Evaluation of Investments in Transmission Network to Sustain Generation and Market Development in SEE

Draft report

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The Southeast European Cooperative Initiative (SECI)
Project Group on "Development of Interconnections of Electric Power Systems of SECI countries for better integration to European System"

PROJECT:
REGIONAL TRANSMISSION SYSTEM PLANNING

Evaluation of Investments in Transmission Network to Sustain Generation and Market Development in SEE

Draft Report

Prepared By:

ELECTRICITY COORDINATING CENTER, Ltd &

ENERGY INSTITUTE HRVOJE POZAR

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Authors: Mr. Nemanja Krajišnik – EKC
Mr. Predrag Mikša – EKC
Mr. Slobodan Marković – EKC
Mr. Goran Majstrović - EIHP
Mr. Nijaz Dizdarevic - EIHP

Project coordinators: Mr. Trajce Čerepnalkovski – MEPSO/NEOTEL
Mr. Kliment Naumoski - MEPSO

Project leaders: Mr. Davor Bajs – EIHP
Mr. Miroslav Vuković - EKC

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ABBREVIATIONS

Country codes

Country	Name	country code nodes	country code ISO
Albania	Shqiperia	A	AL
Bulgaria	Bulgarija	V	BG
Bosnia and Herzegovina	Bosna i Hercegovina	W	BA
Greece	Hellas	G	GR
Hungary	Magyarorszag	M	HU
Croatia	Hrvatska	H	HR
Italy	Italia	I	IT
Macedonia	Makedonija	Y	MK
Romania	Romania	R	RO
Slovenia	Slovenija	L	SI
Turkey	Türkiye	T	TR
Ukraine	Ukraina	U	UA
Serbia	Srbija (s UNMIK-om)	J	RS
Montenegro	Crna Gora	0	ME
--	Fictitious border node	X	--

Abbreviations of Electric Power Utilities (EPUs) and Transmission System Operators (TSOs):

OST TSO of Albania
ESO TSO of Bulgaria
TEL TSO of Romania
MEPSO TSO of Macedonia
EPCG EPU of Montenegro (EPCG TSO is a part of EPU)
NOS ISO of Bosnia and Herzegovina
HEP EPU of Croatia (HEP TSO is a part of EPU)
EMS TSO of Serbia
HTSO ISO of Greece
CENTREL Association of TSOs of Czech Republic, Hungary, Poland and Slovakia
IPS/UPS TSOs of Baltic States and CIS

Other abbreviations

AC Alternating current
DC Direct current
CCGT Combined cycle gas turbine
CHP Combined heat and power
HPP Hydro power plant
NPP Nuclear power plant
TPP Thermal power plant
MW Megawatt
GW/GWh Gigawatt / Gigawatt-hour
HV High voltage
HVDC High voltage direct current
NTC Net transfer capacity
SEE South East Europe
TRM Transmission reliability margin
TSO Transmission system operator
TWh Terawatt-hour
UCTE Union for the Coordination of Transmission of Electricity
TR Transformer
HL High voltage line
OHL Overhead high voltage line

TERMS OF REFERENCE

1. BACKGROUND

1.1 Introduction

Regional Balkans Infrastructure Study (REBIS) – Electricity and Generation Investment Study (GIS) was finished and issued December 31, 2004 by PWC and MWH. The main objective of the Generation Investment Study was to assist the EC, WB and donors in identifying indicative priority list of investments in power generation and related electricity infrastructure from the regional perspective and in line with the objectives of SEE REM. The following were investigated in this project: Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Macedonia, Montenegro, Romania, Serbia and UNMIK. The aim of the study was to determine optimal size, location and timing for construction of new production capacities as well as reinforcement of main interconnection transmission capacity in the SEE region over the next 15 years (2005 – 2020).

It was also necessary to identify priority investments in main transmission interconnections between the countries and sub-regions to help optimize investment in power generation over the time horizon. The expansions of the generation system were optimized over the 15 years horizon (2005 – 2020) for the following three scenarios:

- isolated operation of each power system;
- regional operation of power systems; and
- market conditions.

From 2004 till now, a number of significant changes emerged, concerning primarily the growth of gas price and the decrease of imported coal price that required updating of original GIS. The aim of the new project was to update Generation Investment Study (updated GIS) with some altered fuel prices, according to market development, as well as with some revised constraints to the power system development.

Within those analyses a revision of the GIS base line scenario was performed, with the most probable prices assumed for oil and natural gas. This was the scenario in which all of the old thermal power plant units are scheduled to go to rehabilitation process according to plans given by the utilities. The implementation schedules of the planned projects and all other information were kept the same, for consistency purposes, even though some changes have actually occurred in the actual project schedules, costs, design etc. Cases concerning different CO2 taxes were analyzed as well. The update of GIS has been performed with the following scenarios of power system development:

- Base case with official rehabilitation program (GIS sc1);
- Base case with justified rehabilitation program (GIS sc2);
- High fuel price scenario (GIS sc3);
- Low fuel price scenario (GIS sc4);
- €20/t CO_2 scenario (GIS sc5);

- €30/t CO_2 scenario (GIS sc6);
- High electricity import scenario (GIS sc7);
- Hydro power plants and high fuel price scenario (GIS sc8);
- Hydro power plants with €20/t CO_2 scenario (GIS sc9); and
- Hydro power plants with €30/t CO_2 scenario (GIS sc10).

