABA321    220.00 3WNDTR T2           WND 1 2  SINGLE 461145-463095-465265(1)     150.0     170.3     110.6
 461195*JVALJ321    220.00 3WNDTR T2           WND 1 2  SINGLE 461195-463390-465306(3)     150.0     167.0     107.3

<-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

   CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 460050-460165(1)          : OPEN LINE FROM BUS 460050 [JNSAD311    400.00] TO BUS 460165 [JSRBOB1     400.00] CKT 1
 SINGLE 460070-460151(A)          : OPEN LINE FROM BUS 460070 [JPANC211    400.00] TO BUS 460151 [JBGD2012    400.00] CKT A
 SINGLE 460090-460095(1)          : OPEN LINE FROM BUS 460090 [JRPMLA12    400.00] TO BUS 460095 [JSMIT211    400.00] CKT 1
 SINGLE 460090-460095(1)          : OPEN LINE FROM BUS 460090 [JRPMLA12    400.00] TO BUS 460095 [JSMIT211    400.00] CKT 1
 SINGLE 462875-463355(1)          : OPEN LINE FROM BUS 462875 [JNSAD451    110.00] TO BUS 463355 [JTTNSA51    110.00] CKT 1
 SINGLE 461145-463095-465265(1)   : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463095 [JSABA351    110.00] TO BUS
465265 [JSABA3_1    10.000] CKT 1
 SINGLE 461145-463100-465270(2)   : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463100 [JSABA352    110.00] TO BUS
465270 [JSABA3_2    10.000] CKT 2
 SINGLE 461195-463390-465306(3)   : OPEN LINE FROM BUS 461195 [JVALJ321    220.00] TO BUS 463390 [JVALJ351    110.00] TO BUS
465306 [JVALJ3_3    10.000] CKT 3
```

Figure 5.14: Contingency (n-1) analysis report for Highest export regime 2025 (referent RES, referent CO2)

```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW       %
 460010*JBOR 21     400.00 3WNDTR T3           WND 1 3  SINGLE 460010-462260(2)            300.0     329.8     109.5
 460010*JBOR 21     400.00 462260 JBOR2 52    110.00 2  SINGLE 460010-462255-465400(3)     300.0     330.7     109.8
 460015*JHDJE111    400.00  44101 XPF_DJ11    400.00 1  SINGLE 448004-448018(1)            900.7     913.5     100.5

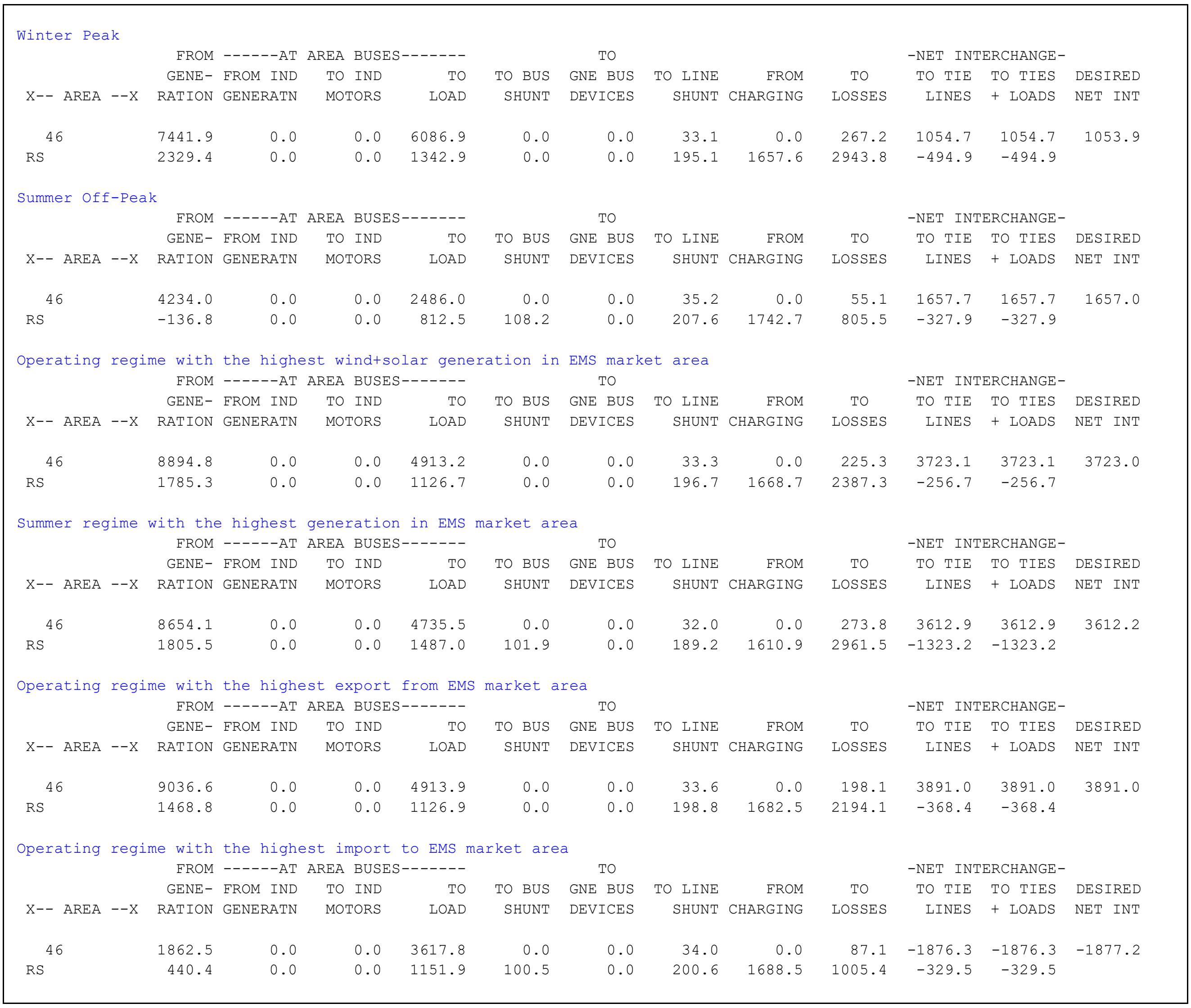
 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 460010-462260(2)         : OPEN LINE FROM BUS 460010 [JBOR 21     400.00] TO BUS 462260 [JBOR2 52    110.00] CKT 2
 SINGLE 460010-462255-465400(3)  : OPEN LINE FROM BUS 460010 [JBOR 21     400.00] TO BUS 462255 [JBOR2 51    110.00] TO BUS
465400 [JBOR2 _2    10.000] CKT 3
 SINGLE 448004-448018(1)         : OPEN LINE FROM BUS 448004 [RP.D.F1     400.00] TO BUS 448018 [RRESIT1     400.00] CKT 1
```

Figure 5.15: Contingency (n-1) analysis report for Highest import regime 2025 (referent RES, referent CO2)

5.3.2 Year 2025-highRES, RES=5400 MW

We first provide the summary report, with data only for EMS market area. We present the area summary for the analyzed six network regimes as follows:



```
Winter Peak
                 FROM ------AT AREA BUSES-------              TO                                -NET INTERCHANGE-
                GENE- FROM IND   TO IND       TO   TO BUS  GNE BUS  TO LINE     FROM      TO    TO TIE  TO TIES  DESIRED
 X-- AREA --X  RATION GENERATN   MOTORS     LOAD    SHUNT  DEVICES    SHUNT CHARGING  LOSSES     LINES  + LOADS  NET INT

   46          7441.9      0.0      0.0   6086.9      0.0      0.0     33.1      0.0   267.2    1054.7   1054.7   1053.9
 RS            2329.4      0.0      0.0   1342.9      0.0      0.0    195.1   1657.6  2943.8    -494.9   -494.9

Summer Off-Peak
                 FROM ------AT AREA BUSES-------              TO                                -NET INTERCHANGE-
                GENE- FROM IND   TO IND       TO   TO BUS  GNE BUS  TO LINE     FROM      TO    TO TIE  TO TIES  DESIRED
 X-- AREA --X  RATION GENERATN   MOTORS     LOAD    SHUNT  DEVICES    SHUNT CHARGING  LOSSES     LINES  + LOADS  NET INT

   46          4234.0      0.0      0.0   2486.0      0.0      0.0     35.2      0.0    55.1    1657.7   1657.7   1657.0
 RS            -136.8      0.0      0.0    812.5    108.2      0.0    207.6   1742.7   805.5    -327.9   -327.9

Operating regime with the highest wind+solar generation in EMS market area
                 FROM ------AT AREA BUSES-------              TO                                -NET INTERCHANGE-
                GENE- FROM IND   TO IND       TO   TO BUS  GNE BUS  TO LINE     FROM      TO    TO TIE  TO TIES  DESIRED
 X-- AREA --X  RATION GENERATN   MOTORS     LOAD    SHUNT  DEVICES    SHUNT CHARGING  LOSSES     LINES  + LOADS  NET INT

   46          8894.8      0.0      0.0   4913.2      0.0      0.0     33.3      0.0   225.3    3723.1   3723.1   3723.0
 RS            1785.3      0.0      0.0   1126.7      0.0      0.0    196.7   1668.7  2387.3    -256.7   -256.7

Summer regime with the highest generation in EMS market area
                 FROM ------AT AREA BUSES-------              TO                                -NET INTERCHANGE-
                GENE- FROM IND   TO IND       TO   TO BUS  GNE BUS  TO LINE     FROM      TO    TO TIE  TO TIES  DESIRED
 X-- AREA --X  RATION GENERATN   MOTORS     LOAD    SHUNT  DEVICES    SHUNT CHARGING  LOSSES     LINES  + LOADS  NET INT

   46          8654.1      0.0      0.0   4735.5      0.0      0.0     32.0      0.0   273.8    3612.9   3612.9   3612.2
 RS            1805.5      0.0      0.0   1487.0    101.9      0.0    189.2   1610.9  2961.5   -1323.2  -1323.2

Operating regime with the highest export from EMS market area
                 FROM ------AT AREA BUSES-------              TO                                -NET INTERCHANGE-
                GENE- FROM IND   TO IND       TO   TO BUS  GNE BUS  TO LINE     FROM      TO    TO TIE  TO TIES  DESIRED
 X-- AREA --X  RATION GENERATN   MOTORS     LOAD    SHUNT  DEVICES    SHUNT CHARGING  LOSSES     LINES  + LOADS  NET INT

   46          9036.6      0.0      0.0   4913.9      0.0      0.0     33.6      0.0   198.1    3891.0   3891.0   3891.0
 RS            1468.8      0.0      0.0   1126.9      0.0      0.0    198.8   1682.5  2194.1    -368.4   -368.4

Operating regime with the highest import to EMS market area
                 FROM ------AT AREA BUSES-------              TO                                -NET INTERCHANGE-
                GENE- FROM IND   TO IND       TO   TO BUS  GNE BUS  TO LINE     FROM      TO    TO TIE  TO TIES  DESIRED
 X-- AREA --X  RATION GENERATN   MOTORS     LOAD    SHUNT  DEVICES    SHUNT CHARGING  LOSSES     LINES  + LOADS  NET INT

   46          1862.5      0.0      0.0   3617.8      0.0      0.0     34.0      0.0    87.1   -1876.3  -1876.3  -1877.2
 RS             440.4      0.0      0.0   1151.9    100.5      0.0    200.6   1688.5  1005.4    -329.5   -329.5
```

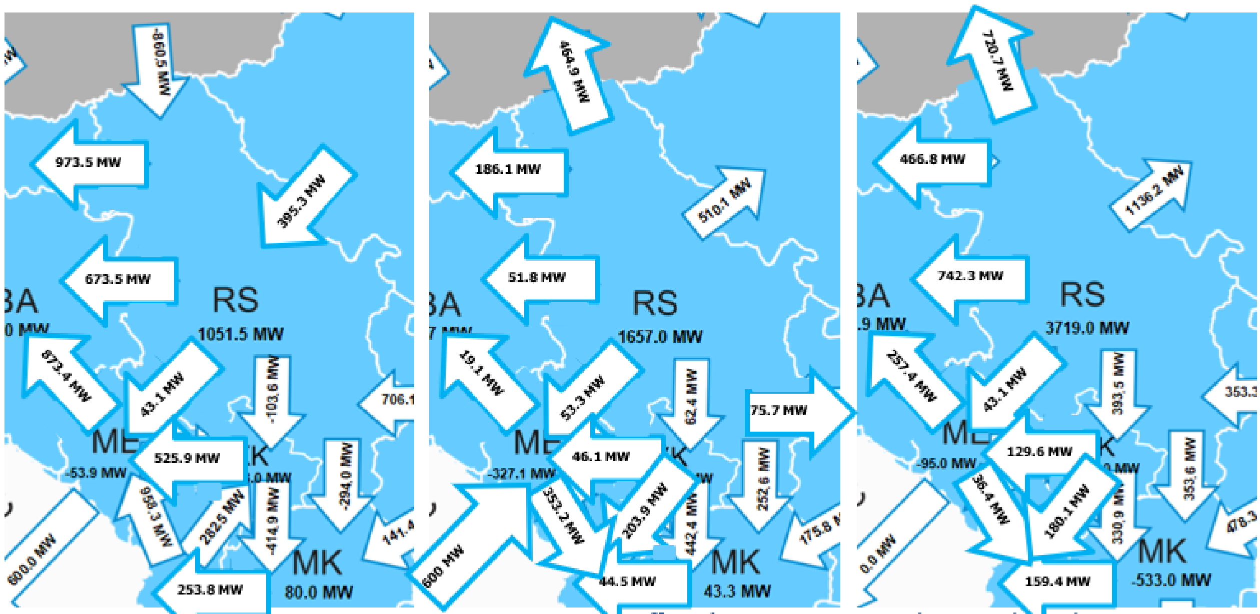
Figure 5.16: Area summary report for 2025 analysed regimes (high RES, referent CO2)

Based on the above area summary report, results for EMS market area are the following:

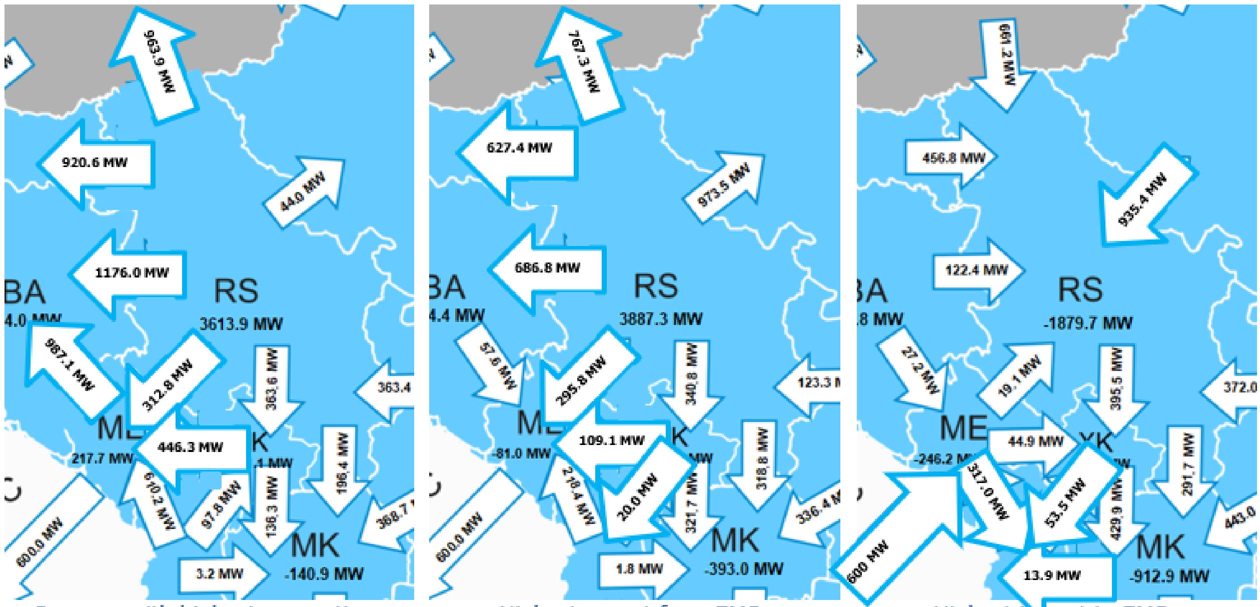
- Winter Peak regime:
  - The total EMS system load is 6087 MW and 1342 MVar
  - Generation is 7442 MW and EMS exports 1054 MW
- Summer Off-Peak regime:
  - The total EMS system load is 2486 MW and 812 MVar
  - Generation is 4234 MW and EMS exports 1657 MW
- Highest wind+solar generation regime:
  - The total EMS system load is 4913 MW and 1127 MVar
  - Generation is 8895 MW and EMS exports 3723 MW
- Summer with highest generation regime:
  - The total EMS system load is 4736 MW and 1487 MVar
  - Generation is 8654 MW and EMS exports 3612 MW
- Highest export from EMS regime:
  - The total EMS system load is 4914 MW and 1127 MVar

  - Generation is 9037 MW and EMS exports 3891 MW
- Highest import to EMS regime:
  - The total EMS system load is 3618 MW and 1152 MVar
  - Generation is 1862 MW and EMS imports 1877 MW

The following figures show the cross-border power exchange map for all six analysed regimes for year 2025 high RES.



Winter Peak Summer Off-Peak Highest wind + solar generation



Summer with highest generation Highest export from EMS Highest import to EMS

Figure 5.17: Cross-border exchanges (MW) and directions between the countries in year 2025 and Referent RES scenario

The following three figures show the 400 kV, 220 kV and 110 kV voltage profiles with maximum, minimum and average values in EMS transmission network for all six analysed regimes. The voltage profiles in the 400 kV and 220 kV network are within limits for all analysed regimes.

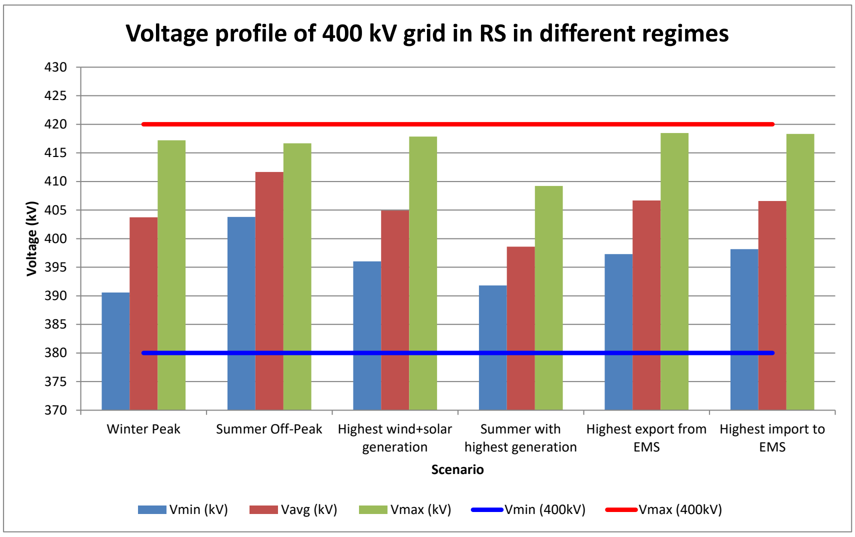


Figure 5.18: 400 kV voltage profiles (minimum, maximum and average) for 2025 analysed regimes (high RES, referent CO2)

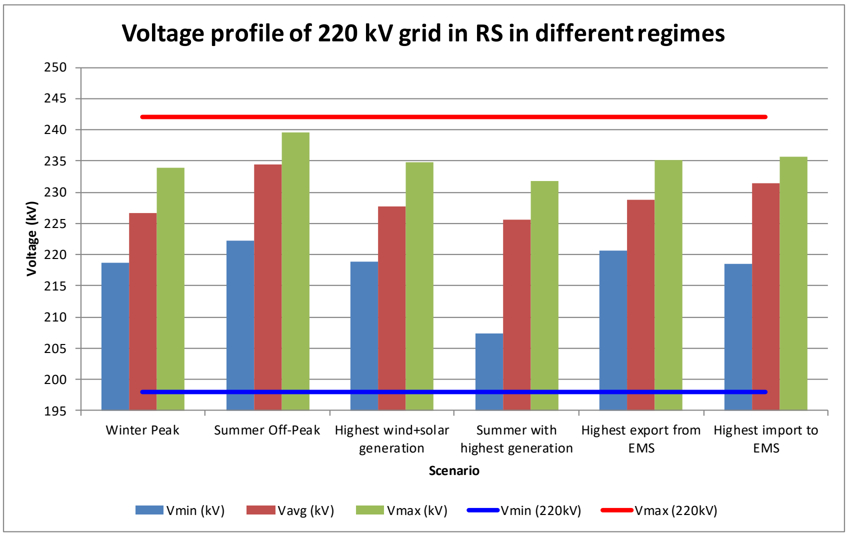


Figure 5.19: 220 kV voltage profiles (minimum, maximum and average) for 2025 analysed regimes (high RES, referent CO2)

In case of 110 kV network, in some nodes voltages above acceptable limits are observed. These problems can be considered as local and can be controlled by fine tuning of the voltage profiles at higher network levels.

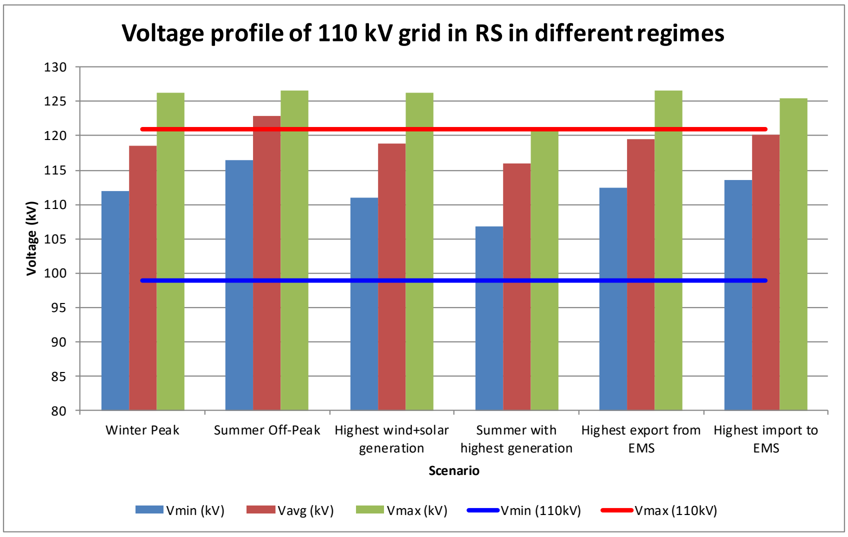


Figure 5.20: 110 kV voltage profiles (minimum, maximum and average) for 2025 analysed regimes (high RES, referent CO2)

The 400 kV and 220 kV elements that are loaded more than 80% are as follows:

```
Winter Peak
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
 460090 JRPMLA12    400.00*   46 460095 JSMIT211    400.00    46  1   1449.4  1330.2   109.0
 461145 JSABA321    220.00*   46 3WNDTR T1            WND 1    46  1    131.7   150.0    87.8

Summer Off-Peak
/
Operating regime with the highest wind+solar generation in EMS market area
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
 460070 JPANC211    400.00*   46 460151 JBGD2012    400.00    46  A    993.3   935.3   106.2
 461010 JBGD1721    220.00*   46 461045 JBGD8 21    220.00    46  1    297.6   331.5    89.8
 461030 JBGD3 22    220.00*   46 461115 JOBREN22    220.00    46  1    305.8   274.4   111.5
 461215 JZREN221    220.00    46 461230 JWKOVA21    220.00*   46  1    226.5   274.4    82.6

Summer regime with the highest generation in EMS market area
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
  31111 XSA_SU11    400.00    99 460105 JSUBO311    400.00*   46  1    973.5  1205.5    80.8
 460005 JBGD8 12    400.00*   46 460060 JOBREN11    400.00    46  1   1002.2  1205.5    83.1
 460070 JPANC211    400.00*   46 460151 JBGD2012    400.00    46  A   1073.6   935.3   114.8
 460090 JRPMLA12    400.00    46 460095 JSMIT211    400.00*   46  1   1682.5  1205.5   139.6
 461000 JBBAST21    220.00*   46 461135 JRHBBA21    220.00    46  1    277.3   331.5    83.6
 461030 JBGD3 22    220.00*   46 461115 JOBREN22    220.00    46  1    221.9   274.4    80.9
 461145 JSABA321    220.00*   46 3WNDTR T1            WND 1    46  1    123.1   150.0    82.0
 461215 JZREN221    220.00*   46 461230 JWKOVA21    220.00    46  1    273.5   274.4    99.7

Operating regime with the highest export from EMS market area
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
 460090 JRPMLA12    400.00*   46 460095 JSMIT211    400.00    46  1   1081.3  1330.2    81.3

Operating regime with the highest import to EMS market area
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
 461000 JBBAST21    220.00*   46 461135 JRHBBA21    220.00    46  1    270.3   331.5    81.5
```

Figure 5.21: List of 400 and 220 kV elements loaded more than 80% for 2025 analysed regimes (high RES, referent CO2)

Again, the most critical regimes are the ones with high export towards West and North-West which has the values between 1929 MW and 3100 MW (Figure 5.16). The maximum export in these directions are in winter peak regime (2506 MW) and summer regime with maximum generation in EMS area (3100 MW). The second regime is even more critical since the operating constraints in the network are higher due to different seasonal settings.

Similar as in 2025 Referent RES case, the overloaded 400kV lines SS Mladost – SS Sremska Mitrovica and SS Pančevo 2 – SS Belgrade 20 points to the potential problems with evacuation of the high amounts of power towards West (and North-West), disregarding what is the source of excess of generation: conventional units or RES. With respect to this problem, plans for network reinforcement that EMS already has (projects "North CSE corridor", interconnection with BA and ME and „Pannonian Corridor") present a solution for these situations. It should only be noted that, these reinforcements are not only provoked by additional RES in Serbian power system but also by other system security requirements. In addition, overloading of 220kV line SS Belgrade 3 – Obrenovac also underline the potential problems with evacuation of the high amounts of power towards West (and North-West), proposed development projects present a solution.

Concerning 110 kV network, situation is somewhat different having in mind that in many cases overloading of this part of the network is directly provoked by expected additional RES capacities or additional industrial load. These issues are taken into account within preparation of the connection solutions for each RES or large industrial complex and do not present a general obstacle for integration of the proposed level of RES capacities.

The complete contingency n-1 reports for the 2025 high RES analyzed regimes are in the Appendix, while we present the edited short reports below. These results confirm the above stated needs for reinforcement of the 400 kV network around Belgrade and at the border with BA and ME

As it can be concluded from the results bellow, the overloading of transformers in 400/110kV SS Belgrade 20 and 220/110kV SS Zrenjanin 2 are directly resolved with reinforcement of 400kV network around Belgrade (development of North CSE Corridor), also the same situation is with overloading of 220kV lines SS Zrenjanin 2 – SS Kovacica and SS Pancevo 2 – SS Vladimirci.

The overloading of 400/110kV TR Jagodina 4 is directly resolved with construction of new 400kV OHL Pozarevac - Jagodina.

On the other side, the overloading of transformers in 220/110kV SS Sabas 3 is a topology problem, these overloadings are not resolved with proposed development projects. Transformers are radially connecting 220kV and 110kV transmission network, supplying two 110kV interconnection lines to BiH (Bijeljina and Zvornik). It is recommended that these transformers should be upgraded with additional capacity in the future.

The 110 kV elements that are loaded more than 80% are as follows:

```
Winter Peak
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
 462825 JNPAZ151    110.00    46 462830 JNPAZ25     110.00*   46  1     88.9   110.5    80.5
 462915 JOSECI5     110.00*   46 463395 JVALJ352    110.00    46  2     93.9   110.5    85.0
  46031 XNP_LE51    110.00*   99 462830 JNPAZ25     110.00    46  1     91.1   110.5    82.4

Summer Off-Peak
/
Operating regime with the highest wind+solar generation in EMS market area
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
 462135 JBGD2 52    110.00*   46 462145 JBGD2251    110.00    46  PP    69.4    78.1    88.9
 462165 JBGD3 51    110.00    46 462180 JBGD335     110.00*   46  1    111.6    78.1   142.9
 462170 JBGD3 52    110.00*   46 462185 JBGD355     110.00    46  1     88.2   106.7    82.7
 462170 JBGD3 52    110.00    46 462935 JPANC151    110.00*   46  1    137.8    78.1   176.4
 462180 JBGD335     110.00    46 462940 JPANC152    110.00*   46  1    123.7    78.1   158.4
 462430 JGRADI5     110.00*   46 463070 JRUDN35     110.00    46  1     90.4   106.7    84.7
 462575 JKOLUB52    110.00*   46 463285 JTAMNZ5     110.00    46  1     68.6    78.1    87.9
 462710 JLESNI5     110.00*   46 463100 JSABA352    110.00    46  1     82.1    78.1   105.1
 462721 JRTINT51    110.00*   46 463390 JVALJ351    110.00    46  1     64.3    78.1    82.3
 462825 JNPAZ151    110.00    46 462830 JNPAZ25     110.00*   46  1     82.7    78.1   105.9
 462865 JNSAD351    110.00*   46 462900 JNSAD95     110.00    46  1     91.0   106.7    85.3
 462900 JNSAD95     110.00*   46 463355 JTTNSA51    110.00    46  1    102.6   106.7    96.2
 462915 JOSECI5     110.00*   46 463395 JVALJ352    110.00    46  2     90.0    78.1   115.2
 462935 JPANC151    110.00    46 462950 JPANC252    110.00*   46  2    146.7   106.7   137.5
 462940 JPANC152    110.00    46 462960 JPANC451    110.00*   46  2    126.3    78.1   161.8
 462945 JPANC251    110.00*   46 462960 JPANC451    110.00    46  1    112.4   106.7   105.3
 462990 JPETRO51    110.00    46 463705 JNERES5     110.00*   46  1     76.7    78.1    98.2
 462995 JPETRO52    110.00*   46 463335 JTMORA5     110.00    46  1     97.2   106.7    91.1
 463330 JTKSTA51    110.00    46 463910 JWKOST51    110.00*   46  1    131.0   106.7   122.7
  13533 XZV_BI51    110.00*   99 462480 JHZVOR51    110.00    46  1    105.9   106.7    99.3
  46031 XNP_LE51    110.00*   99 462830 JNPAZ25     110.00    46  1     68.3    78.1    87.5

Summer regime with the highest generation in EMS market area
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
 462135 JBGD2 52    110.00*   46 462145 JBGD2251    110.00    46  PP    64.5    78.1    82.5
 462165 JBGD3 51    110.00    46 462180 JBGD335     110.00*   46  1    102.3    78.1   131.0
 462170 JBGD3 52    110.00*   46 462185 JBGD355     110.00    46  1     86.0   106.7    80.6
 462170 JBGD3 52    110.00    46 462935 JPANC151    110.00*   46  1    124.4    78.1   159.3
 462180 JBGD335     110.00    46 462940 JPANC152    110.00*   46  1    111.1    78.1   142.3
 462575 JKOLUB52    110.00    46 463285 JTAMNZ5     110.00*   46  1     80.2    78.1   102.7
 462710 JLESNI5     110.00    46 463100 JSABA352    110.00*   46  1    107.8    78.1   138.0
 462721 JRTINT51    110.00    46 463390 JVALJ351    110.00*   46  1     80.4    78.1   103.0
 462915 JOSECI5     110.00    46 463395 JVALJ352    110.00*   46  2    114.1    78.1   146.2
 462935 JPANC151    110.00    46 462950 JPANC252    110.00*   46  2    130.9   106.7   122.7
 462940 JPANC152    110.00    46 462960 JPANC451    110.00*   46  2    113.0    78.1   144.7
 462945 JPANC251    110.00*   46 462960 JPANC451    110.00    46  1    106.9   106.7   100.2
 462990 JPETRO51    110.00    46 463705 JNERES5     110.00*   46  1     62.9    78.1    80.5
 463330 JTKSTA51    110.00    46 463910 JWKOST51    110.00*   46  1    108.8   106.7   102.0
  13531 XBI_LE51    110.00    99 462710 JLESNI5     110.00*   46  1     95.6   106.7    89.6
  13533 XZV_BI51    110.00    99 462480 JHZVOR51    110.00*   46  1    126.5   106.7   118.5

Operating regime with the highest export from EMS market area
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
 462170 JBGD3 52    110.00    46 462935 JPANC151    110.00*   46  1     99.1   110.5    89.7
 462180 JBGD335     110.00    46 462940 JPANC152    110.00*   46  1     89.2   110.5    80.7
 462825 JNPAZ151    110.00    46 462830 JNPAZ25     110.00*   46  1     91.0   110.5    82.3
 462940 JPANC152    110.00    46 462960 JPANC451    110.00*   46  2     91.7   110.5    83.0

 Operating regime with the highest import to EMS market area
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
 462825 JNPAZ151    110.00    46 462830 JNPAZ25     110.00*   46  1     75.5    78.1    96.7
  46031 XNP_LE51    110.00*   99 462830 JNPAZ25     110.00    46  1     69.2    78.1    88.6
```

Figure 5.22: List of 110 kV elements loaded more than 80% for 2025 analysed regimes (high RES, referent CO2)

The edited contingency n-1 analysis reports for 2025 high RES analysed regimes are as follows:

```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW       %
 460090*JRPMLA12    400.00 460095 JSMIT211    400.00 1  BASE CASE                        1330.2   1475.7    109.0
 460026*JJAGO412    400.00 3WNDTR T2           WND 1 2  SINGLE 460025-460026(1C)          300.0    314.9    103.0
 460065*JOBREN12    400.00 460090 JRPMLA12    400.00 1  multiple outages (2)             1330.2   1431.1    105.8
 460060*JOBREN11    400.00 460085 JRPMLA11    400.00 2  SINGLE 460065-460090(1)          1330.2   1431.6    105.8
 460085*JRPMLA11    400.00 460090 JRPMLA12    400.00 1C SINGLE 460065-460090(1)          1330.2   1431.3    105.7
 460151*JBGD2012    400.00 3WNDTR T2           WND 1 2  SINGLE 460150-460151(1C)          300.0    338.9    113.4
 461145*JSABA321    220.00 3WNDTR T1           WND 1 1  multiple outages (2)              150.0    215.4    147.3
 461145*JSABA321    220.00 3WNDTR T2           WND 1 2  multiple outages (2)              150.0    207.5    137.1
 461195*JVALJ321    220.00 3WNDTR T2           WND 1 2  SINGLE 461195-463390-465306(3)    150.0    178.0    115.6
 461215*JZREN221    220.00 3WNDTR T2           WND 1 2  SINGLE 461215-463495-465315(1)    200.0    211.8    106.7
 462870*JNSAD352    110.00 463225 JSRBOB51    110.00 1  multiple outages (3)              110.5    215.5    183.6
 462900*JNSAD95     110.00 463355 JTTNSA51    110.00 1  SINGLE 462875-463355(1)           150.5    170.4    104.9
 462070*JBGD1 5     110.00 464021 JBGD4752    110.00 1  multiple outages (2)              142.9    164.4    106.0
 462070 JBGD1 5     110.00 463531*JBGD2052    110.00 2  SINGLE 462070-463530(1)           150.5    190.1    115.9
 462070 JBGD1 5     110.00 463530*JBGD2051    110.00 1  SINGLE 462070-463531(2)           150.5    190.1    115.9
 462170 JBGD3 52    110.00 462935*JPANC151    110.00 1  SINGLE 460070-460151(A)           110.5    146.7    122.8
 462180 JBGD335     110.00 462940*JPANC152    110.00 1  SINGLE 460070-460151(A)           110.5    128.3    107.7
 462940 JPANC152    110.00 462960*JPANC451    110.00 2  SINGLE 460070-460151(A)           110.5    132.0    110.2
 462285 JBTOP25     110.00 463225*JSRBOB51    110.00 1  SINGLE 460105-460165(1)           110.5    125.3    109.3
 462325 JCRVEN5     110.00 462665*JKULA 5     110.00 1  SINGLE 460105-460165(1)           110.5    114.3    101.2
 462915 JOSECI5     110.00 463395*JVALJ352    110.00 2  multiple outages (2)              110.5    167.1    141.0
 462710 JLESNI5     110.00 463100*JSABA352    110.00 1  SINGLE 460090-460095(1)           110.5    120.5    103.4
 462721 JRTINT51    110.00 463390*JVALJ351    110.00 1  SINGLE 460090-460095(1)           110.5    121.8    102.8
 462985 JPECIN5     110.00 463095*JSABA351    110.00 1  SINGLE 460090-460095(1)            70.3     89.7    121.0
 462825 JNPAZ151    110.00 462830*JNPAZ25     110.00 1  SINGLE 381070-38101(1)            110.5    116.9    103.5
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  multiple outages (3)              110.5    119.2    109.2

 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 381070-38101(1)          : OPEN LINE FROM BUS 381070 [ORIBAR11    400.00] TO BUS 38101 [XRI_PE11    400.00] CKT 1
 SINGLE 460005-460150(A)         : OPEN LINE FROM BUS 460005 [JBGD8 12    400.00] TO BUS 460150 [JBGD2011    400.00] CKT A
 SINGLE 460025-460026(1C)        : OPEN LINE FROM BUS 460025 [JJAGO411    400.00] TO BUS 460026 [JJAGO412    400.00] CKT 1C
 SINGLE 460026-460045(1)         : OPEN LINE FROM BUS 460026 [JJAGO412    400.00] TO BUS 460045 [JNIS2 12    400.00] CKT 1
 SINGLE 460050-460165(1)         : OPEN LINE FROM BUS 460050 [JNSAD311    400.00] TO BUS 460165 [JSRBOB1     400.00] CKT 1
 SINGLE 460060-460085(2)         : OPEN LINE FROM BUS 460060 [JOBREN11    400.00] TO BUS 460085 [JRPMLA11    400.00] CKT 2
 SINGLE 460065-460090(1)         : OPEN LINE FROM BUS 460065 [JOBREN12    400.00] TO BUS 460090 [JRPMLA12    400.00] CKT 1
 SINGLE 460070-460151(A)         : OPEN LINE FROM BUS 460070 [JPANC211    400.00] TO BUS 460151 [JBGD2012    400.00] CKT A
 SINGLE 460085-460090(1C)        : OPEN LINE FROM BUS 460085 [JRPMLA11    400.00] TO BUS 460090 [JRPMLA12    400.00] CKT 1C
 SINGLE 460090-460095(1)         : OPEN LINE FROM BUS 460090 [JRPMLA12    400.00] TO BUS 460095 [JSMIT211    400.00] CKT 1
 SINGLE 460105-460165(1)         : OPEN LINE FROM BUS 460105 [JSUBO311    400.00] TO BUS 460165 [JSRBOB1     400.00] CKT 1
 SINGLE 460150-460151(1C)        : OPEN LINE FROM BUS 460150 [JBGD2011    400.00] TO BUS 460151 [JBGD2012    400.00] CKT 1C
 SINGLE 461010-461045(1)         : OPEN LINE FROM BUS 461010 [JBGD1721    220.00] TO BUS 461045 [JBGD8 21    220.00] CKT 1
 SINGLE 462070-463530(1)         : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463530 [JBGD2051    110.00] CKT 1
 SINGLE 462070-463531(2)         : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463531 [JBGD2052    110.00] CKT 2
 SINGLE 462721-463390(1)         : OPEN LINE FROM BUS 462721 [JRTINT51    110.00] TO BUS 463390 [JVALJ351    110.00] CKT 1
 SINGLE 462875-463355(1)         : OPEN LINE FROM BUS 462875 [JNSAD451    110.00] TO BUS 463355 [JTTNSA51    110.00] CKT 1
 SINGLE 461145-463095-465265(1)  : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463095 [JSABA351    110.00] TO BUS
465265 [JSABA3_1    10.000] CKT 1
 SINGLE 461145-463100-465270(2)  : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463100 [JSABA352    110.00] TO BUS
465270 [JSABA3_2    10.000] CKT 2
 SINGLE 461195-463390-465306(3)  : OPEN LINE FROM BUS 461195 [JVALJ321    220.00] TO BUS 463390 [JVALJ351    110.00] TO BUS
465306 [JVALJ3_3    10.000] CKT 3
 SINGLE 461215-463495-465315(1)  : OPEN LINE FROM BUS 461215 [JZREN221    220.00] TO BUS 463495 [JZREN251    110.00] TO BUS
465315 [JZREN2_1    10.000] CKT 1
 SINGLE 471000-38101(1)          : OPEN LINE FROM BUS 471000 [_PEJA31     400.00] TO BUS 38101 [XRI_PE11    400.00] CKT 1
```

Figure 5.23: Contingency (n-1) analysis report for Winter Peak regime 2025 (high RES, referent CO2)

```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW       %

LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)
```

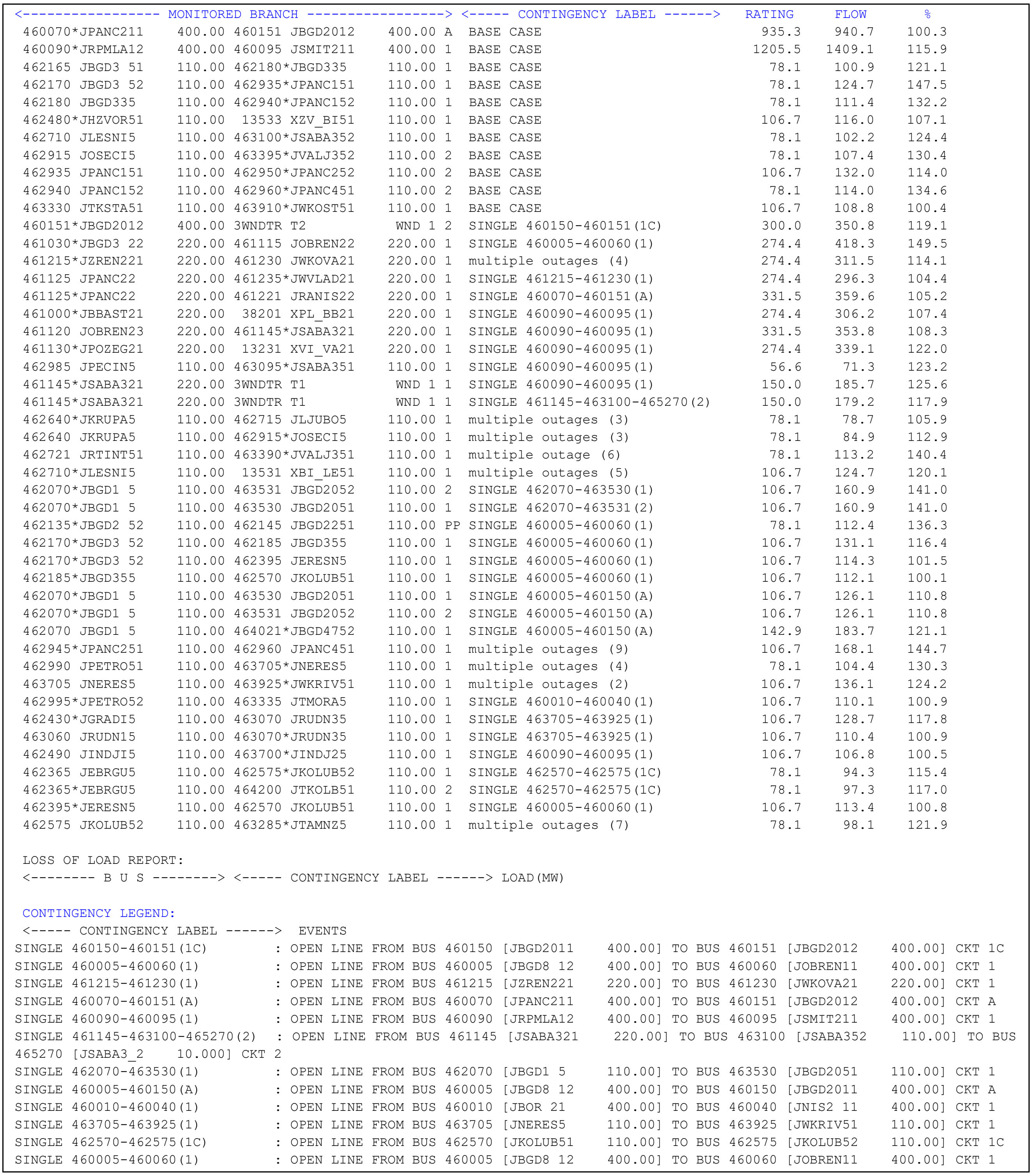
Figure 5.24: Contingency (n-1) analysis report for Summer Off-Peak regime 2025 (high RES, referent CO2)

```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>  RATING     FLOW        %
 462165 JBGD3 51    110.00 462180*JBGD335     110.00 1  BASE CASE                         110.5    119.3    101.0
 462170 JBGD3 52    110.00 462935*JPANC151    110.00 1  BASE CASE                         110.5    146.9    124.7
 462180 JBGD335     110.00 462940*JPANC152    110.00 1  BASE CASE                         110.5    132.0    112.0
 462940 JPANC152    110.00 462960*JPANC451    110.00 2  BASE CASE                         110.5    134.6    114.3
 462935 JPANC151    110.00 462950*JPANC252    110.00 2  BASE CASE                         150.5    156.0    100.0
 460151*JBGD2012    400.00 3WNDTR T2           WND 1 2  SINGLE 460150-460151(1C)          300.0    374.5    126.2
 460070*JPANC211    400.00 460151 JBGD2012    400.00 A  SINGLE 460160-460504(1)          1315.7   1367.4    104.6
 461030*JBGD3 22    220.00 461115 JOBREN22    220.00 1  SINGLE 460005-460060(1)           388.7    566.7    144.0
 461195*JVALJ321    220.00 3WNDTR T2           WND 1 2  SINGLE 461195-463390-465306(3)    150.0    155.7    100.6
 462070*JBGD1 5     110.00 464021 JBGD4752    110.00 1  multiple outages (2)              142.9    198.8    128.2
 462135*JBGD2 52    110.00 462145 JBGD2251    110.00 PP SINGLE 460005-460060(1)           110.5    132.5    112.6
 464015 JBGD455     110.00 464020*JBGD4751    110.00 1  SINGLE 460005-460150(A)           142.9    161.2    104.0
 462990 JPETRO51    110.00 463705*JNERES5     110.00 1  multiple outages (2)              110.5    136.1    119.2
 462900*JNSAD95     110.00 463355 JTTNSA51    110.00 1  SINGLE 462875-463355(1)           150.5    164.1    100.2
 463705 JNERES5     110.00 463925*JWKRIV51    110.00 1  SINGLE 463330-463910(1)           150.5    168.9    108.8
 462430*JGRADI5     110.00 463070 JRUDN35     110.00 1  SINGLE 463705-463925(1)           150.5    155.1    100.3
 463330 JTKSTA51    110.00 463910*JWKOST51    110.00 1  multiple outages (3)              150.5    197.8    126.0
 462915*JOSECI5     110.00 463395 JVALJ352    110.00 2  multiple outages (2)              110.5    125.0    110.8

 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

  CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 460150-460151(1C)        : OPEN LINE FROM BUS 460150 [JBGD2011    400.00] TO BUS 460151 [JBGD2012    400.00] CKT 1C
 SINGLE 460005-460060(1)         : OPEN LINE FROM BUS 460005 [JBGD8 12    400.00] TO BUS 460060 [JOBREN11    400.00] CKT 1
 SINGLE 461195-463390-465306(3)  : OPEN LINE FROM BUS 461195 [JVALJ321    220.00] TO BUS 463390 [JVALJ351    110.00] TO BUS
465306 [JVALJ3_3    10.000] CKT 3
 SINGLE 462430-463070(1)         : OPEN LINE FROM BUS 462430 [JGRADI5     110.00] TO BUS 463070 [JRUDN35     110.00] CKT 1
 SINGLE 463330-463910(1)         : OPEN LINE FROM BUS 463330 [JTKSTA51    110.00] TO BUS 463910 [JWKOST51    110.00] CKT 1
 SINGLE 462875-463355(1)         : OPEN LINE FROM BUS 462875 [JNSAD451    110.00] TO BUS 463355 [JTTNSA51    110.00] CKT 1
 SINGLE 462990-462995(1C)        : OPEN LINE FROM BUS 462990 [JPETRO51    110.00] TO BUS 462995 [JPETRO52    110.00] CKT 1C
 SINGLE 462990-463705(1)         : OPEN LINE FROM BUS 462990 [JPETRO51    110.00] TO BUS 463705 [JNERES5     110.00] CKT 1
 SINGLE 460090-460095(1)         : OPEN LINE FROM BUS 460090 [JRPMLA12    400.00] TO BUS 460095 [JSMIT211    400.00] CKT 1
 SINGLE 462721-463390(1)         : OPEN LINE FROM BUS 462721 [JRTINT51    110.00] TO BUS 463390 [JVALJ351    110.00] CKT 1
 SINGLE 460160-460504(1)         : OPEN LINE FROM BUS 460160 [JSMED31     400.00] TO BUS 460504 [JWPPZ5-1    400.00] CKT 1
```

Figure 5.25: Contingency (n-1) analysis report for Highest wind+solar generation regime 2025 (high RES, referent CO2)



```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW       %
 460070*JPANC211    400.00 460151 JBGD2012    400.00 A  BASE CASE                         935.3    940.7    100.3
 460090*JRPMLA12    400.00 460095 JSMIT211    400.00 1  BASE CASE                        1205.5   1409.1    115.9
 462165 JBGD3 51    110.00 462180*JBGD335     110.00 1  BASE CASE                          78.1    100.9    121.1
 462170 JBGD3 52    110.00 462935*JPANC151    110.00 1  BASE CASE                          78.1    124.7    147.5
 462180 JBGD335     110.00 462940*JPANC152    110.00 1  BASE CASE                          78.1    111.4    132.2
 462480*JHZVOR51    110.00  13533 XZV_BI51    110.00 1  BASE CASE                         106.7    116.0    107.1
 462710 JLESNI5     110.00 463100*JSABA352    110.00 1  BASE CASE                          78.1    102.2    124.4
 462915 JOSECI5     110.00 463395*JVALJ352    110.00 2  BASE CASE                          78.1    107.4    130.4
 462935 JPANC151    110.00 462950*JPANC252    110.00 2  BASE CASE                         106.7    132.0    114.0
 462940 JPANC152    110.00 462960*JPANC451    110.00 2  BASE CASE                          78.1    114.0    134.6
 463330 JTKSTA51    110.00 463910*JWKOST51    110.00 1  BASE CASE                         106.7    108.8    100.4
 460151*JBGD2012    400.00 3WNDTR T2           WND 1 2  SINGLE 460150-460151(1C)          300.0    350.8    119.1
 461030*JBGD3 22    220.00 461115 JOBREN22    220.00 1  SINGLE 460005-460060(1)           274.4    418.3    149.5
 461215*JZREN221    220.00 461230 JWKOVA21    220.00 1  multiple outages (4)              274.4    311.5    114.1
 461125 JPANC22     220.00 461235*JWVLAD21    220.00 1  SINGLE 461215-461230(1)           274.4    296.3    104.4
 461125*JPANC22     220.00 461221 JRANIS22    220.00 1  SINGLE 460070-460151(A)           331.5    359.6    105.2
 461000*JBBAST21    220.00  38201 XPL_BB21    220.00 1  SINGLE 460090-460095(1)           274.4    306.2    107.4
 461120 JOBREN23    220.00 461145*JSABA321    220.00 1  SINGLE 460090-460095(1)           331.5    353.8    108.3
 461130*JPOZEG21    220.00  13231 XVI_VA21    220.00 1  SINGLE 460090-460095(1)           274.4    339.1    122.0
 462985 JPECIN5     110.00 463095*JSABA351    110.00 1  SINGLE 460090-460095(1)            56.6     71.3    123.2
 461145*JSABA321    220.00 3WNDTR T1           WND 1 1  SINGLE 460090-460095(1)           150.0    185.7    125.6
 461145*JSABA321    220.00 3WNDTR T1           WND 1 1  SINGLE 461145-463100-465270(2)    150.0    179.2    117.9
 462640*JKRUPA5     110.00 462715 JLJUBO5     110.00 1  multiple outages (3)               78.1     78.7    105.9
 462640 JKRUPA5     110.00 462915*JOSECI5     110.00 1  multiple outages (3)               78.1     84.9    112.9
 462721 JRTINT51    110.00 463390*JVALJ351    110.00 1  multiple outage (6)                78.1    113.2    140.4
 462710*JLESNI5     110.00  13531 XBI_LE51    110.00 1  multiple outages (5)              106.7    124.7    120.1
 462070*JBGD1 5     110.00 463531 JBGD2052    110.00 2  SINGLE 462070-463530(1)           106.7    160.9    141.0
 462070*JBGD1 5     110.00 463530 JBGD2051    110.00 1  SINGLE 462070-463531(2)           106.7    160.9    141.0
 462135*JBGD2 52    110.00 462145 JBGD2251    110.00 PP SINGLE 460005-460060(1)            78.1    112.4    136.3
 462170*JBGD3 52    110.00 462185 JBGD355     110.00 1  SINGLE 460005-460060(1)           106.7    131.1    116.4
 462170*JBGD3 52    110.00 462395 JERESN5     110.00 1  SINGLE 460005-460060(1)           106.7    114.3    101.5
 462185*JBGD355     110.00 462570 JKOLUB51    110.00 1  SINGLE 460005-460060(1)           106.7    112.1    100.1
 462070*JBGD1 5     110.00 463530 JBGD2051    110.00 1  SINGLE 460005-460150(A)           106.7    126.1    110.8
 462070*JBGD1 5     110.00 463531 JBGD2052    110.00 2  SINGLE 460005-460150(A)           106.7    126.1    110.8
 462070 JBGD1 5     110.00 464021*JBGD4752    110.00 1  SINGLE 460005-460150(A)           142.9    183.7    121.1
 462945*JPANC251    110.00 462960 JPANC451    110.00 1  multiple outages (9)              106.7    168.1    144.7
 462990 JPETRO51    110.00 463705*JNERES5     110.00 1  multiple outages (4)               78.1    104.4    130.3
 463705 JNERES5     110.00 463925*JWKRIV51    110.00 1  multiple outages (2)              106.7    136.1    124.2
 462995*JPETRO52    110.00 463335 JTMORA5     110.00 1  SINGLE 460010-460040(1)           106.7    110.1    100.9
 462430*JGRADI5     110.00 463070 JRUDN35     110.00 1  SINGLE 463705-463925(1)           106.7    128.7    117.8
 463060 JRUDN15     110.00 463070*JRUDN35     110.00 1  SINGLE 463705-463925(1)           106.7    110.4    100.9
 462490 JINDJI5     110.00 463700*JINDJ25     110.00 1  SINGLE 460090-460095(1)           106.7    106.8    100.5
 462365 JEBRGU5     110.00 462575*JKOLUB52    110.00 1  SINGLE 462570-462575(1C)           78.1     94.3    115.4
 462365*JEBRGU5     110.00 464200 JTKOLB51    110.00 2  SINGLE 462570-462575(1C)           78.1     97.3    117.0
 462395*JERESN5     110.00 462570 JKOLUB51    110.00 1  SINGLE 460005-460060(1)           106.7    113.4    100.8
 462575 JKOLUB52    110.00 463285*JTAMNZ5     110.00 1  multiple outages (7)               78.1     98.1    121.9

 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
SINGLE 460150-460151(1C)         : OPEN LINE FROM BUS 460150 [JBGD2011    400.00] TO BUS 460151 [JBGD2012    400.00] CKT 1C
SINGLE 460005-460060(1)          : OPEN LINE FROM BUS 460005 [JBGD8 12    400.00] TO BUS 460060 [JOBREN11    400.00] CKT 1
SINGLE 461215-461230(1)          : OPEN LINE FROM BUS 461215 [JZREN221    220.00] TO BUS 461230 [JWKOVA21    220.00] CKT 1
SINGLE 460070-460151(A)          : OPEN LINE FROM BUS 460070 [JPANC211    400.00] TO BUS 460151 [JBGD2012    400.00] CKT A
SINGLE 460090-460095(1)          : OPEN LINE FROM BUS 460090 [JRPMLA12    400.00] TO BUS 460095 [JSMIT211    400.00] CKT 1
SINGLE 461145-463100-465270(2)   : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463100 [JSABA352    110.00] TO BUS
465270 [JSABA3_2    10.000] CKT 2
SINGLE 462070-463530(1)          : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463530 [JBGD2051    110.00] CKT 1
SINGLE 460005-460150(A)          : OPEN LINE FROM BUS 460005 [JBGD8 12    400.00] TO BUS 460150 [JBGD2011    400.00] CKT A
SINGLE 460010-460040(1)          : OPEN LINE FROM BUS 460010 [JBOR 21     400.00] TO BUS 460040 [JNIS2 11    400.00] CKT 1
SINGLE 463705-463925(1)          : OPEN LINE FROM BUS 463705 [JNERES5     110.00] TO BUS 463925 [JWKRIV51    110.00] CKT 1
SINGLE 462570-462575(1C)         : OPEN LINE FROM BUS 462570 [JKOLUB51    110.00] TO BUS 462575 [JKOLUB52    110.00] CKT 1C
SINGLE 460005-460060(1)          : OPEN LINE FROM BUS 460005 [JBGD8 12    400.00] TO BUS 460060 [JOBREN11    400.00] CKT 1
```

Figure 5.26: Contingency (n-1) analysis report for Summer regime with the highest generation 2025 (high RES, referent CO2)

```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>  RATING    FLOW      %
 461145*JSABA321    220.00 3WNDTR T1           WND 1 1  SINGLE 460090-460095(1)          150.0    162.4    107.4
 461145*JSABA321    220.00 3WNDTR T2           WND 1 2  SINGLE 461145-463095-465265(1)   150.0    163.9    106.6
 461145*JSABA321    220.00 3WNDTR T1           WND 1 1  SINGLE 461145-463100-465270(2)   150.0    169.3    110.2
 461195*JVALJ321    220.00 3WNDTR T2           WND 1 2  SINGLE 461195-463390-465306(3)   150.0    158.1    101.7
 462165 JBGD3 51    110.00 462180*JBGD335     110.00 1  SINGLE 460070-460151(A)          110.5    120.0    100.8
 462180 JBGD335     110.00 462940*JPANC152    110.00 1  multiple outages (2)             110.5    132.7    111.7
 462170 JBGD3 52    110.00 462935*JPANC151    110.00 1  multiple outages (8)             110.5    149.2    125.7
 462940 JPANC152    110.00 462960*JPANC451    110.00 2  multiple outages (3)             110.5    135.3    114.1
 462915*JOSECI5     110.00 463395 JVALJ352    110.00 2  SINGLE 460090-460095(1)          110.5    116.5    100.9

 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 460070-460151(A)          : OPEN LINE FROM BUS 460070 [JPANC211    400.00] TO BUS 460151 [JBGD2012    400.00] CKT A
 SINGLE 460090-460095(1)          : OPEN LINE FROM BUS 460090 [JRPMLA12    400.00] TO BUS 460095 [JSMIT211    400.00] CKT 1
 SINGLE 460150-460151(1C)         : OPEN LINE FROM BUS 460150 [JBGD2011    400.00] TO BUS 460151 [JBGD2012    400.00] CKT 1C
 SINGLE 462165-462180(1)          : OPEN LINE FROM BUS 462165 [JBGD3 51    110.00] TO BUS 462180 [JBGD335     110.00] CKT 1
 SINGLE 462180-462940(1)          : OPEN LINE FROM BUS 462180 [JBGD335     110.00] TO BUS 462940 [JPANC152    110.00] CKT 1
 SINGLE 462935-462950(2)          : OPEN LINE FROM BUS 462935 [JPANC151    110.00] TO BUS 462950 [JPANC252    110.00] CKT 2
 SINGLE 462940-462960(2)          : OPEN LINE FROM BUS 462940 [JPANC152    110.00] TO BUS 462960 [JPANC451    110.00] CKT 2
 SINGLE 462945-462960(1)          : OPEN LINE FROM BUS 462945 [JPANC251    110.00] TO BUS 462960 [JPANC451    110.00] CKT 1
 SINGLE 460070-462945-465085(1)   : OPEN LINE FROM BUS 460070 [JPANC211    400.00] TO BUS 462945 [JPANC251    110.00] TO BUS
465085 [JPANC2_2    10.000] CKT 1
 SINGLE 460070-462950-465090(2)   : OPEN LINE FROM BUS 460070 [JPANC211    400.00] TO BUS 462950 [JPANC252    110.00] TO BUS
465090 [JPANC2_3    10.000] CKT 2
 SINGLE 461145-463095-465265(1)   : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463095 [JSABA351    110.00] TO BUS
465265 [JSABA3_1    10.000] CKT 1
 SINGLE 461145-463100-465270(2)   : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463100 [JSABA352    110.00] TO BUS
465270 [JSABA3_2    10.000] CKT 2
 SINGLE 461195-463390-465306(3)   : OPEN LINE FROM BUS 461195 [JVALJ321    220.00] TO BUS 463390 [JVALJ351    110.00] TO BUS
465306 [JVALJ3_3    10.000] CKT 3
```

Figure 5.27: Contingency (n-1) analysis report for Highest export regime 2025 (high RES, referent CO2)

```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>  RATING    FLOW      %
 462825 JNPAZ151    110.00 462830*JNPAZ25     110.00 1  BASE CASE                         78.1     81.0    100.1
 462170 JBGD3 52    110.00 462935*JPANC151    110.00 1  SINGLE 460070-460151(A)           78.1    102.9    116.4
 462180 JBGD335     110.00 462940*JPANC152    110.00 1  SINGLE 460070-460151(A)           78.1     90.1    102.4
 462070*JBGD1 5     110.00 463531 JBGD2052    110.00 2  multiple outages (2)              106.7     120.9    102.5
 462940*JPANC152    110.00 462960 JPANC451    110.00 2  SINGLE 460070-460151(A)           78.1     92.3    104.8
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  SINGLE 471005-46011(1)            78.1     80.6    103.9

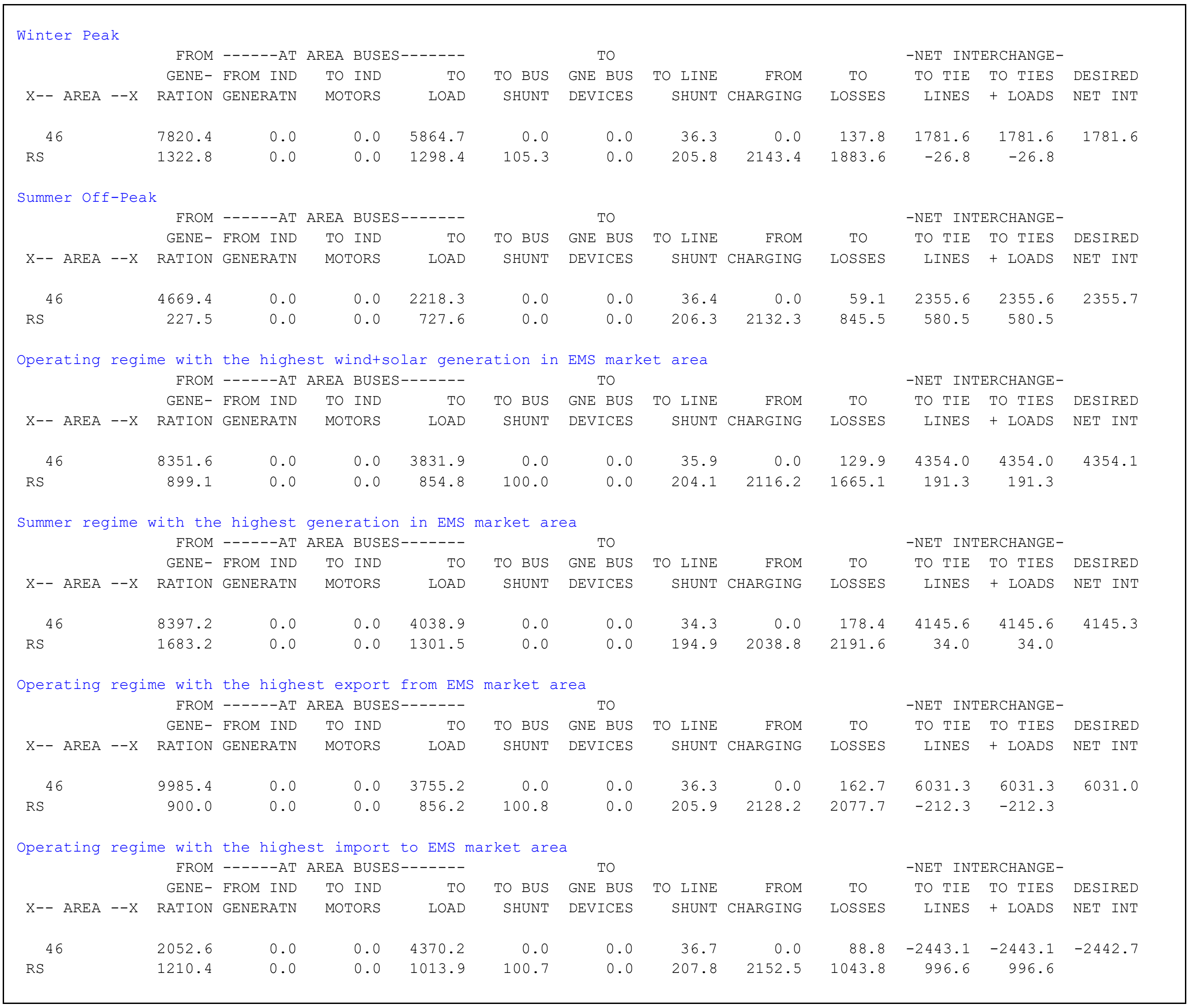
 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 460070-460151(A)     : OPEN LINE FROM BUS 460070 [JPANC211    400.00] TO BUS 460151 [JBGD2012    400.00] CKT
 SINGLE 462070-463530(1)     : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463530 [JBGD2051    110.00] CKT
 SINGLE 462070-463531(2)     : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463531 [JBGD2052    110.00] CKT
 SINGLE 460045-46011(1)      : OPEN LINE FROM BUS 460045 [JNIS2 12    400.00] TO BUS 46011 [XKB_NI11    400.00] CKT 1
 SINGLE 471005-46011(1)      : OPEN LINE FROM BUS 471005 [_KOBSP1     400.00] TO BUS 46011 [XKB_NI11    400.00] CKT 1
```

Figure 5.28: Contingency (n-1) analysis report for Highest import regime 2025 (high RES, referent CO2)

5.3.3 Year 2030-refRES, RES=8100 MW

We first provide the summary report, with data only for EMS market area. We present the area summary for the analyzed six network regimes as follows:



```
Winter Peak
                 FROM ------AT AREA BUSES-------              TO                                -NET INTERCHANGE-
                GENE- FROM IND   TO IND       TO   TO BUS  GNE BUS  TO LINE     FROM      TO    TO TIE   TO TIES  DESIRED
 X-- AREA --X  RATION GENERATN   MOTORS     LOAD    SHUNT  DEVICES    SHUNT CHARGING   LOSSES    LINES   + LOADS  NET INT

   46           7820.4      0.0      0.0   5864.7      0.0      0.0     36.3      0.0    137.8   1781.6   1781.6   1781.6
 RS             1322.8      0.0      0.0   1298.4    105.3      0.0    205.8   2143.4   1883.6    -26.8    -26.8

Summer Off-Peak
                 FROM ------AT AREA BUSES-------              TO                                -NET INTERCHANGE-
                GENE- FROM IND   TO IND       TO   TO BUS  GNE BUS  TO LINE     FROM      TO    TO TIE   TO TIES  DESIRED
 X-- AREA --X  RATION GENERATN   MOTORS     LOAD    SHUNT  DEVICES    SHUNT CHARGING   LOSSES    LINES   + LOADS  NET INT

   46           4669.4      0.0      0.0   2218.3      0.0      0.0     36.4      0.0     59.1   2355.6   2355.6   2355.7
 RS              227.5      0.0      0.0    727.6      0.0      0.0    206.3   2132.3    845.5    580.5    580.5

Operating regime with the highest wind+solar generation in EMS market area
                 FROM ------AT AREA BUSES-------              TO                                -NET INTERCHANGE-
                GENE- FROM IND   TO IND       TO   TO BUS  GNE BUS  TO LINE     FROM      TO    TO TIE   TO TIES  DESIRED
 X-- AREA --X  RATION GENERATN   MOTORS     LOAD    SHUNT  DEVICES    SHUNT CHARGING   LOSSES    LINES   + LOADS  NET INT

   46           8351.6      0.0      0.0   3831.9      0.0      0.0     35.9      0.0    129.9   4354.0   4354.0   4354.1
 RS              899.1      0.0      0.0    854.8    100.0      0.0    204.1   2116.2   1665.1    191.3    191.3

Summer regime with the highest generation in EMS market area
                 FROM ------AT AREA BUSES-------              TO                                -NET INTERCHANGE-
                GENE- FROM IND   TO IND       TO   TO BUS  GNE BUS  TO LINE     FROM      TO    TO TIE   TO TIES  DESIRED
 X-- AREA --X  RATION GENERATN   MOTORS     LOAD    SHUNT  DEVICES    SHUNT CHARGING   LOSSES    LINES   + LOADS  NET INT

   46           8397.2      0.0      0.0   4038.9      0.0      0.0     34.3      0.0    178.4   4145.6   4145.6   4145.3
 RS             1683.2      0.0      0.0   1301.5      0.0      0.0    194.9   2038.8   2191.6     34.0     34.0

Operating regime with the highest export from EMS market area
                 FROM ------AT AREA BUSES-------              TO                                -NET INTERCHANGE-
                GENE- FROM IND   TO IND       TO   TO BUS  GNE BUS  TO LINE     FROM      TO    TO TIE   TO TIES  DESIRED
 X-- AREA --X  RATION GENERATN   MOTORS     LOAD    SHUNT  DEVICES    SHUNT CHARGING   LOSSES    LINES   + LOADS  NET INT

   46           9985.4      0.0      0.0   3755.2      0.0      0.0     36.3      0.0    162.7   6031.3   6031.3   6031.0
 RS              900.0      0.0      0.0    856.2    100.8      0.0    205.9   2128.2   2077.7   -212.3   -212.3

Operating regime with the highest import to EMS market area
                 FROM ------AT AREA BUSES-------              TO                                -NET INTERCHANGE-
                GENE- FROM IND   TO IND       TO   TO BUS  GNE BUS  TO LINE     FROM      TO    TO TIE   TO TIES  DESIRED
 X-- AREA --X  RATION GENERATN   MOTORS     LOAD    SHUNT  DEVICES    SHUNT CHARGING   LOSSES    LINES   + LOADS  NET INT

   46           2052.6      0.0      0.0   4370.2      0.0      0.0     36.7      0.0     88.8  -2443.1  -2443.1  -2442.7
 RS             1210.4      0.0      0.0   1013.9    100.7      0.0    207.8   2152.5   1043.8    996.6    996.6
```

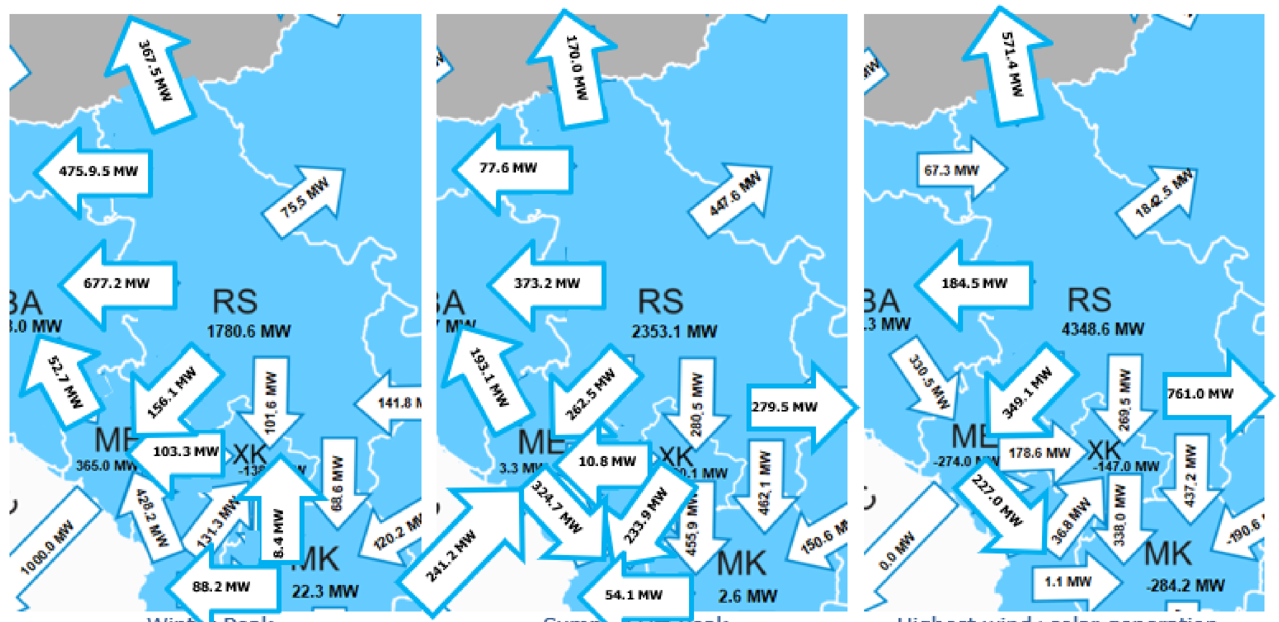
Figure 5.29: Area summary report for 2030 analysed regimes (referent RES, referent CO2)

Based on the above area summary report, results for EMS market area are the following:

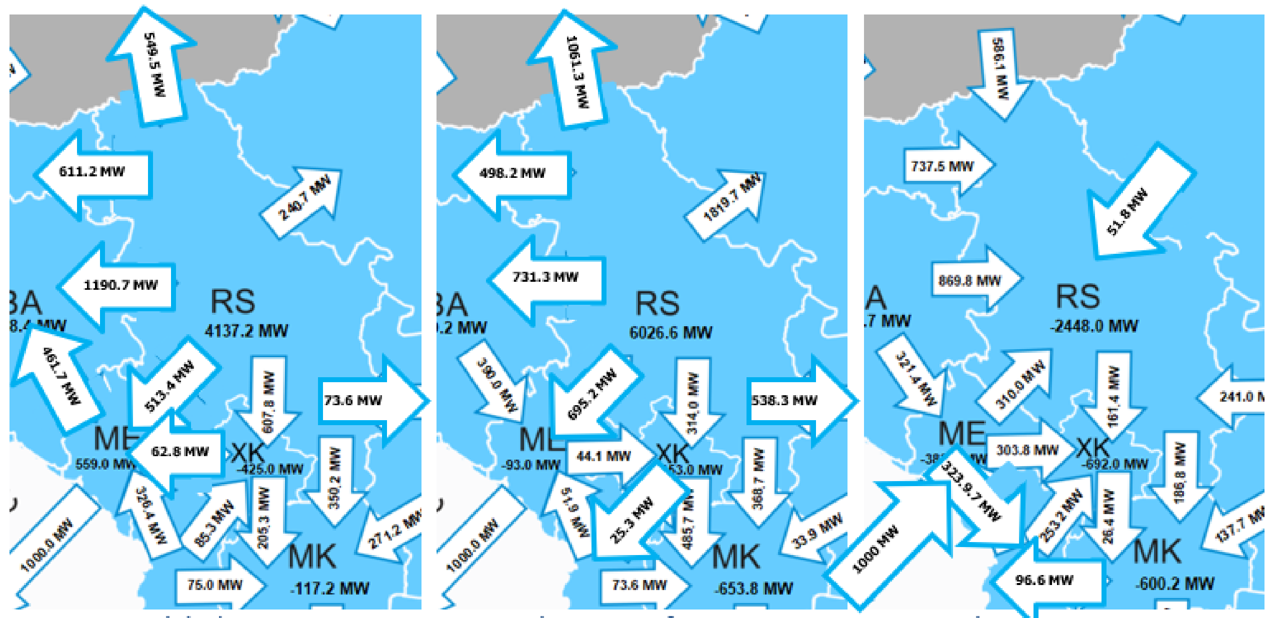
- Winter Peak regime:
  - The total EMS system load is 5865 MW and 1298 MVar
  - Generation is 7820 MW and EMS exports 1781 MW
- Summer Off-Peak regime:
  - The total EMS system load is 2218 MW and 727 MVar
  - Generation is 4669 MW and EMS exports 2355 MW
- Highest wind+solar generation regime:
  - The total EMS system load is 3832 MW and 855 MVar
  - Generation is 8352 MW and EMS exports 4354 MW
- Summer with highest generation regime:
  - The total EMS system load is 4039 MW and 1301 MVar
  - Generation is 8397 MW and EMS exports 4145 MW
- Highest export from EMS regime:
  - The total EMS system load is 3755 MW and 856 MVar

  - Generation is 9985 MW and EMS exports 6031 MW
- Highest import to EMS regime:
  - The total EMS system load is 4370 MW and 1014 MVar
  - Generation is 2053 MW and EMS imports 2442 MW

The following figures show the cross-border power exchange map for all six analysed regimes for year 2030 referent RES.



Winte Peak Summ Off-Peak Highest wind+solar generation



Summer with highest generation Highest export from EMS Highest mport to EMS

Figure 5.30: Cross-border exchanges (MW) and directions between the countries in year 2025 and Referent RES scenario

The following three figures show the 400 kV, 220 kV and 110 kV voltage profiles with maximum, minimum and average values in EMS transmission network for all six analysed regimes. The voltage profiles in the 400 kV and 220 kV network are within limits for all analysed regimes.

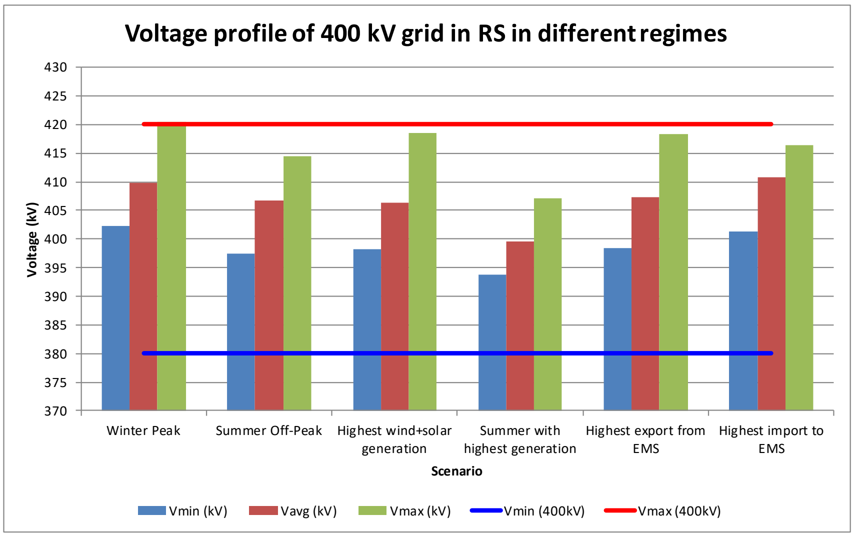


Figure 5.31: 400 kV voltage profiles (minimum, maximum and average) for 2030 analyzed regimes (referent RES, referent CO2)

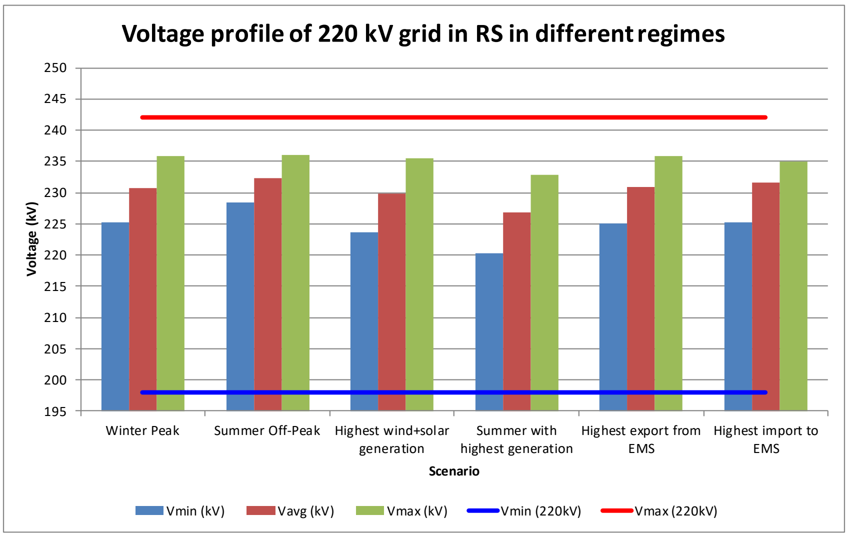


Figure 5.32: 220 kV voltage profiles (minimum, maximum and average) for 2030 analyzed regimes (referent RES, referent CO2)

In case of 110 kV network, in some nodes voltages above acceptable limits are observed. These problems can be considered as local and can be controlled by fine tunning of the voltage profiles at higher network levels.

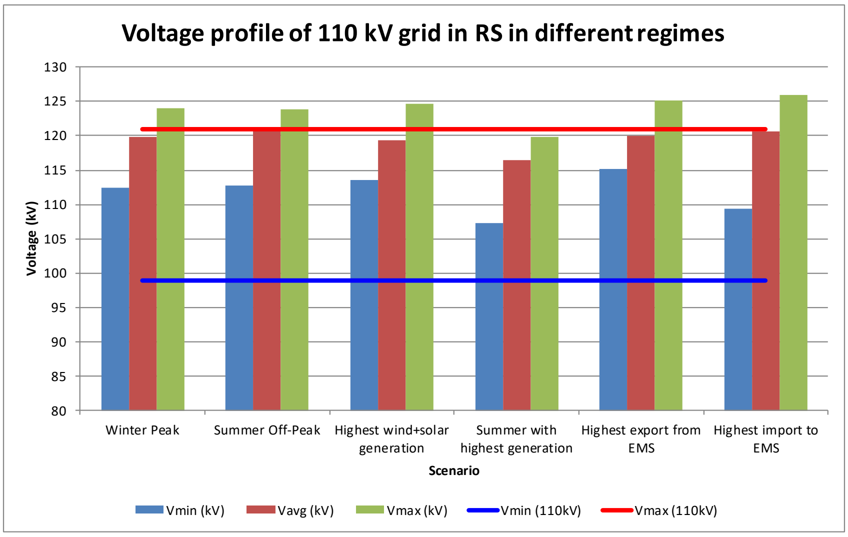


Figure 5.33: 110 kV voltage profiles (minimum, maximum and average) for 2030 analysed regimes (referent RES, referent CO2)

The 400 kV and 220 kV elements that are loaded more than 80% are as follows:

```
Winter Peak
/
Summer Off-Peak
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
 460035 JLESK211     400.00    46 460037 JLESK212     400.00*   46  1C    278.6   238.2   117.0
 461000 JBBAST21     220.00    46 461135 JRHBBA21     220.00*   46  1     269.0   331.5    81.2

Operating regime with the highest wind+solar generation in EMS market area
/
Summer regime with the highest generation in EMS market area
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
 460035 JLESK211     400.00    46 460037 JLESK212     400.00*   46  1C    390.3   238.2   163.8

Operating regime with the highest export from EMS market area
/
Operating regime with the highest import to EMS market area
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
 461000 JBBAST21     220.00*   46 461135 JRHBBA21     220.00    46  1     273.9   331.5    82.6
```

Figure 5.34: List of 400 and 220 kV elements loaded more than 80% for 2030 analysed regimes (referent RES, referent CO2)

In 2030, export towards West and North-West is higher than in 2025, but system can operate without issues since planned reinforcements in the network (project "North CSE Corridor", interconnections with BA and ME and „Pannonian Corridor ") are included. The highest export is noted in the summer regime with maximum generation in EMS area - 2351 MW.

Concerning 110 kV network, all reinforcements already planned by EMS contribute to secure system operation and number of lines with loading above 80% is significantly lower than in the 2025 Scenarios.

The complete contingency n-1 analysis reports for 2025 high RES analysed regimes are given in Appendix, while the edited shorten reports are presented bellow. These results do not compromise the above given considerations.

The 110 kV elements that are loaded more than 80% are as follows:

```
Winter Peak
/
Summer Off-Peak
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
  46031 XNP_LE51    110.00*   99 462830 JNPAZ25     110.00    46  1     71.8    78.1    91.9
 462710 JLESNI5     110.00*   46 463100 JSABA352    110.00    46  1     65.3    78.1    83.7
 462825 JNPAZ151    110.00    46 462830 JNPAZ25     110.00*   46  1     71.7    78.1    91.7

Operating regime with the highest wind+solar generation in EMS market area
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
  46031 XNP_LE51    110.00*   99 462830 JNPAZ25     110.00    46  1    120.3   110.5   108.8
 462825 JNPAZ151    110.00    46 462830 JNPAZ25     110.00*   46  1    126.7   110.5   114.7

Summer regime with the highest generation in EMS market area
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
  13531 XBI_LE51    110.00*   99 462710 JLESNI5     110.00    46  1     88.0   106.7    82.5
  13533 XZV_BI51    110.00*   99 462480 JHZVOR51    110.00    46  1    119.6   106.7   112.1
  46031 XNP_LE51    110.00*   99 462830 JNPAZ25     110.00    46  1    127.5    78.1   163.3
 462710 JLESNI5     110.00*   46 463100 JSABA352    110.00    46  1     90.1    78.1   115.3
 462825 JNPAZ151    110.00    46 462830 JNPAZ25     110.00*   46  1    128.8    78.1   164.9
 462915 JOSECI5     110.00*   46 463395 JVALJ352    110.00    46  2     81.8    78.1   104.8
 462990 JPETRO51    110.00    46 463705 JNERES5     110.00*   46  1     68.1    78.1    87.1
 463330 JTKSTA51    110.00    46 463910 JWKOST51    110.00*   46  1    110.3   106.7   103.4

Operating regime with the highest export from EMS market area
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
  46031 XNP_LE51    110.00*   99 462830 JNPAZ25     110.00    46  1    100.6   110.5    91.0
 462825 JNPAZ151    110.00    46 462830 JNPAZ25     110.00*   46  1    107.1   110.5    97.0

Operating regime with the highest import to EMS market area
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
  46031 XNP_LE51    110.00*   99 462830 JNPAZ25     110.00    46  1    122.0    78.1   156.2
 462825 JNPAZ151    110.00    46 462830 JNPAZ25     110.00*   46  1    131.8    78.1   168.8
```

Figure 5.35: List of 110 kV elements loaded more than 80% for 2030 analysed regimes (referent RES, referent CO2)

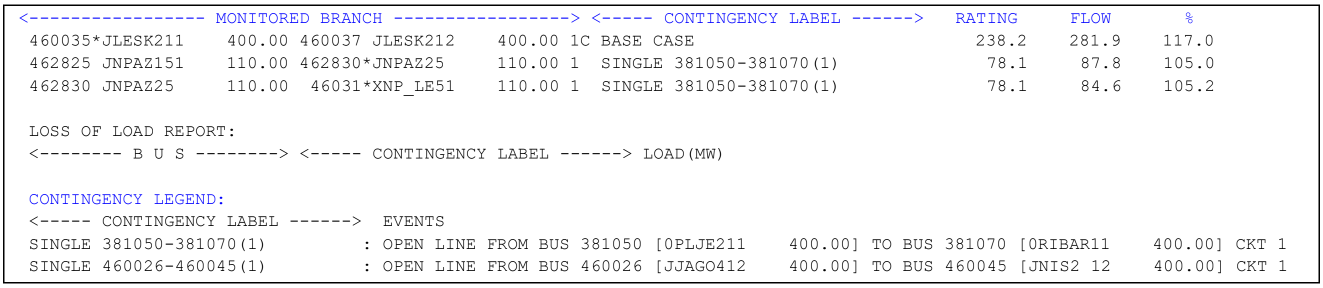
The edited contingency n-1 analysis reports for 2030 referent RES analysed regimes are as follows:

```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>  RATING     FLOW       %
 462900 JNSAD95     110.00 463355*JTTNSA51    110.00 1  SINGLE 462875-463355(1)            150.5    173.0    104.4


 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 462875-463355(1)          : OPEN LINE FROM BUS 462875 [JNSAD451    110.00] TO BUS 463355 [JTTNSA51    110.00] CKT 1
```

Figure 5.36: Contingency (n-1) analysis report for Winter Peak regime 2030 (referent RES, referent CO2)

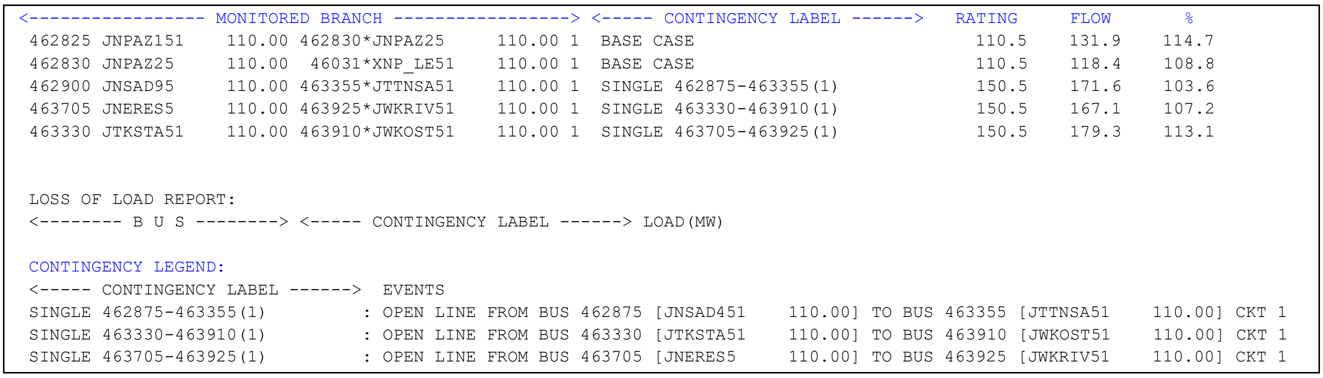


```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>  RATING    FLOW       %
 460035*JLESK211    400.00 460037 JLESK212    400.00 1C BASE CASE                        238.2    281.9    117.0
 462825 JNPAZ151    110.00 462830*JNPAZ25     110.00 1  SINGLE 381050-381070(1)           78.1     87.8    105.0
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  SINGLE 381050-381070(1)           78.1     84.6    105.2

 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 381050-381070(1)         : OPEN LINE FROM BUS 381050 [OPLJE211    400.00] TO BUS 381070 [ORIBAR11    400.00] CKT 1
 SINGLE 460026-460045(1)         : OPEN LINE FROM BUS 460026 [JJAGO412    400.00] TO BUS 460045 [JNIS2 12    400.00] CKT 1
```

Figure 5.37: Contingency (n-1) analysis report for Summer Off-Peak regime 2030 (referent RES,referent CO2)

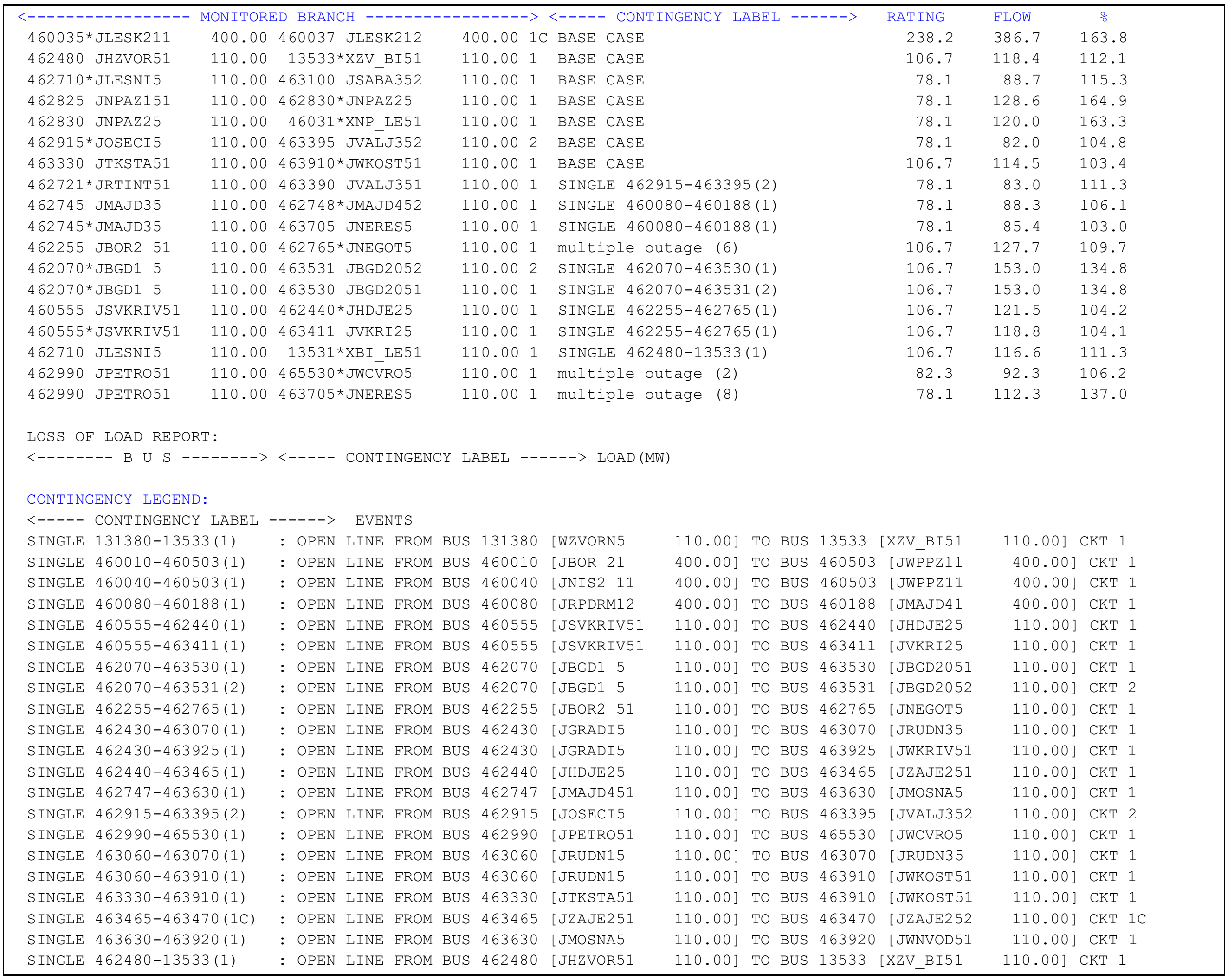


```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>  RATING    FLOW       %
 462825 JNPAZ151    110.00 462830*JNPAZ25     110.00 1  BASE CASE                        110.5    131.9    114.7
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  BASE CASE                        110.5    118.4    108.8
 462900 JNSAD95     110.00 463355*JTTNSA51    110.00 1  SINGLE 462875-463355(1)          150.5    171.6    103.6
 463705 JNERES5     110.00 463925*JWKRIV51    110.00 1  SINGLE 463330-463910(1)          150.5    167.1    107.2
 463330 JTKSTA51    110.00 463910*JWKOST51    110.00 1  SINGLE 463705-463925(1)          150.5    179.3    113.1


 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 462875-463355(1)         : OPEN LINE FROM BUS 462875 [JNSAD451    110.00] TO BUS 463355 [JTTNSA51    110.00] CKT 1
 SINGLE 463330-463910(1)         : OPEN LINE FROM BUS 463330 [JTKSTA51    110.00] TO BUS 463910 [JWKOST51    110.00] CKT 1
 SINGLE 463705-463925(1)         : OPEN LINE FROM BUS 463705 [JNERES5     110.00] TO BUS 463925 [JWKRIV51    110.00] CKT 1
```

Figure 5.38: Contingency (n-1) analysis report for Highest wind+solar generation regime 2030 (referent RES, referent CO2)

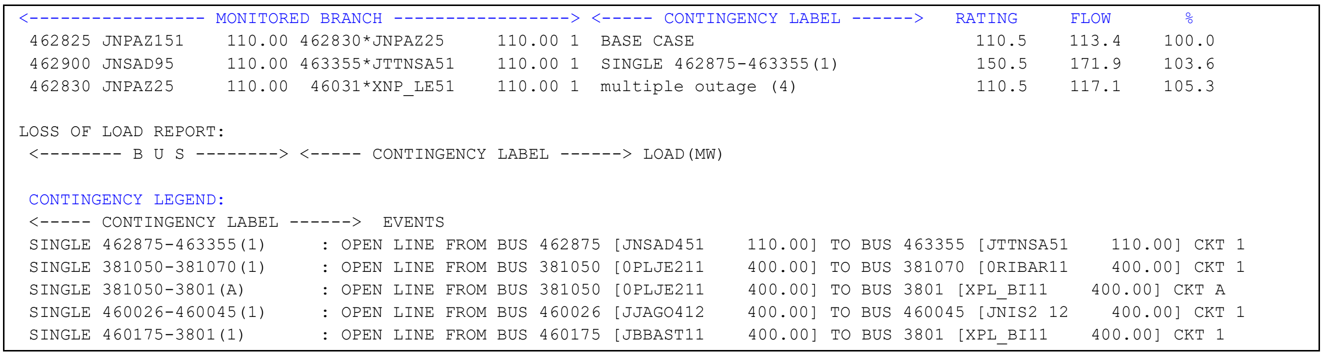


```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>  RATING    FLOW       %
 460035*JLESK211    400.00 460037 JLESK212    400.00 1C BASE CASE                        238.2    386.7    163.8
 462480 JHZVOR51    110.00  13533*XZV_BI51    110.00 1  BASE CASE                        106.7    118.4    112.1
 462710*JLESNI5     110.00 463100 JSABA352    110.00 1  BASE CASE                         78.1     88.7    115.3
 462825 JNPAZ151    110.00 462830*JNPAZ25     110.00 1  BASE CASE                         78.1    128.6    164.9
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  BASE CASE                         78.1    120.0    163.3
 462915*JOSECI5     110.00 463395 JVALJ352    110.00 2  BASE CASE                         78.1     82.0    104.8
 463330 JTKSTA51    110.00 463910*JWKOST51    110.00 1  BASE CASE                        106.7    114.5    103.4
 462721*JRTINT51    110.00 463390 JVALJ351    110.00 1  SINGLE 462915-463395(2)           78.1     83.0    111.3
 462745 JMAJD35     110.00 462748*JMAJD452    110.00 1  SINGLE 460080-460188(1)           78.1     88.3    106.1
 462745*JMAJD35     110.00 463705 JNERES5     110.00 1  SINGLE 460080-460188(1)           78.1     85.4    103.0
 462255 JBOR2 51    110.00 462765*JNEGOT5     110.00 1  multiple outage (6)              106.7    127.7    109.7
 462070*JBGD1 5     110.00 463531 JBGD2052    110.00 2  SINGLE 462070-463530(1)          106.7    153.0    134.8
 462070*JBGD1 5     110.00 463530 JBGD2051    110.00 1  SINGLE 462070-463531(2)          106.7    153.0    134.8
 460555 JSVKRIV51   110.00 462440*JHDJE25     110.00 1  SINGLE 462255-462765(1)          106.7    121.5    104.2
 460555*JSVKRIV51   110.00 463411 JVKRI25     110.00 1  SINGLE 462255-462765(1)          106.7    118.8    104.1
 462710 JLESNI5     110.00  13531*XBI_LE51    110.00 1  SINGLE 462480-13533(1)           106.7    116.6    111.3
 462990 JPETRO51    110.00 465530*JWCVRO5     110.00 1  multiple outage (2)               82.3     92.3    106.2
 462990 JPETRO51    110.00 463705*JNERES5     110.00 1  multiple outage (8)               78.1    112.3    137.0

 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 131380-13533(1)     : OPEN LINE FROM BUS 131380 [WZVORN5     110.00] TO BUS 13533 [XZV_BI51    110.00] CKT 1
 SINGLE 460010-460503(1)    : OPEN LINE FROM BUS 460010 [JBOR 21     400.00] TO BUS 460503 [JWPPZ11     400.00] CKT 1
 SINGLE 460040-460503(1)    : OPEN LINE FROM BUS 460040 [JNIS2 11    400.00] TO BUS 460503 [JWPPZ11     400.00] CKT 1
 SINGLE 460080-460188(1)    : OPEN LINE FROM BUS 460080 [JRPDRM12    400.00] TO BUS 460188 [JMAJD41     400.00] CKT 1
 SINGLE 460555-462440(1)    : OPEN LINE FROM BUS 460555 [JSVKRIV51   110.00] TO BUS 462440 [JHDJE25     110.00] CKT 1
 SINGLE 460555-463411(1)    : OPEN LINE FROM BUS 460555 [JSVKRIV51   110.00] TO BUS 463411 [JVKRI25     110.00] CKT 1
 SINGLE 462070-463530(1)    : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463530 [JBGD2051    110.00] CKT 1
 SINGLE 462070-463531(2)    : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463531 [JBGD2052    110.00] CKT 2
 SINGLE 462255-462765(1)    : OPEN LINE FROM BUS 462255 [JBOR2 51    110.00] TO BUS 462765 [JNEGOT5     110.00] CKT 1
 SINGLE 462430-463070(1)    : OPEN LINE FROM BUS 462430 [JGRADI5     110.00] TO BUS 463070 [JRUDN35     110.00] CKT 1
 SINGLE 462430-463925(1)    : OPEN LINE FROM BUS 462430 [JGRADI5     110.00] TO BUS 463925 [JWKRIV51    110.00] CKT 1
 SINGLE 462440-463465(1)    : OPEN LINE FROM BUS 462440 [JHDJE25     110.00] TO BUS 463465 [JZAJE251    110.00] CKT 1
 SINGLE 462747-463630(1)    : OPEN LINE FROM BUS 462747 [JMAJD451    110.00] TO BUS 463630 [JMOSNA5     110.00] CKT 1
 SINGLE 462915-463395(2)    : OPEN LINE FROM BUS 462915 [JOSECI5     110.00] TO BUS 463395 [JVALJ352    110.00] CKT 2
 SINGLE 462990-465530(1)    : OPEN LINE FROM BUS 462990 [JPETRO51    110.00] TO BUS 465530 [JWCVRO5     110.00] CKT 1
 SINGLE 463060-463070(1)    : OPEN LINE FROM BUS 463060 [JRUDN15     110.00] TO BUS 463070 [JRUDN35     110.00] CKT 1
 SINGLE 463060-463910(1)    : OPEN LINE FROM BUS 463060 [JRUDN15     110.00] TO BUS 463910 [JWKOST51    110.00] CKT 1
 SINGLE 463330-463910(1)    : OPEN LINE FROM BUS 463330 [JTKSTA51    110.00] TO BUS 463910 [JWKOST51    110.00] CKT 1
 SINGLE 463465-463470(1C)   : OPEN LINE FROM BUS 463465 [JZAJE251    110.00] TO BUS 463470 [JZAJE252    110.00] CKT 1C
 SINGLE 463630-463920(1)    : OPEN LINE FROM BUS 463630 [JMOSNA5     110.00] TO BUS 463920 [JWNVOD51    110.00] CKT 1
 SINGLE 462480-13533(1)     : OPEN LINE FROM BUS 462480 [JHZVOR51    110.00] TO BUS 13533 [XZV_BI51    110.00] CKT 1
```

Figure 5.39: Contingency (n-1) analysis report for Summer regime with the highest generation 2030 (referent RES, referent CO2)

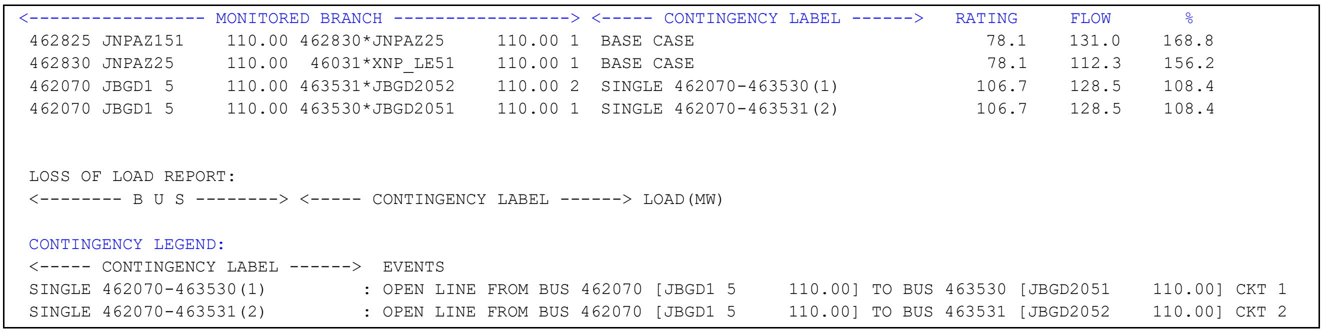


```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>  RATING    FLOW       %
 462825 JNPAZ151    110.00 462830*JNPAZ25     110.00 1  BASE CASE                        110.5    113.4    100.0
 462900 JNSAD95     110.00 463355*JTTNSA51    110.00 1  SINGLE 462875-463355(1)          150.5    171.9    103.6
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  multiple outage (4)              110.5    117.1    105.3

LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 462875-463355(1)      : OPEN LINE FROM BUS 462875 [JNSAD451    110.00] TO BUS 463355 [JTTNSA51    110.00] CKT 1
 SINGLE 381050-381070(1)      : OPEN LINE FROM BUS 381050 [0PLJE211    400.00] TO BUS 381070 [0RIBAR11    400.00] CKT 1
 SINGLE 381050-3801(A)        : OPEN LINE FROM BUS 381050 [0PLJE211    400.00] TO BUS 3801 [XPL_BI11    400.00] CKT A
 SINGLE 460026-460045(1)      : OPEN LINE FROM BUS 460026 [JJAGO412    400.00] TO BUS 460045 [JNIS2 12    400.00] CKT 1
 SINGLE 460175-3801(1)        : OPEN LINE FROM BUS 460175 [JBBAST11    400.00] TO BUS 3801 [XPL_BI11    400.00] CKT 1
```

Figure 5.40: Contingency (n-1) analysis report for Highest export regime 2030 (referent RES, referent CO2)



```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW       %
 462825 JNPAZ151    110.00 462830*JNPAZ25     110.00 1  BASE CASE                           78.1    131.0    168.8
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  BASE CASE                           78.1    112.3    156.2
 462070 JBGD1 5     110.00 463531*JBGD2052    110.00 2  SINGLE 462070-463530(1)            106.7    128.5    108.4
 462070 JBGD1 5     110.00 463530*JBGD2051    110.00 1  SINGLE 462070-463531(2)            106.7    128.5    108.4

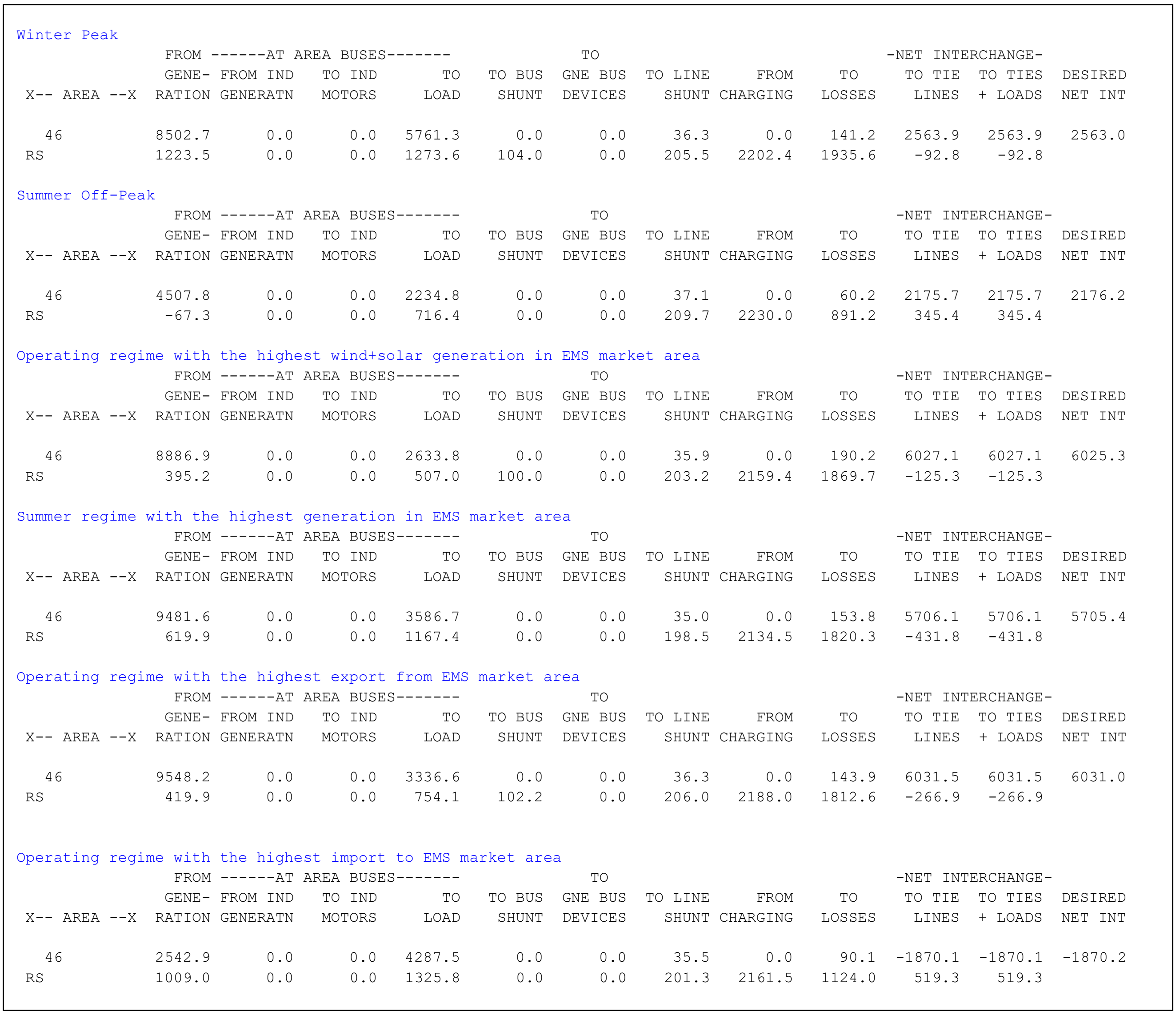

 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 462070-463530(1)         : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463530 [JBGD2051    110.00] CKT 1
 SINGLE 462070-463531(2)         : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463531 [JBGD2052    110.00] CKT 2
```

Figure 5.41: Contingency (n-1) analysis report for Highest import regime 2030 (referent RES,referent CO2)

5.3.4 Year 2030-highRES, RES=17000MW

We first provide the summary report, with data only for EMS market area. We present the area summary for the analyzed six network regimes as follows:



```
Winter Peak
                FROM ------AT AREA BUSES-------              TO                            -NET INTERCHANGE-
                GENE- FROM IND   TO IND      TO   TO BUS  GNE BUS  TO LINE     FROM     TO    TO TIE  TO TIES  DESIRED
 X-- AREA --X  RATION GENERATN   MOTORS     LOAD   SHUNT  DEVICES    SHUNT CHARGING  LOSSES    LINES  + LOADS  NET INT

   46          8502.7      0.0      0.0   5761.3     0.0      0.0     36.3      0.0   141.2   2563.9   2563.9   2563.0
 RS            1223.5      0.0      0.0   1273.6   104.0      0.0    205.5   2202.4  1935.6    -92.8    -92.8

Summer Off-Peak
                 FROM ------AT AREA BUSES-------              TO                            -NET INTERCHANGE-
                GENE- FROM IND   TO IND      TO   TO BUS  GNE BUS  TO LINE     FROM     TO    TO TIE  TO TIES  DESIRED
 X-- AREA --X  RATION GENERATN   MOTORS     LOAD   SHUNT  DEVICES    SHUNT CHARGING  LOSSES    LINES  + LOADS  NET INT

   46          4507.8      0.0      0.0   2234.8     0.0      0.0     37.1      0.0    60.2   2175.7   2175.7   2176.2
 RS             -67.3      0.0      0.0    716.4     0.0      0.0    209.7   2230.0   891.2    345.4    345.4

Operating regime with the highest wind+solar generation in EMS market area
                 FROM ------AT AREA BUSES-------              TO                            -NET INTERCHANGE-
                GENE- FROM IND   TO IND      TO   TO BUS  GNE BUS  TO LINE     FROM     TO    TO TIE  TO TIES  DESIRED
 X-- AREA --X  RATION GENERATN   MOTORS     LOAD   SHUNT  DEVICES    SHUNT CHARGING  LOSSES    LINES  + LOADS  NET INT

   46          8886.9      0.0      0.0   2633.8     0.0      0.0     35.9      0.0   190.2   6027.1   6027.1   6025.3
 RS             395.2      0.0      0.0    507.0   100.0      0.0    203.2   2159.4  1869.7   -125.3   -125.3

Summer regime with the highest generation in EMS market area
                 FROM ------AT AREA BUSES-------              TO                            -NET INTERCHANGE-
                GENE- FROM IND   TO IND      TO   TO BUS  GNE BUS  TO LINE     FROM     TO    TO TIE  TO TIES  DESIRED
 X-- AREA --X  RATION GENERATN   MOTORS     LOAD   SHUNT  DEVICES    SHUNT CHARGING  LOSSES    LINES  + LOADS  NET INT

   46          9481.6      0.0      0.0   3586.7     0.0      0.0     35.0      0.0   153.8   5706.1   5706.1   5705.4
 RS             619.9      0.0      0.0   1167.4     0.0      0.0    198.5   2134.5  1820.3   -431.8   -431.8

Operating regime with the highest export from EMS market area
                 FROM ------AT AREA BUSES-------              TO                            -NET INTERCHANGE-
                GENE- FROM IND   TO IND      TO   TO BUS  GNE BUS  TO LINE     FROM     TO    TO TIE  TO TIES  DESIRED
 X-- AREA --X  RATION GENERATN   MOTORS     LOAD   SHUNT  DEVICES    SHUNT CHARGING  LOSSES    LINES  + LOADS  NET INT

   46          9548.2      0.0      0.0   3336.6     0.0      0.0     36.3      0.0   143.9   6031.5   6031.5   6031.0
 RS             419.9      0.0      0.0    754.1   102.2      0.0    206.0   2188.0  1812.6   -266.9   -266.9


Operating regime with the highest import to EMS market area
                 FROM ------AT AREA BUSES-------              TO                            -NET INTERCHANGE-
                GENE- FROM IND   TO IND      TO   TO BUS  GNE BUS  TO LINE     FROM     TO    TO TIE  TO TIES  DESIRED
 X-- AREA --X  RATION GENERATN   MOTORS     LOAD   SHUNT  DEVICES    SHUNT CHARGING  LOSSES    LINES  + LOADS  NET INT

   46          2542.9      0.0      0.0   4287.5     0.0      0.0     35.5      0.0    90.1  -1870.1  -1870.1  -1870.2
 RS            1009.0      0.0      0.0   1325.8     0.0      0.0    201.3   2161.5  1124.0    519.3    519.3
```

Figure 5.42: Area summary report for 2030 analysed regimes (high RES, referent CO2)

Based on the above area summary report, results for EMS market area are the following:

- Winter Peak regime:
    - The total EMS system load is 5761 MW and 1274 MVar
    - Generation is 8503 MW and EMS exports 2563 MW
- Summer Off-Peak regime:
    - The total EMS system load is 2735 MW and 716 MVar
    - Generation is 4508 MW and EMS exports 2176 MW
- Highest wind+solar generation regime:
    - The total EMS system load is 2634 MW and 507 MVar
    - Generation is 8887 MW and EMS exports 6025 MW
- Summer with highest generation regime:
    - The total EMS system load is 3587 MW and 1167 MVar
    - Generation is 9482 MW and EMS exports 5705 MW
- Highest export from EMS regime:

  - The total EMS system load is 3337 MW and 754 MVar
  - Generation is 9548 MW and EMS exports 6031 MW
- Highest import to EMS regime:
  - The total EMS system load is 4287 MW and 1326 MVar
  - Generation is 2543 MW and EMS imports 1870 MW

The following figures show the cross-border power exchange map for all six analysed regimes for year 2030 high RES.

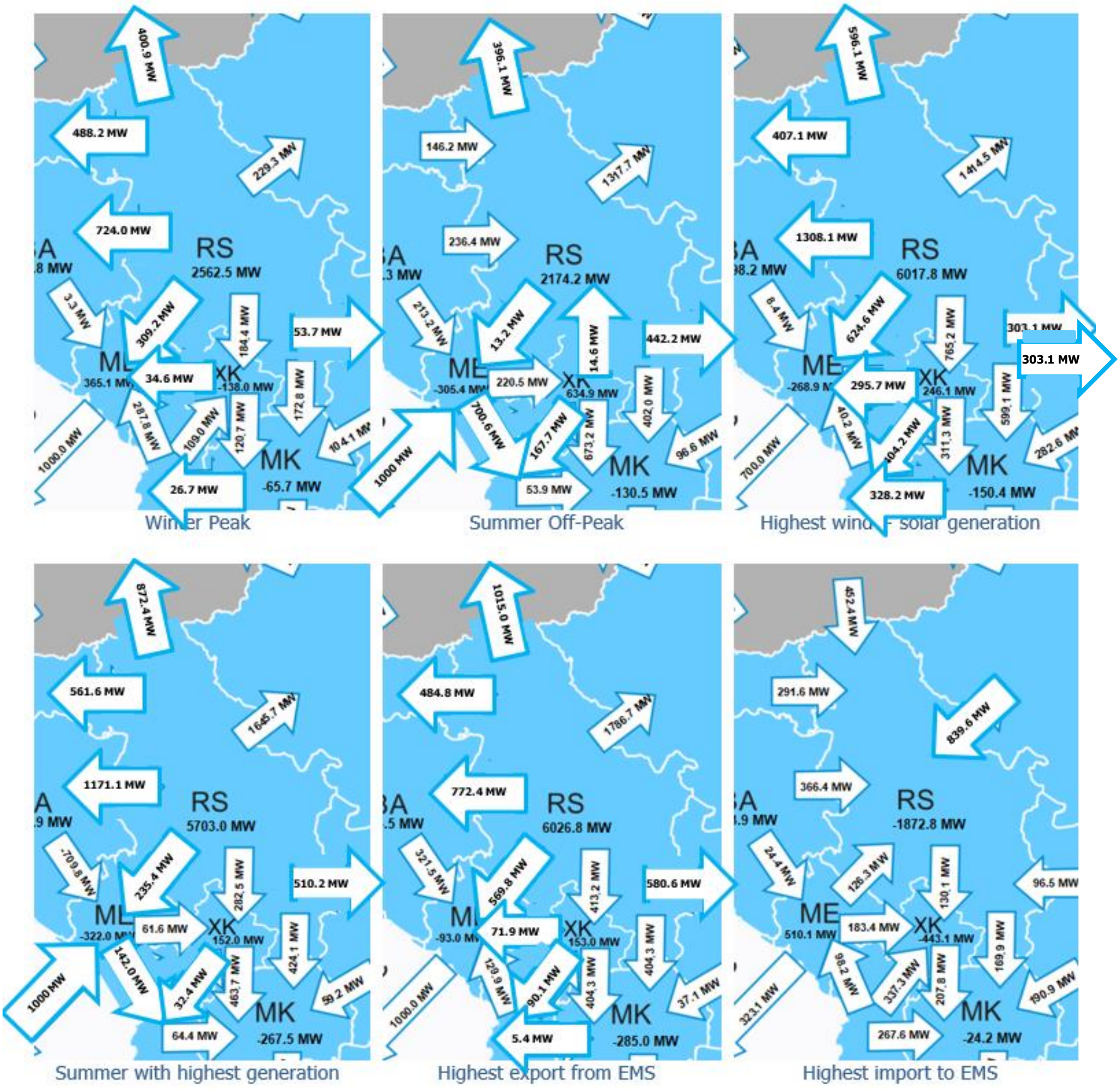


Figure 5.43: Cross-border exchanges (MW) and directions between the countries in year 2025 and High RES scenario

The following three figures show the 400 kV, 220 kV and 110 kV voltage profiles with maximum, minimum and average values in EMS transmission network for all six analysed regimes. The voltage profiles in the 400 kV network are within limits for all analysed regimes.

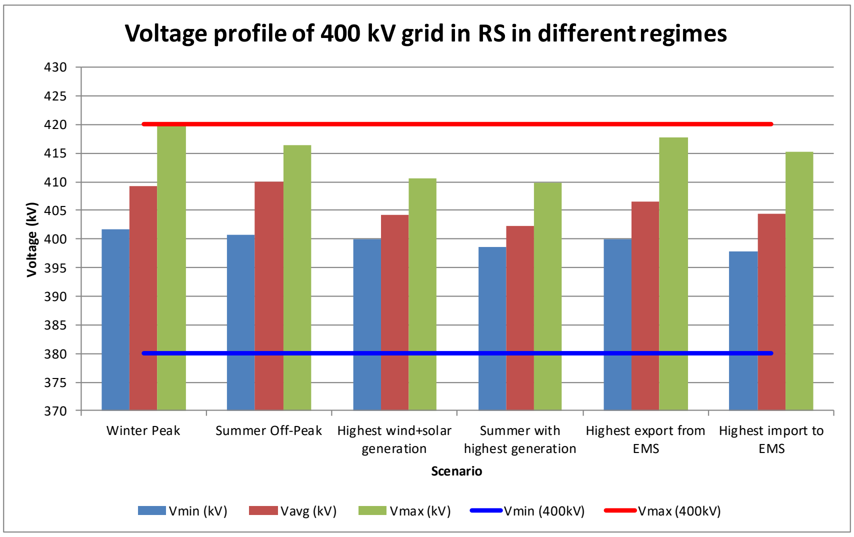


Figure 5.44: 400 kV voltage profiles (minimum, maximum and average) for 2030 analyzed regimes (high RES, referent CO2)

Voltage profiles in the 220 kV network are also within limits for all analysed regimes.

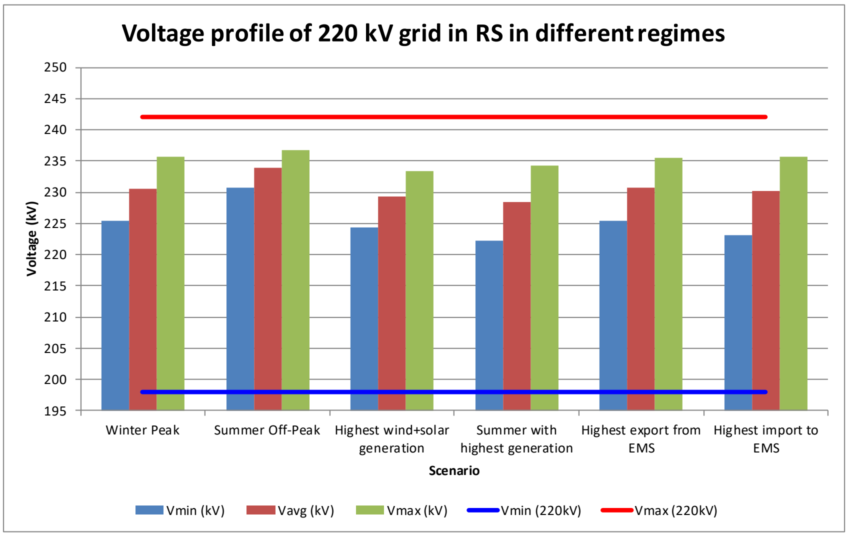


Figure 5.45: 220 kV voltage profiles (minimum, maximum and average) for 2030 analyzed regimes (high RES, referent CO2)

In case of 110 kV network, in some nodes voltages above acceptable limits are observed. These problems can be considered as local and can be controlled by fine tuning of the voltage profiles at higher network levels.

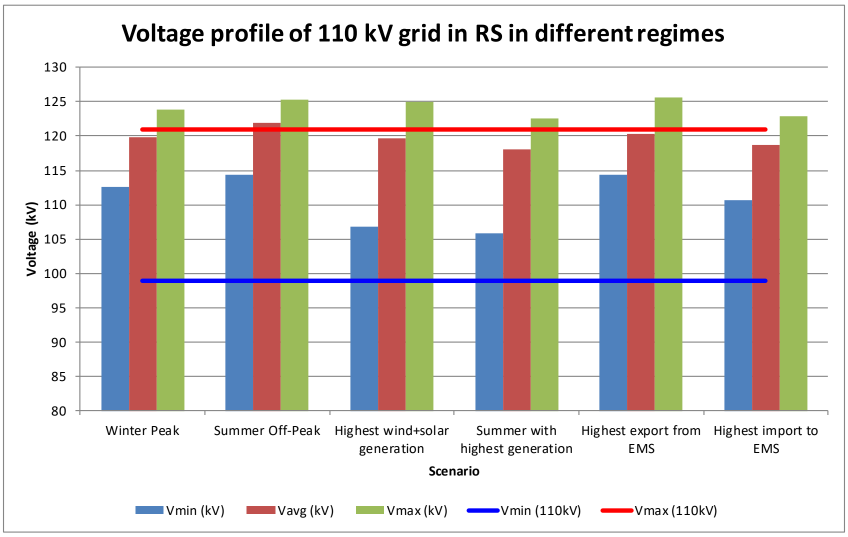


Figure 5.46: 110 kV voltage profiles (minimum, maximum and average) for 2030 analyzed regimes (high RES, referent CO2)

The 400 kV and 220 kV elements that are loaded more than 80% are as follows:

```
Winter Peak
/
Summer Off-Peak
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
 461000 JBBAST21     220.00    46 461135 JRHBBA21     220.00*   46  1    269.6   331.5    81.3

Operating regime with the highest wind+solar generation in EMS market area
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
 460040 JNIS2 11     400.00    46 460503 JWPPZ11      400.00*   46  1   1073.5  1330.2    80.7

Summer regime with the highest generation in EMS market area
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
 460035 JLESK211     400.00    46 460037 JLESK212     400.00*   46  1C    354.5   238.2   148.8

Operating regime with the highest export from EMS market area
/
Operating regime with the highest import to EMS market area
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
 460035 JLESK211     400.00    46 460037 JLESK212     400.00*   46  1C    241.0   238.2   101.2
```

Figure 5.47: List of 400 and 220 kV elements loaded more than 80% for 2030 analyzed regimes (high RES, referent CO2)

As it can be seen, no issues are expected in the 400 kV and 220 kV network even with export of 2604 MW towards West and North-West in summer regime with maximum generation in EMS area.

Concerning 110 kV network, all reinforcements already planned by EMS contribute to secure system operation and list of the lines with loading above 80% is significantly shorter than in the 2025 Scenarios.

The complete contingency n-1 analysis reports for 2030 high RES analyzed regimes are given in Appendix, while the edited shorten reports are presented below. These results do not compromise the above given considerations.

Compared with the previous results, there is one new overloading recorded in summer regime with highest generation. Part of the project "North CSE Corridor" is a second 400kV interconnection between SS Đerdap and SS Portile de Fier (RO), both tie-lines are in operation in 2030. In summer regime with the highest generation Serbia is exporting 5705MW, with 1646 MW towards Romania. This is an extreme regime, problem can be resolved with remedial actions i.e. re-dispatch of HPP Đerdap 1.

The 110 kV elements that are loaded more than 80% are as follows:

```
Winter Peak
/
Summer Off-Peak
/
Operating regime with the highest wind+solar generation in EMS market area
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
  46031 XNP_LE51    110.00*   99 462830 JNPAZ25     110.00    46  1     95.3   110.5    86.3
 462710 JLESNI5     110.00*   46 463100 JSABA352    110.00    46  1    132.9   110.5   120.3
 462825 JNPAZ151    110.00    46 462830 JNPAZ25     110.00*   46  1     99.3   110.5    89.8
 462915 JOSECI5     110.00*   46 463395 JVALJ352    110.00    46  2    106.5   110.5    96.4

Summer regime with the highest generation in EMS market area
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
  13531 XBI_LE51    110.00*   99 462710 JLESNI5     110.00    46  1     94.5   106.7    88.5
  13533 XZV_BI51    110.00*   99 462480 JHZVOR51    110.00    46  1     88.3   106.7    82.7
  46031 XNP_LE51    110.00*   99 462830 JNPAZ25     110.00    46  1     81.3    78.1   104.0
 462640 JKRUPA5     110.00*   46 462915 JOSECI5     110.00    46  1     66.5    78.1    85.1
 462710 JLESNI5     110.00*   46 463100 JSABA352    110.00    46  1    117.4    78.1   150.3
 462721 JRTINT51    110.00*   46 463390 JVALJ351    110.00    46  1     80.8    78.1   103.5
 462825 JNPAZ151    110.00    46 462830 JNPAZ25     110.00*   46  1     81.7    78.1   104.6
 462915 JOSECI5     110.00*   46 463395 JVALJ352    110.00    46  2    116.1    78.1   148.7

Operating regime with the highest export from EMS market area
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
  46031 XNP_LE51    110.00*   99 462830 JNPAZ25     110.00    46  1     93.2   110.5    84.3
 462825 JNPAZ151    110.00    46 462830 JNPAZ25     110.00*   46  1     97.6   110.5    88.4

Operating regime with the highest import to EMS market area
X--------- FROM BUS ----------X X---------- TO BUS -----------X
   BUS# X-- NAME --X BASKV  AREA   BUS# X-- NAME --X BASKV  AREA CKT LOADING  RATING PERCENT
  46031 XNP_LE51    110.00*   99 462830 JNPAZ25     110.00    46  1     88.1    78.1   112.8
 462745 JMAJD35     110.00    46 462748 JMAJD452    110.00*   46  1     65.6    78.1    84.0
 462745 JMAJD35     110.00*   46 463705 JNERES5     110.00    46  1     63.2    78.1    80.9
 462825 JNPAZ151    110.00    46 462830 JNPAZ25     110.00*   46  1     92.7    78.1   118.7
```

Figure 5.48: List of 110 kV elements loaded more than 80% for 2030 analysed regimes (high RES, referent CO2)

The edited contingency n-1 analysis reports for 2030 high RES analysed regimes are as follows:

```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW       %
 462900 JNSAD95     110.00 463355*JTTNSA51    110.00 1  SINGLE 462875-463355(1)            150.5     173.0     104.3


 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 462875-463355(1)         : OPEN LINE FROM BUS 462875 [JNSAD451    110.00] TO BUS 463355 [JTTNSA51    110.00] CKT 1
```

Figure 5.49: Contingency (n-1) analysis report for Winter Peak regime 2030 (high RES, referent CO2)

```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW       %
 460035*JLESK211    400.00 460037 JLESK212    400.00 1C BASE CASE                          238.2     355.0     145.0


 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)
```

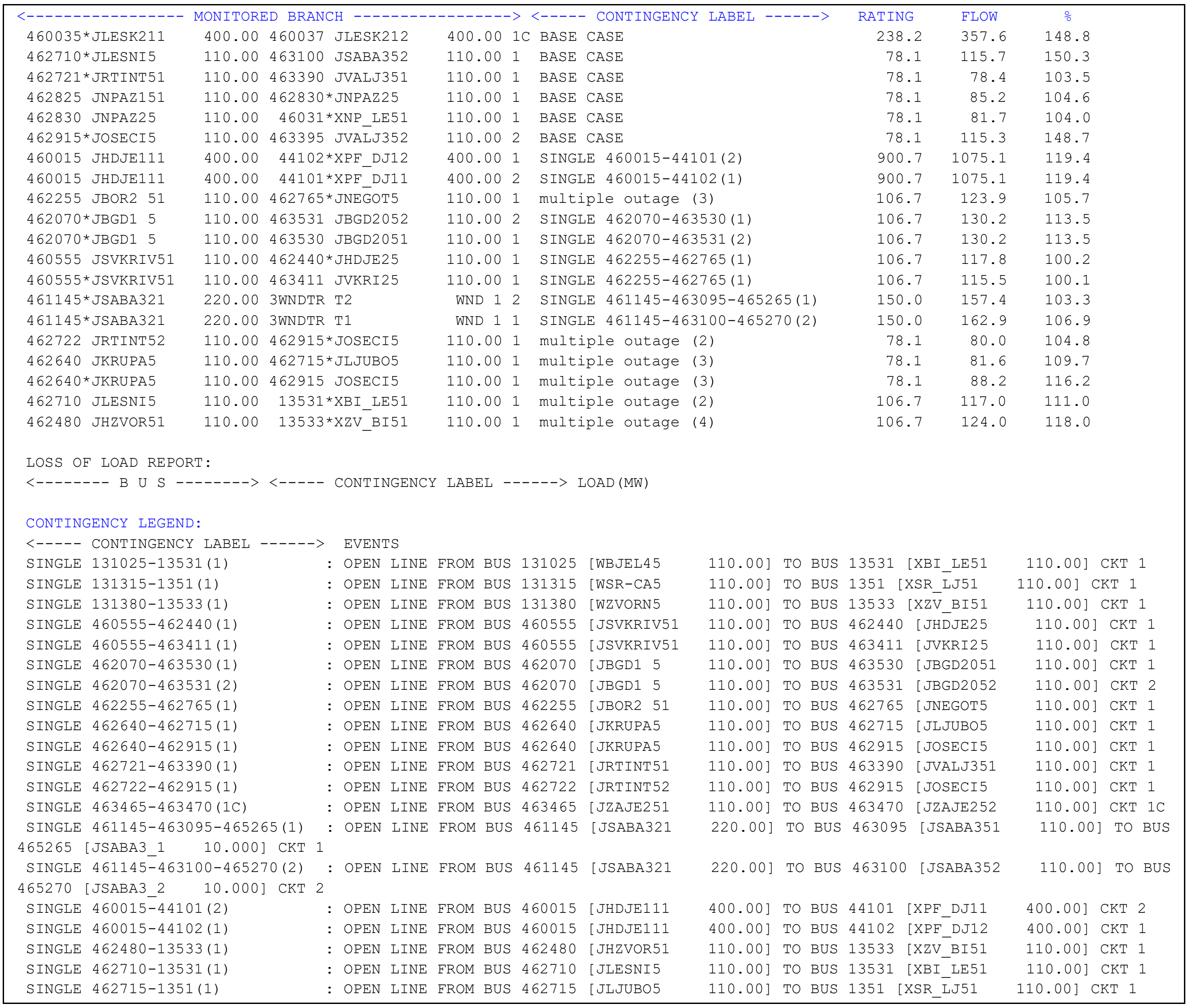
Figure 5.50: Contingency (n-1) analysis report for Summer Off-Peak regime 2030 (high RES, referent CO2)

```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW       %
 462710*JLESNI5     110.00 463100 JSABA352    110.00 1  BASE CASE                          110.5     130.1     120.3
 462915*JOSECI5     110.00 463395 JVALJ352    110.00 2  BASE CASE                          110.5     113.1     100.4
 462900 JNSAD95     110.00 463355*JTTNSA51    110.00 1  SINGLE 462875-463355(1)            150.5     171.1     103.3
 462825 JNPAZ151    110.00 462830*JNPAZ25     110.00 1  SINGLE 460045-46011(1)             110.5     128.9     110.0
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  SINGLE 460045-46011(1)             110.5     118.9     106.3
 462825 JNPAZ151    110.00 462830*JNPAZ25     110.00 1  SINGLE 471005-46011(1)             110.5     129.2     110.3
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  SINGLE 471005-46011(1)             110.5     119.1     106.6
 462480 JHZVOR51    110.00  13533*XZV_BI51    110.00 1  SINGLE 462640-462715(1)            150.5     150.6     102.6
 462480 JHZVOR51    110.00  13533*XZV_BI51    110.00 1  SINGLE 462640-462915(1)            150.5     151.2     103.0


 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

  CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 462875-463355(1)    : OPEN LINE FROM BUS 462875 [JNSAD451    110.00] TO BUS 463355 [JTTNSA51    110.00] CKT 1
 SINGLE 460045-46011(1)     : OPEN LINE FROM BUS 460045 [JNIS2 12    400.00] TO BUS 46011 [XKB_NI11    400.00] CKT 1
 SINGLE 462640-462715(1)    : OPEN LINE FROM BUS 462640 [JKRUPA5     110.00] TO BUS 462715 [JLJUBO5     110.00] CKT 1
 SINGLE 462640-462915(1)    : OPEN LINE FROM BUS 462640 [JKRUPA5     110.00] TO BUS 462915 [JOSECI5     110.00] CKT 1
 SINGLE 462710-13531(1)     : OPEN LINE FROM BUS 462710 [JLESNI5     110.00] TO BUS 13531 [XBI_LE51    110.00] CKT 1
 SINGLE 462715-1351(1)      : OPEN LINE FROM BUS 462715 [JLJUBO5     110.00] TO BUS 1351 [XSR_LJ51    110.00] CKT 1
```

Figure 5.51: Contingency (n-1) analysis report for Highest wind+solar generation regime 2030 (high RES, referent CO2)

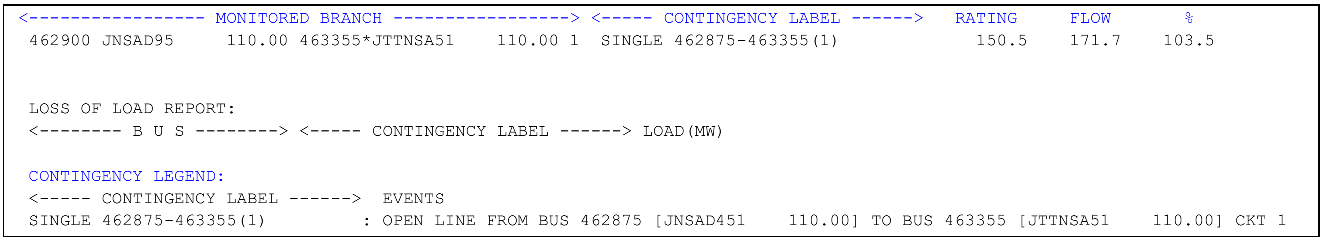


```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>  RATING    FLOW      %
 460035*JLESK211    400.00 460037 JLESK212    400.00 1C BASE CASE                       238.2    357.6    148.8
 462710*JLESNI5     110.00 463100 JSABA352    110.00 1  BASE CASE                        78.1    115.7    150.3
 462721*JRTINT51    110.00 463390 JVALJ351    110.00 1  BASE CASE                        78.1     78.4    103.5
 462825 JNPAZ151    110.00 462830*JNPAZ25     110.00 1  BASE CASE                        78.1     85.2    104.6
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  BASE CASE                        78.1     81.7    104.0
 462915*JOSECI5     110.00 463395 JVALJ352    110.00 2  BASE CASE                        78.1    115.3    148.7
 460015 JHDJE111    400.00  44102*XPF_DJ12    400.00 1  SINGLE 460015-44101(2)          900.7   1075.1    119.4
 460015 JHDJE111    400.00  44101*XPF_DJ11    400.00 2  SINGLE 460015-44102(1)          900.7   1075.1    119.4
 462255 JBOR2 51    110.00 462765*JNEGOT5     110.00 1  multiple outage (3)             106.7    123.9    105.7
 462070*JBGD1 5     110.00 463531 JBGD2052    110.00 2  SINGLE 462070-463530(1)         106.7    130.2    113.5
 462070*JBGD1 5     110.00 463530 JBGD2051    110.00 1  SINGLE 462070-463531(2)         106.7    130.2    113.5
 460555 JSVKRIV51   110.00 462440*JHDJE25     110.00 1  SINGLE 462255-462765(1)         106.7    117.8    100.2
 460555*JSVKRIV51   110.00 463411 JVKRI25     110.00 1  SINGLE 462255-462765(1)         106.7    115.5    100.1
 461145*JSABA321    220.00 3WNDTR T2           WND 1 2  SINGLE 461145-463095-465265(1)  150.0    157.4    103.3
 461145*JSABA321    220.00 3WNDTR T1           WND 1 1  SINGLE 461145-463100-465270(2)  150.0    162.9    106.9
 462722 JRTINT52    110.00 462915*JOSECI5     110.00 1  multiple outage (2)              78.1     80.0    104.8
 462640 JKRUPA5     110.00 462715*JLJUBO5     110.00 1  multiple outage (3)              78.1     81.6    109.7
 462640*JKRUPA5     110.00 462915 JOSECI5     110.00 1  multiple outage (3)              78.1     88.2    116.2
 462710 JLESNI5     110.00  13531*XBI_LE51    110.00 1  multiple outage (2)             106.7    117.0    111.0
 462480 JHZVOR51    110.00  13533*XZV_BI51    110.00 1  multiple outage (4)             106.7    124.0    118.0

 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 131025-13531(1)          : OPEN LINE FROM BUS 131025 [WBJEL45     110.00] TO BUS 13531 [XBI_LE51    110.00] CKT 1
 SINGLE 131315-1351(1)           : OPEN LINE FROM BUS 131315 [WSR-CA5     110.00] TO BUS 1351 [XSR_LJ51    110.00] CKT 1
 SINGLE 131380-13533(1)          : OPEN LINE FROM BUS 131380 [WZVORN5     110.00] TO BUS 13533 [XZV_BI51    110.00] CKT 1
 SINGLE 460555-462440(1)         : OPEN LINE FROM BUS 460555 [JSVKRIV51   110.00] TO BUS 462440 [JHDJE25     110.00] CKT 1
 SINGLE 460555-463411(1)         : OPEN LINE FROM BUS 460555 [JSVKRIV51   110.00] TO BUS 463411 [JVKRI25     110.00] CKT 1
 SINGLE 462070-463530(1)         : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463530 [JBGD2051    110.00] CKT 1
 SINGLE 462070-463531(2)         : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463531 [JBGD2052    110.00] CKT 2
 SINGLE 462255-462765(1)         : OPEN LINE FROM BUS 462255 [JBOR2 51    110.00] TO BUS 462765 [JNEGOT5     110.00] CKT 1
 SINGLE 462640-462715(1)         : OPEN LINE FROM BUS 462640 [JKRUPA5     110.00] TO BUS 462715 [JLJUBO5     110.00] CKT 1
 SINGLE 462640-462915(1)         : OPEN LINE FROM BUS 462640 [JKRUPA5     110.00] TO BUS 462915 [JOSECI5     110.00] CKT 1
 SINGLE 462721-463390(1)         : OPEN LINE FROM BUS 462721 [JRTINT51    110.00] TO BUS 463390 [JVALJ351    110.00] CKT 1
 SINGLE 462722-462915(1)         : OPEN LINE FROM BUS 462722 [JRTINT52    110.00] TO BUS 462915 [JOSECI5     110.00] CKT 1
 SINGLE 463465-463470(1C)        : OPEN LINE FROM BUS 463465 [JZAJE251    110.00] TO BUS 463470 [JZAJE252    110.00] CKT 1C
 SINGLE 461145-463095-465265(1)  : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463095 [JSABA351    110.00] TO BUS
465265 [JSABA3_1    10.000] CKT 1
 SINGLE 461145-463100-465270(2)  : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463100 [JSABA352    110.00] TO BUS
465270 [JSABA3_2    10.000] CKT 2
 SINGLE 460015-44101(2)          : OPEN LINE FROM BUS 460015 [JHDJE111    400.00] TO BUS 44101 [XPF_DJ11    400.00] CKT 2
 SINGLE 460015-44102(1)          : OPEN LINE FROM BUS 460015 [JHDJE111    400.00] TO BUS 44102 [XPF_DJ12    400.00] CKT 1
 SINGLE 462480-13533(1)          : OPEN LINE FROM BUS 462480 [JHZVOR51    110.00] TO BUS 13533 [XZV_BI51    110.00] CKT 1
 SINGLE 462710-13531(1)          : OPEN LINE FROM BUS 462710 [JLESNI5     110.00] TO BUS 13531 [XBI_LE51    110.00] CKT 1
 SINGLE 462715-1351(1)           : OPEN LINE FROM BUS 462715 [JLJUBO5     110.00] TO BUS 1351 [XSR_LJ51    110.00] CKT 1
```

Figure 5.52: Contingency (n-1) analysis report for Summer regime with the highest generation 2030 (high RES, referent CO2)



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<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>  RATING    FLOW      %
 462900 JNSAD95     110.00 463355*JTTNSA51    110.00 1  SINGLE 462875-463355(1)         150.5    171.7    103.5


 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 462875-463355(1)         : OPEN LINE FROM BUS 462875 [JNSAD451    110.00] TO BUS 463355 [JTTNSA51    110.00] CKT 1
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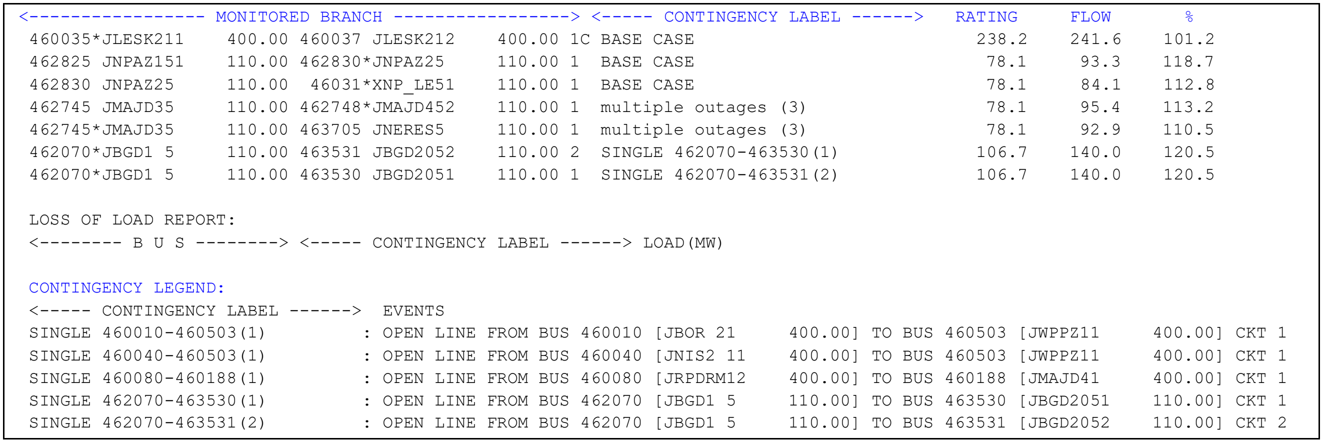
Figure 5.53: Contingency (n-1) analysis report for Highest export regime 2030 (referent RES, referent CO2)



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<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW       %
 460035*JLESK211    400.00 460037 JLESK212    400.00 1C BASE CASE                           238.2    241.6    101.2
 462825 JNPAZ151    110.00 462830*JNPAZ25     110.00 1  BASE CASE                            78.1     93.3    118.7
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  BASE CASE                            78.1     84.1    112.8
 462745 JMAJD35     110.00 462748*JMAJD452    110.00 1  multiple outages (3)                 78.1     95.4    113.2
 462745*JMAJD35     110.00 463705 JNERES5     110.00 1  multiple outages (3)                 78.1     92.9    110.5
 462070*JBGD1 5     110.00 463531 JBGD2052    110.00 2  SINGLE 462070-463530(1)             106.7    140.0    120.5
 462070*JBGD1 5     110.00 463530 JBGD2051    110.00 1  SINGLE 462070-463531(2)             106.7    140.0    120.5

 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 460010-460503(1)         : OPEN LINE FROM BUS 460010 [JBOR 21     400.00] TO BUS 460503 [JWPPZ11     400.00] CKT 1
 SINGLE 460040-460503(1)         : OPEN LINE FROM BUS 460040 [JNIS2 11    400.00] TO BUS 460503 [JWPPZ11     400.00] CKT 1
 SINGLE 460080-460188(1)         : OPEN LINE FROM BUS 460080 [JRPDRM12    400.00] TO BUS 460188 [JMAJD41     400.00] CKT 1
 SINGLE 462070-463530(1)         : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463530 [JBGD2051    110.00] CKT 1
 SINGLE 462070-463531(2)         : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463531 [JBGD2052    110.00] CKT 2
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Figure 5.54: Contingency (n-1) analysis report for Highest import regime 2030 (high RES, referent CO2)

5.4 Summary of the impacts of RES integration on transmission network

The input for the load flow and voltage profile calculations are the transmission network models for the existing network state and for the future perspective states (2025 and 2030) that were prepared and approved by EMS.

These models have been updated with respect to new RES projects and their connection at specific locations as presented in chapter 5.1.

It should be noted that all additional locations and points of connection proposed in this Report are unofficial, and should not be understood as the official opinion or solutions of EMS. We developed these proposals to analyze the high-level needs for network reinforcements and to assess the corresponding costs.

In addition, we incorporated the results of the market analysis of hourly generation dispatch, loads and balances into these network models. We conducted detailed network simulations for specific hours suggested by the market results that we believe are critical regimes for network security and reliability.

To effectively combine the network and market analysis, we extracted hourly load and dispatch data from the Plexos model, and convert it to PSS/E format, and then executed the precise network simulation using the detailed AC network model.

Based on results from the market analysis, we created regional models for six regimes:

- Winter Peak
- Summer Off-Peak
- Operating regime with the highest wind+solar generation in EMS market area

  - Summer regime with the highest generation in EMS market area
  - Operating regime with the highest export from EMS market area
  - Operating regime with the highest import to EMS market area

The focus of these analyses are on the regimes that could present a significant challenge for secure operation of the transmission network with possible overloading of the network elements.

With the aim to analyse more stressed situation for EMS transmission network, results from the market simulations carried out with referent CO2 tax (at rather low level of 23 and 27 EUR/t) have been selected. This is due to the fact that in this case high thermal generation and high export from EMS market area is expected which presents higher stress for the network.

The results of the transmission network operation analyses (load-flow calculations, voltage profile and contingency n-1 analyses) in the presence of high RES capacities, showed that network reinforcements that includes planned project "North CSE Corridor", „Pannonian Corridor" and reinforcements of the interconnections with Bosnia and Hercegovina and Montenegro (together with new 400 kV corridor to Bajina Basta), are necessary to provide secure system operation already for the referent level of RES capacities in 2025 (even for only 2700 MW of RES capacities).

Planned reinforcements provide sufficient support to network operation for all RES scenarios in both analysed years: 2025 and 2030 and integration of more than 8000 MW of RES capacity. . These projects are already included in the EMS's transmission network development plan for 2030 and they should have the highest priority with the aim to support efficient RES integration.

Investment costs (CAPEX) for additional main network reinforcements mentioned above are estimated on the level of 367 MEUR, based on [15, 16]:

- Project North CSE Corridor with SS Belgrade 50: 83.5 MEUR [15]
- 400 kV interconnections Bajina Basta – Visegrad and Bajina Basta – Pljevlja, with 400 kV reinforcement from SS Obrenovac: 143 MEUR [16]
- New 400 kV line Pozarevac – Jagodina: 37.8 MEUR
- Pannonian Corridor": 103 MEUR

Table 5.17: CAPEX – North CSE Corridor [15]

A	**Overhead Line**	**Number of OHL routes**	**OHL length (km)**	**Unit Price (€ / km)**	**Total Price (€)**
1	2x400kV OHL Belgrade 50 – SWY Čibuk 1	1	83	420,000	34,860,000
2	Lead-in of 400 kV OHL no. 450 into SS Belgrade 50	2	12	280,000	6,720,000
3	Lead-in of 2x110 kV OHL no.1178A/B into SS Belgrade 50	2	7	260,000	3,640,000
4	Lead-in of 2x110 kV OHL no.104/8 into SS Belgrade 50	2	12	260,000	6,240,000
5	Underground cable 110 kV SS Belgrade 50 - SS "Airport" (future)	2	8	700,000	11,200,000
6	400kV OHL Djerdap I – Portile de Fier	1	7	500,000	3,850,000
	Total Overhead Lines (€)				**66,510,000**
B	**Substation Belgrade 50**				
	Substation 400/110kV Belgrade 50 (€, round up)				**17,000,000**
	Total OHL + SS (€)				**83,510,000**

Table 5.18: CAPEX – 400 kV interconnections Bajina Basta – Visegrad and Bajina Basta – Pljevlja, with 400 kV reinforcement from SS Obrenovac [16]

	Overhead Line	**Number of OHL routes**	**OHL length (km)**	**Unit Price (€ / km)**	**Total Price (€)**
1	Section III 2 x 400 kV OHL from SS Obrenovac to SS Bajina Basta	1			89,680,000
2	Section IV 400 kV interconnections Bajina Basta – Visegrad and Bajina Basta – Pljevja	1			53,200,000
	Total Overhead Lines (€)				**142,880,000**

Table 5.19: CAPEX – 400 kV OHL Pozarevac – Jagodina [consultant’s estimation]

	Overhead Line	**Number of OHL routes**	**OHL length (km)**	**Unit Price (€ / km)**	**Total Price (€)**
1	1 x 400 kV OHL from Pozarevac to Jagodina	1	90	420,000	37,800,000
	Total Overhead Lines (€)				**37,800,000**

Table 5.20: CAPEX – Pannonian Corridor [EMS estimation]

	Overhead Line	**Number of OHL routes**	**OHL length (km)**	**Unit Price (€ / km)**	**Total Price (€)**
1	2 x 400 kV interconnection from Subotica 3 to Sandorfalva (HU)	2			19,800,000
2	2 x 400 kV OHL from Novi Sad 3 to Sombor 3	2			43,500,000
3	2 x 400 kV OHL from Belgrade 50 to Sremska Mitrovica 2	2			39,500,000
	Total Overhead Lines (€)				**102,800,000**

As additional support to RES integration, our recommendation is that implementation of the elements of the smart control of transmission network, like control of line temperature and Dynamic Line Rating (DLR) should become more widespread. There are already examples of implementation of these projects in EMS, but they should be more numerous.

This study does not cover the dynamic stability of the power system under high RES conditions, which is also crucial to determining the limits of RES integration to maintain the integrity of the power system and its stable operation within acceptable limits. For that purpose, it will be necessary in the near future to conduct a detailed study of the system’s dynamic stability with a large share of RES. EMS AD, PE EPS and Elektrodistribucija Srbije d.o.o. would all benefit from this analysis.

6 THE IMPACTS OF RES INTEGRATION ON THE CORE BUSINESS PROCESSES OF EMS

The main objective of this task is to analyze the impact of envisaged changes in the Serbian power sector, especially those which will stimulate increasing penetration of renewable energy sources (RES) and potentially impact the core business processes of the Serbian TSO.

This task has two major activities:

- Assess the current state of the regulatory and technical framework related to the integration of RES
- Provide recommendations and guidelines for eventual improvements of EMS business procedures to facilitate higher RES penetration, as well as to keep the required level of system security and stability

We assess the current state of the regulatory and technical framework related to the integration of RES in the next chapter, while we provide recommendations for further development and possible improvements in Chapter 6.2.

6.1 Current state assessment

Four major areas are highlighted in the assessment of the current state:

- Regulatory framework and RES support schemes
- Connection procedure and investments in necessary network reinforcement
- System operation
- Wholesale and Balancing market design

6.1.1 Regulatory framework and RES support schemes

During 2021, the Serbian Government adopted a new Energy Law and a Law on the use of renewable sources. In addition, after the adoption of these new laws, they launched work on a new Energy Development Strategy through 2050.

Regarding RES development, the new Energy Law specifies that the Government is allowed to prescribe the following important terms:

- The Government is allowed to prescribe the obligation of the electricity supplier to provide the minimum share of renewable energy in total electricity sold.

- The national goal for decarbonization in terms of greenhouse gas emissions reduction and required energy from RES sources[18]

The Law on the use of renewable sources prescribes the following terms relevant for RES development in Serbia:

- Financial support mechanisms to encourage RES deployment comprises the use of both a premium feed-in-tariff (market premium) and a feed-in-tariff (for smaller installations and pilot projects). These areas of support relate to the price of electricity generated by RES capacities, balancing responsibility, the right to have priority access to the system, and other incentives prescribed by other laws.
- RES producers, outside of the incentive system described in the previous bullet, will not be responsible for balancing, and will have priority access to the system, as applicable incentive mechanisms other than a premium feed-in tariff.
- The level of support or quota will be organized through a tendering procedure.

The feed-in-premium (market premium) represents a supplement to the wholesale market price for electricity provided by market premium users and sold on the electricity market. It is determined in eurocents per kWh throughout the auction procedure. It is paid monthly and could be related to the total installed capacity, or only a part of the total power plant capacity.

The methodology to determine the maximum feed-in premium tariff will be developed by the National Regulatory Agency, and the auction process must meet one or more of these conditions:

- the long-term potential of certain new and innovative technologies exists;
- the need for diversification of renewable sources of energy is fulfilled;
- network constraints and system stability are preserved; and
- the costs of integration into the system are acceptable.

Due to network constraints and system stability, auctions could be conducted for specific geographical areas for one or more types of renewable power plants.

The Serbian Government will determine the available quota based on the Energy Law and other valid planning documents, international obligations, available data on existing capacities, planned needs or other data relevant to quota setting.

The auction process will be conducted on a public procurement basis. Among other information, the public procurement invitation will contain available quotas per power plant type and allowed installed capacity, as well as the maximum market premium tariff, i.e., maximum purchase price.

Until decided otherwise, selected bidders shall sign a market premium agreement with the guaranteed supplier (currently Electric Power Utility of Serbia).

The incentive period lasts for 15 years from the day of the first payment of the market premium.

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[18] NECP is in preparation. It is expected to be finalized during summer 2022.

It should be emphasized that the guaranteed supplier is balance responsible for producers from renewable energy sources, whether they are in or out of the market premium system, until the establishment of a liquid organized intraday electricity market. However, if the realized production of electricity producers from renewable sources deviates more than the allowed percentage of imbalance in the settlement period, producers shall bear balancing costs by paying a fixed fee for each kWh of deviation of their realized production from the plan reported to the guaranteed supplier.

According to the Law, the Government shall regulate in more detail the allowed percentage of balance deviation, the determination method, and the fixed fee to the balance responsible party for balance deviation outside the allowed percentage of balance deviation. They will also regulate the model of balance responsibility contract, the rights and obligations of renewable electricity producers/balance responsible party, and the criteria for determining the liquidity of the intraday market.

Comparison between new Serbian Laws and EU good practice and legal framework related to RES integration shows that they are not fully harmonized, with the following differences:

[3] In the EU, with the adoption of the new CEP-Clean Energy Package in 2019, the implicit incentives of priority dispatch and balance responsibility for variable solar and wind RES connected to the transmission system no longer exist.

Article 5 of EU Regulation 2019/943 provides for this type of incentive exclusively for power plants smaller than 400 kW, but does not allow this type of incentive for power plants with installed power greater than 400 kW.

[4] The Law on the Use of RES in Serbia from 2021 in the part concerning additional implicit incentives for RES introduces these implicit incentives (priority dispatch, balance responsibility, etc.), contrary to the current EU rules and practice in this field.

Also, the Law on the Use of RES from 2021 in Article 11 introduces a priority dispatch for all renewable energy sources, which is in direct conflict with EU practice and with the EU legal and regulatory framework (Article 12 of EU regulations 2019 / 943) where again the mentioned incentive is allowed only for power plants smaller than 400 kW.

These implicit incentive measures, which were abandoned in Europe since 2019, can have affect the well functioning of the power system and the optimal inclusion of variable RES into the system.

Our analyses took into account current rules based on the Serbian legal framework, and also possible changes that will enable harmonization with the EU's practice and legal framework, and which can be beneficial for the TSO, customers and RES developers. Within these analyses, we have qualified and quantified the impacts of different changes in RES integration rules, and present technical and economic basis for decision makers to consider potential changes to the current rules and legal framework for RES integration. We present these results and recommendations in Chapter 6.2.

6.1.2 Connection procedure and investments in necessary network reinforcement

EMS has established and published on its website a transparent and non-discriminatory procedure for the connection of facilities to the transmission system and part of the distribution system managed by the transmission system operator. The existing procedure is currently updated in accordance with the terms and conditions in the new Energy Law.

The main challenge will be to update the procedure. According to the new Energy Law, the TSO may not deny the connection of facilities on the basis of potential network constraints such as congestion in remote parts of the transmission network, and may not deny the connection of facilities based on additional costs due to construction of the missing transmission infrastructure. What the TSO can do in the above-mentioned cases is to offer to the RES applicant a reduced maximum installed capacity or connection subject to operational restrictions (output curtailment), with approval of such restriction by the NRA.

The Energy Law prescribes that when an applicant for connection chooses a connection that is subject to operational restrictions, the transmission system operator is not obliged to pay compensation for the implemented restrictions.

Following up the Energy Law, a new regulation on the conditions of delivery and supply of electricity is in the final stage of adoption. This regulation prescribes the terms and conditions for issuing connection approval, and it is a prerequisite for updating the existing connection procedure.

The draft version of this regulation stipulates that the application process initiates with a connection study. EMS creates a connection study based on the Investor's request. The connection study with the determined connection method, approved by the Investor, enters into force by handing over the instrument of financial security to the TSO from the connection agreement in case of project non-realization. The validity period of the connection study and connection agreement is 3 years.

As prescribed in the recently adopted Energy Law, the draft version of the new regulation deals further with possibilities for connection subject to operational restrictions. The transmission system operator may define operational restrictions (i.e., limitation of the approved power plant output).

Notably, in the case of connection of RES power plants, the Law states that operational restrictions may be applied only if the expected power curtailment is less than 5% of their total annual production, and if this measure is more economically viable than the construction of the missing transmission infrastructure.

The TSO should determine operational restrictions in the process of preparing the Connection Study. It is envisaged that when the agreed method of connection between the RES plant and the TSO implies such restrictions, the TSO shall submit a request to the NRA for approval.

If the selected connection method implies the limitations identified in the Connection Study, the TSO shall provide the following in its request to the NRA:

1) a list of elements of the transmission and distribution system that may cause the need to implement restrictions;

2) the estimated amount of energy per year that is subject to operational restrictions and/or the amount of limited approved power for the selected connection method;

3) a list of elements whose unavailability leads to production restrictions resulting from the choice of the RES developer's (the Client's) connection method.

The estimated amount of energy subject to restriction may not include energy not delivered due to:

1) loss of elements owned by the Client;

2) failure of both circuits of the connecting double-circuit transmission line, if double-circuit transmission line is a Client's request;

3) unavailability of the transmission bay in the existing substation owned by the TSO, or in the existing substation owned by the DSO.

If the NRA does not approve the defined restrictions, the connection of the facility requires both the construction of the connection and the missing infrastructure.

6.1.3 System operation

Currently, the total installed capacity of large-scale RES in the Serbian power system is 374 MW (100% wind power plants) while the amount of distributed RES generation is still not significant. That is, the Serbian power system is in the early stage of RES development, with RES penetration no more than a few percent of annual energy demand. Therefore, currently, RES deployment has no significant impact on power system operation linked to additional investments and incentives in flexibility; structural surpluses of RES leading to curtailment; enhanced cooperation between TSO and DSO; advanced forecasting of RES; redispatching mechanism, etc.

In addition, EMS has recently deployed two innovative real-time system operation tools in the National Dispatching Center which they could use to facilitate the integration of high shares of RES into the power system:

- Wind power generation forecasting obtained currently from a single service provider
- Dynamic Line Rating, which aims to reduce congestion on power lines, optimize asset utilization and improve efficiency and reduce costs

Our network analyses included high levels of RES capacities, and took into account all currently applied improvements in system operation control.

6.1.4 Wholesale market

Figure 6.1 presents a timeline for Serbian electricity market development. Liberalization of the electricity market began in 2004 with the adoption of the Energy Law, which established new market participants with new roles, such as the TSO (transmission system operator – EMS), National regulator (AERS), State Electric power utility (EPS - producer, distribution, supply), and traders.

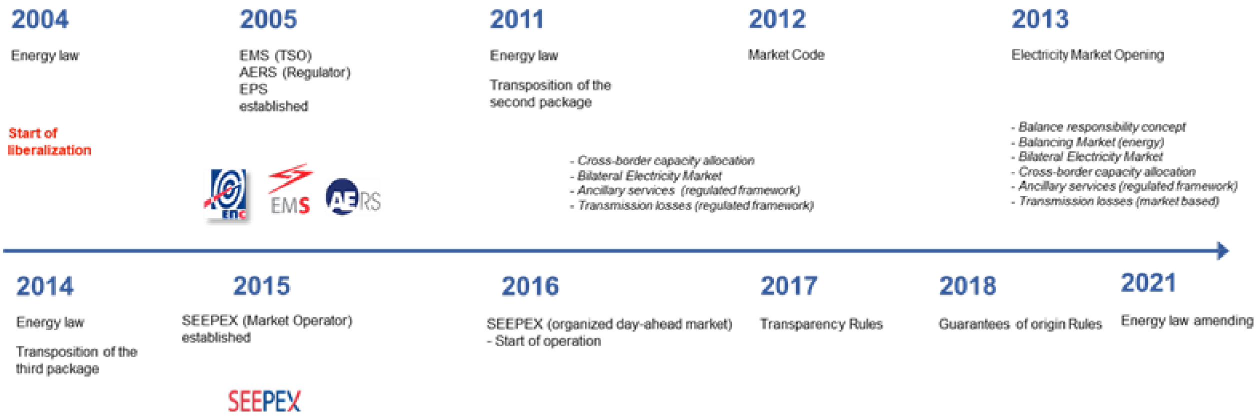

Figure 6.1: Timeline for the development of the electricity market in Serbia

Due to the position of Serbia as a natural transit hub, Serbia developed a bilateral market, primarily to provide for electricity transit through the Serbian power grid and trade with EPS. Amendments to the Energy law (2011) and the adoption of the Market and Grid Codes have created the conditions for further market opening. Balance responsibility concept, a balancing market, common cross-border allocation procedures were established. Final consumers, excluding households and small consumers, were obliged to procure electricity on the market.

Further market development was made possible by a new amendment to the Energy law in 2014. This established the power exchange, and opened a wholesale market for foreign traders, and these changes allowed the development of bilateral trade and a day-ahead market. Serbia has also implemented the option to obtain guarantees of origin for electricity produced from renewable sources. The last amendments to the Energy law, which took place at the beginning of 2021, aim to create a positive environment for significant RES investments, as well as for the potential market coupling of the Serbian day-ahead and intraday markets with neighboring markets.

Trading between market participants currently takes place across several different timescales ranging from futures/forward market to ex-post administration. Each of these timescales is typically associated with a different segment of the market.

Figure 6.2 presents a generic market timeline and the predominant trading activity likely to occur in each time period in Serbia. All these market segments have an impact on final consumers' participation in the free market. Trade begins a year in advance on the financial market (futures / forward) or through bilateral trade (annual, quarterly, monthly, weekly products), continues on the spot market (day-ahead and intraday) and the balancing market, and ends with the administration of balancing responsible parties (BRPs), after the real-time period (after a delivery period).

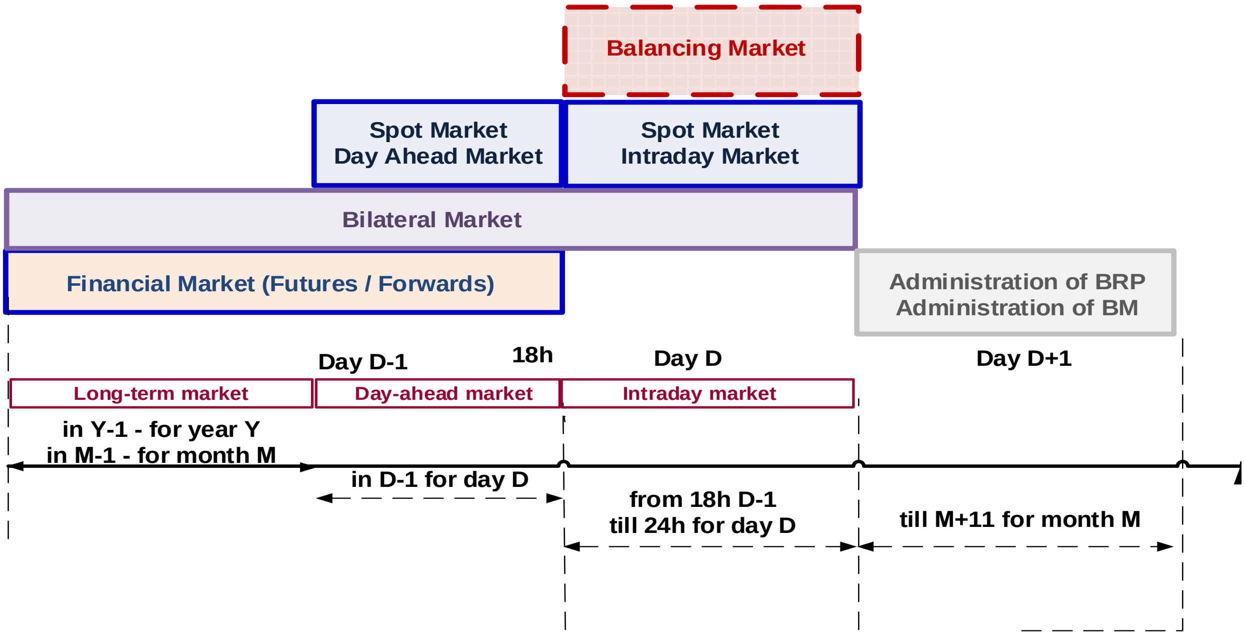

Figure 6.2: Generic timeline of market operations in Serbia

The overview of different segments of the Serbian wholesale market are given below:

- **Financial market (Forward/Futures) market**

  Forward trading is typically used by market participants to hedge themselves against the volatility of daily and hourly market prices. For this reason, suppliers/final consumers may use the forward market to cover their physical positions as required to satisfy their demand or, in the case of producers, for selling their available output. Forward trading may comprise a wide range of different products, ranging from forward contracts for physical delivery to futures contracts which are financially settled against a reference price. The European Energy Exchange (EEX) introduced Serbian power futures in partnership with SEEPEX on 03.06.2019.

- **Bilateral market**

  A bilateral market is a written agreement between two parties in which each party promises performance. In other words, one party agrees to provide electricity to the other party for payment. The general characteristics of these contracts include price, quantity, delivery period, and defining the two parties. At a set time before delivery (gate closure time), the participants nominate their net contract sales and purchases to the transmission system operator. The risk of this way of trading is the guarantee for the delivery of electricity and the price in the future.

- **Spot market/Power exchange**

  Whereas in a forward/futures market delivery will take place at a future date, a spot market is defined as a market where electricity is sold and bought for near-term delivery in an organized way. The term spot market is used to refer to the organized day-ahead and intraday market with a physical product. The spot market is used to cover all trading taking place between the day-ahead and real-time. SEEPEX is a power exchange in Serbia responsible to organize day-ahead and intraday markets.

Day-ahead market: a day-ahead market, as its name implies, operates one day in advance of actual delivery. By this time, participants typically have sufficient information on e.g. demand forecasts, whilst especially thermal producers already need to decide on their production schedules as they may not be able to start or stop their plants at short notice. Consequently, trading in the day-ahead market tends to be most liquid when measured in terms of the number of transactions.

The annual volume of electricity traded on the day-ahead market via SEEPEX is at a level of 2.8 TWh (2020), and it has recorded constant growth in the last few years since the market opening (2016). However, this still represents less than 10% of electricity consumption in Serbia, and SEEPEX remains less liquid compared to the neighboring EU day-ahead power markets (Hungary, Romania, Slovenia, Croatia). For example, the annual volume of electricity traded on the Hungarian day-ahead market HUPX was at a level of 25.2 TWh in 2020, i.e., nine times greater than SEEPEX. A notable boost of liquidity can be expected if SEEPEX joins the pan-European market coupling.

Intraday market: intra-day trading can be seen as an extension of the day-ahead phase where market participants can adjust their contractual position to manage their overall demand and supply balance. This would reduce their risks of being out of balance and being obliged to pay imbalance settlement prices. Intra-day trading in Serbia is performed in a bilateral market, hence there is no organized market for this segment yet.

The plan is to introduce intra-day sessions on SEEPEX in the near future. It should be also noted that based on the experience of more mature EU markets, without participation in pan-European intraday market coupling, and with a low incentive for RES to balance its forecast error between day-ahead and intraday, there is a significant chance that such market would face significant liquidity problems.

Possible market improvements would come with the implementation of balancing responsibility for RES owners. This would significantly boost intraday market liquidity, since RES owners would need to be more proactive in selling or buying the surplus or deficit created by inaccurate day-ahead forecasts on an intraday market, in order to avoid their exposure to imbalance settlement pricing from the balancing energy market.

6.1.5 Balancing market

The Serbian balancing market is regulated primarily with the Market and Grid Codes, Energy Law and the Law on the use of renewable sources. These regulations stipulate the roles of TSO, balancing system providers (BSPs) and BRPs, as well as the procurement of balancing capacity, balancing energy and imbalance settlement.

The main role of EMS in the electricity balancing market is to procure balancing services from BSPs in order to ensure operational security. The new energy laws allow EMS to procure energy on regional and pan-European balancing markets.

According to the same Law, all producers (including RES) are obliged to offer EMS all unused capacity for balancing purposes. Though there is no explicit prequalification process for becoming a BSP, the Grid Code defines the technical characteristics for providing aFRR and mFRR, but only for HPP and TPP units.

According to the Market Code, BRPs must strive to be balanced and take financial responsibility for their scheduled and real-time imbalances. Each market participant should be responsible for their imbalances, or they can transfer their balancing responsibility to other BRPs. By default, consumers with full supply contracts transfer their balance responsibility to their suppliers.

The new Energy Law excludes RES from balancing responsibility and envisages that a guaranteed supplier will be responsible for RES imbalances until the establishment of a liquid intraday market. The NRA (AERS) will be responsible for assessing intraday market liquidity. The same Law also stipulates that RES producers will be financially responsible for imbalances higher than a certain acceptable level and that they will be charged with a fixed price.

According to current information from involved experts, the draft by-law will prescribe quite a high percentage of allowed (non-payable) imbalances for RES. A high percentage will not stimulate RES generators to be as balanced as possible, so this percentage should be determined with caution.

Balancing capacity procurement

Currently, the EMS Grid Code stipulates the following required capacity:

- 160 MW band for aFRR
- 300 MW for upward mFRR
- 150 MW for downward mFRR

This level of the reserve includes common dimensioning inside the SMM block.

This required reserve is procured annually in a bilateral agreement between EMS and the dominant power producer (EPS). Reserve prices are regulated by AERS, and for 2021 are as follows:

- aFRR: 13 €/MW
- Upward mFRR: 4.1 €/MW
- Downward mFRR reserve: Free of charge

While the standard product is not defined, reserve capacity is procured on an hourly basis and costs for the provision of these reserves are passed through to end consumers.

Sharing and/or exchange of the balancing reserve with other TSOs is currently not implemented.

Balancing energy procurement

The procurement of balancing energy is a market-based process conducted by EMS. EMS is buying/selling balancing energy from/to the dominant participants (EPS) and the neighboring TSOs (e.g NOSBiH and CGES). Procurement of energy from EPS is based on explicit bids and merit order lists, while procurement from the neighboring TSOs is based on bilateral contracts.

Considering the pan-European platform for balancing cooperation, the most interesting currently for EMS is the Imbalance Netting Platform (IGCC), and EMS is a non-operational member with a plan to go-live in 2022. In addition, EMS currently has the status of observer in the Manually Activated Reserves Initiative (MARI), a project related to cooperation in the provision of mFRR. Activities related to the other two projects (PICASSO-related to aFRR and TERRE-related to replacement reserve) are still postponed.

Some of the characteristics of the balancing energy procurement process are as follows:

- Gate closure time for the acceptance of explicit bids is 60 minutes
- The price in the explicit bid needs to be between 0,1 EUR/MWh and 500 EUR/MWh
- The price difference in the explicit bid, between upward and downward activation of the first 100 MWh has to be less than 30 EUR/MWh.
- Pricing in the case of explicit offers is pay-as-bid
- Price in the case of procurement from neighboring TSOs is either defined in the contract or it is double the SEEPEX day-ahead (DA) price
- The price of energy from activated aFRR is based on explicit bids, but it depends also on the activation of mFRR
- The calculated amount of activated energy upward and downward are netted per product

Imbalance settlement

The imbalance for each BRP and each settlement period (one hour) is based on:

- Actual position
- Scheduled position
- Activated balancing energy

EMS is implementing single imbalance pricing. The calculated imbalance price is equal to the weighted average price of all activated balancing energy bids, and has the following limitations:

- The imbalance price cannot be negative
- It can be a maximum of 1.5 times higher than the maximum price of all activated bids

Some of the distinctive features of the EMS imbalance settlement process are:

- Imbalances that are above so-called acceptable levels are penalized (0.5 or 1.3 penalization factor, for long or short position respectively.
- BRPs that have unbalanced schedules are also penalized (2 or 4 times average annual price of balancing energy, for long and short positions respectively).

6.1.6 Transmission tariff

Different cost items related to energy transmission provide the basis to determine transmission tariffs. Transmission tariffs are calculated by the TSO and approved by the NRA.

Similar to ENTSO-E members, the transmission tariff in Serbia has three components:

- Costs related to infrastructure

- Cost related to system services
- Cost related to losses

AERS' (Serbian NRA) annual report [14] provided information about transmission tariffs in Serbia (and other countries) in 2020 (Figure 6.3), and the values for Serbia are:

- 1.8 EUR/MWh for infrastructure
- 0.9 EUR/MWh for system services
- 1.5 EUR/MWh for losses

With these transmission tariffs (and consumption of 34.5 TWh), the regulated revenue for EMS in 2020 was around 145 MEUR.

Costs related to infrastructure mainly include costs for system operation and maintenance, as well as part of the financial obligation related to new investments and loan payments.

Based on results of the transmission network operation analyses with high RES capacities (chapter 5.5), network reinforcements are necessary to strengthen the network around Belgrade and Pancevo and interconnections to BA and ME as well as Pannonian corridor, just to provide secure system operation already for the referent level of RES capacities in 2025 (2700 MW). These reinforcements will provide sufficient support to network operation for all RES scenarios in both analyzed years (2025 and 2030), and they are already included in the EMS's transmission network development plan for 2030. Investment costs (CAPEX) for additional main network reinforcements are estimated at 367 MEUR. With an annuity factor of 7% and O&M costs estimated as 1% of CAPEX, the annuity of the additional infrastructure costs are estimated as 29 MEUR or a need to increase the tariff by 0.82 EUR/MWh. In comparison to the total tariff from 2020 (4.2 EUR/MWh), this represents an increase of almost 20%.

Of course the additional network reinforcement and costs are not purely due to additional RES integration, but also required to renew the network (e.g., replacing the old 220 kV network with new 400 kV lines) and to strengthen interconnections with neighboring countries to support higher exports (interconnection with BA and ME).

Balancing reserve procurement costs are also included in tariffs, in the costs related to system services. In addition, system services include costs related to the provision of voltage control and black start services, but around 90% are for balancing reserve procurement costs.

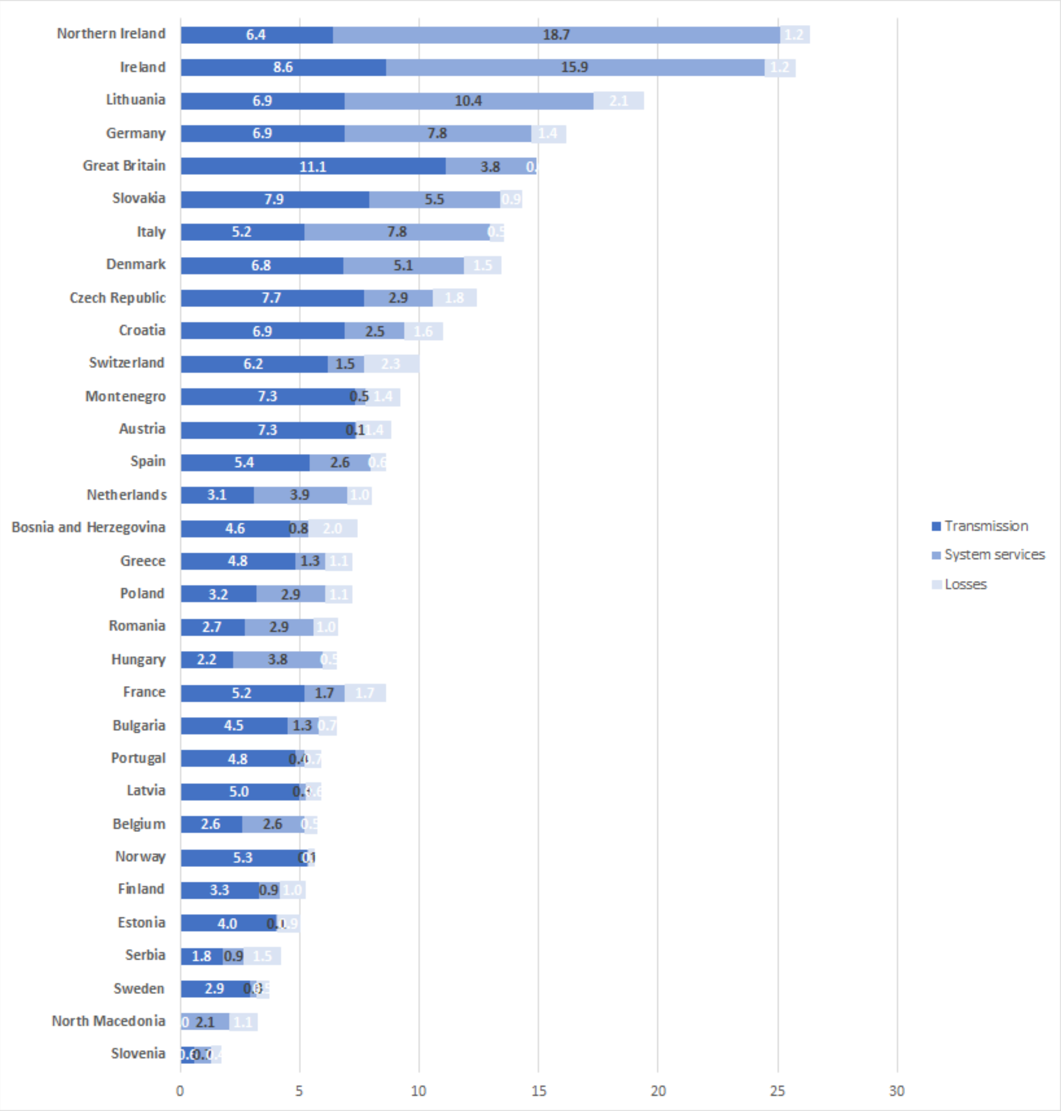

Figure 6.3: Transmission tariff structure in 2020 (EUR/MWh), source ENTSO-E

When costs for balancing reserve procurement (see Figure 4.16 in chapter 4.1.4) are translated into transmission tariffs (for different assumptions related to price of mFRR downward), we can determine the part of the transmission tariff related to system services for different levels of RES, as shown in Figure 6.4.

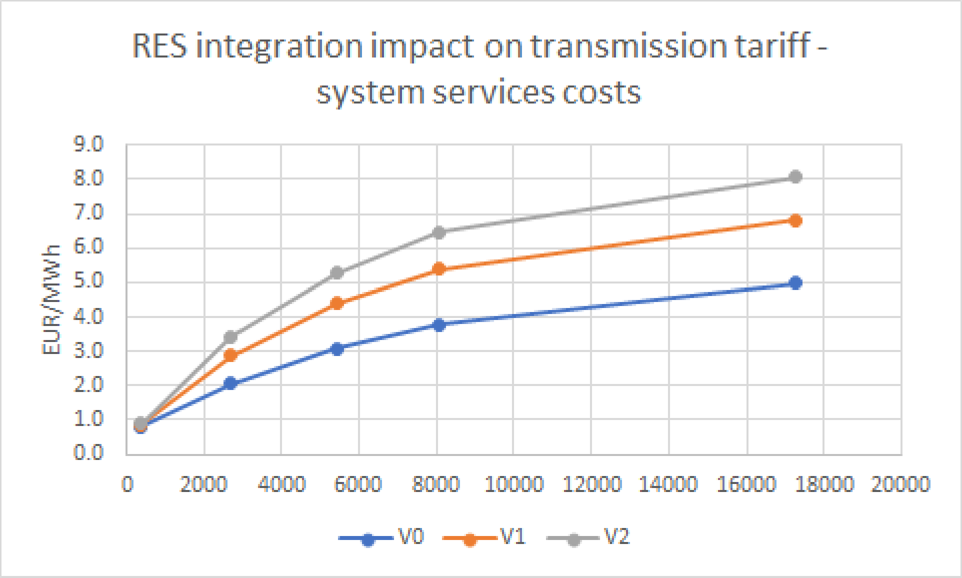

Figure 6.4: RES integration impact on transmission tariff - system services costs[19]

Based on figure above it can be seen that increase to 17,000 MW of RES capacities would increase system service costs more than five times in comparison to today (from 0.9 EUR/MWh to 5 EUR/MWh) or even more, if the price for mFRR downward does not stay at zero as it is today.

In comparison to the total tariff from 2020 (4.2 EUR/MWh), the increase of 2 EUR/MWh for 2700 MW of RES capacity in V1 case[19], represents an increase of almost 50%, which is notably higher than for infrastructure costs (11%). This shows that transmission tariffs are impacted by high levels of RES capacities mainly due to system services and balancing. Having this in mind, all recommendations that would lead to savings in system costs should have high priority to keep transmission tariffs as low as possible.

Concerning the part of tariffs related to losses, impact of RES integration is neglected having in mind different factors that have more evident and stronger impact on losses or corresponding costs then different levels of RES capacity (network reinforcements, wholesale market prices, efficiency of the procurement of the energy that covers the losses…).

Figure 6.5 summarizes the impact of different levels of RES integration on transmission tariffs. The impacts related to system costs are obvious.

Such costs for RES integration are common in North America and Western Europe, and are an issue that all countries in SEE will face as RES becomes a larger share of regional electricity supply. To lower these costs, best allocate risk, and accelerate RES development in Serbia, this report makes numerous recommendations, tailored to Serbia, taking into account best practices worldwide.

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[19] V0 – mFRRdownward price is zero
V1 – mFRRdownward prices is equal to price of mFRRupward **- Referent**
V2 – mFRRdownaward price is based on average price in the region

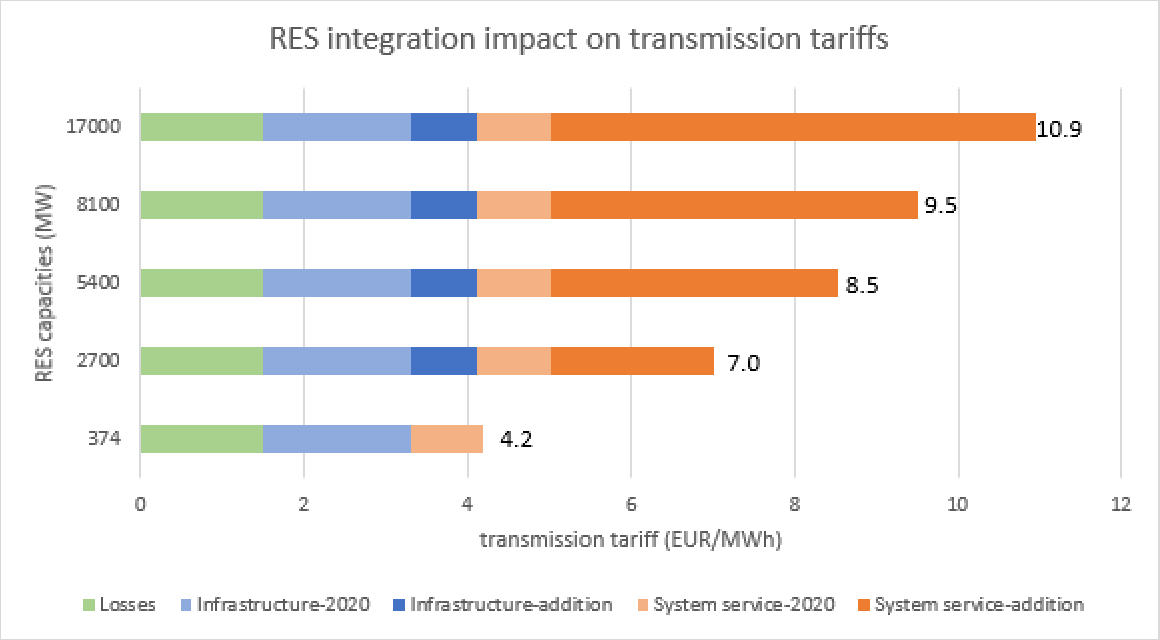


Figure 6.5: RES integration impact on transmission tariff - system services costs -V1 case

6.1.7 Summary

Based on our review of the current regulatory documents and technical regulations, we have recognized certain critical elements related to RES integration. The summary of the critical elements include the following:

25. Serbia introduced major changes to its support scheme with respect to the market integration of RES by introducing the Feed-in Premium. The previous RES support scheme, Feed-in Tariff, was quite attractive from a commercial perspective, but there was a technical limit not to install more than 500 MW due to system balancing issues.
26. Determination of the future level of support or quota will be organized through a tendering procedure. The auctions could be conducted for specific geographical areas or on the country level, and for one or more types of renewable power plants.
27. The available quota is determined by the Serbian Government based on the Energy Law and other valid planning documents, international obligations, available data on existing capacities, planned needs or other data relevant to setting this quota.
28. RES producers are exempt from balancing responsibilities until the establishment of a liquid organized intraday electricity market, as long as they deviate less than the allowed percentage of imbalance in the settlement period. The allowed percentage of imbalance will be determined by the Government.
29. Until the establishment of a liquid organized intraday electricity market, the Guaranteed Supplier (Electric Power Utility of Serbia) is responsible for RES imbalances.

30. RES producers are treated equal to other power plants regarding priority of connection i.e., connections are realized in the order of connection applications.
31. Serbia currently applies the same connection charges for conventional and RES generating plants, i.e., there is no financial support related to grid connection.
32. Regarding the access of RES electricity to the grid, a priority dispatch is applied for all RES power plants. Therefore, a maximum amount of RES electricity is used in the system and power from RES producers will only be curtailed as the last option in case of bottlenecks.
33. RES investors pay only for transmission infrastructure necessary for connection in accordance with the shallow connection charge scheme.
34. In the case of grid congestion due to the connection of a new applicant, the TSO can offer to the applicant a reduced maximum installed capacity or connection subject to operational restrictions (output curtailment up to 5% of total annual production), if such restriction is approved by the NRA.
35. A strategic energy development plan for Serbia to 2050 is currently underway in accordance with the new Energy Law, along with a corresponding national action plan to use RES.
36. Current (2020) RES deployment has no significant impact on power system operation.
37. Two innovative real-time system operation tools were recently deployed:
    a. Wind power generation forecasting obtained currently from a single service provider
    b. Dynamic Line Rating, which aims to reduce congestion on power lines, optimize asset utilization and improve efficiency and reduce costs
38. Wholesale market trades in Serbia are mainly conducted through bilateral trading.
39. Organized day-ahead trading is enabled on the power exchange, SEEPEX.
40. Power futures trading enabled on the EEX.
41. There is no organized intraday market, but this is planned for the near future.
42. There is no participation yet in European market coupling processes (day-ahead, intraday).
43. Prices for balancing services are regulated by the NRA. There is no remuneration for FCR and mFRR downward reserve.
44. There is one dominant incumbent balancing services provider (the state-owned power utility)
45. There is a balancing mechanism, with a number of regulated elements, and no balancing market competition is yet in place.
46. The greatest impact of RES integration in the transmission tariffs is related to system costs, so all recommendations that would lead to savings in system costs should have high priority.
47. There are bilateral contracts for balancing energy exchange with neighboring TSOs (CGES and NOSBiH).
48. EMS is still not an operational member of the pan-European balancing processes and platforms (IGCC, PICASSO, MARI, TERRE), although EMS' accession to the IGCC process is expected in 2022.

We focused further activities in this project on developing proposals to improve EMS' RES integration procedures, with parallel support to secure system operation, as summarized in the next chapter.

6.2 Recommendations for improvements in the process of RES integration

There are two key areas that can have a positive impact on RES integration, while assuring safe and reliable power system operation:

- Improvements with respect to the general RES integration process and connection procedure
- Improvements in market design and system operation control

While these areas involve different Serbian power sector participants (e.g., the Ministry, Regulator, Production Companies), our recommendations focus on EMS and processes under its control.

6.2.1 Improvements with respect to general RES integration process and connection procedure

The long-term process of RES integration in Serbia shall be governed by national energy development strategies and the 10-year national energy and climate plans (NECPs). To better develop and implement these plans, EMS, as a transmission system operator, should provide its opinion on the technical feasibility of various RES scenarios, and the required balancing services and transmission infrastructure.

To avoid transmission network congestion and preserve system security and stability, we strongly recommend auctions for specific geographical areas, determined by EMS, for specific types of renewable power plants.

On a shorter term time horizon (3-5 years), EMS should be involved more actively in determining the appropriate level of RES integration considering its obligation to preserve power system security and stability. The main focus of EMS' involvement would be to determine required balancing reserves based on historic system imbalance data and the potential for regional cooperation, as well as short-term management of eventual network congestions.

Growing volumes of RES generation with variable power outputs will increase system balancing requirements and decrease the short-term availability of conventional balancing service providers, thus affecting efficient RES integration in Serbia. AERS and other relevant institutions should carefully consider how to develop and put in place regulatory mechanisms to achieve the goals of such integration as efficiently and economically as possible.

In that sense, new electricity directives and regulations clearly state that all market participants should be financially responsible for the imbalances they cause in the system, representing the difference between the allocated volume and the final position in the market. On the other hand, they also require the efficient functioning of the intraday and balancing markets to enable market participants to balance themselves as closely as possible to real time.

Considering current rules of Serbian Energy Law and Law on the use of renewable sources as well as the maturity of relevant market aspects in Serbia, we provide the following recommendations to manage the transition period until the intraday and balancing markets are functioning well:

- Bigger market agents should be established to facilitate the aggregation of RES units to enable economies of scale
- The balancing responsibility for variable RES units, and the relationship between RES market agents and the guaranteed supplier, should be regulated based on the Law on renewable sources, Article 10, Para. 11, and include these major elements:
    - Rules for paying penalties or receiving revenues for the generated imbalances
    - Definition of a percentage of deviations for which the imbalances are not penalized through so-called "tolerance bands" for different types of RES units
    - Imbalance pricing scheme
    - Technical requirements for forecasting activities
    - The economically-viable share of incurred balancing costs of RES integration in total system costs

Chapter 6.2.2 provides details on the impacts of RES integration on intraday and balancing markets.

Beside monitoring the changes in balancing costs with more RES, the NRA should also monitor and supervise network infrastructure development costs. In general, we recommend a new regulation that deals with options for the TSO to reduce network infrastructure costs or defer necessary infrastructure investments by introducing improved N-1 contingency risk management, up to the level that it will not deteriorate overall system security and stability. In parallel, the NRA should establish a congestion management ancillary service market.

Considering the strong complementarity between the phases of RES grid connection and grid development, it is challenging to resolve how to share costs for large grid reinforcement or long waiting times linked to the building of new lines. Better coordination between grid upgrades and improvements in Serbia, and RES development would consider the following aspects:

- Regular collection of data on RES development from public national registries, and the collection of reliable data on RES development targets
- Harmonization of the grid code and connection procedures, to reduce long lead times and to simplify complex procedures
- Development of regulatory guideline on the national level for the development of the power system, to better align the pace of grid and RES-E development. This guideline should allow for better queue management and avoid "virtual saturation" of the grid in case when EMS receive a large number of grid connection applications within a limited time frame before construction has begun. This guideline should address the following possible solutions:
    - Deposit requirements for connection rights
    - Inserting obligatory milestones into the application-realization process to maintain the pace of connections and prevent the blocking of connection points
    - Harmonizing time-duration of required construction licenses and energy permits during project development, with obligatory milestones for RES connection applicants

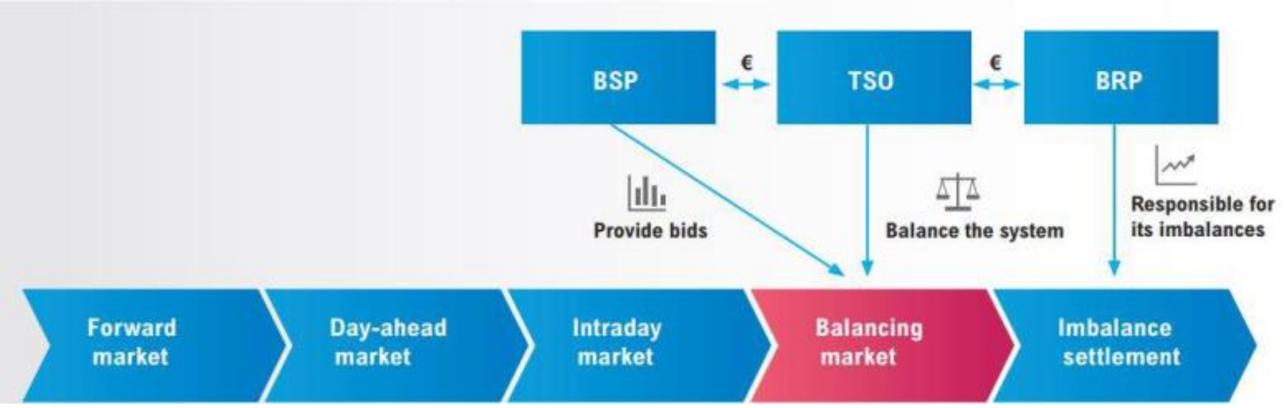
In North America, such procedures have led to much shorter RES development timeframes.

- Introducing a hybrid system, i.e., a system in which the Investor would pay for the connection and for part of the reinforcement works in case of a lack of grid capacity, respecting at the same time rules of non-discriminatory and transparent access.

6.2.2 Improvements in market design and system operation control

6.2.2.1 Balancing Responsibility for RES generation

'Balance Responsible Party' (BRP) means a market participant or its chosen representative responsible for its imbalances in the electricity market.



Current Serbian legislation does not recognize RES generators as the ones that should bear (financial) responsibility for their imbalances.

However, the latest European Electricity Regulation (14/06/2019 - Regulation (EU) 2019/943) adopted under the Clean Energy Packages, recognizes the importance of proper market set up, which assumes that almost all market participants are BRPs. In principle, all market participants must be responsible for the imbalances they cause in the system. For renewable energy producers active on the market, this means that they need to bear the risk of incorrect predictions for production, e.g., due to incorrect wind, weather-dependent energy generation forecasts. This creates incentives to improve forecasts or pay for better forecast services.

The European Electricity Regulation 2019/943 Article 5. defines that:

Article 5

Balance responsibility

1. All market participants shall be responsible for the imbalances they cause in the system ('balance responsibility'). To that end, market participants shall either be balance responsible parties or shall contractually delegate their responsibility to a balance responsible party of their choice. Each balance responsible party shall be financially responsible for its imbalances and shall strive to be balanced or shall help the electricity system to be balanced.

2. Member States may provide derogations from balance responsibility only for:

(a) demonstration projects for innovative technologies, subject to approval by the regulatory authority, provided that those derogations are limited to the time and extent necessary for achieving the demonstration purposes;

(b) power-generating facilities using renewable energy sources with an installed electricity capacity of less than 400 kW;

(c) installations benefitting from support approved by the Commission under Union State aid rules pursuant to Articles 107, 108 and 109 TFEU, and commissioned before 4 July 2019.

Member States may, without prejudice to Articles 107 and 108 TFEU, provide incentives to market participants which are fully or partly exempted from balancing responsibility to accept full balancing responsibility.

3. When a Member State provides a derogation in accordance with paragraph 2, it shall ensure that the financial responsibility for imbalances is fulfilled by another market participant.

4. For power-generating facilities commissioned from 1 January 2026, point (b) of paragraph 2 shall apply only to generating installations using renewable energy sources with an installed electricity capacity of less than 200 kW.

Hence, there is some room for derogation, this is only for demonstration project or RES plants under 0.4 MW until 2026, and under 0.2 MW from 2026 onwards.

For this reason, we recommend that Serbia follow the best European practice and introduce the balancing responsibility for new RES generators. This will provide incentives for RES producers to provide better forecasts of their generation, and will decrease system balancing reserve requirements and associated balancing costs, which otherwise will be paid by customers.

At the same time, to mitigate the financial risks for RES owners from the introduction of balancing responsibility, it is also important to implement further actions to improve market design (intraday market creation, cross border market integration, shorter imbalance settlement period). This will make the power system and electricity market operation more efficient. While RES producers will bear financial responsibility for their production deviations, they will also be able to proactively trade on the intraday market and update their forecasts closer to real time.

6.2.2.2 Wholesale market development

As described in Chapter 6.1.4, currently (beginning of 2022) there is no organized intraday market in Serbia. The intraday market supports the day-ahead market in helping secure the necessary balance between supply and demand, by enabling trades closer to the physical delivery of electricity.

The importance of intraday markets for electricity in Europe is increasing together with the growing need for short-term adjustments due to the greater penetration of intermittent generation from renewable energy sources into the electricity systems. **For this reason, we recommend establishing an organized intraday market in Serbia as an important step in unlocking the potential for economic and efficient large-scale RES integration.**

This organized intraday market should be established in a way that is non-discriminatory and transparent, and that maximizes the opportunities for market participants to engage in short term trading and hedge system imbalances.

For smaller market zones with high market concentration, such as Serbia, the establishment of an organized intraday market is often hindered by the fear of low market liquidity. To adjust for this, the introduction of balancing responsibility for RES producers will stimulate them to proactively sell and buy electricity on the intraday market closer to real time to cover their imbalances, and would increase intraday market liquidity. In addition, cross border market integration could make a big difference. For example, in neighboring Hungary, intraday market liquidity rose from 156 GWh in 2019 to 2529 GWh in 2021 when they joined the pan-European intraday market coupling. Such market integration leads to increased market liquidity, while also creating robust price signals.

By implementing all necessary legal, regulatory and technical aspects, Serbia should aim to join the processes of the European Single Day Ahead Coupling (SDAC) and Single Intraday Coupling (SIDC). Such an integrated day-ahead and intraday market with EU countries will increase the overall efficiency of trading in Serbia by promoting effective competition, increasing liquidity and enabling a more efficient utilization of all generation resources.

The SDAC and SIDC allocate scarce cross-border transmission capacity in the most efficient way by coupling wholesale electricity markets from different regions through a common algorithm, simultaneously considering cross-border transmission constraints, and thereby maximizing social welfare. The European Union Agency for the Cooperation of Energy Regulators (ACER) states in one of its recent reports [11] that the annual welfare gains for Europe from finalizing the integration of short-term electricity markets is now 1.5 billion €. Further, ACER states that there are 300 billion € of potential welfare gains over the next decade from keeping market integration at pace, including benefits from coordinated security of supply and increased cross-zonal capacity. This highlights the importance of joining this process and harvesting some of these benefits for Serbia.

In April 2022, the new regional power exchange ADEX (Alpine-Adriatic Danube Power Exchange) was formed based upon a merger between BSP Southpool and SEEPEX. In the beginning, the ADEX will cover trading in the bidding zones of Serbia and Slovenia, with the aim to become a regional power exchange for Central and South-Eastern Europe. EPEX SPOT, the Transmission System Operators (TSOs), ELES and EMS, will act as founding shareholders of the newly established power exchange ADEX. The proclaimed short-term goals of ADEX are to deliver a new harmonized intraday market in Serbia and to couple the key Serbian Day-ahead market with the pan-European Single Day-Ahead Coupling (SDAC).

As mentioned in prior sections, the current Serbian Law of Renewables usage, in Article 10, states that until the establishment of a liquid organized intraday electricity market in Serbia, the Guaranteed Supplier (Electric Power Utility of Serbia) is responsible for RES imbalances.

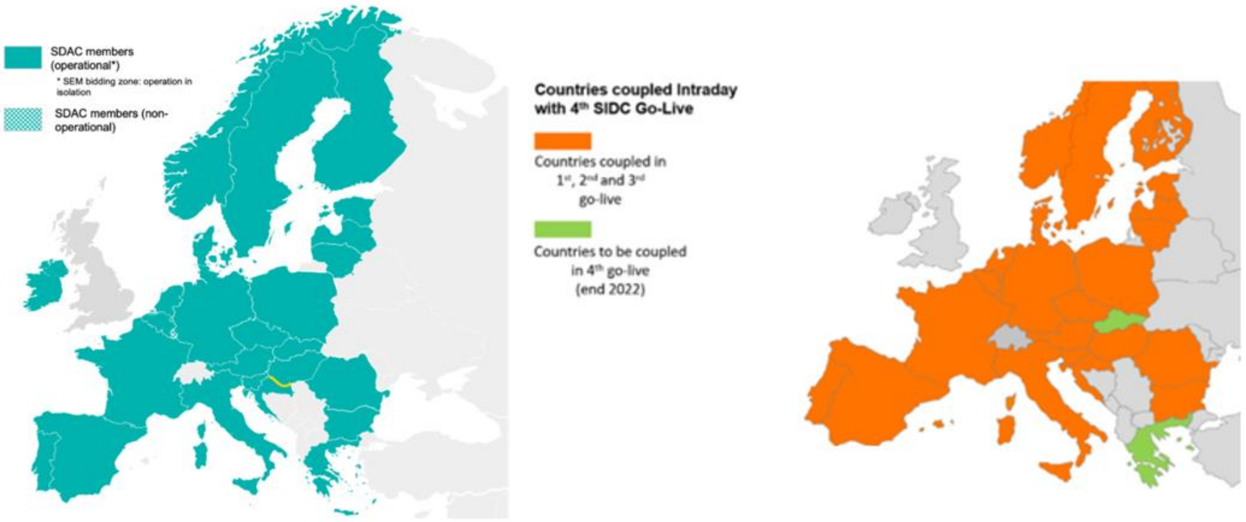


Figure 6.6: Current status of market integration in Europe: Day ahead (left) and intraday (right)

For renewables in Serbia, an organized intraday market will enable RES producers to make market position adjustments from the day ahead to the intraday horizon in an efficient manner. The cost of balancing energy activations would decrease, as a notable share of imbalances will be traded on the ID market, and the cost of balancing reserve procurement would also decrease (imbalances traded on ID market → smaller deviations for balancing market → lower FRR requirement).

The more mature European energy markets, such as Germany, Austria, and Belgium have shown significant benefits from more developed market designs. Our analysis of data from the ENTSO-E Transparency platform shows that forecasts are 29.5% more accurate for onshore wind and 32.3% more accurate for solar PV when comparing the day-ahead and intraday horizons, under conditions in which there is: (1) BRP implemented for RES; (2) the opportunity to trade on the a liquid ID market; and (3) a 15-minute imbalance settlement period. These are significant savings, which Serbia could strive to achieve as well.

6.2.2.3 Imbalance settlement period

Imbalance settlement period (ISP) means the time unit for which balance responsible parties' imbalance is calculated. It takes place ex post and aims to calculate the energy arising from any imbalances of the participants in the balancing market compared to their latest schedule.

We recommended that Serbia adapt its current market mechanism to provide a 15-minute settlement period, taking into account these factors:

- The increasing amount of intermittent energy
- Incentivizing proactive BRP balancing close to real-time for more cost efficiency
- Increasing the possibilities to trade ancillary services
- Harmonizing with the electricity market in ENTSO-E

- Harmonizing with EU legislation[20]

The implementation of 15-minute settlement period will allow trading much closer to the delivery time and increase the opportunities for imbalance management between market participants. The actions and processes necessary to move toward the 15-minute settlement period should be coordinated by EMS in cooperation with Energy Agency (AERS) and all the participants in the market.

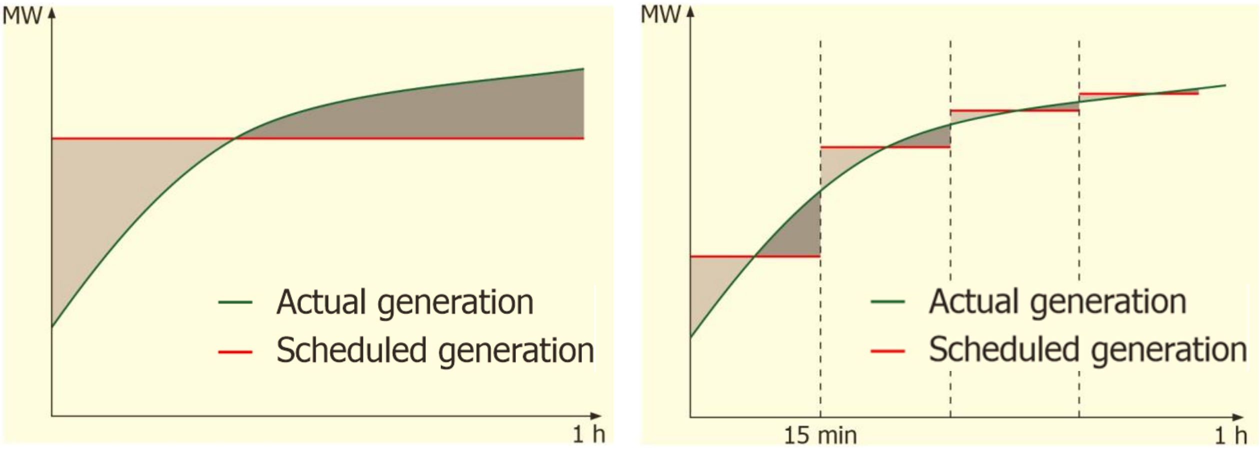


Figure 6.7: 1-hour Vs 15-minute imbalance settlement period

In order to ensure a smooth and consistent implementation of a 15-minute settlement period, the following market and operational aspects should be considered:

- Wholesale day-ahead and intraday market
- Balancing market
- TSO-BRP imbalance settlement
- Metering data

It should be noted that moving to a 15-minute time resolution affects a large portion of business processes, especially in the IT sector, for all the market participants, including system operators.

For EMS, most business processes are already shaped to a 15-minute settlement period, such as scheduling and metering data. However, EMS would need to upgrade its balancing market settlement tool to suit a 15-minute time resolution.

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[20] Commission regulation (EU) 2017/2195 of 23 November 2017 establishing a guideline on electricity guideline (hereinafter EBGL Regulation) sets requirements for target balancing markets and settlement in European Union. Article 53(1) states that: By three years after the entry into force of this Regulation, all TSOs shall apply the imbalance settlement period (ISP) of 15 minutes in all scheduling areas while ensuring that all boundaries of market time unit shall coincide with boundaries of the imbalance settlement period.
REGULATION (EU) 2019/943 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 5 June 2019 on the internal market for electricity, Article 8, paragraph 4: By 1 January 2021, the imbalance settlement period shall be 15 minutes in all scheduling areas, unless regulatory authorities have granted a derogation or an exemption. Derogations may be granted only until 31 December 2024

According to available information from EMS, this upgrade to a 15-minute time resolution should not be too complex or expensive, considering that the existing software vendor has already developed this solution for neighboring TSOs.

On the other hand, it will be more complex for market participants to modify their business processes in trading, balance management and scheduling systems. We recommend the implementation of a 15-minute imbalance settlement period in two major phases:

- Phase 1 – Implementation of 15-minute imbalance settlement capability on the TSO-TSO, TSO-BRP and TSO-BSP business process levels
- Phase 2 – Implementation of a 15-minute ISP on the DSOs level

Day-ahead and intraday markets

The electricity market operator shall allow market participants to trade energy in time intervals at least as short as the defined imbalance settlement period in both day-ahead and intraday markets.

Balancing products

Standard product characteristics for aFRR and mFRR should be adapted to a 15-minute ISP.

6.2.2.4 Priority dispatch

The Serbian Law on the use of renewable sources enables full priority dispatch for all RES capacities, even if they are not incentivized, and operators of transmission or distribution systems are obliged to accept generation from these sources, except when the security of the system is endangered. There are no time limitations for this obligation envisaged in the Law.

On the other hand, EU Electricity Regulation[21] in Article 12 sets out the rules on power generation dispatch. Large new renewable energy installations no longer benefit from priority dispatch, which means that all RES capacities commissioned after 4 July 2019 will need to operate according to market based dispatch. Existing installations that already benefit from priority dispatch can continue to do so. Priority dispatch is also maintained for new small-scale installations up to 400 kW (decreasing to 200 kW in January 2026), and for demonstration projects for innovative technologies.

These provisions mean that, as a starting point, electricity producers bear the responsibilities related to buying and selling the electricity they generate. Another aspect of market operation crucial for renewables is the potential for curtailment (or other forms of downward re-dispatch), especially as we achieve higher levels of renewable energy integration into Serbia's electricity system.

So, as already determined by EU regulation, **we recommend that the priority dispatch rule in Serbia be changed to facilitate more efficient future RES integration**. To enable this process, some preconditions should be satisfied:

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[21] Regulation (EU) 2019/943 of the European Parliament and of the Council of 5 June 2019

- There should be no priority dispatch for any other technology (including must-run arrangements for conventional generators);
- A liquid intraday market with gate closure near real-time should be established;
- A balancing market that allows for the competitive participation of wind producers (short gate closure time, separate up/downwards products, etc.) should be established; and
- Curtailment rules and congestion management processes should be defined, clear and transparent for all market parties.

With non-priority dispatch, renewable producers are exposed to several types of risks.

The main risks are price risks (if the market price is lower than expected, thus reducing revenue) and imbalance risks (if production is not as forecast and scheduled, thus creating imbalance costs). Producers can reduce those risks, and partly hedge against their impact, either themselves or through third-party service providers. The electricity producer can bear the responsibilities and complexities of operating in the wholesale market itself, or delegate them contractually to a third party (an aggregator, a supplier, or another type of service provider). It would, of course, be a commercial decision to outsource to a third-party service provider.

Lower than expected prices on short-term markets can be hedged by trading electricity on long-term markets (e.g., either via specific power purchase agreements selling renewable electricity or on general forward markets). To mitigate imbalance risks, producers of weather-dependent energy generation should use the best forecasting methods available as a basis for scheduling.

In addition, relevant national authorities should also consider providing clear explanations of how the market rules will affect producers in their specific bidding zone and circumstances

6.2.2.5 Cooperation within SMM LFC block

Within the ENTSO-E CE synchronous area, control actions and reserve volumes are organized with a decentralized structure of LFC Blocks and LFC Areas. In most cases in ENTSO-E CE, the LFC Blocks consist of one LFC Area, but there are also several LFC Blocks that consist of multiple LFC Areas. One of these is the SMM LFC block, comprised of Serbia, North Macedonia and Montenegro.

The TSOs participating in the LFC Blocks can significantly decrease their needed volume of balancing reserves by adopting the dimensioning concept on the LFC Block level, and allocating these responsibilities to all member TSOs. This means that in the initial step, the reserve sizing is determined for the whole LFC Block rather than each participating TSO (LFC Area).

Using common dimensioning, the total amount of balancing reserve determined for the LFC Block can be split among the participating TSOs using a ratio agreed upon in their operational agreement.

Common dimensioning of balancing reserve is applied within the SMM block, but it is currently a non-obliged operational procedure. FRR common dimensioning continues to be an opportunity to lower the required reserve on the level of LFC block, also according to System Operation Guidelines, as stated in the Part IV, Load-Frequency Control and Reserves (Articles 119, 157, 160).

Articles related to FRR dimensioning also recognize that all TSOs of an LFC block shall determine the reserve, while "... recognizing any possible geographical limitations for its distributions with the LFC block". Knowing that SMM block members are at the same time Bidding Zones (this is not so in e.g. German Control Block), at least the Cross Zonal Capacity among them required for the application of common reserve needs to be formally recognized and made available.

Our analysis and results in Chapter 4 indicate that the use of common dimensioning in SMM LFC block could reduce the future cost of balancing reserves in Serbia from 10 MEUR/y to 28 MEUR/y, depending on the balancing reserve pricing case and RES scenario.

In addition to the common dimensioning of balancing reserves, cooperation within the LFC block can unlock the potential to apply pre-netting under pan-European Imbalance Netting cooperation, which can additionally reduce balancing energy activations and balancing costs.

We recommend the implementation of common dimensioning within SMM LFC block and pre-netting under pan-European Imbalance Netting cooperation.

6.2.2.6 Cross border balancing integration (EU projects)

The Electricity Balancing Guideline (EB GL) is a Network Code that promotes and regulates cross zonal sharing of resources in order to ensure that real-time generation equals demand in the most economic and efficient way. Considering this goal and former regional initiatives of some ENTSO-e TSOs, EB GL envisages the following balancing cooperation on the European level:

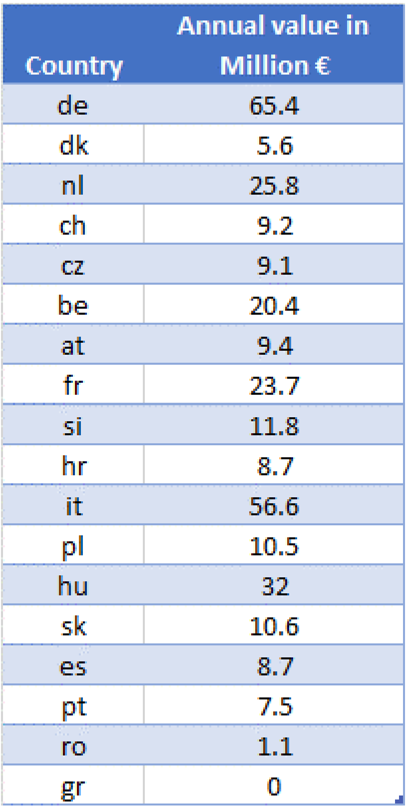
- **IGCC (International Grid Control Cooperation) Project**

IGCC, which started as a regional project in 2010, has grown to an implementation project covering 23 countries and 27 TSOs, as shown in Figure 6.8. In 2016, It has been chosen by ENTSO-E to become the European Platform for the imbalance netting process (IN-Platform) as defined by the guideline on electricity balancing (EB GL Art. 22).

Figure 6.8: IGCC membership status

Imbalance netting is the process agreed between TSOs of two or more LFC areas that allows avoiding the simultaneous activation of frequency restoration reserves (FRR) in opposite directions. The aFRR demand of participating LFC areas is reported to the aFRR optimization system, which returns a correction signal to the secondary controllers of each IGCC operational member. In this sense, by netting imbalances, the counter-activation of aFRR balancing energy is avoided and therefore the use of aFRR is optimized. Annual savings per country in 2021 in the value of netted imbalances are given in Table 6.1. Notably, nearly every operational member of IGCC made substantial savings.

Table 6.1: Annual value of the benefits of netted imbalances in million € for 2021



Country	Annual value in Million €
de	65.4
dk	5.6
nl	25.8
ch	9.2
cz	9.1
be	20.4
at	9.4
fr	23.7
si	11.8
hr	8.7
it	56.6
pl	10.5
hu	32
sk	10.6
es	8.7
pt	7.5
ro	1.1
gr	0

EMS is still not an operational member of IGCC, but has a plan to go-live in 2022; given the potential benefits, we support this move. Also, as a member of the SMM LFC block, Serbia can exercise both pre-netting with SMM block members (CGES, MEPSO) and later participate in imbalance netting with other European LFC blocks that are members of the IGCC cooperation.

Our analyses of RES impact on balancing costs takes the benefits of imbalance netting into account.

- **PICASSO and MARI Projects**

In 2017, the PICASSO and MARI projects were selected to become the aFRR and mFRR European platforms. Figure 6.9 shows the members and observers for these initiatives. The aFRR and mFRR platforms aim to select the most economical and efficient aFRR/mFRR bids while considering available cross-border capacities. The AOF optimizes the activation of standard aFRR/mFRR balancing energy bids and the demand of the TSOs connected to the platform.

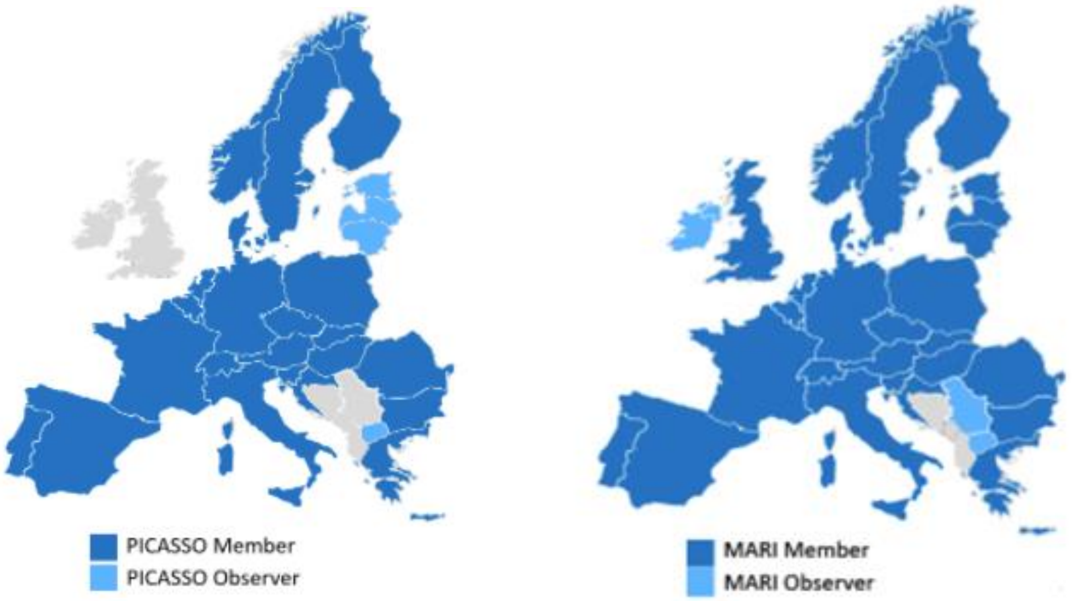


Figure 6.9: PICASSO and MARI membership status

According to the EB regulation, July 2022 was the legal deadline for the go-live of the aFRR and mFRR platforms. As given in the aFRR and mFRR accession roadmaps (Figure 6.10 and Figure 6.11), most countries opted for derogation, so most of them will go-live on these platforms after 2023.

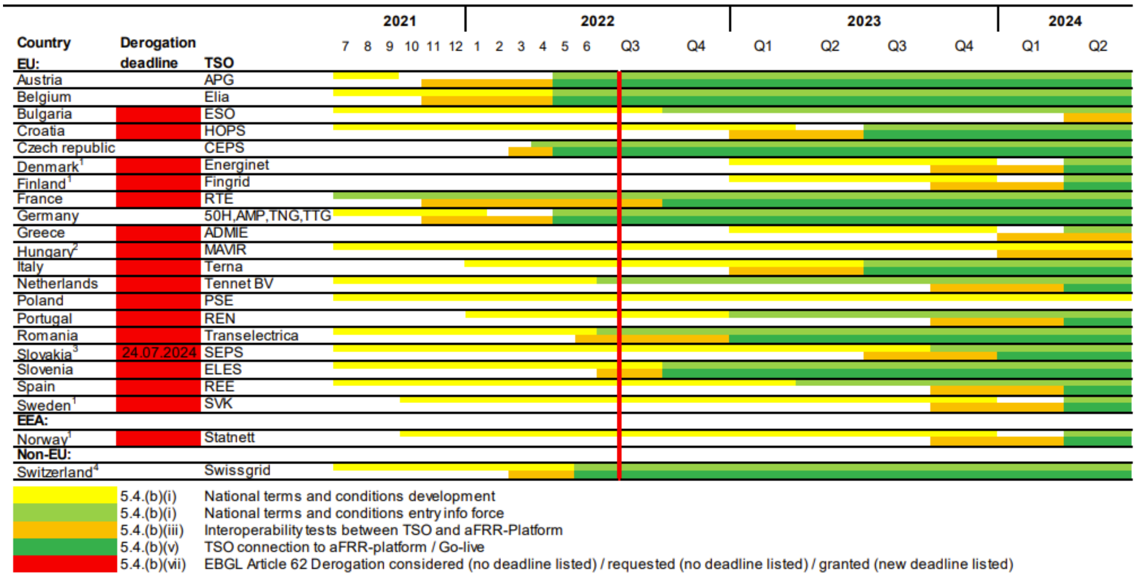


Figure 6.10: aFRR-platform accession roadmap, October 2021

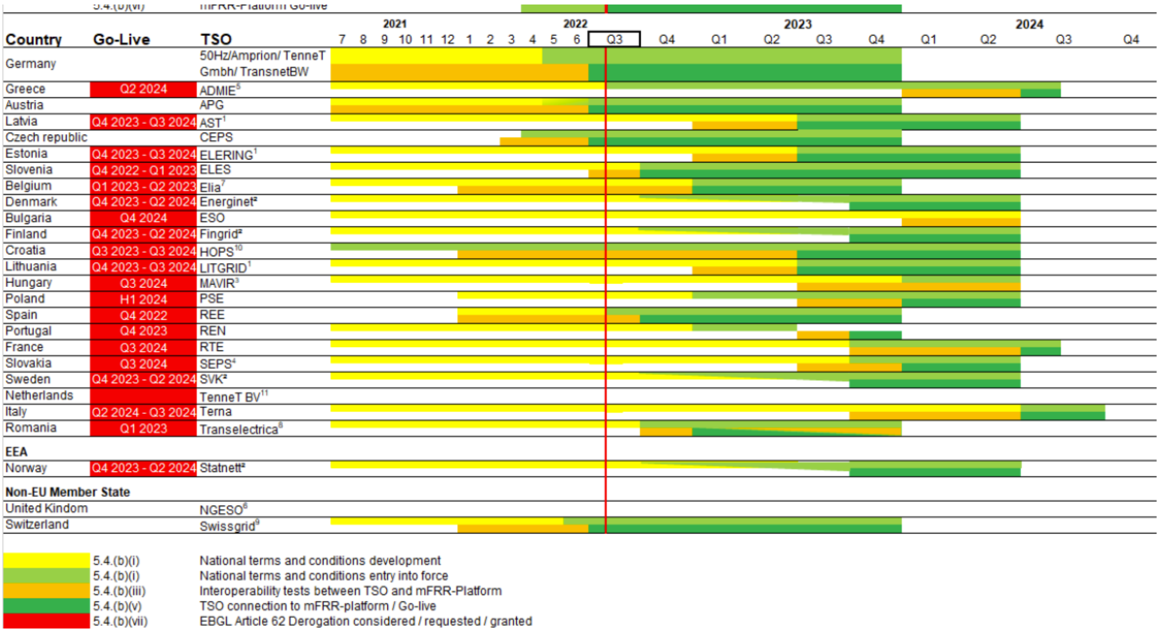


Figure 6.11: mFRR-platform accession roadmap, October 2021

Currently, EMS is an observer in the MARI project and does not participate in the PICASSO project. In order to become an operational member of aFRR-platform and mFRR platforms, EMS would need to fulfill a series of conditions given in aFRR IF and mFRR IF, such as:

- Develop national terms and conditions related to balancing, according to article 18 of EBGL
- Pricing for balancing energy should be defined according to Article 30 of EBGL (e.g pay as cleared instead of pay as bid)
- Define the standard aFRR and mFRR products
- Set up gate closure time to 25 minutes before the beginning of the validity period of aFRR/mFRR bid

We recommend that EMS pursue meeting these conditions. Considering that in Serbia there is only one BSP, with only a partially limited possibility to set up FRR prices, participation in the European afRR and mFRR platform would introduce competition in the balancing market and possibly lower balancing energy prices. Also, in times of domestic scarcity, which are increasing with the increase of RES capacities (e.g., Figure 4.20), EMS would have access to the economically optimal cross-border source of FRR. At the same time, EPS as the only BSP in Serbia would be able to deliver its product to other LFC areas. Quantifying the possible benefits of introducing European aFRR and mFRR platforms through EMS into Serbia is out of the scope of this study.

Participation of EMS in the TERRE project is not envisaged since the balancing mechanism in Serbia does not include RR.

6.2.2.7 Dynamic Reserve dimensioning

One of the options to improve the power system balancing process and thus enable better integration of variable renewables sources is to introduce novel methods for balancing reserve dimensioning.

As an example, the machine learning algorithm for dynamic reserve dimensioning was successfully implemented in Belgium.

The dynamic sizing method determines the required capacity on a daily basis, using the estimated probability of facing a system imbalance during the next day. This risk is estimated based on historical observations of system conditions by means of machine learning algorithms.

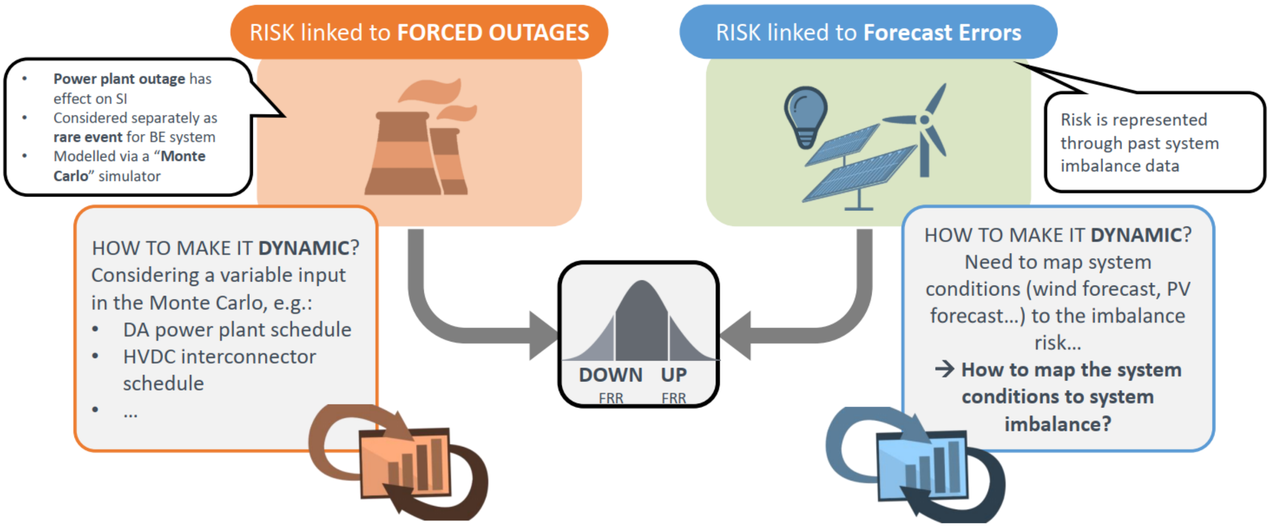


Figure 6.12: Dynamic reserve sizing [12]

As technical prerequisites to apply the method, the Serbian TSO would need to implement the AI based algorithms for dynamic reserve sizing, as well as to conduct the additional regular input data collection for training AI based algorithms.

The implementation of the method could generate two-fold benefits:

- Notable reduction of FRR to be procured.
- Increase of the reliability: more reserve is procured during the risky periods, less during normal periods.

We show an example of these benefits in Figure 6.13 (Belgium experience). In 80% - 85% of time, the machine learning methods forecast lower FRR requirements compared to the classic static dimensioning approach. 10% - 15% of the time, the situation in the system is such that more FRR would be needed.

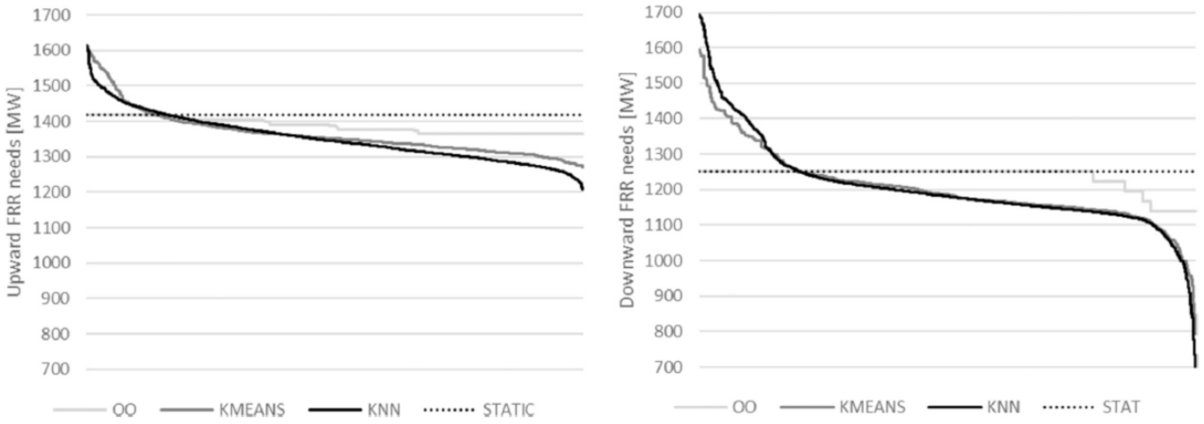


Figure 6.13: Elia experience with dynamic reserve sizing [12]

Based on the documented experience from Elia [13], ENTSO-E TSO determined that the average decrease of FRR needs with Dynamic Reserve Sizing was 7%.

In order to understand the potential impact of introducing dynamic reserve sizing in Serbia in the context of future large scale RES integration, we applied this estimate. For our study scenarios, the estimated savings would range from 4 MEUR/y to 20 MEUR/y. On the other hand, the estimated costs of implementation are in range of 0.75 MEUR/y - 1 MEUR/y [13]. **We recommend that EMS consider introducing dynamic reserve sizing in Serbia.**

6.2.2.8 Balancing capacity remuneration: marginal pricing instead of pay-as-bid

With a paid-as-cleared remuneration (also referred to as "marginal pricing"), bidders have an incentive to submit bids priced at their marginal costs, as they know they will obtain contributions to their long-term costs and profits from the difference between their bid price and the clearing price. Under paid-as-bid, such markups to cover long-term costs and profits need to be included in the bid prices. In a perfectly competitive market, paid-as-cleared and paid-as-bid lead to the same procurement costs. However, in a non-perfectly competitive market, paid-as-cleared and paid-as bid affect the market and procurement differently.

Investigations carried out by some of EU TSOs (ELIA) show that introduction of paid-as-cleared remuneration in a non-perfectly competitive market (like the balancing capacity market is) is likely to increase market attractiveness because homogeneous services become remunerated equally, forecasting effort is reduced and the market thereby better acts as a level-playing field, irrespective of bidders' market shares. These impacts can be expected only when a reasonable level of liquidity and competition exist at the time of implementation, or is reached shortly afterwards.

The paid-as-bid mechanism used today has its merits when the market still shows an insufficient level of competition and the emergence of sufficient competition would take a longer time. Making the transition to paid-as-cleared for mFRR and aFRR capacity would seem feasible and desirable, provided that the markets evolve to higher levels of liquidity and competition than is the case today.

Having in mind that in the next short-term period (3-5 years) changes in market design in Serbia will be focused on implementation of intra-day market and 15-min ISP, we recommend that marginal pricing for balancing reserve procurement be left for consideration after these changes.

6.2.2.9 Quantitative estimates of potential benefits

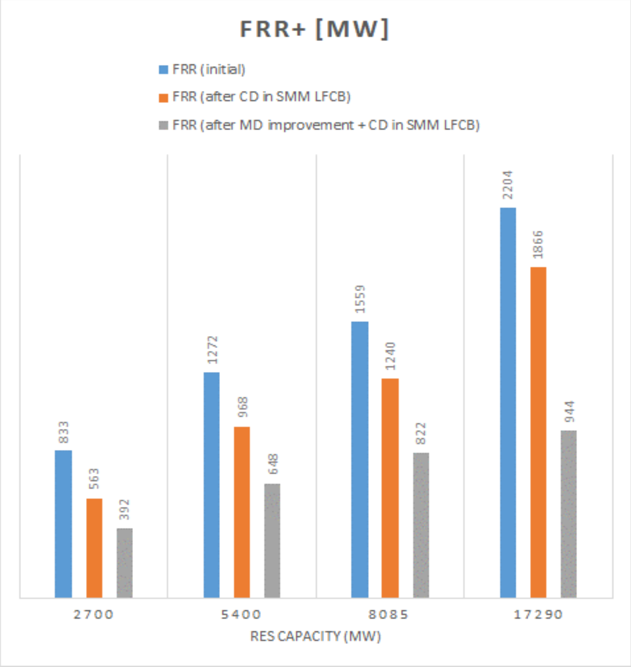
To support the above recommendations, we performed a preliminary quantitative impact assessment. We note that there are a number of interdependencies between different proposed actions, as well as reactions of other market players, and this assessment cannot include all of them.

Hence, such analysis only provides a tentative estimate, i.e., an **order of magnitude** for the potential benefits. Still, the results clearly demonstrate the importance of a proactive approach for decision makers (Government, Ministry, NRA, TSO), as well as the need to understand and implement decisions based on the lessons learned from more mature power systems and electricity markets with high share of renewables. The reforms should both aim to follow the best European practices, while also tailoring them to suit the specifics of the Serbian energy sector and economy.

This assessment includes the above-mentioned impacts of:

- Common reserve dimensioning in SMM block
- Recommended improvement of market design
- Dynamic reserve dimensioning

The impacts on the balancing reserve requirement and costs are presented in the following figures.



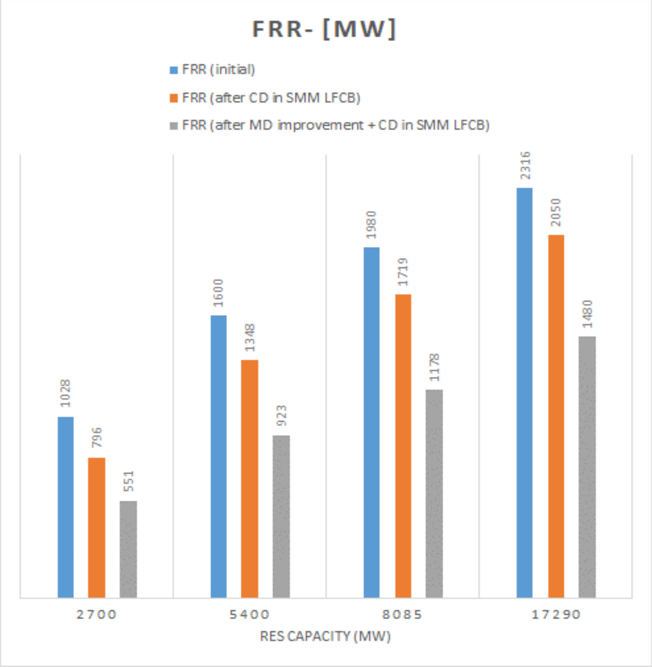


Figure 6.14: Impact of recommended market design (MD) improvements and SMM common dimensioning (CD) on balancing reserve requirements under different RES integration scenarios [22]

The results show that by adopting and implementing proposed measures, the total FRR needs (in MW) could decrease 46% on average across all scenarios.

This can be translated to an economic savings in the range of 44 MEUR/y – 107 MEUR/y, depending on the scenario, or 43% on average.

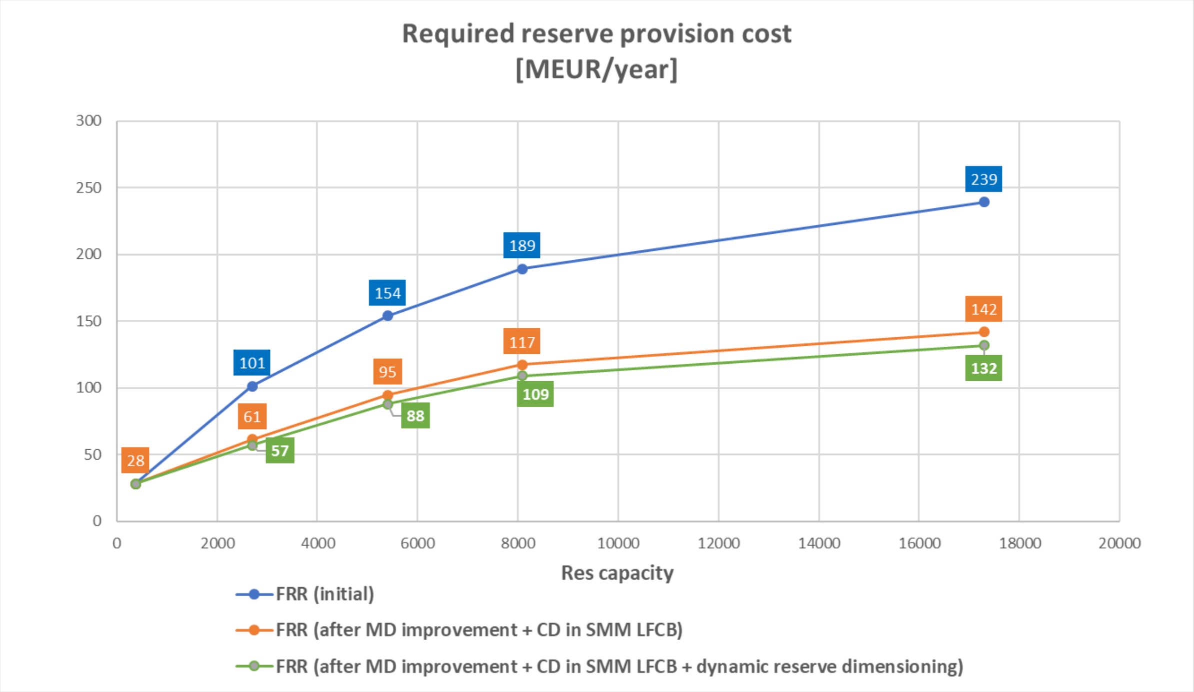


Figure 6.15: Impact of recommended market design (MD) improvements and SMM common dimensioning (CD) on balancing reserve costs[23] *under different RES integration scenarios*

The above assessed benefits can be translated into benefits for transmission tariffs in the following manner (Figure 6.16):

- System services costs part of transmission tariffs in 2020 (when there was 374 MW of RES capacity in the system) was 0.9 EUR/MWh
- An increase to 17 GW of RES capacity would increase these costs to 6.2 EUR/MWh (with same prices for mFRR upward and mFRR downward)
- With MD improvement and CD in the SMM LFC block, these costs would increase to just 3.7 EUR/MWh or 40% less
- With the additional benefit from dynamic reserve dimensioning, system service costs would increase to just 3.4 EUR/MWh, or 7 % less.

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[22] Balancing reserve procurement costs for the assumption of the same prices for mFRRupward and mFRRdownward (V1)

[23] Required reserve provision cost for mFRR down reserve price equal to upward mFRR reserve price (V1 pricing option).

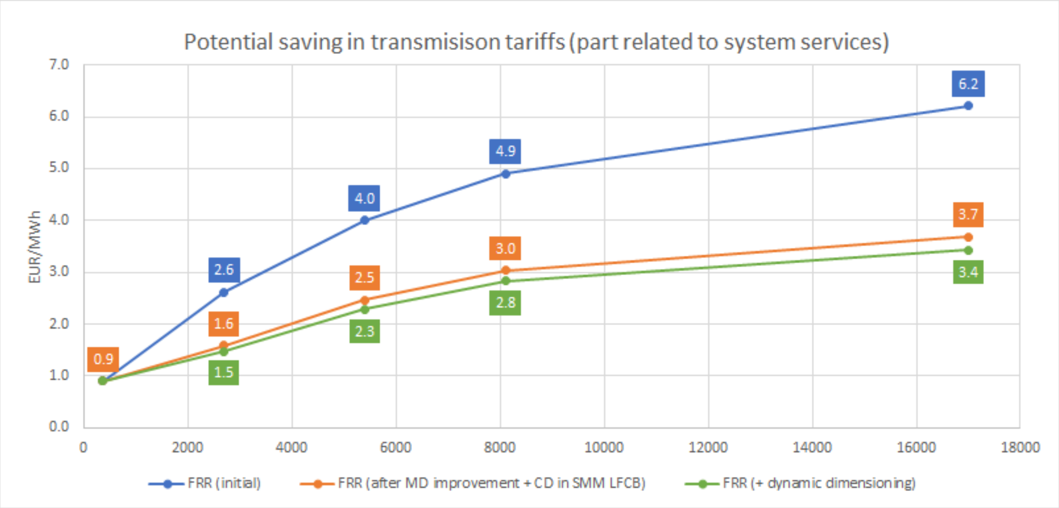

Figure 6.16: Impact of recommended market design (MD) improvements and SMM common dimensioning (CD) on transmission tariffs under different RES integration scenarios

In total, there would be about a 30% benefit at the level of total transmission tariffs.

6.2.3 Summary of the recommendations

Based on the analyses, assessments and considerations presented in the previous chapters, we have summarized here the main recommendations for improvements in EMS business processes. It is challenging to divide these measures between relevant parties, e.g., Government, Regulatory Agency and TSO, since in almost all cases there is an interdependency in developing and implementing each process. There are few processes that are purely technical and organizational and that can be developed and implemented by EMS without involvement of other relevant parties.

With respect to this we organized this summary around two main aspects that can have positive impact on RES integration while assuring safe and reliable power system operation:

C. Improvements with respect to general RES integration process and connection procedure

Considering the strong complementarity between the phases of grid connection of RES and grid development, a key issue to resolve is how to share costs for large grid reinforcement or waiting times linked to the building of new lines. Better coordination between grid operation, upgrades and RES development would consider the following aspects:

- Regular collection of data on RES development from public national registries and collection of reliable data on development targets
- Harmonization of a grid code and connection procedures to reduce lead times and simplify procedures
- Development of regulatory guidelines on the national level for the development of the power system, to better align the pace of grid and RES-E development. This guideline should allow for better queue management and avoid “virtual saturation” of the grid in case EMS receives

a large number of grid connection within a limited time frame before construction has begun. This guideline should address these solutions:
  - Deposit requirements for connection rights
  - Inserting obligatory milestones into the application-realization process to maintain the pace of connection and prevent the blocking of connection points
  - Harmonizing the time-duration of required construction licenses and energy permits during project development, with obligatory milestones for RES connection applicants
- Introducing a hybrid system, i.e., a system in which the Investor would pay for the connection and for part of the reinforcement works in case of a lack of grid capacity, respecting at the same time rules of non-discriminatory and transparent access.

D. Improvements in market design and system operation control

Market design, priority dispatch and balancing responsibility

To further support RES integration into Serbian power system, it is important to further develop the wholesale and balancing market.

The latest European Electricity Regulation (14/06/2019 - Regulation (EU) 2019/943) adopted under Clean Energy Packages, recognizes the importance of proper market set up, which assumes that all market participants must be responsible for the imbalances they cause in the system. For renewable energy producers active on the market, this means that they need to bear the risk of incorrect predictions for production, e.g., due to incorrect wind forecasts.

The same Regulation, in Article 12 sets out the rules on power generation dispatch. Large new renewable energy installations no longer benefit from priority dispatch, which means that all RES capacities commissioned after 4 July 2019 will need to operate according to market based dispatch.

Currently, Serbian Energy Law and Law on the use of renewable sources still provides priority dispatch for RES producers and does not require RES producers to be balancing responsible. Balancing responsibility is expected to be introduced when a liquid intra-day market becomes operational in Serbia. There is no time limitation related to priority dispatch in the Laws.

As previously commented, we strongly recommend that Serbia follow the best European practice and introduce balancing responsibility for new RES generators. This action will provide an incentive for better forecasting of RES generation, and consequently decrease balancing reserve requirements and associated balancing costs, following the guidelines below.

In the context of renewables, an organized intraday market will enable market position adjustments from the day ahead to the intraday horizon in an efficient manner for RES generation. The cost of balancing energy activations would decrease (due to the fact that notable share of imbalances will be traded on the ID market) and the cost of balancing reserve procurement would also decrease (imbalances traded on ID market → smaller deviations for balancing market → lower FRR requirement).

The key question from our perspective is when to introduce RES balancing responsibility without priority dispatch, and how to mitigate the financial risks for RES owners of such changes in Serbia.

To do so, we recommend further actions to improve market design, including: intraday market creation, cross border market integration, and a shorter imbalance settlement period, so that Serbia can achieve more efficient power system and electricity market operation. While RES producers will bear financial responsibility for their own deviations, they will also be able to proactively trade on the intraday market and update their forecasts closer to real time.

ISP reduction to 15 minutes

We recommend that EMS implement a 15-minute imbalance settlement period in two major phases:

- Phase 1 – Implementation of 15-minute imbalance settlement capability on TSO-TSO, TSO-BRP and TSO-BSP business process level
- Phase 2 – Implementation of 15-minute ISP on DSOs level

Common dimensioning in SMM LFC block

Common dimensioning of balancing reserve is applied within the SMM block, but currently in the form of non-obliged operational procedure. FRR common dimensioning is an opportunity for Serbia to lower the required reserve on the level of LFC block, also according to System Operation Guidelines, as stated in the Part IV, Load-Frequency Control and Reserves (Articles 119, 157, 160).

Knowing that the SMM block members are at the same time Bidding Zones (this is not so in the German Control Block, for example), at least the Cross Zonal Capacity among them required for the application of common reserve needs to be formally recognized and made available.

EMS, together with CGES and MEPSO, are working to further improve balancing cooperation in the SMM LFC block. The main result of that work will be an operational agreement, which will include technical conditions and methodologies that will satisfy the following objectives:

- Develop a methodology for determining the total level of FRR on the LFC block level
- Analyze available transmission capacities for the purpose of FRR common dimensioning inside SMM block
- Analyze available cross-zonal capacities for FRR sharing with neighboring LFC blocks
- Work on a methodology for determining the minimum share of the aFRR in the total FRR
- Determine common technical requirements at the SMM block level for the availability and quality of system services
- Develop a methodology for the treatment and allocation of cross-zonal transmission capacities for the needs of joint procurement of reserves
- Develop a methodology for the treatment and allocation of cross-zonal transmission capacities for the needs of regional cooperation with neighboring control blocks / areas regarding the sharing of FRR balance reserve
- Develop a mechanism to conduct auctions and activations for joint reserve procurement

Cross-border balancing cooperation

Currently, EMS is an observer in the MARI project and does not participate in the PICASSO project. We recommend that EMS join both projects. In order to become an operational member of aFRR-platform and mFRR platforms (MARI and PICASSO), EMS should fulfill a series of conditions given in aFRR IF and mFRR IF, such as:

- Develop national terms and conditions related to balancing, according to article 18 of EBGL
- Pricing for balancing energy should be defined according to Article 30 of EBGL (e.g pay as cleared instead of pay as bid)
- Define the standard aFRR and mFRR products
- Set up gate closure time to 25 minutes before the beginning of the validity period of aFRR/mFRR bid

Dynamic Reserve Dimensioning

As technical prerequisites to apply this method, the Serbian TSO would need to implement the AI based algorithms for dynamic reserve sizing, as well as conduct the additional regular input data collection for training using AI based algorithms.

7 CONCLUSIONS

The purpose of this report is twofold:

1. To evaluate and present the impacts of different levels of RES capacities in Serbia on the wholesale and balancing market operation as well as network operation, and
2. To develop recommendations for improvements in EMS' business processes that should enable more efficient RES integration, while preserving safe and secure system operation.

These proposals for potential improvements of procedures and mechanisms are related to all aspects of EMS' business connected with RES (i.e., the regulatory framework and RES support schemes, connection procedure and investments in necessary network reinforcement, system operation, and wholesale and balancing markets). In this process, we also assessed potential quantitative and qualitative benefits of the proposed improvements, as applicable.

Based on our analyses and assessments, we summarized the main recommendations to improve EMS' business processes, taking into account the strong interdependency with processes developed and implemented by Government and the Regulatory Agency.

Importantly, these results are a function of the installed RES capacities in the analyzed scenarios: approximately 2.7 GW, 5.4 GW, and 8.1 GW. The last scenario, with 17 GW in RES capacities, is a theoretical exercise to protect EMS in an unlikely scenario.

The impact of high RES on wholesale market operation shows that with more RES capacity in the Serbian power system, wholesale market prices will decrease, rather modestly (up to 11%), even in the case of an 17 GW of RES capacity. By comparison, changes in CO2 prices would bring significantly higher changes in wholesale market prices. Also, generation from thermal units generally depends more on CO2 prices and their market position than on the level of RES, though when RES levels rise substantially, TPP generation falls as well, even at low CO2 price levels.

Regarding the impact of high RES on the balancing market and corresponding costs shows that with more RES, Serbia must procure a higher balancing reserve and activate more reserves to cover the RES deviations. This shows that more RES will pose higher costs for both the procurement of balancing reserves and balancing energy. For an additional 17 GW in RES, the system balancing cost would reach between 215 MEUR and 450 MEUR, starting from just 50 MEUR in 2020.

The part of these costs that relates only to balancing reserve procurement are in the range of 174 MEUR and 283 MEUR. Expressed in transmission tariffs, this is between 5 EUR/MWh and 8 EUR/MWh, which is a notable increase compared to the value in 2020 of 0.9 EUR/MWh.

Intraday market development, stronger cross-border balancing cooperation, and the implementation of dynamic reserve dimensioning would reduce total transmission tariffs by around 30%.

From a technical perspective, it is plausible to integrate 2.7 GW of RES and satisfy the system's balancing requirements. For higher RES capacities, EMS should consider the addition of new flexible sources (such as PSPs, batteries, etc.) as a step toward ensuring normal power system operation and compliance with ENTSO-E standards.

The impact of high RES on the transmission network shows that reinforcements already planned for 2030 (in the latest EMS transmission network plan) can provide satisfactory support to system operation. By contrast, the transmission network as planned in 2025 cannot provide safe operation of the system in some operating regimes and regimes with high exports that could cause overloading in the network. This points to the importance of close synchronization of RES integration with network development in the next several years in particular.

Planned investments in the main network reinforcement through 2030 (North CSE Corridor and the interconnection with BA and ME) would increase the transmission tariffs by around 0.46 EUR/MWh, which is around 26% of the part of the transmission tariff related to infrastructure, or 11% of total transmission tariffs in 2020.

The impact of higher RES on increases in transmission tariffs related to system services are significantly higher than the increase related to infrastructure. Taking into account the benefits that can be gained by improvements in system balancing (30%), we believe that processes that will enable improvements in system operation and balancing should be high on the list of the processes on which EMS, together with Government and the Regulatory Agency, should work.

We also recommend that these processes be improved in line with the best European practice, to introduce balancing responsibility for new RES generators, exclude priority dispatch and improve balancing cooperation within the SMM LFC block. These actions will provide incentives for better forecasting RES generation, and decrease balancing reserve requirements and balancing costs.

Beside these areas, we recommend that improvements in EMS' business processes focus on:

- Regularly collecting data on RES development from public national registries, and the collection of reliable data on development targets;
- Harmonizing a grid code and connection procedures to reduce long lead times and to simplify complex procedures
- Developing national regulatory guidelines to develop the power system, to better align the pace of grid and RES-E development. These guidelines should allow for better queue management and avoid "virtual saturation" of the grid when EMS receives a large number of grid connection applications within a limited time frame before construction has begun.
- Introducing a hybrid system, i.e., a system in which the Investor must pay for the connection and for part of the reinforcement works in case of a lack of grid capacity, respecting at the same time rules of non-discriminatory and transparent access.
- Implementing an ISP of 15 minutes
- Participating in the MARI and PICASSO projects
- Implementing dynamic reserve dimensioning

We respectfully submit this analysis and these recommendations for EMS to consider to support the smooth adoption of substantial RES capacity and the major transformation taking place in the Serbian and regional power systems on behalf of electricity customers in Serbia.

8 APPENDIX

8.1 Results of the network simulations

8.1.1 2025- refRES

Figure 8.1: Cross-border exhanges (MW) and directions between the countries for Winter Peak regime 2025 (referent RES, referent CO2)

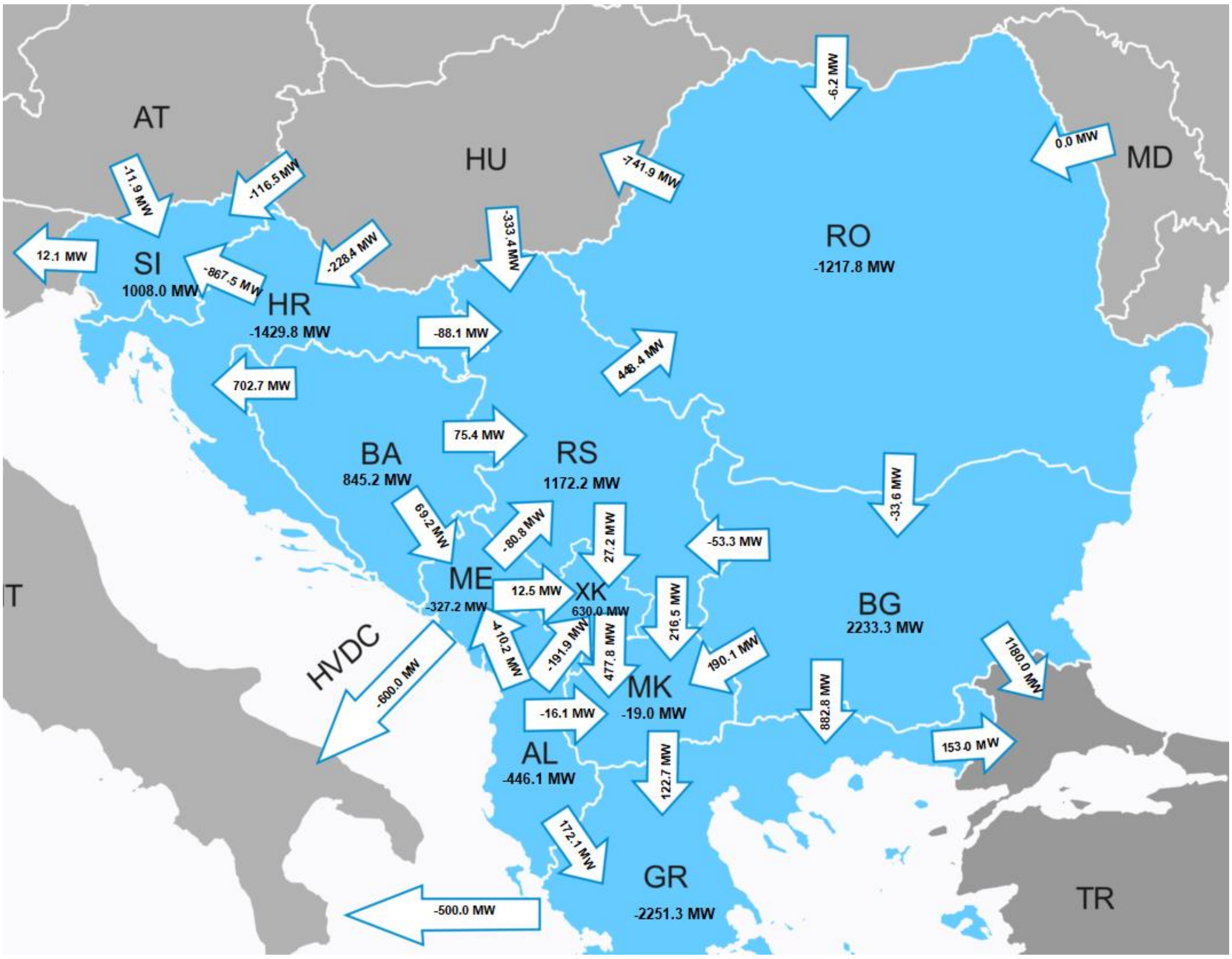

Figure 8.2: Cross-border exhanges (MW) and directions between the countries for Summer Off-Peak regime 2025 (referent RES, referent CO2)

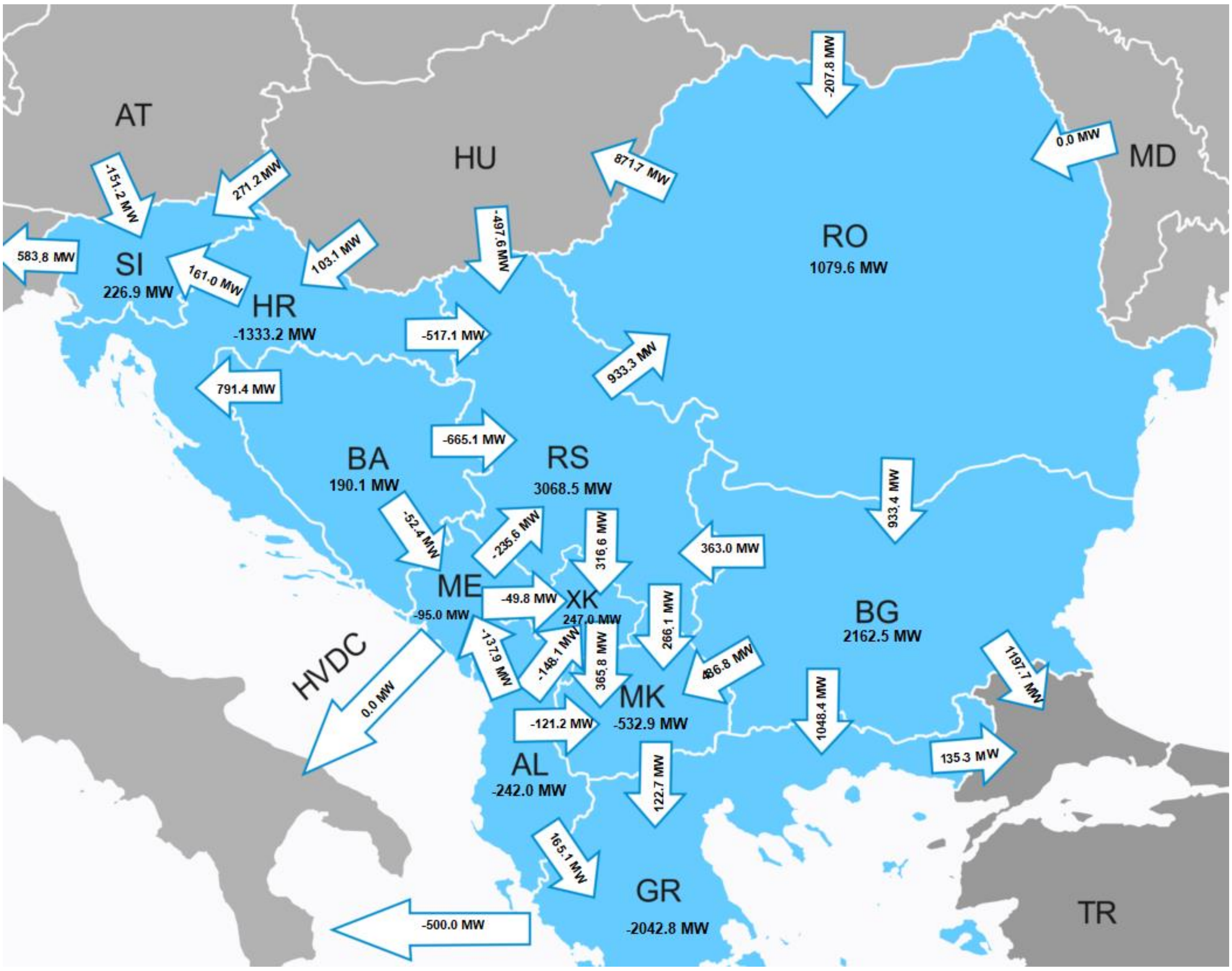

Figure 8.3: Cross-border exhanges (MW) and directions between the countries for Highest wind+solar generation regime 2025 (referent RES, referent CO2)

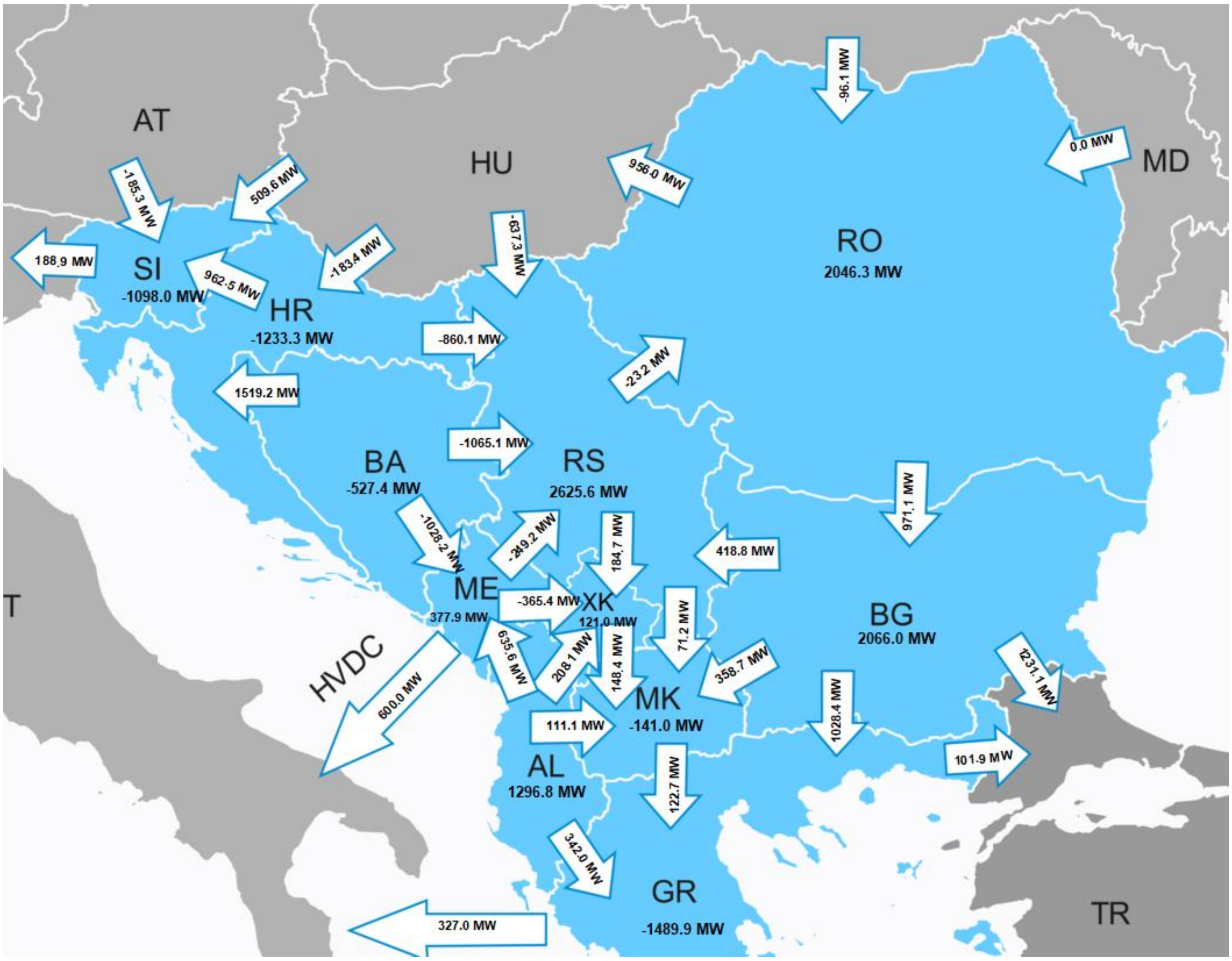

Figure 8.4: Cross-border exhanges (MW) and directions between the countries for Summer regime with the highest generation 2025 (referent RES, referent CO2)

Figure 8.5: Cross-border exhanges (MW) and directions between the countries for Highest export regime 2025 (referent RES, referent CO2)

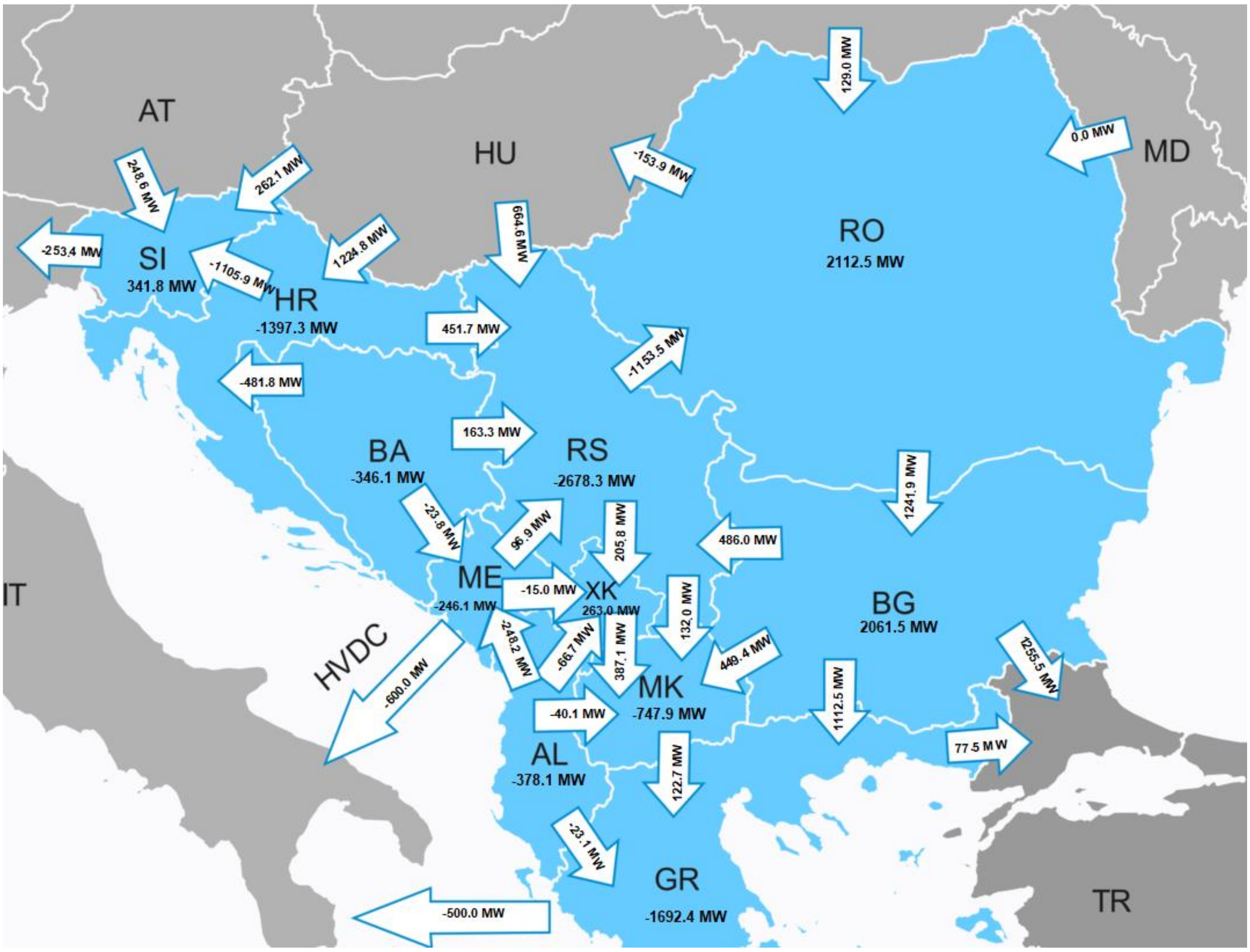

Figure 8.6: Cross-border exhanges (MW) and directions between the countries for Highest import regime 2025 (referent RES, referent CO2)

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<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>  RATING    FLOW       %
 460090*JRPMLA12    400.00 460095 JSMIT211    400.00 1  BASE CASE                        1330.2   1451.6    107.3
 460065*JOBREN12    400.00 460090 JRPMLA12    400.00 1  SINGLE 460060-460085(2)          1330.2   1428.2    105.7
 460060*JOBREN11    400.00 460085 JRPMLA11    400.00 2  SINGLE 460065-460090(1)          1330.2   1428.2    105.7
 460065*JOBREN12    400.00 460090 JRPMLA12    400.00 1  SINGLE 460085-460090(1C)         1330.2   1382.5    102.3
 460085*JRPMLA11    400.00 460090 JRPMLA12    400.00 1C SINGLE 460065-460090(1)          1330.2   1417.8    104.8
 460151*JBGD2012    400.00 3WNDTR T2           WND 1 2  SINGLE 460150-460151(1C)          300.0    342.5    114.7
 460026*JJAGO412    400.00 3WNDTR T2           WND 1 2  SINGLE 460025-460026(1C)          300.0    335.0    109.9
 461145*JSABA321    220.00 3WNDTR T1           WND 1 1  SINGLE 460090-460095(1)           150.0    206.9    141.3
 461145*JSABA321    220.00 3WNDTR T2           WND 1 2  SINGLE 460090-460095(1)           150.0    187.3    127.9
 461145*JSABA321    220.00 3WNDTR T2           WND 1 2  SINGLE 461145-463095-465265(1)    150.0    195.7    129.3
 461145*JSABA321    220.00 3WNDTR T1           WND 1 1  SINGLE 461145-463100-465270(2)    150.0    202.2    133.6
 462070*JBGD1 5     110.00 464021 JBGD4752    110.00 1  SINGLE 460005-460060(1)           142.9    156.5    101.5
 462070*JBGD1 5     110.00 464021 JBGD4752    110.00 1  SINGLE 460005-460150(A)           142.9    167.9    108.4
 462170 JBGD3 52    110.00 462935*JPANC151    110.00 1  SINGLE 460070-460151(A)           110.5    147.4    123.4
 462180 JBGD335     110.00 462940*JPANC152    110.00 1  SINGLE 460070-460151(A)           110.5    128.5    107.9
 462070 JBGD1 5     110.00 464021*JBGD4752    110.00 1  SINGLE 461010-461045(1)           142.9    155.1    102.0
 462070 JBGD1 5     110.00 463531*JBGD2052    110.00 2  SINGLE 462070-463530(1)           150.5    193.6    118.2
 462070 JBGD1 5     110.00 463530*JBGD2051    110.00 1  SINGLE 462070-463531(2)           150.5    193.6    118.2
 462940 JPANC152    110.00 462960*JPANC451    110.00 2  SINGLE 460070-460151(A)           110.5    132.3    110.5
 462870*JNSAD352    110.00 463225 JSRBOB51    110.00 1  SINGLE 460050-460165(1)           110.5    221.1    188.8
 462870*JNSAD352    110.00 463225 JSRBOB51    110.00 1  SINGLE 460105-460165(1)           110.5    152.8    129.9
 462870*JNSAD352    110.00 463225 JSRBOB51    110.00 1  SINGLE 462865-463725(2)           110.5    119.7    101.9
 462900*JNSAD95     110.00 463355 JTTNSA51    110.00 1  SINGLE 462875-463355(1)           150.5    175.7    108.3
 462900*JNSAD95     110.00 463355 JTTNSA51    110.00 1  SINGLE 463355-464240(2)           150.5    163.8    100.9
 462870*JNSAD352    110.00 463225 JSRBOB51    110.00 1  SINGLE 460090-460095(1)           110.5    130.7    113.5
 462825 JNPAZ151    110.00 462830*JNPAZ25     110.00 1  SINGLE 381070-38101(1)            110.5    116.9    103.6
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  SINGLE 381070-38101(1)            110.5    119.3    109.4
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  SINGLE 460026-460045(1)           110.5    110.6    101.5
 462825 JNPAZ151    110.00 462830*JNPAZ25     110.00 1  SINGLE 471000-38101(1)            110.5    117.1    103.8
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  SINGLE 471000-38101(1)            110.5    119.3    109.5
 462985 JPECIN5     110.00 463095*JSABA351    110.00 1  SINGLE 460090-460095(1)            70.3     89.1    119.9
 462285 JBTOP25     110.00 463225*JSRBOB51    110.00 1  SINGLE 460105-460165(1)           110.5    126.4    110.8
 462325 JCRVEN5     110.00 462665*JKULA 5     110.00 1  SINGLE 460105-460165(1)           110.5    114.6    102.1
 461195*JVALJ321    220.00 3WNDTR T2           WND 1 2  SINGLE 461195-463390-465306(3)    150.0    163.6    106.2
 462915 JOSECI5     110.00 463395*JVALJ352    110.00 2  SINGLE 460090-460095(1)           110.5    152.0    127.7
 461215*JZREN221    220.00 3WNDTR T2           WND 1 2  SINGLE 461215-463495-465315(1)    200.0    217.8    110.0

 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 381070-38101(1)          : OPEN LINE FROM BUS 381070 [ORIBAR11    400.00] TO BUS 38101 [XRI_PE11    400.00] CKT 1
 SINGLE 460005-460060(1)         : OPEN LINE FROM BUS 460005 [JBGD8 12    400.00] TO BUS 460060 [JOBREN11    400.00] CKT 1
 SINGLE 460005-460150(A)         : OPEN LINE FROM BUS 460005 [JBGD8 12    400.00] TO BUS 460150 [JBGD2011    400.00] CKT A
 SINGLE 460025-460026(1C)        : OPEN LINE FROM BUS 460025 [JJAGO411    400.00] TO BUS 460026 [JJAGO412    400.00] CKT 1C
 SINGLE 460026-460045(1)         : OPEN LINE FROM BUS 460026 [JJAGO412    400.00] TO BUS 460045 [JNIS2 12    400.00] CKT 1
 SINGLE 460050-460165(1)         : OPEN LINE FROM BUS 460050 [JNSAD311    400.00] TO BUS 460165 [JSRBOB1     400.00] CKT 1
 SINGLE 460060-460085(2)         : OPEN LINE FROM BUS 460060 [JOBREN11    400.00] TO BUS 460085 [JRPMLA11    400.00] CKT 2
 SINGLE 460065-460090(1)         : OPEN LINE FROM BUS 460065 [JOBREN12    400.00] TO BUS 460090 [JRPMLA12    400.00] CKT 1
 SINGLE 460070-460151(A)         : OPEN LINE FROM BUS 460070 [JPANC211    400.00] TO BUS 460151 [JBGD2012    400.00] CKT A
 SINGLE 460085-460090(1C)        : OPEN LINE FROM BUS 460085 [JRPMLA11    400.00] TO BUS 460090 [JRPMLA12    400.00] CKT 1C
 SINGLE 460090-460095(1)         : OPEN LINE FROM BUS 460090 [JRPMLA12    400.00] TO BUS 460095 [JSMIT211    400.00] CKT 1
 SINGLE 460105-460165(1)         : OPEN LINE FROM BUS 460105 [JSUBO311    400.00] TO BUS 460165 [JSRBOB1     400.00] CKT 1
 SINGLE 460150-460151(1C)        : OPEN LINE FROM BUS 460150 [JBGD2011    400.00] TO BUS 460151 [JBGD2012    400.00] CKT 1C
 SINGLE 461010-461045(1)         : OPEN LINE FROM BUS 461010 [JBGD1721    220.00] TO BUS 461045 [JBGD8 21    220.00] CKT 1
 SINGLE 462070-463530(1)         : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463530 [JBGD2051    110.00] CKT 1
 SINGLE 462070-463531(2)         : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463531 [JBGD2052    110.00] CKT 2
 SINGLE 462865-463725(2)         : OPEN LINE FROM BUS 462865 [JNSAD351    110.00] TO BUS 463725 [JSRBO25     110.00] CKT 2
 SINGLE 462875-463355(1)         : OPEN LINE FROM BUS 462875 [JNSAD451    110.00] TO BUS 463355 [JTTNSA51    110.00] CKT 1
 SINGLE 463355-464240(2)         : OPEN LINE FROM BUS 463355 [JTTNSA51    110.00] TO BUS 464240 [JKAC 5      110.00] CKT 2
 SINGLE 461145-463095-465265(1)  : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463095 [JSABA351    110.00] TO BUS
465265 [JSABA3_1    10.000] CKT 1
 SINGLE 461145-463100-465270(2)  : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463100 [JSABA352    110.00] TO BUS
465270 [JSABA3_2    10.000] CKT 2
 SINGLE 461195-463390-465306(3)  : OPEN LINE FROM BUS 461195 [JVALJ321    220.00] TO BUS 463390 [JVALJ351    110.00] TO BUS
465306 [JVALJ3_3    10.000] CKT 3
 SINGLE 461215-463495-465315(1)  : OPEN LINE FROM BUS 461215 [JZREN221    220.00] TO BUS 463495 [JZREN251    110.00] TO BUS
465315 [JZREN2_1    10.000] CKT 1
 SINGLE 471000-38101(1)          : OPEN LINE FROM BUS 471000 [_PEJA31     400.00] TO BUS 38101 [XRI_PE11    400.00] CKT 1
```

Figure 8.7: Contingency (n-1) analysis report for Winter Peak regime 2025 (referent RES, referent CO2)

```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>  RATING    FLOW       %

LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)
```

Figure 8.8: Contingency (n-1) analysis report for Summer Off-Peak regime 2025 (referent RES, referent CO2)

```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW       %
 461145*JSABA321    220.00 3WNDTR T1           WND 1 1  SINGLE 460090-460095(1)             150.0     158.3    104.5
 461145*JSABA321    220.00 3WNDTR T2           WND 1 2  SINGLE 461145-463095-465265(1)      150.0     167.2    108.7
 461145*JSABA321    220.00 3WNDTR T1           WND 1 1  SINGLE 461145-463100-465270(2)      150.0     172.7    112.3
 461195*JVALJ321    220.00 3WNDTR T2           WND 1 2  SINGLE 461195-463390-465306(3)      150.0     164.8    105.9
 462870*JNSAD352    110.00 463225 JSRBOB51    110.00 1  SINGLE 460050-460165(1)             110.5     123.8    103.4
 462900*JNSAD95     110.00 463355 JTTNSA51    110.00 1  SINGLE 462875-463355(1)             150.5     168.2    102.5
 462940 JPANC152    110.00 462960*JPANC451    110.00 2  SINGLE 460070-460151(A)             110.5     127.3    107.1
 462170 JBGD3 52    110.00 462935*JPANC151    110.00 1  SINGLE 462180-462940(1)             110.5     121.0    101.8
 462170 JBGD3 52    110.00 462935*JPANC151    110.00 1  SINGLE 462940-462960(2)             110.5     121.6    102.3
 462170 JBGD3 52    110.00 462935*JPANC151    110.00 1  SINGLE 462945-462960(1)             110.5     125.6    105.7
 462170 JBGD3 52    110.00 462935*JPANC151    110.00 1  SINGLE 460070-460151(A)             110.5     141.0    118.4
 462180 JBGD335     110.00 462940*JPANC152    110.00 1  SINGLE 460070-460151(A)             110.5     124.8    104.8
 462915*JOSECI5     110.00 463395 JVALJ352    110.00 2  SINGLE 460090-460095(1)             110.5     117.6    102.4

 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 460050-460165(1)         : OPEN LINE FROM BUS 460050 [JNSAD311    400.00] TO BUS 460165 [JSRBOB1     400.00] CKT 1
 SINGLE 460070-460151(A)         : OPEN LINE FROM BUS 460070 [JPANC211    400.00] TO BUS 460151 [JBGD2012    400.00] CKT A
 SINGLE 460070-460151(A)         : OPEN LINE FROM BUS 460070 [JPANC211    400.00] TO BUS 460151 [JBGD2012    400.00] CKT A
 SINGLE 460070-460151(A)         : OPEN LINE FROM BUS 460070 [JPANC211    400.00] TO BUS 460151 [JBGD2012    400.00] CKT A
 SINGLE 460090-460095(1)         : OPEN LINE FROM BUS 460090 [JRPMLA12    400.00] TO BUS 460095 [JSMIT211    400.00] CKT 1
 SINGLE 460090-460095(1)         : OPEN LINE FROM BUS 460090 [JRPMLA12    400.00] TO BUS 460095 [JSMIT211    400.00] CKT 1
 SINGLE 462180-462940(1)         : OPEN LINE FROM BUS 462180 [JBGD335     110.00] TO BUS 462940 [JPANC152    110.00] CKT 1
 SINGLE 462875-463355(1)         : OPEN LINE FROM BUS 462875 [JNSAD451    110.00] TO BUS 463355 [JTTNSA51    110.00] CKT 1
 SINGLE 462940-462960(2)         : OPEN LINE FROM BUS 462940 [JPANC152    110.00] TO BUS 462960 [JPANC451    110.00] CKT 2
 SINGLE 462945-462960(1)         : OPEN LINE FROM BUS 462945 [JPANC251    110.00] TO BUS 462960 [JPANC451    110.00] CKT 1
 SINGLE 461145-463095-465265(1)  : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463095 [JSABA351    110.00] TO BUS
465265 [JSABA3_1    10.000] CKT 1
 SINGLE 461145-463100-465270(2)  : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463100 [JSABA352    110.00] TO BUS
465270 [JSABA3_2    10.000] CKT 2
 SINGLE 461195-463390-465306(3)  : OPEN LINE FROM BUS 461195 [JVALJ321    220.00] TO BUS 463390 [JVALJ351    110.00] TO BUS
465306 [JVALJ3_3    10.000] CKT 3
```

Figure 8.9: Contingency (n-1) analysis report for Highest wind+solar generation regime 2025 (referent RES, referent CO2)

```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW      %
 460090*JRPMLA12    400.00 460095 JSMIT211    400.00 1  BASE CASE                        1205.5   1272.6    104.3
 462170 JBGD3 52    110.00 462935*JPANC151    110.00 1  BASE CASE                          78.1    105.4    123.9
 462180 JBGD335     110.00 462940*JPANC152    110.00 1  BASE CASE                          78.1     93.3    110.0
 462480*JHZVOR51    110.00  13533 XZV_BI51    110.00 1  BASE CASE                         106.7    109.8    100.3
 462710 JLESNI5     110.00 463100*JSABA352    110.00 1  BASE CASE                          78.1     90.3    109.0
 462915 JOSECI5     110.00 463395*JVALJ352    110.00 2  BASE CASE                          78.1    103.8    124.9
 462940 JPANC152    110.00 462960*JPANC451    110.00 2  BASE CASE                          78.1     95.9    112.4
 462945*JPANC251    110.00 462960 JPANC451    110.00 1  BASE CASE                         106.7    115.5    100.9
 462165 JBGD3 51    110.00 462180*JBGD335     110.00 1  BASE CASE                          78.1     82.9    100.7
 462935 JPANC151    110.00 462950*JPANC252    110.00 2  BASE CASE                         106.7    112.7    100.7
 462721*JRTINT51    110.00 463390 JVALJ351    110.00 1  BASE CASE                          78.1     68.9     88.5
 460070*JPANC211    400.00 460151 JBGD2012    400.00 A  BASE CASE                         935.3    801.5     86.4
 461215*JZREN221    220.00 461230 JWKOVA21    220.00 1  BASE CASE                         274.4    254.2     92.4
 462640 JKRUPA5     110.00 462915*JOSECI5     110.00 1  SINGLE 131380-13533(1)             78.1     83.9    105.3
 462710*JLESNI5     110.00  13531 XBI_LE51    110.00 1  SINGLE 131380-13533(1)            106.7    109.2    100.0
 461030*JBGD3 22    220.00 461115 JOBREN22    220.00 1  SINGLE 460005-460060(1)           274.4    351.3    125.0
 462135*JBGD2 52    110.00 462145 JBGD2251    110.00 PP SINGLE 460005-460060(1)            78.1    101.1    121.9
 462170*JBGD3 52    110.00 462185 JBGD355     110.00 1  SINGLE 460005-460060(1)           106.7    120.2    106.1
 462070*JBGD1 5     110.00 463530 JBGD2051    110.00 1  SINGLE 460005-460150(A)           106.7    117.9    103.0
 462070*JBGD1 5     110.00 463531 JBGD2052    110.00 2  SINGLE 460005-460150(A)           106.7    117.9    103.0
 462070 JBGD1 5     110.00 464021*JBGD4752    110.00 1  SINGLE 460005-460150(A)           142.9    163.3    107.0
 462870*JNSAD352    110.00 463225 JSRBOB51    110.00 1  SINGLE 460050-460165(1)            78.1    108.7    128.8
 461000*JBBAST21    220.00  38201 XPL_BB21    220.00 1  SINGLE 460090-460095(1)           274.4    291.3    100.7
 461120 JOBREN23    220.00 461145*JSABA321    220.00 1  SINGLE 460090-460095(1)           331.5    345.3    104.7
 461130*JPOZEG21    220.00  13231 XVI_VA21    220.00 1  SINGLE 460090-460095(1)           274.4    315.1    111.7
 461145*JSABA321    220.00 3WNDTR T1           WND 1 1  SINGLE 460090-460095(1)           150.0    181.3    121.4
 461145*JSABA321    220.00 3WNDTR T2           WND 1 2  SINGLE 460090-460095(1)           150.0    164.1    109.9
 462575 JKOLUB52    110.00 463285*JTAMNZ5     110.00 1  SINGLE 460090-460095(1)            78.1     86.9    106.9
 462640 JKRUPA5     110.00 462915*JOSECI5     110.00 1  SINGLE 460090-460095(1)            78.1     80.3    104.6
 462710*JLESNI5     110.00  13531 XBI_LE51    110.00 1  SINGLE 460090-460095(1)           106.7    114.5    108.3
 462985 JPECIN5     110.00 463095*JSABA351    110.00 1  SINGLE 460090-460095(1)            56.6     69.7    118.8
 460151*JBGD2012    400.00 3WNDTR T2           WND 1 2  SINGLE 460150-460151(1C)          300.0    313.1    105.9
 462575 JKOLUB52    110.00 463285*JTAMNZ5     110.00 1  SINGLE 461115-461195(1)            78.1     84.1    103.0
 462070*JBGD1 5     110.00 463531 JBGD2052    110.00 2  SINGLE 462070-463530(1)           106.7    157.4    137.2
 462070*JBGD1 5     110.00 463530 JBGD2051    110.00 1  SINGLE 462070-463531(2)           106.7    157.4    137.2
 462835 JNPAZO5     110.00 462980*JPAZOV5     110.00 1  SINGLE 462210-463690(2)           106.7    109.9    100.3
 462980*JPAZOV5     110.00 463690 JKRNJE5     110.00 2  SINGLE 462230-462835(2)           106.7    110.8    102.9
 462365 JEBRGU5     110.00 462575*JKOLUB52    110.00 1  SINGLE 462570-462575(1C)           78.1     84.0    101.9
 462365*JEBRGU5     110.00 464200 JTKOLB51    110.00 2  SINGLE 462570-462575(1C)           78.1     86.7    103.6
 463330 JTKSTA51    110.00 463910*JWKOST51    110.00 1  SINGLE 463705-463925(1)           106.7    114.6    102.7
 461145*JSABA321    220.00 3WNDTR T2           WND 1 2  SINGLE 461145-463095-465265(1)     150.0    177.0    115.9
 461145*JSABA321    220.00 3WNDTR T1           WND 1 1  SINGLE 461145-463100-465270(2)     150.0    183.2    120.0
 462640 JKRUPA5     110.00 462915*JOSECI5     110.00 1  SINGLE 462480-13533(1)             78.1     83.9    105.3
 462710*JLESNI5     110.00  13531 XBI_LE51    110.00 1  SINGLE 462480-13533(1)            106.7    109.2    100.0

 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 131380-13533(1)          : OPEN LINE FROM BUS 131380 [WZVORN5     110.00] TO BUS 13533 [XZV_BI51    110.00] CKT 1
 SINGLE 460005-460060(1)         : OPEN LINE FROM BUS 460005 [JBGD8 12    400.00] TO BUS 460060 [JOBREN11    400.00] CKT 1
 SINGLE 460005-460150(A)         : OPEN LINE FROM BUS 460005 [JBGD8 12    400.00] TO BUS 460150 [JBGD2011    400.00] CKT A
 SINGLE 460050-460165(1)         : OPEN LINE FROM BUS 460050 [JNSAD311    400.00] TO BUS 460165 [JSRBOB1     400.00] CKT 1
 SINGLE 460090-460095(1)         : OPEN LINE FROM BUS 460090 [JRPMLA12    400.00] TO BUS 460095 [JSMIT211    400.00] CKT 1
 SINGLE 460150-460151(1C)        : OPEN LINE FROM BUS 460150 [JBGD2011    400.00] TO BUS 460151 [JBGD2012    400.00] CKT 1C
 SINGLE 461115-461195(1)         : OPEN LINE FROM BUS 461115 [JOBREN22    220.00] TO BUS 461195 [JVALJ321    220.00] CKT 1
 SINGLE 462070-463530(1)         : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463530 [JBGD2051    110.00] CKT 1
 SINGLE 462070-463531(2)         : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463531 [JBGD2052    110.00] CKT 2
 SINGLE 462210-463690(2)         : OPEN LINE FROM BUS 462210 [JBGD5 52    110.00] TO BUS 463690 [JKRNJE5     110.00] CKT 2
 SINGLE 462230-462835(2)         : OPEN LINE FROM BUS 462230 [JBGD9 51    110.00] TO BUS 462835 [JNPAZO5     110.00] CKT 2
 SINGLE 462570-462575(1C)        : OPEN LINE FROM BUS 462570 [JKOLUB51    110.00] TO BUS 462575 [JKOLUB52    110.00] CKT 1C
 SINGLE 463705-463925(1)         : OPEN LINE FROM BUS 463705 [JNERES5     110.00] TO BUS 463925 [JWKRIV51    110.00] CKT 1
 SINGLE 461145-463095-465265(1)  : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463095 [JSABA351    110.00] TO BUS
465265 [JSABA3_1    10.000] CKT 1
 SINGLE 461145-463100-465270(2)  : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463100 [JSABA352    110.00] TO BUS
465270 [JSABA3_2    10.000] CKT 2
 SINGLE 462480-13533(1)          : OPEN LINE FROM BUS 462480 [JHZVOR51    110.00] TO BUS 13533 [XZV_BI51    110.00] CKT 1
```

Figure 8.10: Contingency (n-1) analysis report for Summer regime with the highest generation 2025 (referent RES, referent CO2)

```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW       %
 462870*JNSAD352    110.00 463225 JSRBOB51    110.00 1  SINGLE 460050-460165(1)            110.5    128.7    107.5
 462170 JBGD3 52    110.00 462935*JPANC151    110.00 1  SINGLE 460070-460151(A)            110.5    128.5    107.5
 462915*JOSECI5     110.00 463395 JVALJ352    110.00 2  SINGLE 460090-460095(1)            110.5    117.1    101.3
 462900*JNSAD95     110.00 463355 JTTNSA51    110.00 1  SINGLE 462875-463355(1)            150.5    168.1    102.4
 461145*JSABA321    220.00 3WNDTR T1           WND 1 1  SINGLE 460090-460095(1)            150.0    165.7    109.4
 461145*JSABA321    220.00 3WNDTR T2           WND 1 2  SINGLE 461145-463095-465265(1)     150.0    170.3    110.6
 461145*JSABA321    220.00 3WNDTR T1           WND 1 1  SINGLE 461145-463100-465270(2)     150.0    175.9    114.3
 461195*JVALJ321    220.00 3WNDTR T2           WND 1 2  SINGLE 461195-463390-465306(3)     150.0    167.0    107.3

 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

   CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 460050-460165(1)          : OPEN LINE FROM BUS 460050 [JNSAD311    400.00] TO BUS 460165 [JSRBOB1     400.00] CKT 1
 SINGLE 460070-460151(A)          : OPEN LINE FROM BUS 460070 [JPANC211    400.00] TO BUS 460151 [JBGD2012    400.00] CKT A
 SINGLE 460090-460095(1)          : OPEN LINE FROM BUS 460090 [JRPMLA12    400.00] TO BUS 460095 [JSMIT211    400.00] CKT 1
 SINGLE 460090-460095(1)          : OPEN LINE FROM BUS 460090 [JRPMLA12    400.00] TO BUS 460095 [JSMIT211    400.00] CKT 1
 SINGLE 462875-463355(1)          : OPEN LINE FROM BUS 462875 [JNSAD451    110.00] TO BUS 463355 [JTTNSA51    110.00] CKT 1
 SINGLE 461145-463095-465265(1)   : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463095 [JSABA351    110.00] TO BUS
465265 [JSABA3_1    10.000] CKT 1
 SINGLE 461145-463100-465270(2)   : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463100 [JSABA352    110.00] TO BUS
465270 [JSABA3_2    10.000] CKT 2
 SINGLE 461195-463390-465306(3)   : OPEN LINE FROM BUS 461195 [JVALJ321    220.00] TO BUS 463390 [JVALJ351    110.00] TO BUS
465306 [JVALJ3_3    10.000] CKT 3
```

Figure 8.11: Contingency (n-1) analysis report for Highest export regime 2025 (referent RES, referent CO2)

```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW       %
 460010*JBOR 21     400.00 3WNDTR T3           WND 1 3  SINGLE 460010-462260(2)            300.0    329.8    109.5
 460010*JBOR 21     400.00 462260 JBOR2 52    110.00 2  SINGLE 460010-462255-465400(3)     300.0    330.7    109.8
 460015*JHDJE111    400.00  44101 XPF_DJ11    400.00 1  SINGLE 448004-448018(1)            900.7    913.5    100.5

 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 460010-462260(2)         : OPEN LINE FROM BUS 460010 [JBOR 21     400.00] TO BUS 462260 [JBOR2 52    110.00] CKT 2
 SINGLE 460010-462255-465400(3)  : OPEN LINE FROM BUS 460010 [JBOR 21     400.00] TO BUS 462255 [JBOR2 51     110.00] TO BUS
465400 [JBOR2 _2    10.000] CKT 3
 SINGLE 448004-448018(1)         : OPEN LINE FROM BUS 448004 [RP.D.F1     400.00] TO BUS 448018 [RRESIT1     400.00] CKT 1
```

Figure 8.12: Contingency (n-1) analysis report for Highest import regime 2025 (referent RES, referent CO2)

8.1.2 2025- highRES

Figure 8.13: Cross-border exhanges (MW) and directions between the countries for Winter Peak regime 2025 (high RES, referent CO2)

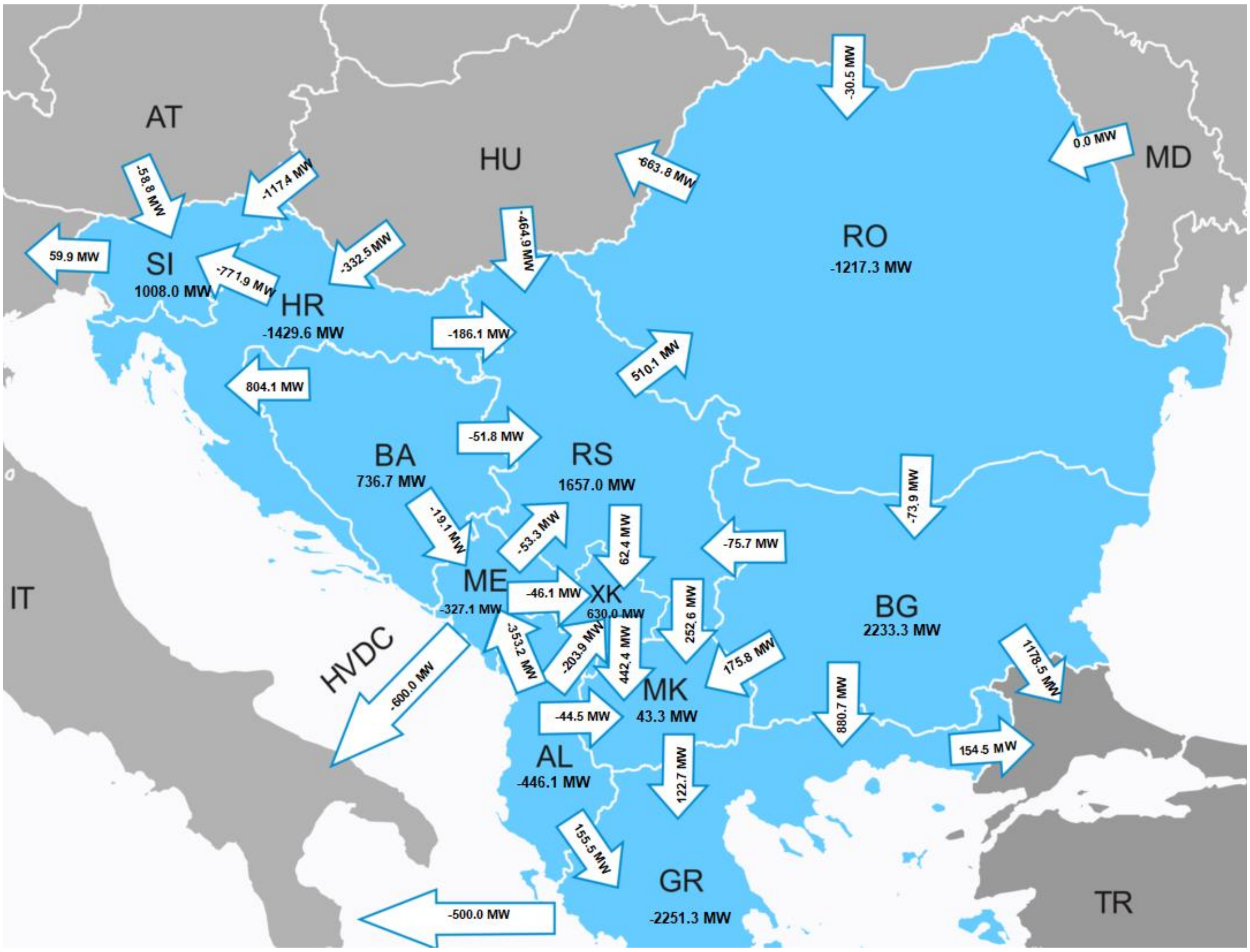

Figure 8.14: Cross-border exhanges (MW) and directions between the countries for Summer Off-Peak regime 2025 (high RES, referent CO2)

Figure 8.15: Cross-border exhanges (MW) and directions between the countries for Highest wind+solar generation regime 2025 (high RES, referent CO2)

Figure 8.16: Cross-border exhanges (MW) and directions between the countries for Summer regime with the highest generation 2025 (high RES, referent CO2)

Figure 8.17: Cross-border exhanges (MW) and directions between the countries for Highest export regime 2025 (high RES, referent CO2)

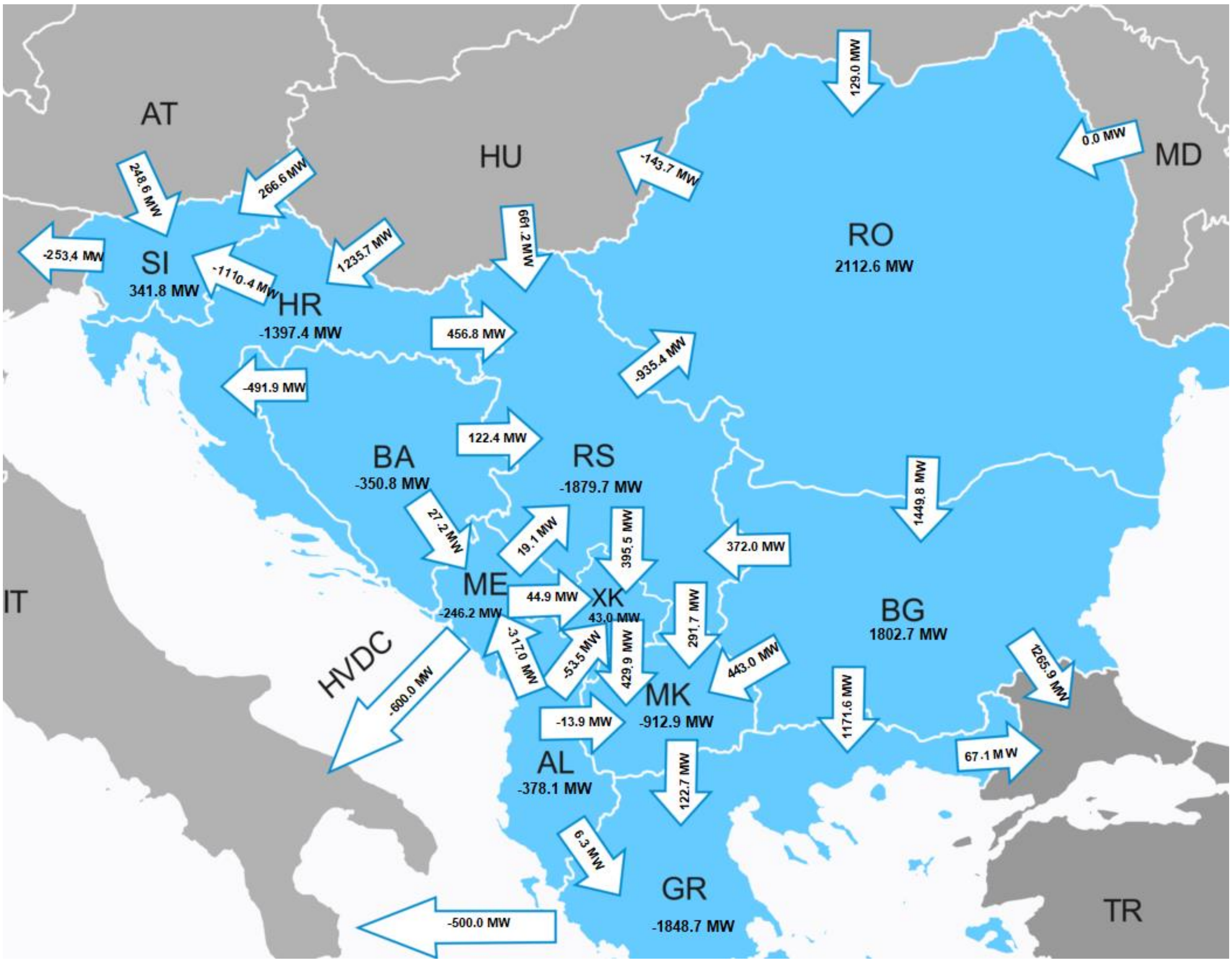

Figure 8.18: Cross-border exhanges (MW) and directions between the countries for Highest import regime 2025 (high RES, referent CO2)

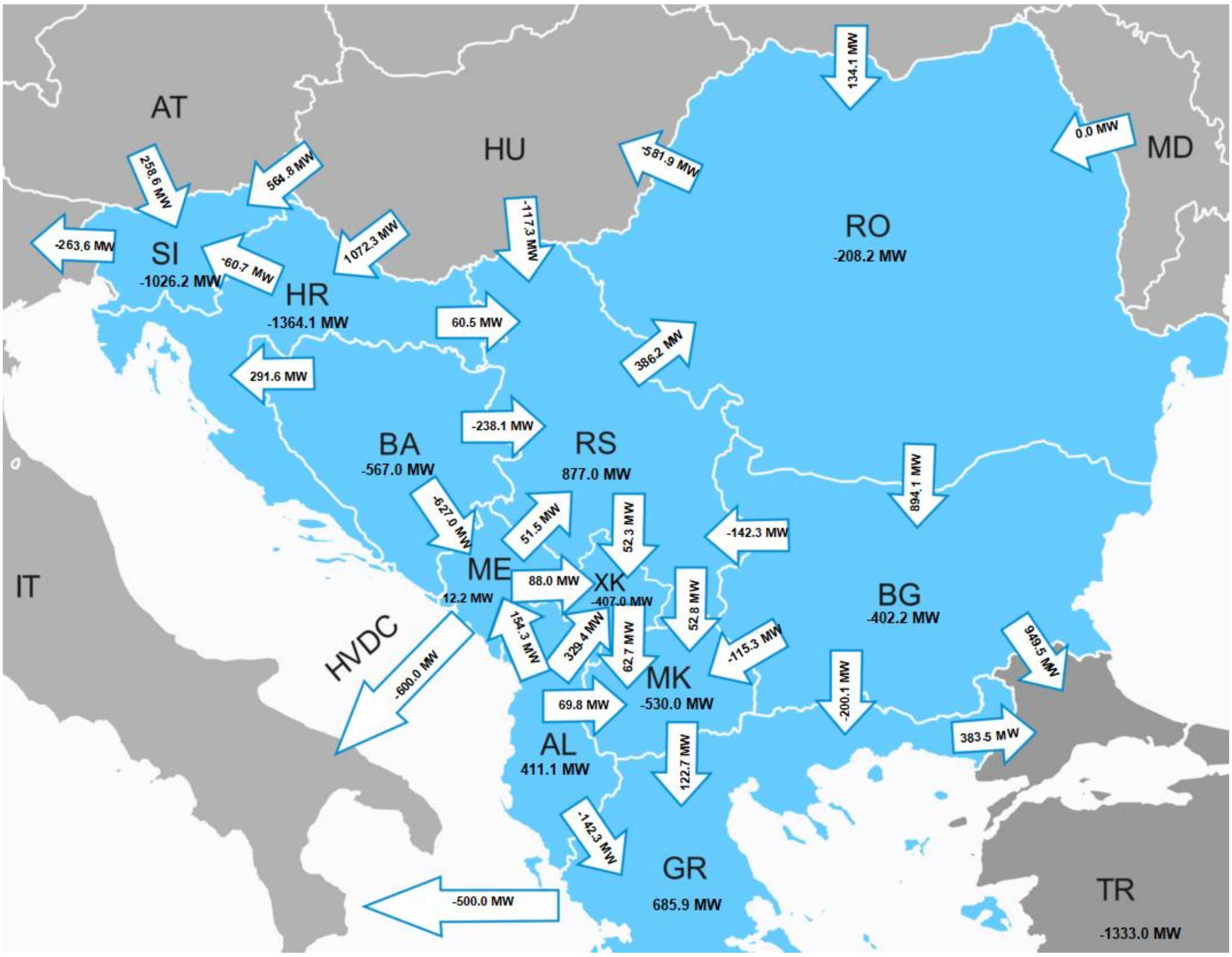

Figure 8.19: Cross-border exhanges (MW) and directions between the countries for Summer regime with the highest generation 2025 (high RES, high CO2)

```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING    FLOW       %
 460090*JRPMLA12    400.00 460095 JSMIT211    400.00 1  BASE CASE                        1330.2   1475.7    109.0
 460026*JJAGO412    400.00 3WNDTR T2           WND 1 2  SINGLE 460025-460026(1C)          300.0    314.9    103.0
 460065*JOBREN12    400.00 460090 JRPMLA12    400.00 1  SINGLE 460060-460085(2)          1330.2   1431.1    105.8
 460060*JOBREN11    400.00 460085 JRPMLA11    400.00 2  SINGLE 460065-460090(1)          1330.2   1431.6    105.8
 460065*JOBREN12    400.00 460090 JRPMLA12    400.00 1  SINGLE 460085-460090(1C)         1330.2   1394.8    103.1
 460085*JRPMLA11    400.00 460090 JRPMLA12    400.00 1C SINGLE 460065-460090(1)          1330.2   1431.3    105.7
 460151*JBGD2012    400.00 3WNDTR T2           WND 1 2  SINGLE 460150-460151(1C)          300.0    338.9    113.4
 461145*JSABA321    220.00 3WNDTR T1           WND 1 1  SINGLE 460090-460095(1)           150.0    215.4    147.3
 461145*JSABA321    220.00 3WNDTR T2           WND 1 2  SINGLE 460090-460095(1)           150.0    194.9    133.4
 461145*JSABA321    220.00 3WNDTR T2           WND 1 2  SINGLE 461145-463095-465265(1)    150.0    207.5    137.1
 461145*JSABA321    220.00 3WNDTR T1           WND 1 1  SINGLE 461145-463100-465270(2)    150.0    214.3    141.7
 461195*JVALJ321    220.00 3WNDTR T2           WND 1 2  SINGLE 461195-463390-465306(3)    150.0    178.0    115.6
 461215*JZREN221    220.00 3WNDTR T2           WND 1 2  SINGLE 461215-463495-465315(1)    200.0    211.8    106.7
 462870*JNSAD352    110.00 463225 JSRBOB51    110.00 1  SINGLE 460050-460165(1)           110.5    215.5    183.6
 462870*JNSAD352    110.00 463225 JSRBOB51    110.00 1  SINGLE 460090-460095(1)           110.5    127.7    110.6
 462870*JNSAD352    110.00 463225 JSRBOB51    110.00 1  SINGLE 460105-460165(1)           110.5    148.4    126.0
 462900*JNSAD95     110.00 463355 JTTNSA51    110.00 1  SINGLE 462875-463355(1)           150.5    170.4    104.9
 462070 JBGD1 5     110.00 464021*JBGD4752    110.00 1  SINGLE 461010-461045(1)           142.9    153.0    100.6
 462070 JBGD1 5     110.00 463531*JBGD2052    110.00 2  SINGLE 462070-463530(1)           150.5    190.1    115.9
 462070 JBGD1 5     110.00 463530*JBGD2051    110.00 1  SINGLE 462070-463531(2)           150.5    190.1    115.9
 462070*JBGD1 5     110.00 464021 JBGD4752    110.00 1  SINGLE 460005-460150(A)           142.9    164.4    106.0
 462170 JBGD3 52    110.00 462935*JPANC151    110.00 1  SINGLE 460070-460151(A)           110.5    146.7    122.8
 462180 JBGD335     110.00 462940*JPANC152    110.00 1  SINGLE 460070-460151(A)           110.5    128.3    107.7
 462940 JPANC152    110.00 462960*JPANC451    110.00 2  SINGLE 460070-460151(A)           110.5    132.0    110.2
 462285 JBTOP25     110.00 463225*JSRBOB51    110.00 1  SINGLE 460105-460165(1)           110.5    125.3    109.3
 462325 JCRVEN5     110.00 462665*JKULA 5     110.00 1  SINGLE 460105-460165(1)           110.5    114.3    101.2
 462915*JOSECI5     110.00 463395 JVALJ352    110.00 2  SINGLE 462721-463390(1)           110.5    130.6    114.0
 462915 JOSECI5     110.00 463395*JVALJ352    110.00 2  SINGLE 460090-460095(1)           110.5    167.1    141.0
 462710 JLESNI5     110.00 463100*JSABA352    110.00 1  SINGLE 460090-460095(1)           110.5    120.5    103.4
 462721 JRTINT51    110.00 463390*JVALJ351    110.00 1  SINGLE 460090-460095(1)           110.5    121.8    102.8
 462985 JPECIN5     110.00 463095*JSABA351    110.00 1  SINGLE 460090-460095(1)            70.3     89.7    121.0
 462825 JNPAZ151    110.00 462830*JNPAZ25     110.00 1  SINGLE 471000-38101(1)            110.5    117.1    103.7
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  SINGLE 471000-38101(1)            110.5    119.2    109.3
 462825 JNPAZ151    110.00 462830*JNPAZ25     110.00 1  SINGLE 381070-38101(1)            110.5    116.9    103.5
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  SINGLE 381070-38101(1)            110.5    119.2    109.2
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  SINGLE 460026-460045(1)           110.5    109.2    100.0


 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 381070-38101(1)          : OPEN LINE FROM BUS 381070 [ORIBAR11    400.00] TO BUS 38101 [XRI_PE11    400.00] CKT 1
 SINGLE 460005-460150(A)         : OPEN LINE FROM BUS 460005 [JBGD8 12    400.00] TO BUS 460150 [JBGD2011    400.00] CKT A
 SINGLE 460025-460026(1C)        : OPEN LINE FROM BUS 460025 [JJAGO411    400.00] TO BUS 460026 [JJAGO412    400.00] CKT 1C
 SINGLE 460026-460045(1)         : OPEN LINE FROM BUS 460026 [JJAGO412    400.00] TO BUS 460045 [JNIS2 12    400.00] CKT 1
 SINGLE 460050-460165(1)         : OPEN LINE FROM BUS 460050 [JNSAD311    400.00] TO BUS 460165 [JSRBOB1     400.00] CKT 1
 SINGLE 460060-460085(2)         : OPEN LINE FROM BUS 460060 [JOBREN11    400.00] TO BUS 460085 [JRPMLA11    400.00] CKT 2
 SINGLE 460065-460090(1)         : OPEN LINE FROM BUS 460065 [JOBREN12    400.00] TO BUS 460090 [JRPMLA12    400.00] CKT 1
 SINGLE 460070-460151(A)         : OPEN LINE FROM BUS 460070 [JPANC211    400.00] TO BUS 460151 [JBGD2012    400.00] CKT A
 SINGLE 460085-460090(1C)        : OPEN LINE FROM BUS 460085 [JRPMLA11    400.00] TO BUS 460090 [JRPMLA12    400.00] CKT 1C
 SINGLE 460090-460095(1)         : OPEN LINE FROM BUS 460090 [JRPMLA12    400.00] TO BUS 460095 [JSMIT211    400.00] CKT 1
 SINGLE 460105-460165(1)         : OPEN LINE FROM BUS 460105 [JSUBO311    400.00] TO BUS 460165 [JSRBOB1     400.00] CKT 1
 SINGLE 460150-460151(1C)        : OPEN LINE FROM BUS 460150 [JBGD2011    400.00] TO BUS 460151 [JBGD2012    400.00] CKT 1C
 SINGLE 461010-461045(1)         : OPEN LINE FROM BUS 461010 [JBGD1721    220.00] TO BUS 461045 [JBGD8 21    220.00] CKT 1
 SINGLE 462070-463530(1)         : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463530 [JBGD2051    110.00] CKT 1
 SINGLE 462070-463531(2)         : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463531 [JBGD2052    110.00] CKT 2
 SINGLE 462721-463390(1)         : OPEN LINE FROM BUS 462721 [JRTINT51    110.00] TO BUS 463390 [JVALJ351    110.00] CKT 1
 SINGLE 462875-463355(1)         : OPEN LINE FROM BUS 462875 [JNSAD451    110.00] TO BUS 463355 [JTTNSA51    110.00] CKT 1
 SINGLE 461145-463095-465265(1)  : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463095 [JSABA351    110.00] TO BUS
465265 [JSABA3_1    10.000] CKT 1
 SINGLE 461145-463100-465270(2)  : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463100 [JSABA352    110.00] TO BUS
465270 [JSABA3_2    10.000] CKT 2
 SINGLE 461195-463390-465306(3)  : OPEN LINE FROM BUS 461195 [JVALJ321    220.00] TO BUS 463390 [JVALJ351    110.00] TO BUS
465306 [JVALJ3_3    10.000] CKT 3
 SINGLE 461215-463495-465315(1)  : OPEN LINE FROM BUS 461215 [JZREN221    220.00] TO BUS 463495 [JZREN251    110.00] TO BUS
465315 [JZREN2_1    10.000] CKT 1
 SINGLE 471000-38101(1)          : OPEN LINE FROM BUS 471000 [_PEJA31     400.00] TO BUS 38101 [XRI_PE11    400.00] CKT 1
```

Figure 8.20: Contingency (n-1) analysis report for Winter Peak regime 2025 (high RES, referent CO2)

```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING    FLOW       %

LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)
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Figure 8.21: Contingency (n-1) analysis report for Summer Off-Peak regime 2025 (high RES, referent CO2)

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<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW       %
 462165 JBGD3 51    110.00 462180*JBGD335     110.00 1  BASE CASE                          110.5    119.3    101.0
 462170 JBGD3 52    110.00 462935*JPANC151    110.00 1  BASE CASE                          110.5    146.9    124.7
 462180 JBGD335     110.00 462940*JPANC152    110.00 1  BASE CASE                          110.5    132.0    112.0
 462940 JPANC152    110.00 462960*JPANC451    110.00 2  BASE CASE                          110.5    134.6    114.3
 462935 JPANC151    110.00 462950*JPANC252    110.00 2  BASE CASE                          150.5    156.0    100.0
 460151*JBGD2012    400.00 3WNDTR T2           WND 1 2  SINGLE 460150-460151(1C)           300.0    374.5    126.2
 460070*JPANC211    400.00 460151 JBGD2012    400.00 A  SINGLE 460160-460504(1)           1315.7   1367.4    104.6
 461030*JBGD3 22    220.00 461115 JOBREN22    220.00 1  SINGLE 460005-460060(1)            388.7    566.7    144.0
 461195*JVALJ321    220.00 3WNDTR T2           WND 1 2  SINGLE 461195-463390-465306(3)     150.0    155.7    100.6
 462070*JBGD1 5     110.00 464021 JBGD4752    110.00 1  SINGLE 460005-460060(1)            142.9    162.7    105.5
 462135*JBGD2 52    110.00 462145 JBGD2251    110.00 PP SINGLE 460005-460060(1)            110.5    132.5    112.6
 462070*JBGD1 5     110.00 464021 JBGD4752    110.00 1  SINGLE 460005-460150(A)            142.9    198.8    128.2
 464015 JBGD455     110.00 464020*JBGD4751    110.00 1  SINGLE 460005-460150(A)            142.9    161.2    104.0
 462990 JPETRO51    110.00 463705*JNERES5     110.00 1  SINGLE 462430-463070(1)            110.5    120.0    104.9
 462990 JPETRO51    110.00 463705*JNERES5     110.00 1  SINGLE 463330-463910(1)            110.5    136.1    119.2
 462900*JNSAD95     110.00 463355 JTTNSA51    110.00 1  SINGLE 462875-463355(1)            150.5    164.1    100.2
 463705 JNERES5     110.00 463925*JWKRIV51    110.00 1  SINGLE 463330-463910(1)            150.5    168.9    108.8
 462430*JGRADI5     110.00 463070 JRUDN35     110.00 1  SINGLE 463705-463925(1)            150.5    155.1    100.3
 463330 JTKSTA51    110.00 463910*JWKOST51    110.00 1  SINGLE 463705-463925(1)            150.5    197.8    126.0
 463330 JTKSTA51    110.00 463910*JWKOST51    110.00 1  SINGLE 462990-462995(1C)           150.5    169.9    107.7
 463330 JTKSTA51    110.00 463910*JWKOST51    110.00 1  SINGLE 462990-463705(1)            150.5    166.2    105.6
 462915*JOSECI5     110.00 463395 JVALJ352    110.00 2  SINGLE 460090-460095(1)            110.5    125.0    110.8
 462915*JOSECI5     110.00 463395 JVALJ352    110.00 2  SINGLE 462721-463390(1)            110.5    122.3    108.1


 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

  CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 460150-460151(1C)        : OPEN LINE FROM BUS 460150 [JBGD2011    400.00] TO BUS 460151 [JBGD2012    400.00] CKT 1C
 SINGLE 460005-460060(1)         : OPEN LINE FROM BUS 460005 [JBGD8 12    400.00] TO BUS 460060 [JOBREN11    400.00] CKT 1
 SINGLE 461195-463390-465306(3)  : OPEN LINE FROM BUS 461195 [JVALJ321    220.00] TO BUS 463390 [JVALJ351    110.00] TO BUS
465306 [JVALJ3_3    10.000] CKT 3
 SINGLE 462430-463070(1)         : OPEN LINE FROM BUS 462430 [JGRADI5     110.00] TO BUS 463070 [JRUDN35     110.00] CKT 1
 SINGLE 463330-463910(1)         : OPEN LINE FROM BUS 463330 [JTKSTA51    110.00] TO BUS 463910 [JWKOST51    110.00] CKT 1
 SINGLE 462875-463355(1)         : OPEN LINE FROM BUS 462875 [JNSAD451    110.00] TO BUS 463355 [JTTNSA51    110.00] CKT 1
 SINGLE 462990-462995(1C)        : OPEN LINE FROM BUS 462990 [JPETRO51    110.00] TO BUS 462995 [JPETRO52    110.00] CKT 1C
 SINGLE 462990-463705(1)         : OPEN LINE FROM BUS 462990 [JPETRO51    110.00] TO BUS 463705 [JNERES5     110.00] CKT 1
 SINGLE 460090-460095(1)         : OPEN LINE FROM BUS 460090 [JRPMLA12    400.00] TO BUS 460095 [JSMIT211    400.00] CKT 1
 SINGLE 462721-463390(1)         : OPEN LINE FROM BUS 462721 [JRTINT51    110.00] TO BUS 463390 [JVALJ351    110.00] CKT 1
 SINGLE 460160-460504(1)         : OPEN LINE FROM BUS 460160 [JSMED31     400.00] TO BUS 460504 [JWPPZ5-1    400.00] CKT 1
```

Figure 8.22: Contingency (n-1) analysis report for Highest wind+solar generation regime 2025 (high RES, referent CO2)

```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>  RATING     FLOW       %
 460070*JPANC211    400.00 460151 JBGD2012    400.00 A  BASE CASE                        935.3    918.7    100.3
 460090*JRPMLA12    400.00 460095 JSMIT211    400.00 1  BASE CASE                       1205.5   1409.1    115.9
 462165 JBGD3 51    110.00 462180*JBGD335     110.00 1  BASE CASE                         78.1    100.9    121.1
 462170 JBGD3 52    110.00 462935*JPANC151    110.00 1  BASE CASE                         78.1    124.7    147.5
 462180 JBGD335     110.00 462940*JPANC152    110.00 1  BASE CASE                         78.1    111.4    132.2
 462480*JHZVOR51    110.00  13533 XZV_BI51    110.00 1  BASE CASE                        106.7    116.0    107.1
 462710 JLESNI5     110.00 463100*JSABA352    110.00 1  BASE CASE                         78.1    102.2    124.4
 462915 JOSECI5     110.00 463395*JVALJ352    110.00 2  BASE CASE                         78.1    107.4    130.4
 462935 JPANC151    110.00 462950*JPANC252    110.00 2  BASE CASE                        106.7    132.0    114.0
 462940 JPANC152    110.00 462960*JPANC451    110.00 2  BASE CASE                         78.1    114.0    134.6
 463330 JTKSTA51    110.00 463910*JWKOST51    110.00 1  BASE CASE                        106.7    108.8    100.4
 462945*JPANC251    110.00 462960 JPANC451    110.00 1  BASE CASE                        106.7    107.6     92.8
 462575 JKOLUB52    110.00 463285*JTAMNZ5     110.00 1  BASE CASE                         78.1     77.6     95.2
 462721*JRTINT51    110.00 463390 JVALJ351    110.00 1  BASE CASE                         78.1     70.9     92.1
 462710*JLESNI5     110.00  13531 XBI_LE51    110.00 1  SINGLE 130130-13131(1)           106.7    107.4    100.6
 462640*JKRUPA5     110.00 462715 JLJUBO5     110.00 1  SINGLE 131380-13533(1)            78.1     80.6    104.0
 462640 JKRUPA5     110.00 462915*JOSECI5     110.00 1  SINGLE 131380-13533(1)            78.1     88.0    111.5
 462710*JLESNI5     110.00  13531 XBI_LE51    110.00 1  SINGLE 131380-13533(1)           106.7    118.3    109.2
 461030*JBGD3 22    220.00 461115 JOBREN22    220.00 1  SINGLE 460005-460060(1)          274.4    418.3    149.5
 461215*JZREN221    220.00 461230 JWKOVA21    220.00 1  SINGLE 460005-460060(1)          274.4    311.5    114.1
 462135*JBGD2 52    110.00 462145 JBGD2251    110.00 PP SINGLE 460005-460060(1)           78.1    112.4    136.3
 462170*JBGD3 52    110.00 462185 JBGD355     110.00 1  SINGLE 460005-460060(1)          106.7    131.1    116.4
 462170*JBGD3 52    110.00 462395 JERESN5     110.00 1  SINGLE 460005-460060(1)          106.7    114.3    101.5
 462185*JBGD355     110.00 462570 JKOLUB51    110.00 1  SINGLE 460005-460060(1)          106.7    112.1    100.1
 462395*JERESN5     110.00 462570 JKOLUB51    110.00 1  SINGLE 460005-460060(1)          106.7    113.4    100.8
 462070*JBGD1 5     110.00 463530 JBGD2051    110.00 1  SINGLE 460005-460150(A)          106.7    126.1    110.8
 462070*JBGD1 5     110.00 463531 JBGD2052    110.00 2  SINGLE 460005-460150(A)          106.7    126.1    110.8
 462070 JBGD1 5     110.00 464021*JBGD4752    110.00 1  SINGLE 460005-460150(A)          142.9    183.7    121.1
 462990 JPETRO51    110.00 463705*JNERES5     110.00 1  SINGLE 460010-460040(1)           78.1     81.1    101.9
 462995*JPETRO52    110.00 463335 JTMORA5     110.00 1  SINGLE 460010-460040(1)          106.7    110.1    100.9
 461125*JPANC22     220.00 461221 JRANIS22    220.00 1  SINGLE 460070-460151(A)          331.5    359.6    105.2
 461000*JBBAST21    220.00  38201 XPL_BB21    220.00 1  SINGLE 460090-460095(1)          274.4    306.2    107.4
 461120 JOBREN23    220.00 461145*JSABA321    220.00 1  SINGLE 460090-460095(1)          331.5    353.8    108.3
 461130*JPOZEG21    220.00  13231 XVI_VA21    220.00 1  SINGLE 460090-460095(1)          274.4    339.1    122.0
 461145*JSABA321    220.00 3WNDTR T1           WND 1 1  SINGLE 460090-460095(1)          150.0    185.7    125.6
 461145*JSABA321    220.00 3WNDTR T2           WND 1 2  SINGLE 460090-460095(1)          150.0    168.1    113.7
 462490 JINDJI5     110.00 463700*JINDJ25     110.00 1  SINGLE 460090-460095(1)          106.7    106.8    100.5
 462640*JKRUPA5     110.00 462715 JLJUBO5     110.00 1  SINGLE 460090-460095(1)           78.1     78.7    105.9
 462640 JKRUPA5     110.00 462915*JOSECI5     110.00 1  SINGLE 460090-460095(1)           78.1     84.9    112.9
 462710*JLESNI5     110.00  13531 XBI_LE51    110.00 1  SINGLE 460090-460095(1)          106.7    124.7    120.1
 462985 JPECIN5     110.00 463095*JSABA351    110.00 1  SINGLE 460090-460095(1)           56.6     71.3    123.2
 460151*JBGD2012    400.00 3WNDTR T2           WND 1 2  SINGLE 460150-460151(1C)         300.0    350.8    119.1
 461215*JZREN221    220.00 461230 JWKOVA21    220.00 1  SINGLE 461125-461221(1)          274.4    282.9    103.5
 461215*JZREN221    220.00 461230 JWKOVA21    220.00 1  SINGLE 461125-461235(1)          274.4    288.9    105.8
 461125 JPANC22     220.00 461235*JWVLAD21    220.00 1  SINGLE 461215-461230(1)          274.4    296.3    104.4
 461215*JZREN221    220.00 461230 JWKOVA21    220.00 1  SINGLE 461220-461250(1)          274.4    273.6    100.0
 462070*JBGD1 5     110.00 463531 JBGD2052    110.00 2  SINGLE 462070-463530(1)          106.7    160.9    141.0
 462070*JBGD1 5     110.00 463530 JBGD2051    110.00 1  SINGLE 462070-463531(2)          106.7    160.9    141.0
 462990 JPETRO51    110.00 463705*JNERES5     110.00 1  SINGLE 462430-463070(1)           78.1     92.5    115.4
 463705 JNERES5     110.00 463925*JWKRIV51    110.00 1  SINGLE 462430-463070(1)          106.7    119.3    108.7
 462365 JEBRGU5     110.00 462575*JKOLUB52    110.00 1  SINGLE 462570-462575(1C)          78.1     94.3    115.4
 462365*JEBRGU5     110.00 464200 JTKOLB51    110.00 2  SINGLE 462570-462575(1C)          78.1     97.3    117.0
 462990 JPETRO51    110.00 463705*JNERES5     110.00 1  SINGLE 463060-463070(1)           78.1     82.6    103.1
 462990 JPETRO51    110.00 463705*JNERES5     110.00 1  SINGLE 463330-463910(1)           78.1    104.4    130.3
 463705 JNERES5     110.00 463925*JWKRIV51    110.00 1  SINGLE 463330-463910(1)          106.7    136.1    124.2
 462430*JGRADI5     110.00 463070 JRUDN35     110.00 1  SINGLE 463705-463925(1)          106.7    128.7    117.8
 463060 JRUDN15     110.00 463070*JRUDN35     110.00 1  SINGLE 463705-463925(1)          106.7    110.4    100.9
 461145*JSABA321    220.00 3WNDTR T2           WND 1 2  SINGLE 461145-463095-465265(1)    150.0    173.2    113.9
 461145*JSABA321    220.00 3WNDTR T1           WND 1 1  SINGLE 461145-463100-465270(2)    150.0    179.2    117.9
 462710*JLESNI5     110.00  13531 XBI_LE51    110.00 1  SINGLE 460095-13131(1)           106.7    107.5    100.7
 462640*JKRUPA5     110.00 462715 JLJUBO5     110.00 1  SINGLE 462480-13533(1)            78.1     80.6    104.0
 462640 JKRUPA5     110.00 462915*JOSECI5     110.00 1  SINGLE 462480-13533(1)            78.1     88.0    111.5
 462710*JLESNI5     110.00  13531 XBI_LE51    110.00 1  SINGLE 462480-13533(1)           106.7    118.3    109.2

 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

  CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 130130-13131(1)         : OPEN LINE FROM BUS 130130 [WTUGLJ1     400.00] TO BUS 13131 [XUG_SM11    400.00] CKT 1
 SINGLE 131380-13533(1)         : OPEN LINE FROM BUS 131380 [WZVORN5     110.00] TO BUS 13533 [XZV_BI51    110.00] CKT 1
 SINGLE 460005-460060(1)         : OPEN LINE FROM BUS 460005 [JBGD8 12    400.00] TO BUS 460060 [JOBREN11    400.00] CKT 1
 SINGLE 460010-460040(1)         : OPEN LINE FROM BUS 460010 [JBOR 21     400.00] TO BUS 460040 [JNIS2 11    400.00] CKT 1
 SINGLE 460070-460151(A)         : OPEN LINE FROM BUS 460070 [JPANC211    400.00] TO BUS 460151 [JBGD2012    400.00] CKT A
 SINGLE 460090-460095(1)         : OPEN LINE FROM BUS 460090 [JRPMLA12    400.00] TO BUS 460095 [JSMIT211    400.00] CKT 1
 SINGLE 460150-460151(1C)         : OPEN LINE FROM BUS 460150 [JBGD2011    400.00] TO BUS 460151 [JBGD2012    400.00] CKT 1C
 SINGLE 461125-461221(1)         : OPEN LINE FROM BUS 461125 [JPANC22     220.00] TO BUS 461221 [JRANIS22    220.00] CKT 1
 SINGLE 461125-461235(1)         : OPEN LINE FROM BUS 461125 [JPANC22     220.00] TO BUS 461235 [JWVLAD21    220.00] CKT 1
 SINGLE 461215-461230(1)         : OPEN LINE FROM BUS 461215 [JZREN221    220.00] TO BUS 461230 [JWKOVA21    220.00] CKT 1
 SINGLE 461220-461250(1)         : OPEN LINE FROM BUS 461220 [JRANIS21    220.00] TO BUS 461250 [JTTPAN21    220.00] CKT 1
```

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 SINGLE 462070-463530(1)         : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463530 [JBGD2051    110.00] CKT 1
 SINGLE 462070-463531(2)         : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463531 [JBGD2052    110.00] CKT 2
 SINGLE 462430-463070(1)         : OPEN LINE FROM BUS 462430 [JGRADI5     110.00] TO BUS 463070 [JRUDN35     110.00] CKT 1
 SINGLE 462570-462575(1C)         : OPEN LINE FROM BUS 462570 [JKOLUB51    110.00] TO BUS 462575 [JKOLUB52    110.00] CKT 1C
 SINGLE 463060-463070(1)         : OPEN LINE FROM BUS 463060 [JRUDN15     110.00] TO BUS 463070 [JRUDN35     110.00] CKT 1
 SINGLE 463330-463910(1)         : OPEN LINE FROM BUS 463330 [JTKSTA51    110.00] TO BUS 463910 [JWKOST51    110.00] CKT 1
 SINGLE 463705-463925(1)         : OPEN LINE FROM BUS 463705 [JNERES5     110.00] TO BUS 463925 [JWKRIV51    110.00] CKT 1
 SINGLE 461145-463095-465265(1)         : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463095 [JSABA351    110.00]
TO BUS 465265 [JSABA3_1    10.000] CKT 1
 SINGLE 461145-463100-465270(2)         : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463100 [JSABA352    110.00]
TO BUS 465270 [JSABA3_2    10.000] CKT 2
 SINGLE 460095-13131(1)         : OPEN LINE FROM BUS 460095 [JSMIT211    400.00] TO BUS 13131 [XUG_SM11    400.00] CKT 1
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Figure 8.23: Contingency (n-1) analysis report for Summer regime with the highest generation 2025 (high RES, referent CO2)

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<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW       %
 461145*JSABA321    220.00 3WNDTR T1          WND 1 1  SINGLE 460090-460095(1)          150.0     162.4    107.4
 461145*JSABA321    220.00 3WNDTR T2          WND 1 2  SINGLE 461145-463095-465265(1)   150.0     163.9    106.6
 461145*JSABA321    220.00 3WNDTR T1          WND 1 1  SINGLE 461145-463100-465270(2)   150.0     169.3    110.2
 461195*JVALJ321    220.00 3WNDTR T2          WND 1 2  SINGLE 461195-463390-465306(3)   150.0     158.1    101.7
 462165 JBGD3 51    110.00 462180*JBGD335     110.00 1  SINGLE 460070-460151(A)         110.5     120.0    100.8
 462180 JBGD335     110.00 462940*JPANC152    110.00 1  SINGLE 460070-460151(A)         110.5     132.7    111.7
 462180 JBGD335     110.00 462940*JPANC152    110.00 1  SINGLE 460070-462945-465085(1)  110.5     117.0    100.3
 462170 JBGD3 52    110.00 462935*JPANC151    110.00 1  SINGLE 460070-460151(A)         110.5     149.2    125.7
 462170 JBGD3 52    110.00 462935*JPANC151    110.00 1  SINGLE 460150-460151(1C)        110.5     125.1    105.4
 462170 JBGD3 52    110.00 462935*JPANC151    110.00 1  SINGLE 462165-462180(1)         110.5     122.5    103.4
 462170 JBGD3 52    110.00 462935*JPANC151    110.00 1  SINGLE 462180-462940(1)         110.5     125.9    106.3
 462170 JBGD3 52    110.00 462935*JPANC151    110.00 1  SINGLE 462940-462960(2)         110.5     126.6    106.8
 462170 JBGD3 52    110.00 462935*JPANC151    110.00 1  SINGLE 462945-462960(1)         110.5     125.3    105.6
 462170 JBGD3 52    110.00 462935*JPANC151    110.00 1  SINGLE 460070-462945-465085(1)  110.5     119.0    101.4
 462170 JBGD3 52    110.00 462935*JPANC151    110.00 1  SINGLE 460070-462950-465090(2)  110.5     122.2    104.1
 462940 JPANC152    110.00 462960*JPANC451    110.00 2  SINGLE 460070-462945-465085(1)  110.5     118.5    102.3
 462940 JPANC152    110.00 462960*JPANC451    110.00 2  SINGLE 462935-462950(2)         110.5     118.9    100.5
 462940 JPANC152    110.00 462960*JPANC451    110.00 2  SINGLE 460070-460151(A)         110.5     135.3    114.1
 462915*JOSECI5     110.00 463395 JVALJ352    110.00 2  SINGLE 460090-460095(1)         110.5     116.5    100.9

 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 460070-460151(A)          : OPEN LINE FROM BUS 460070 [JPANC211    400.00] TO BUS 460151 [JBGD2012    400.00] CKT A
 SINGLE 460090-460095(1)          : OPEN LINE FROM BUS 460090 [JRPMLA12    400.00] TO BUS 460095 [JSMIT211    400.00] CKT 1
 SINGLE 460150-460151(1C)         : OPEN LINE FROM BUS 460150 [JBGD2011    400.00] TO BUS 460151 [JBGD2012    400.00] CKT 1C
 SINGLE 462165-462180(1)          : OPEN LINE FROM BUS 462165 [JBGD3 51    110.00] TO BUS 462180 [JBGD335     110.00] CKT 1
 SINGLE 462180-462940(1)          : OPEN LINE FROM BUS 462180 [JBGD335     110.00] TO BUS 462940 [JPANC152    110.00] CKT 1
 SINGLE 462935-462950(2)          : OPEN LINE FROM BUS 462935 [JPANC151    110.00] TO BUS 462950 [JPANC252    110.00] CKT 2
 SINGLE 462940-462960(2)          : OPEN LINE FROM BUS 462940 [JPANC152    110.00] TO BUS 462960 [JPANC451    110.00] CKT 2
 SINGLE 462945-462960(1)          : OPEN LINE FROM BUS 462945 [JPANC251    110.00] TO BUS 462960 [JPANC451    110.00] CKT 1
 SINGLE 460070-462945-465085(1)   : OPEN LINE FROM BUS 460070 [JPANC211    400.00] TO BUS 462945 [JPANC251    110.00] TO BUS
465085 [JPANC2_2    10.000] CKT 1
 SINGLE 460070-462950-465090(2)   : OPEN LINE FROM BUS 460070 [JPANC211    400.00] TO BUS 462950 [JPANC252    110.00] TO BUS
465090 [JPANC2_3    10.000] CKT 2
 SINGLE 461145-463095-465265(1)   : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463095 [JSABA351    110.00] TO BUS
465265 [JSABA3_1    10.000] CKT 1
 SINGLE 461145-463100-465270(2)   : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463100 [JSABA352    110.00] TO BUS
465270 [JSABA3_2    10.000] CKT 2
 SINGLE 461195-463390-465306(3)   : OPEN LINE FROM BUS 461195 [JVALJ321    220.00] TO BUS 463390 [JVALJ351    110.00] TO BUS
465306 [JVALJ3_3    10.000] CKT 3
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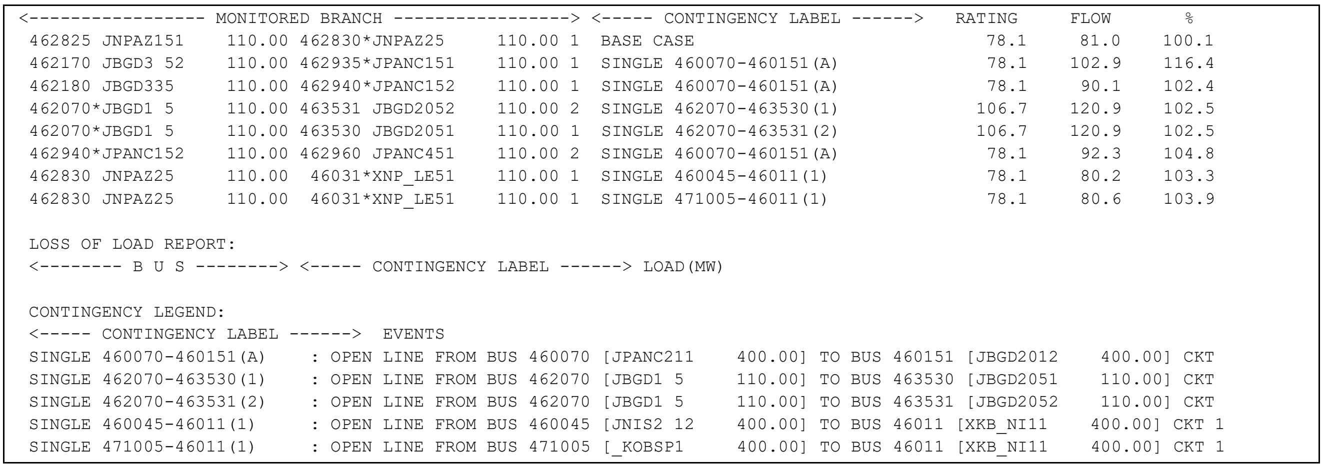
Figure 8.24: Contingency (n-1) analysis report for Highest export regime 2025 (high RES, referent CO2)



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<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW       %
 462825 JNPAZ151    110.00 462830*JNPAZ25     110.00 1  BASE CASE                           78.1      81.0    100.1
 462170 JBGD3 52    110.00 462935*JPANC151    110.00 1  SINGLE 460070-460151(A)             78.1     102.9    116.4
 462180 JBGD335     110.00 462940*JPANC152    110.00 1  SINGLE 460070-460151(A)             78.1      90.1    102.4
 462070*JBGD1 5     110.00 463531 JBGD2052    110.00 2  SINGLE 462070-463530(1)            106.7     120.9    102.5
 462070*JBGD1 5     110.00 463530 JBGD2051    110.00 1  SINGLE 462070-463531(2)            106.7     120.9    102.5
 462940*JPANC152    110.00 462960 JPANC451    110.00 2  SINGLE 460070-460151(A)             78.1      92.3    104.8
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  SINGLE 460045-46011(1)              78.1      80.2    103.3
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  SINGLE 471005-46011(1)              78.1      80.6    103.9

 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 460070-460151(A)     : OPEN LINE FROM BUS 460070 [JPANC211    400.00] TO BUS 460151 [JBGD2012    400.00] CKT
 SINGLE 462070-463530(1)     : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463530 [JBGD2051    110.00] CKT
 SINGLE 462070-463531(2)     : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463531 [JBGD2052    110.00] CKT
 SINGLE 460045-46011(1)      : OPEN LINE FROM BUS 460045 [JNIS2 12    400.00] TO BUS 46011 [XKB_NI11    400.00] CKT 1
 SINGLE 471005-46011(1)      : OPEN LINE FROM BUS 471005 [_KOBSP1     400.00] TO BUS 46011 [XKB_NI11    400.00] CKT 1
```

Figure 8.25: Contingency (n-1) analysis report for Highest import regime 2025 (high RES, referent CO2)

8.1.3 2030- refRES

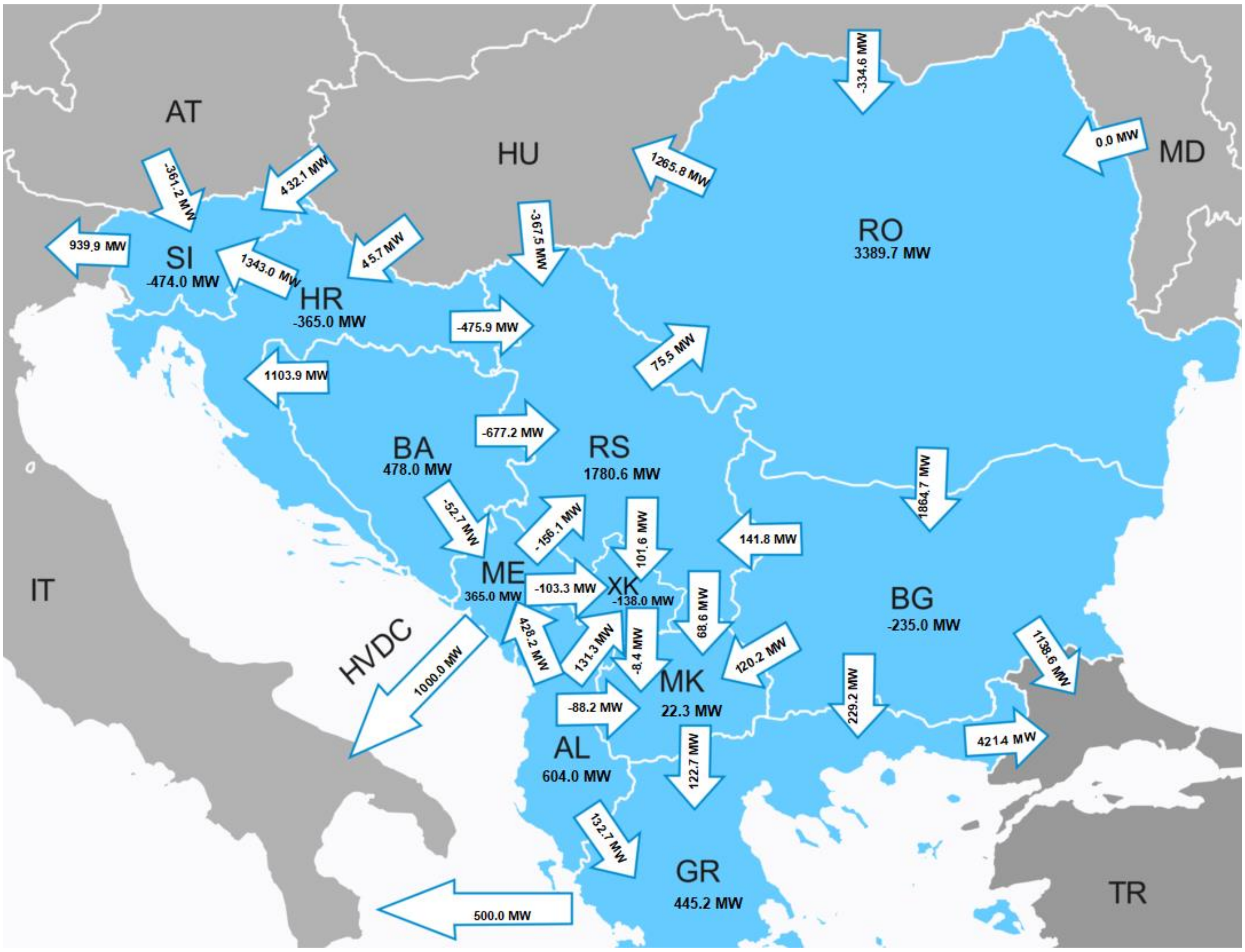


Figure 8.26: Cross-border exhanges (MW) and directions between the countries for Winter Peak regime 2030 (referent RES, referent CO2)

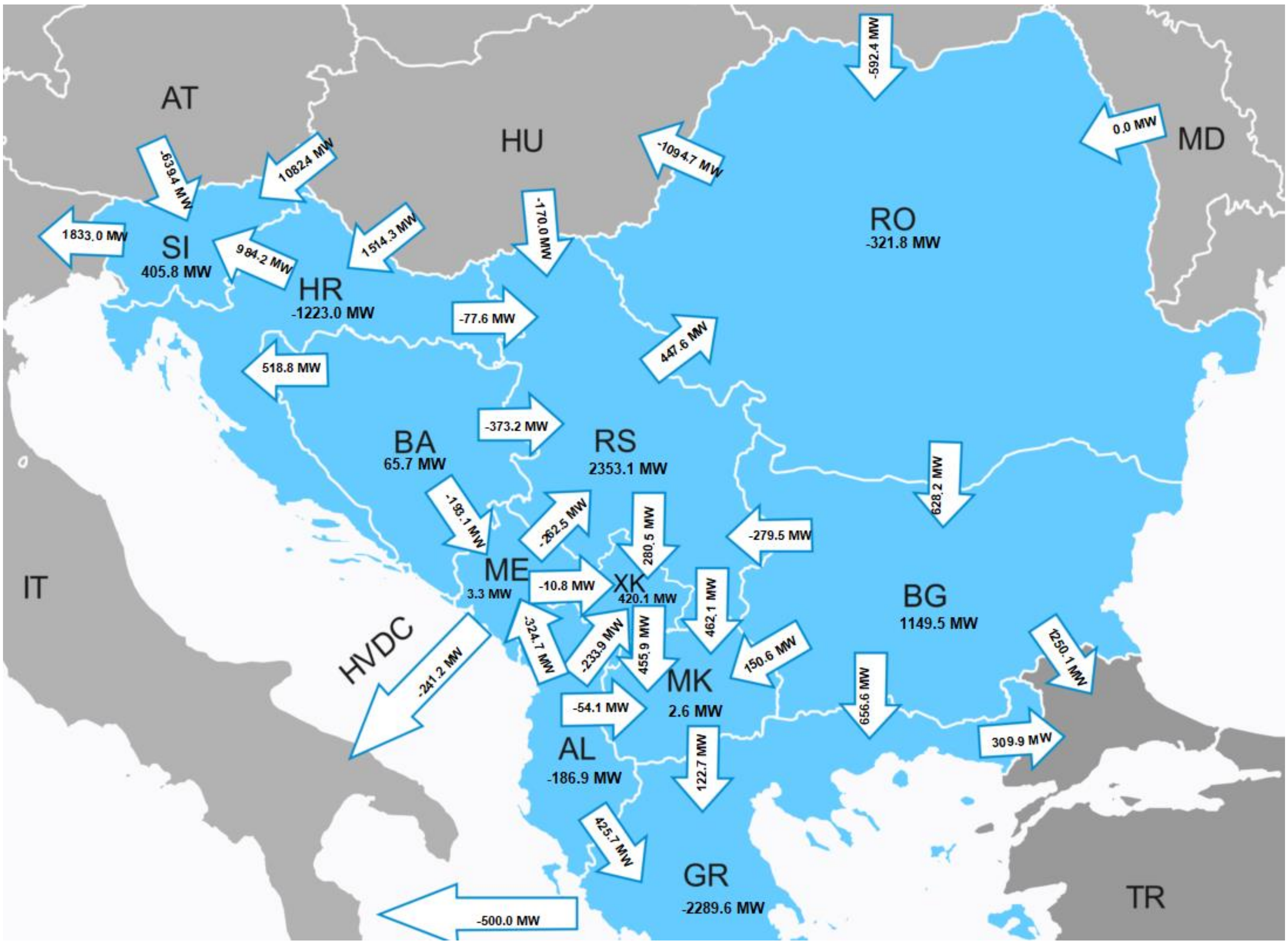


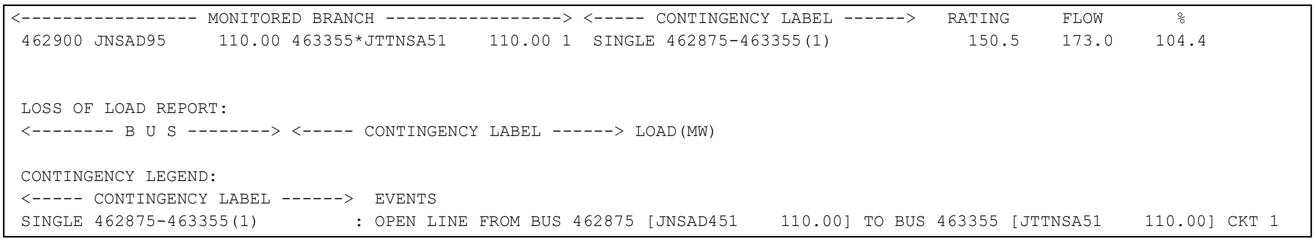
Figure 8.27: Cross-border exhanges (MW) and directions between the countries for Summer Off-Peak regime 2030 (referent RES, referent CO2)

Figure 8.28: Cross-border exhanges (MW) and directions between the countries for Highest wind+solar generation regime 2030 (referent RES, referent CO2)

Figure 8.29: Cross-border exhanges (MW) and directions between the countries for Summer regime with the highest generation 2030 (referent RES, referent CO2)

Figure 8.30: Cross-border exhanges (MW) and directions between the countries for Highest export regime 2030 (referent RES, referent CO2)

Figure 8.31: Cross-border exhanges (MW) and directions between the countries for Highest import regime 2030 (referent RES, referent CO2)



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<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW       %
 462900 JNSAD95      110.00 463355*JTTNSA51     110.00 1  SINGLE 462875-463355(1)            150.5     173.0    104.4


 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 462875-463355(1)          : OPEN LINE FROM BUS 462875 [JNSAD451    110.00] TO BUS 463355 [JTTNSA51    110.00] CKT 1
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Figure 8.32: Contingency (n-1) analysis report for Winter Peak regime 2030 (referent RES, referent CO2)

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<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW       %
 460035*JLESK211    400.00 460037 JLESK212    400.00 1C BASE CASE                         238.2    281.9    117.0
 462825 JNPAZ151    110.00 462830*JNPAZ25     110.00 1  SINGLE 381050-381070(1)            78.1     87.8    105.0
 462825 JNPAZ151    110.00 462830*JNPAZ25     110.00 1  SINGLE 460026-460045(1)            78.1     83.8    100.1
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  SINGLE 460026-460045(1)            78.1     80.8    100.3
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  SINGLE 381050-381070(1)            78.1     84.6    105.2


 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 381050-381070(1)         : OPEN LINE FROM BUS 381050 [0PLJE211    400.00] TO BUS 381070 [0RIBAR11    400.00] CKT 1
 SINGLE 460026-460045(1)         : OPEN LINE FROM BUS 460026 [JJAGO412    400.00] TO BUS 460045 [JNIS2 12    400.00] CKT 1
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Figure 8.33: Contingency (n-1) analysis report for Summer Off-Peak regime 2030 (referent RES,referent CO2)

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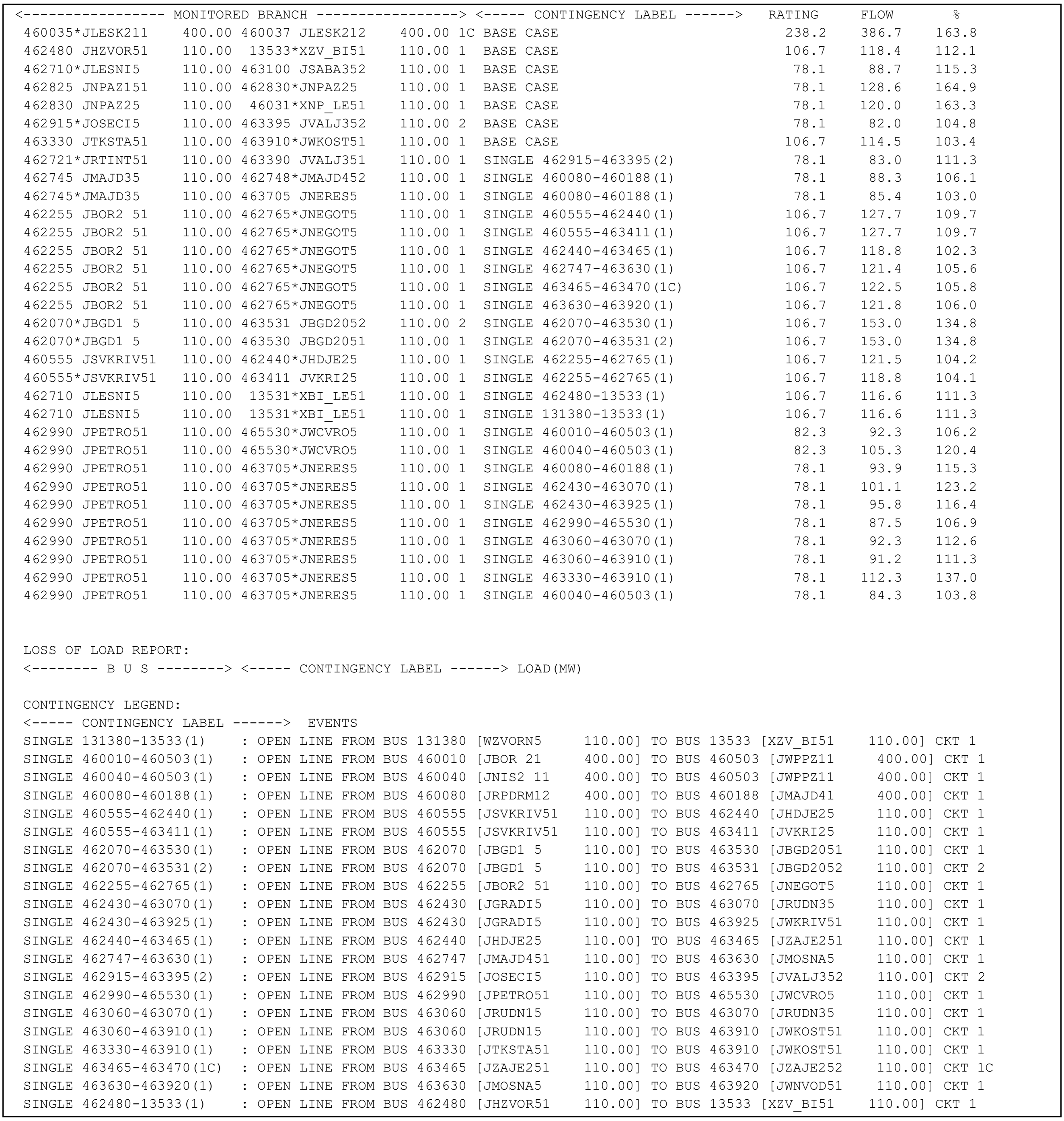
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW       %
 462825 JNPAZ151    110.00 462830*JNPAZ25     110.00 1  BASE CASE                         110.5    131.9    114.7
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  BASE CASE                         110.5    118.4    108.8
 462900 JNSAD95     110.00 463355*JTTNSA51    110.00 1  SINGLE 462875-463355(1)           150.5    171.6    103.6
 463705 JNERES5     110.00 463925*JWKRIV51    110.00 1  SINGLE 463330-463910(1)           150.5    167.1    107.2
 463330 JTKSTA51    110.00 463910*JWKOST51    110.00 1  SINGLE 463705-463925(1)           150.5    179.3    113.1


 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 462875-463355(1)         : OPEN LINE FROM BUS 462875 [JNSAD451    110.00] TO BUS 463355 [JTTNSA51    110.00] CKT 1
 SINGLE 463330-463910(1)         : OPEN LINE FROM BUS 463330 [JTKSTA51    110.00] TO BUS 463910 [JWKOST51    110.00] CKT 1
 SINGLE 463705-463925(1)         : OPEN LINE FROM BUS 463705 [JNERES5     110.00] TO BUS 463925 [JWKRIV51    110.00] CKT 1
```

Figure 8.34: Contingency (n-1) analysis report for Highest wind+solar generation regime 2030 (referent RES, referent CO2)



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<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW       %
 460035*JLESK211    400.00 460037 JLESK212    400.00 1C BASE CASE                       238.2     386.7     163.8
 462480 JHZVOR51    110.00  13533*XZV_BI51    110.00 1  BASE CASE                       106.7     118.4     112.1
 462710*JLESNI5     110.00 463100 JSABA352    110.00 1  BASE CASE                        78.1      88.7     115.3
 462825 JNPAZ151    110.00 462830*JNPAZ25     110.00 1  BASE CASE                        78.1     128.6     164.9
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  BASE CASE                        78.1     120.0     163.3
 462915*JOSECI5     110.00 463395 JVALJ352    110.00 2  BASE CASE                        78.1      82.0     104.8
 463330 JTKSTA51    110.00 463910*JWKOST51    110.00 1  BASE CASE                       106.7     114.5     103.4
 462721*JRTINT51    110.00 463390 JVALJ351    110.00 1  SINGLE 462915-463395(2)          78.1      83.0     111.3
 462745 JMAJD35     110.00 462748*JMAJD452    110.00 1  SINGLE 460080-460188(1)          78.1      88.3     106.1
 462745*JMAJD35     110.00 463705 JNERES5     110.00 1  SINGLE 460080-460188(1)          78.1      85.4     103.0
 462255 JBOR2 51    110.00 462765*JNEGOT5     110.00 1  SINGLE 460555-462440(1)         106.7     127.7     109.7
 462255 JBOR2 51    110.00 462765*JNEGOT5     110.00 1  SINGLE 460555-463411(1)         106.7     127.7     109.7
 462255 JBOR2 51    110.00 462765*JNEGOT5     110.00 1  SINGLE 462440-463465(1)         106.7     118.8     102.3
 462255 JBOR2 51    110.00 462765*JNEGOT5     110.00 1  SINGLE 462747-463630(1)         106.7     121.4     105.6
 462255 JBOR2 51    110.00 462765*JNEGOT5     110.00 1  SINGLE 463465-463470(1C)        106.7     122.5     105.8
 462255 JBOR2 51    110.00 462765*JNEGOT5     110.00 1  SINGLE 463630-463920(1)         106.7     121.8     106.0
 462070*JBGD1 5     110.00 463531 JBGD2052    110.00 2  SINGLE 462070-463530(1)         106.7     153.0     134.8
 462070*JBGD1 5     110.00 463530 JBGD2051    110.00 1  SINGLE 462070-463531(2)         106.7     153.0     134.8
 460555 JSVKRIV51   110.00 462440*JHDJE25     110.00 1  SINGLE 462255-462765(1)         106.7     121.5     104.2
 460555*JSVKRIV51   110.00 463411 JVKRI25     110.00 1  SINGLE 462255-462765(1)         106.7     118.8     104.1
 462710 JLESNI5     110.00  13531*XBI_LE51    110.00 1  SINGLE 462480-13533(1)          106.7     116.6     111.3
 462710 JLESNI5     110.00  13531*XBI_LE51    110.00 1  SINGLE 131380-13533(1)          106.7     116.6     111.3
 462990 JPETRO51    110.00 465530*JWCVRO5     110.00 1  SINGLE 460010-460503(1)          82.3      92.3     106.2
 462990 JPETRO51    110.00 465530*JWCVRO5     110.00 1  SINGLE 460040-460503(1)          82.3     105.3     120.4
 462990 JPETRO51    110.00 463705*JNERES5     110.00 1  SINGLE 460080-460188(1)          78.1      93.9     115.3
 462990 JPETRO51    110.00 463705*JNERES5     110.00 1  SINGLE 462430-463070(1)          78.1     101.1     123.2
 462990 JPETRO51    110.00 463705*JNERES5     110.00 1  SINGLE 462430-463925(1)          78.1      95.8     116.4
 462990 JPETRO51    110.00 463705*JNERES5     110.00 1  SINGLE 462990-465530(1)          78.1      87.5     106.9
 462990 JPETRO51    110.00 463705*JNERES5     110.00 1  SINGLE 463060-463070(1)          78.1      92.3     112.6
 462990 JPETRO51    110.00 463705*JNERES5     110.00 1  SINGLE 463060-463910(1)          78.1      91.2     111.3
 462990 JPETRO51    110.00 463705*JNERES5     110.00 1  SINGLE 463330-463910(1)          78.1     112.3     137.0
 462990 JPETRO51    110.00 463705*JNERES5     110.00 1  SINGLE 460040-460503(1)          78.1      84.3     103.8


 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 131380-13533(1)    : OPEN LINE FROM BUS 131380 [WZVORN5     110.00] TO BUS 13533 [XZV_BI51    110.00] CKT 1
 SINGLE 460010-460503(1)   : OPEN LINE FROM BUS 460010 [JBOR 21     400.00] TO BUS 460503 [JWPPZ11     400.00] CKT 1
 SINGLE 460040-460503(1)   : OPEN LINE FROM BUS 460040 [JNIS2 11    400.00] TO BUS 460503 [JWPPZ11     400.00] CKT 1
 SINGLE 460080-460188(1)   : OPEN LINE FROM BUS 460080 [JRPDRM12    400.00] TO BUS 460188 [JMAJD41     400.00] CKT 1
 SINGLE 460555-462440(1)   : OPEN LINE FROM BUS 460555 [JSVKRIV51   110.00] TO BUS 462440 [JHDJE25     110.00] CKT 1
 SINGLE 460555-463411(1)   : OPEN LINE FROM BUS 460555 [JSVKRIV51   110.00] TO BUS 463411 [JVKRI25     110.00] CKT 1
 SINGLE 462070-463530(1)   : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463530 [JBGD2051    110.00] CKT 1
 SINGLE 462070-463531(2)   : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463531 [JBGD2052    110.00] CKT 2
 SINGLE 462255-462765(1)   : OPEN LINE FROM BUS 462255 [JBOR2 51    110.00] TO BUS 462765 [JNEGOT5     110.00] CKT 1
 SINGLE 462430-463070(1)   : OPEN LINE FROM BUS 462430 [JGRADI5     110.00] TO BUS 463070 [JRUDN35     110.00] CKT 1
 SINGLE 462430-463925(1)   : OPEN LINE FROM BUS 462430 [JGRADI5     110.00] TO BUS 463925 [JWKRIV51    110.00] CKT 1
 SINGLE 462440-463465(1)   : OPEN LINE FROM BUS 462440 [JHDJE25     110.00] TO BUS 463465 [JZAJE251    110.00] CKT 1
 SINGLE 462747-463630(1)   : OPEN LINE FROM BUS 462747 [JMAJD451    110.00] TO BUS 463630 [JMOSNA5     110.00] CKT 1
 SINGLE 462915-463395(2)   : OPEN LINE FROM BUS 462915 [JOSECI5     110.00] TO BUS 463395 [JVALJ352    110.00] CKT 2
 SINGLE 462990-465530(1)   : OPEN LINE FROM BUS 462990 [JPETRO51    110.00] TO BUS 465530 [JWCVRO5     110.00] CKT 1
 SINGLE 463060-463070(1)   : OPEN LINE FROM BUS 463060 [JRUDN15     110.00] TO BUS 463070 [JRUDN35     110.00] CKT 1
 SINGLE 463060-463910(1)   : OPEN LINE FROM BUS 463060 [JRUDN15     110.00] TO BUS 463910 [JWKOST51    110.00] CKT 1
 SINGLE 463330-463910(1)   : OPEN LINE FROM BUS 463330 [JTKSTA51    110.00] TO BUS 463910 [JWKOST51    110.00] CKT 1
 SINGLE 463465-463470(1C)  : OPEN LINE FROM BUS 463465 [JZAJE251    110.00] TO BUS 463470 [JZAJE252    110.00] CKT 1C
 SINGLE 463630-463920(1)   : OPEN LINE FROM BUS 463630 [JMOSNA5     110.00] TO BUS 463920 [JWNVOD51    110.00] CKT 1
 SINGLE 462480-13533(1)    : OPEN LINE FROM BUS 462480 [JHZVOR51    110.00] TO BUS 13533 [XZV_BI51    110.00] CKT 1
```

Figure 8.35: Contingency (n-1) analysis report for Summer regime with the highest generation 2030 (referent RES, referent CO2)

```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW       %
 462825 JNPAZ151    110.00 462830*JNPAZ25     110.00 1  BASE CASE                         110.5    113.4    100.0
 462900 JNSAD95     110.00 463355*JTTNSA51    110.00 1  SINGLE 462875-463355(1)           150.5    171.9    103.6
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  SINGLE 381050-381070(1)           110.5    117.1    105.3
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  SINGLE 381050-3801(A)             110.5    113.6    102.0
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  SINGLE 460026-460045(1)           110.5    116.9    104.9
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  SINGLE 460175-3801(1)             110.5    113.4    101.9


 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 462875-463355(1)      : OPEN LINE FROM BUS 462875 [JNSAD451    110.00] TO BUS 463355 [JTTNSA51    110.00] CKT 1
 SINGLE 381050-381070(1)      : OPEN LINE FROM BUS 381050 [0PLJE211    400.00] TO BUS 381070 [0RIBAR11    400.00] CKT 1
 SINGLE 381050-3801(A)        : OPEN LINE FROM BUS 381050 [0PLJE211    400.00] TO BUS 3801 [XPL_BI11    400.00] CKT A
 SINGLE 460026-460045(1)      : OPEN LINE FROM BUS 460026 [JJAGO412    400.00] TO BUS 460045 [JNIS2 12    400.00] CKT 1
 SINGLE 460175-3801(1)        : OPEN LINE FROM BUS 460175 [JBBAST11    400.00] TO BUS 3801 [XPL_BI11    400.00] CKT 1
```

Figure 8.36: Contingency (n-1) analysis report for Highest export regime 2030 (referent RES, referent CO2)

```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW       %
 462825 JNPAZ151    110.00 462830*JNPAZ25     110.00 1  BASE CASE                          78.1    131.0    168.8
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  BASE CASE                          78.1    112.3    156.2
 462070 JBGD1 5     110.00 463531*JBGD2052    110.00 2  SINGLE 462070-463530(1)           106.7    128.5    108.4
 462070 JBGD1 5     110.00 463530*JBGD2051    110.00 1  SINGLE 462070-463531(2)           106.7    128.5    108.4


 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 462070-463530(1)          : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463530 [JBGD2051    110.00] CKT 1
 SINGLE 462070-463531(2)          : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463531 [JBGD2052    110.00] CKT 2
```

Figure 8.37: Contingency (n-1) analysis report for Highest import regime 2030 (referent RES,referent CO2)

8.1.4 2030- highRES

Figure 8.38: Cross-border exhanges (MW) and directions between the countries for Winter Peak regime 2030 (high RES, referent CO2)

Figure 8.39: Cross-border exhanges (MW) and directions between the countries for Summer Off-Peak regime 2030 (high RES, referent CO2)

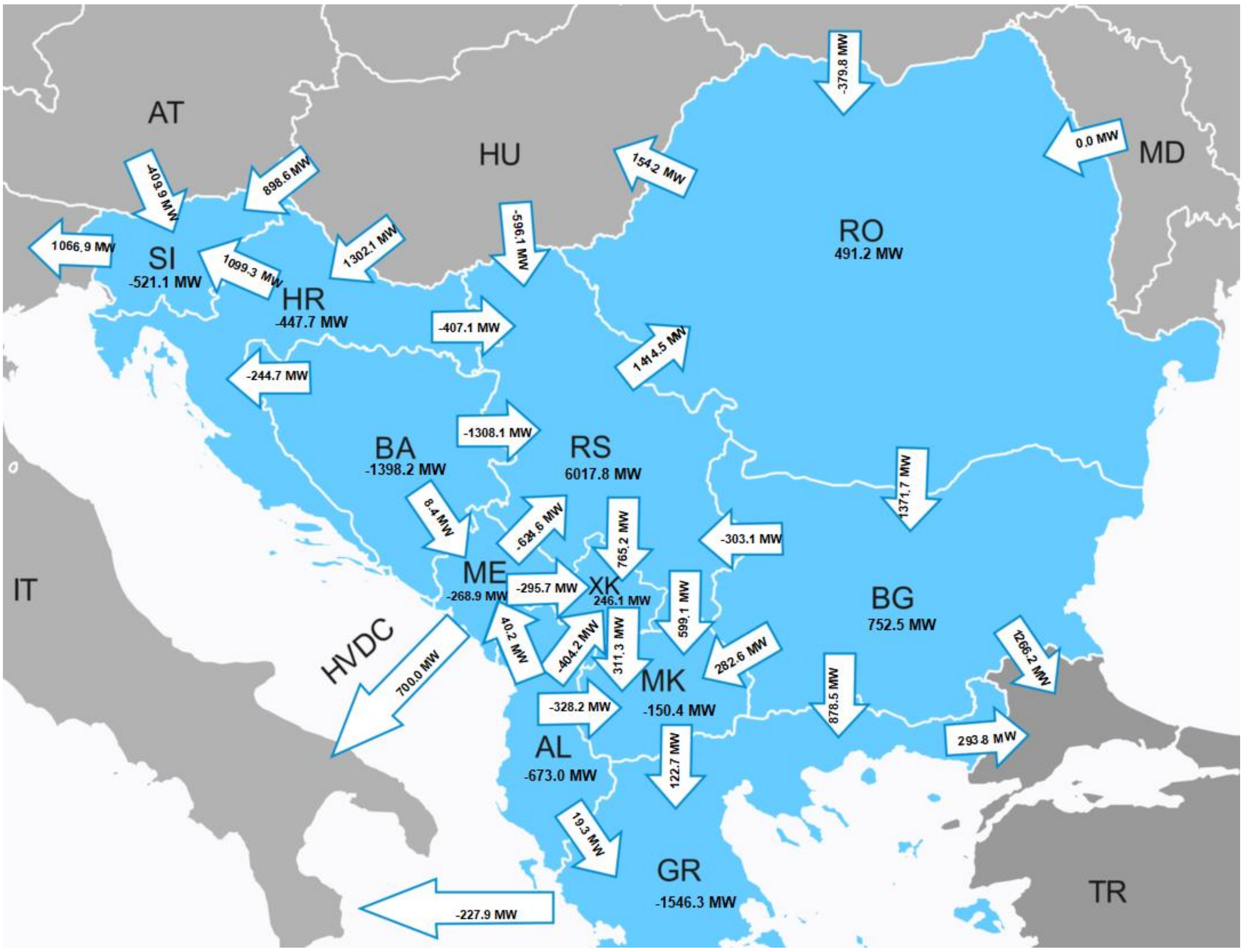


Figure 8.40: Cross-border exhanges (MW) and directions between the countries for Highest wind+solar generation regime 2030 (high RES, referent CO2)

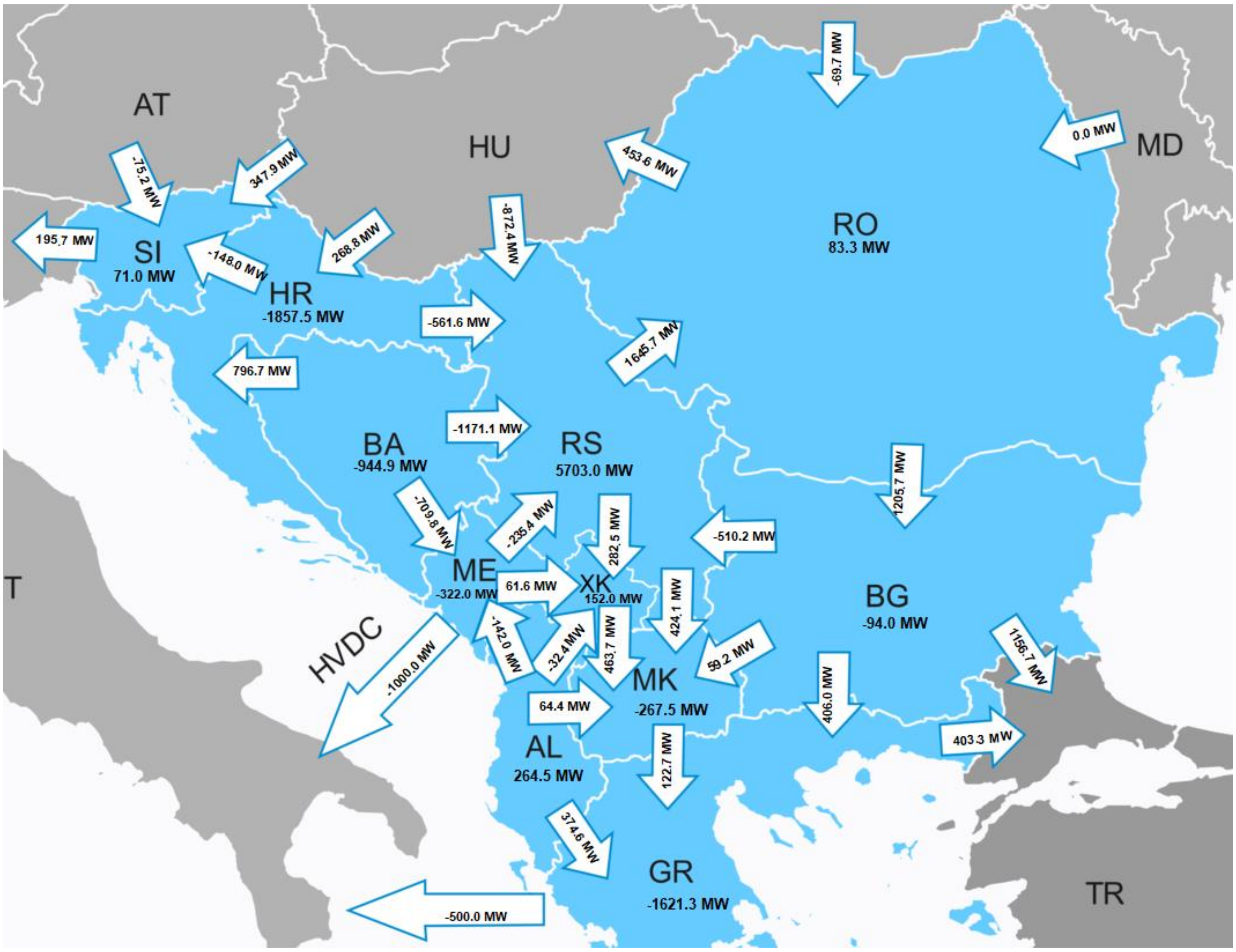


Figure 8.41: Cross-border exhanges (MW) and directions between the countries for Summer regime with the highest generation 2030 (high RES, referent CO2)

Figure 8.42: Cross-border exhanges (MW) and directions between the countries for Highest export regime 2030 (high RES, referent CO2)

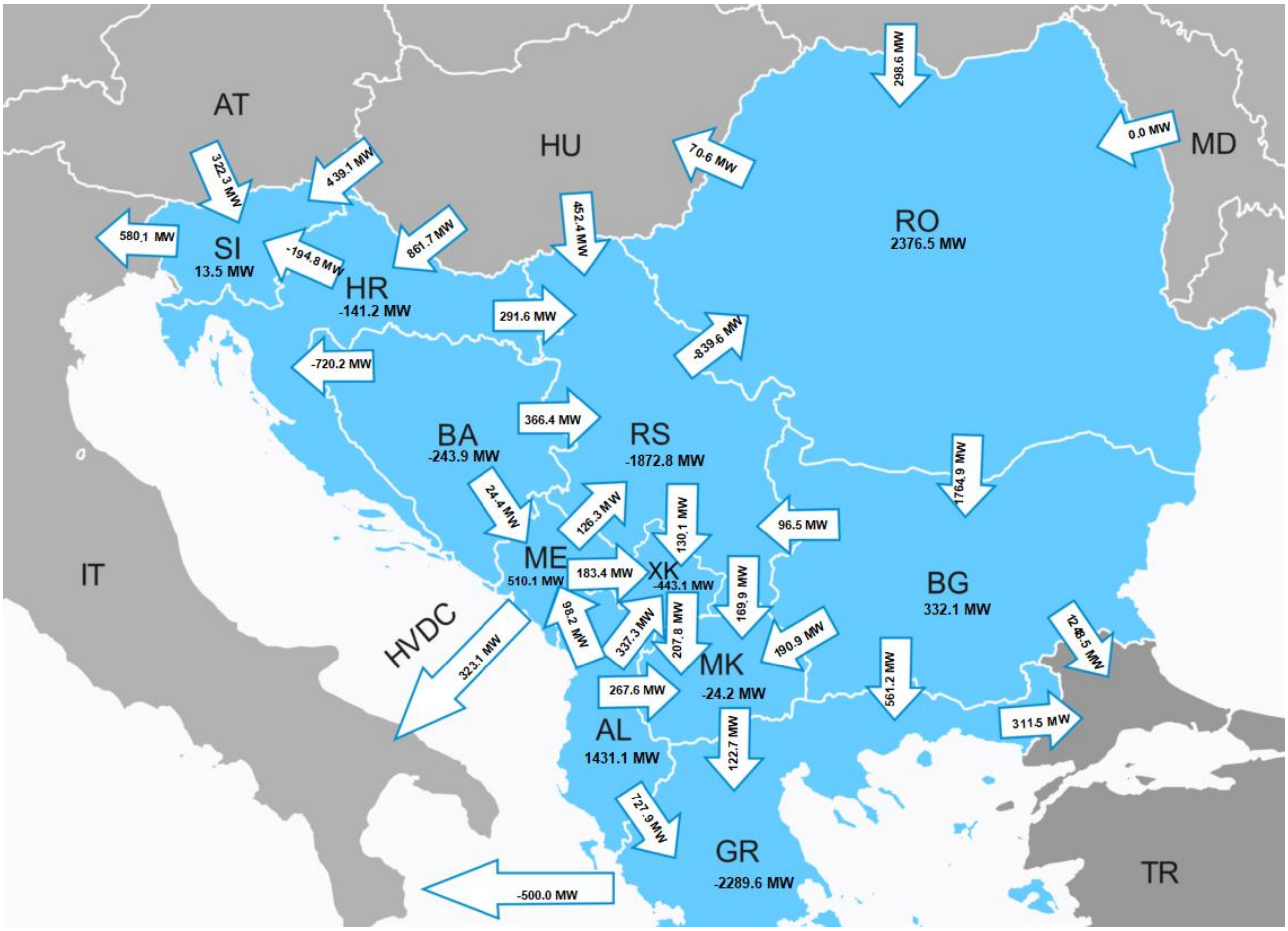


Figure 8.43: Cross-border exhanges (MW) and directions between the countries for Highest import regime 2030 (high RES, referent CO2)

```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW        %
 462900 JNSAD95      110.00 463355*JTTNSA51    110.00 1   SINGLE 462875-463355(1)            150.5     173.0    104.3


 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

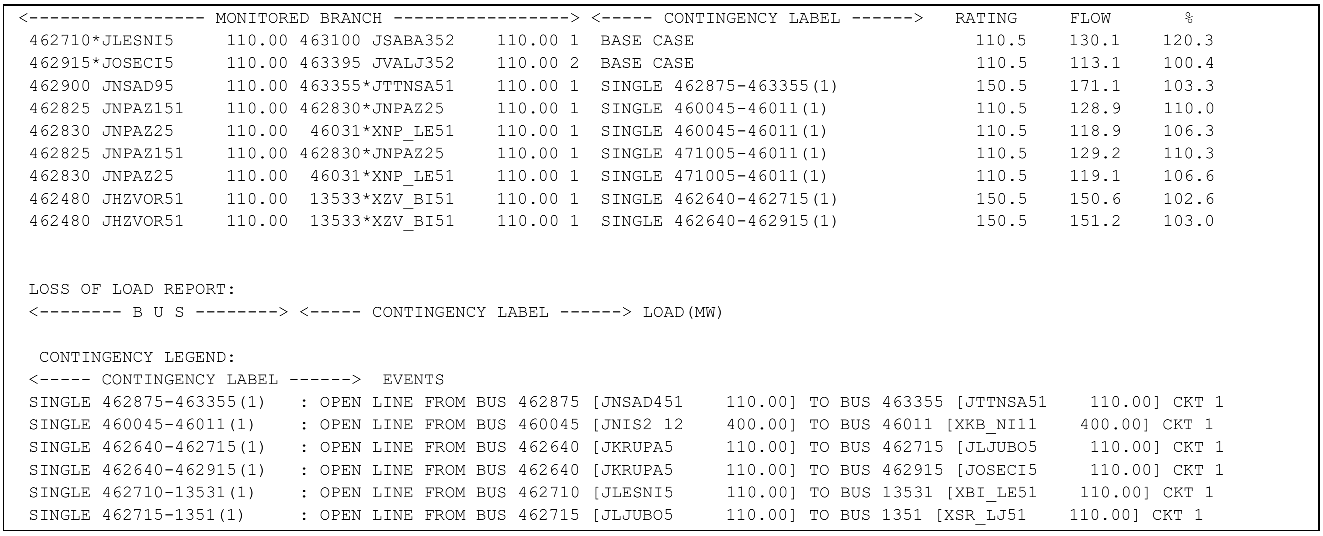
 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>   EVENTS
 SINGLE 462875-463355(1)          : OPEN LINE FROM BUS 462875 [JNSAD451    110.00] TO BUS 463355 [JTTNSA51    110.00] CKT 1
```

Figure 8.44: Contingency (n-1) analysis report for Winter Peak regime 2030 (referent RES, referent CO2)

```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW        %
 460035*JLESK211     400.00 460037 JLESK212    400.00 1C BASE CASE                          238.2     355.0    145.0


 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)
```

Figure 8.45: Contingency (n-1) analysis report for Summer Off-Peak regime 2030 (referent RES, referent CO2)



```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW       %
 462710*JLESNI5     110.00 463100 JSABA352    110.00 1  BASE CASE                         110.5    130.1    120.3
 462915*JOSECI5     110.00 463395 JVALJ352    110.00 2  BASE CASE                         110.5    113.1    100.4
 462900 JNSAD95     110.00 463355*JTTNSA51    110.00 1  SINGLE 462875-463355(1)           150.5    171.1    103.3
 462825 JNPAZ151    110.00 462830*JNPAZ25     110.00 1  SINGLE 460045-46011(1)            110.5    128.9    110.0
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  SINGLE 460045-46011(1)            110.5    118.9    106.3
 462825 JNPAZ151    110.00 462830*JNPAZ25     110.00 1  SINGLE 471005-46011(1)            110.5    129.2    110.3
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  SINGLE 471005-46011(1)            110.5    119.1    106.6
 462480 JHZVOR51    110.00  13533*XZV_BI51    110.00 1  SINGLE 462640-462715(1)           150.5    150.6    102.6
 462480 JHZVOR51    110.00  13533*XZV_BI51    110.00 1  SINGLE 462640-462915(1)           150.5    151.2    103.0


 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

  CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 462875-463355(1)    : OPEN LINE FROM BUS 462875 [JNSAD451    110.00] TO BUS 463355 [JTTNSA51    110.00] CKT 1
 SINGLE 460045-46011(1)     : OPEN LINE FROM BUS 460045 [JNIS2 12    400.00] TO BUS 46011 [XKB_NI11    400.00] CKT 1
 SINGLE 462640-462715(1)    : OPEN LINE FROM BUS 462640 [JKRUPA5     110.00] TO BUS 462715 [JLJUBO5     110.00] CKT 1
 SINGLE 462640-462915(1)    : OPEN LINE FROM BUS 462640 [JKRUPA5     110.00] TO BUS 462915 [JOSECI5     110.00] CKT 1
 SINGLE 462710-13531(1)     : OPEN LINE FROM BUS 462710 [JLESNI5     110.00] TO BUS 13531 [XBI_LE51    110.00] CKT 1
 SINGLE 462715-1351(1)      : OPEN LINE FROM BUS 462715 [JLJUBO5     110.00] TO BUS 1351 [XSR_LJ51    110.00] CKT 1
```

Figure 8.46: Contingency (n-1) analysis report for Highest wind+solar generation regime 2030 (referent RES, referent CO2)

```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING    FLOW      %
 460035*JLESK211    400.00 460037 JLESK212    400.00 1C BASE CASE                         238.2    357.6    148.8
 462710*JLESNI5     110.00 463100 JSABA352    110.00 1  BASE CASE                          78.1    115.7    150.3
 462721*JRTINT51    110.00 463390 JVALJ351    110.00 1  BASE CASE                          78.1     78.4    103.5
 462825 JNPAZ151    110.00 462830*JNPAZ25     110.00 1  BASE CASE                          78.1     85.2    104.6
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  BASE CASE                          78.1     81.7    104.0
 462915*JOSECI5     110.00 463395 JVALJ352    110.00 2  BASE CASE                          78.1    115.3    148.7
 460015 JHDJE111    400.00  44102*XPF_DJ12    400.00 1  SINGLE 460015-44101(2)            900.7   1075.1    119.4
 460015 JHDJE111    400.00  44101*XPF_DJ11    400.00 2  SINGLE 460015-44102(1)            900.7   1075.1    119.4
 461145*JSABA321    220.00 3WNDTR T2           WND 1 2  SINGLE 461145-463095-465265(1)    150.0    157.4    103.3
 461145*JSABA321    220.00 3WNDTR T1           WND 1 1  SINGLE 461145-463100-465270(2)    150.0    162.9    106.9
 462640 JKRUPA5     110.00 462715*JLJUBO5     110.00 1  SINGLE 131380-13533(1)             78.1     81.6    109.7
 462640*JKRUPA5     110.00 462915 JOSECI5     110.00 1  SINGLE 131380-13533(1)             78.1     88.2    116.2
 462710 JLESNI5     110.00  13531*XBI_LE51    110.00 1  SINGLE 131380-13533(1)            106.7    117.0    111.0
 462255 JBOR2 51    110.00 462765*JNEGOT5     110.00 1  SINGLE 460555-462440(1)           106.7    123.9    105.7
 462255 JBOR2 51    110.00 462765*JNEGOT5     110.00 1  SINGLE 460555-463411(1)           106.7    123.9    105.7
 462255 JBOR2 51    110.00 462765*JNEGOT5     110.00 1  SINGLE 463465-463470(1C)          106.7    117.5    100.3
 462070*JBGD1 5     110.00 463531 JBGD2052    110.00 2  SINGLE 462070-463530(1)           106.7    130.2    113.5
 462070*JBGD1 5     110.00 463530 JBGD2051    110.00 1  SINGLE 462070-463531(2)           106.7    130.2    113.5
 460555 JSVKRIV51   110.00 462440*JHDJE25     110.00 1  SINGLE 462255-462765(1)           106.7    117.8    100.2
 460555*JSVKRIV51   110.00 463411 JVKRI25     110.00 1  SINGLE 462255-462765(1)           106.7    115.5    100.1
 462722*JRTINT52    110.00 462915 JOSECI5     110.00 1  SINGLE 462640-462915(1)            78.1     76.8    101.1
 462722 JRTINT52    110.00 462915*JOSECI5     110.00 1  SINGLE 462721-463390(1)            78.1     80.0    104.8
 462640*JKRUPA5     110.00 462715 JLJUBO5     110.00 1  SINGLE 462722-462915(1)            78.1     77.5    101.2
 462640*JKRUPA5     110.00 462915 JOSECI5     110.00 1  SINGLE 462722-462915(1)            78.1     82.3    107.5
 462640 JKRUPA5     110.00 462715*JLJUBO5     110.00 1  SINGLE 462480-13533(1)             78.1     81.6    109.7
 462640*JKRUPA5     110.00 462915 JOSECI5     110.00 1  SINGLE 462480-13533(1)             78.1     88.2    116.2
 462710 JLESNI5     110.00  13531*XBI_LE51    110.00 1  SINGLE 462480-13533(1)            106.7    117.0    111.0
 462480 JHZVOR51    110.00  13533*XZV_BI51    110.00 1  SINGLE 462710-13531(1)            106.7    124.0    118.0
 462480 JHZVOR51    110.00  13533*XZV_BI51    110.00 1  SINGLE 462715-1351(1)             106.7    115.3    110.8
 462480 JHZVOR51    110.00  13533*XZV_BI51    110.00 1  SINGLE 462640-462715(1)           106.7    116.7    112.2
 462480 JHZVOR51    110.00  13533*XZV_BI51    110.00 1  SINGLE 462640-462915(1)           106.7    119.5    115.1


 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
SINGLE 131025-13531(1)          : OPEN LINE FROM BUS 131025 [WBJEL45     110.00] TO BUS 13531 [XBI_LE51    110.00] CKT 1
SINGLE 131315-1351(1)           : OPEN LINE FROM BUS 131315 [WSR-CA5     110.00] TO BUS 1351 [XSR_LJ51    110.00] CKT 1
SINGLE 131380-13533(1)          : OPEN LINE FROM BUS 131380 [WZVORN5     110.00] TO BUS 13533 [XZV_BI51    110.00] CKT 1
SINGLE 460555-462440(1)         : OPEN LINE FROM BUS 460555 [JSVKRIV51   110.00] TO BUS 462440 [JHDJE25     110.00] CKT 1
SINGLE 460555-463411(1)         : OPEN LINE FROM BUS 460555 [JSVKRIV51   110.00] TO BUS 463411 [JVKRI25     110.00] CKT 1
SINGLE 462070-463530(1)         : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463530 [JBGD2051    110.00] CKT 1
SINGLE 462070-463531(2)         : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463531 [JBGD2052    110.00] CKT 2
SINGLE 462255-462765(1)         : OPEN LINE FROM BUS 462255 [JBOR2 51    110.00] TO BUS 462765 [JNEGOT5     110.00] CKT 1
SINGLE 462640-462715(1)         : OPEN LINE FROM BUS 462640 [JKRUPA5     110.00] TO BUS 462715 [JLJUBO5     110.00] CKT 1
SINGLE 462640-462915(1)         : OPEN LINE FROM BUS 462640 [JKRUPA5     110.00] TO BUS 462915 [JOSECI5     110.00] CKT 1
SINGLE 462721-463390(1)         : OPEN LINE FROM BUS 462721 [JRTINT51    110.00] TO BUS 463390 [JVALJ351    110.00] CKT 1
SINGLE 462722-462915(1)         : OPEN LINE FROM BUS 462722 [JRTINT52    110.00] TO BUS 462915 [JOSECI5     110.00] CKT 1
SINGLE 463465-463470(1C)        : OPEN LINE FROM BUS 463465 [JZAJE251    110.00] TO BUS 463470 [JZAJE252    110.00] CKT 1C
SINGLE 461145-463095-465265(1)   : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463095 [JSABA351    110.00] TO BUS
465265 [JSABA3_1    10.000] CKT 1
SINGLE 461145-463100-465270(2)   : OPEN LINE FROM BUS 461145 [JSABA321    220.00] TO BUS 463100 [JSABA352    110.00] TO BUS
465270 [JSABA3_2    10.000] CKT 2
SINGLE 460015-44101(2)          : OPEN LINE FROM BUS 460015 [JHDJE111    400.00] TO BUS 44101 [XPF_DJ11    400.00] CKT 2
SINGLE 460015-44102(1)          : OPEN LINE FROM BUS 460015 [JHDJE111    400.00] TO BUS 44102 [XPF_DJ12    400.00] CKT 1
SINGLE 462480-13533(1)          : OPEN LINE FROM BUS 462480 [JHZVOR51    110.00] TO BUS 13533 [XZV_BI51    110.00] CKT 1
SINGLE 462710-13531(1)          : OPEN LINE FROM BUS 462710 [JLESNI5     110.00] TO BUS 13531 [XBI_LE51    110.00] CKT 1
SINGLE 462715-1351(1)           : OPEN LINE FROM BUS 462715 [JLJUBO5     110.00] TO BUS 1351 [XSR_LJ51    110.00] CKT 1
```

Figure 8.47: Contingency (n-1) analysis report for Summer regime with the highest generation 2030 (referent RES, referent CO2)

```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING    FLOW      %
 462900 JNSAD95     110.00 463355*JTTNSA51    110.00 1  SINGLE 462875-463355(1)           150.5    171.7    103.5


 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 462875-463355(1)         : OPEN LINE FROM BUS 462875 [JNSAD451    110.00] TO BUS 463355 [JTTNSA51    110.00] CKT 1
```

Figure 8.48: Contingency (n-1) analysis report for Highest export regime 2030 (referent RES, referent CO2)

```
<----------------- MONITORED BRANCH -----------------> <----- CONTINGENCY LABEL ------>   RATING     FLOW       %
 460035*JLESK211    400.00 460037 JLESK212    400.00 1C BASE CASE                         238.2    241.6    101.2
 462825 JNPAZ151    110.00 462830*JNPAZ25     110.00 1  BASE CASE                          78.1     93.3    118.7
 462830 JNPAZ25     110.00  46031*XNP_LE51    110.00 1  BASE CASE                          78.1     84.1    112.8
 462745 JMAJD35     110.00 462748*JMAJD452    110.00 1  SINGLE 460010-460503(1)            78.1     90.0    106.1
 462745 JMAJD35     110.00 462748*JMAJD452    110.00 1  SINGLE 460040-460503(1)            78.1     91.4    107.5
 462745 JMAJD35     110.00 462748*JMAJD452    110.00 1  SINGLE 460080-460188(1)            78.1     95.4    113.2
 462745*JMAJD35     110.00 463705 JNERES5     110.00 1  SINGLE 460010-460503(1)            78.1     87.2    103.3
 462745*JMAJD35     110.00 463705 JNERES5     110.00 1  SINGLE 460040-460503(1)            78.1     88.6    104.7
 462745*JMAJD35     110.00 463705 JNERES5     110.00 1  SINGLE 460080-460188(1)            78.1     92.9    110.5
 462070*JBGD1 5     110.00 463531 JBGD2052    110.00 2  SINGLE 462070-463530(1)           106.7    140.0    120.5
 462070*JBGD1 5     110.00 463530 JBGD2051    110.00 1  SINGLE 462070-463531(2)           106.7    140.0    120.5


 LOSS OF LOAD REPORT:
 <-------- B U S --------> <----- CONTINGENCY LABEL ------> LOAD(MW)

 CONTINGENCY LEGEND:
 <----- CONTINGENCY LABEL ------>  EVENTS
 SINGLE 460010-460503(1)         : OPEN LINE FROM BUS 460010 [JBOR 21     400.00] TO BUS 460503 [JWPPZ11     400.00] CKT 1
 SINGLE 460040-460503(1)         : OPEN LINE FROM BUS 460040 [JNIS2 11    400.00] TO BUS 460503 [JWPPZ11     400.00] CKT 1
 SINGLE 460080-460188(1)         : OPEN LINE FROM BUS 460080 [JRPDRM12    400.00] TO BUS 460188 [JMAJD41     400.00] CKT 1
 SINGLE 462070-463530(1)         : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463530 [JBGD2051    110.00] CKT 1
 SINGLE 462070-463531(2)         : OPEN LINE FROM BUS 462070 [JBGD1 5     110.00] TO BUS 463531 [JBGD2052    110.00] CKT 2
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Figure 8.49: Contingency (n-1) analysis report for Highest import regime 2030 (referent RES,referent CO2)

TABLE OF FIGURES

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