It should be stressed that the updated GIS gives only types and sizes of new power plants for different planning scenarios, without their location and market engagement (Table 1), unlike the original GIS from 2004. The reason for that is the usage of WASP model only, whereas GTmax was used in previous stage as well. Such results are extremely inconvenient for transmission system planning because of many uncertainties related to different possible locations for large power plants and their unknown market engagement. Transmission system development strongly depends on the new power plants location and their engagement (market bids), so additional planning scenarios for transmission system have to be defined.

Table 1 Unknown locations of new power plants from updated GIS

		1	2	3	4	5	6	7	8	9	10
Combined cycle											
	Nr	2	3	10	2	-	16	17	2	16	10
MW	2015	768	1248	3840	768	-	7296	7584	768	7280	3851
Imported Coal											
	Nr		2		3	-					
MW	2015		940		1410	-					
Open Cycle											
	Nr				1	-				Lignite Subcritical (450 MW)	
MW	2015			194	96	-			Lignite Subcritical (450 MW)		
							Lignite Subcritical (450 MW)		Lignite Subcritical (275 MW)x3		
							Imported Coal Su	Imported Coal Su	Imported Coal Supercritical(470 MW		Imported Coal Su
								Nuclear (925 MW)x2			Nuclear (925 MW
Unknown location											
MW		**768**	**2188**	**4034**	**2274**	**-**	**8216**	**10844**	**2513**	**7730**	**6911**

The main results from updated GIS are shown in Figure 1 [1].

For the base cases with official rehabilitation program and justified rehabilitation program there are differences concerning the following:

- smaller amount of new CCGT (1300 MW in GIS sc 1 and 2100 MW in GIS sc2 in comparison to 3000 MW in original GIS); and

- increased usage of imported coal (1500 MW in GIS sc1 and 2500 MW in GIS sc2 in comparison to 0 MW in original GIS).

Results of GIS Update
Updated vs Original GIS

	Rehabs (MW)	New Plants (MW)	Key Selections of New Plants
Original GIS Base	11,574	11,000	Kosovo: 4,200MW (4x300, 6x500) CCGTs: 3,000MW (5x300, 3x500) OCGTs: None (constrained) Imported Coal: None (constrained) Nuclear: None (except Cernavoda 2/3 & Belene)
Updated GIS Base	11,574	11,022	Kosovo: 4,300MW (6x300, 5x500) CCGTs: 1,300MW (1x300, 2x500) OCGTs: 100MW Imported Coal: 1500MW (3x500 MW) Nuclear: None (except Cernavoda 2/3 & Belene)
Updated GIS Base w/ justified rehab	9,361	12,696	Kosovo: 4,800MW(6x300+6x500) [max] CCGTs: 2,100MW (2X300+3X500) OCGTs: None Imported Coal: 2,500MW (5x500) Nuclear: None (except Cernavoda 2/3 & Belene)

9,361MWs out of 11,574MWs are cost effective to be rehabilitated
Key options: Kosovo, CCGTs and imported coal

SEEC

Figure 1 The main results of updated GIS [1]

1.2 Prerequisites and assumptions

The study titled *Evaluation of investments in transmission network to sustain generation and market development in SEE* should be based on findings and conclusions of updated GIS. All existing conclusions concerning transmission network from previous project (original GIS from 2004) should be checked and analyzed once again due to significant changes which appeared in SEE region in last period and adjusted to defined planning criteria and methodology for projects prioritization from the study titled *Transmission network investment criteria* [2].

1.3 Regional demand

Modeling of demand should be the same as in original GIS. Winter peak situation has to be analyzed. Electricity demand of the countries not considered in GIS but included in transmission system model should be modeled according to *UCTE System Adequacy Forecast 2006 till 2015*.

1.4 Regional power balance

Three levels of regional power balance should be observed, depending on the hydrological conditions (dry and wet hydrology):

- power import in GIS countries[1] (during dry hydrological conditions);
- zero balance of GIS countries (during wet hydrological conditions); and
- power export from GIS countries (during wet hydrological conditions).

[1] *GIS countries* is a common name for the countries and UNMIK analyzed in Generation Investment Study which are at the same time the Contracting Parties to the Energy Community Treaty: Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Macedonia, Montenegro, Romania, Serbia and UNMIK.

Amounts of power import and power export will be determined after detailed analysis of national power balances for 2015, as predicted by TSOs' representatives.

1.5 Generators engagement

Modeling of generators engagement should respect regional power balance. Two hydrological conditions should be observed:

- dry hydrology; and
- wet hydrology.

Generators engagement in each GIS country will be determined by the representatives from TSO's, based on the existing dispatching practice and marginal costs, as well as on the basis of original GIS market engagement. Electricity supply of the countries not considered in GIS but included in transmission system model should be modeled according to *UCTE System Adequacy Forecast 2006 till 2015*.

1.6 Electricity exchanges

Exchange tables between GIS countries should be harmonized and approved by the representatives from TSOs. Power exchanges of the countries not considered in GIS but included in transmission system model should be harmonized as well.

2. OBJECTIVE

The main objective of the study is to assist the EC, WB and donors to identify an indicative priority list of investments in power generation and related electricity infrastructure from the regional perspective and in line with the objectives of the SEE electricity market. The study should identify priority investments in main transmission interconnections and internal lines between the countries and sub-regions to sustain investments in power generation and support market exchanges over the study horizon.

All findings, proposals and conclusions from previous study should be checked according to new changes, respecting new priority list for generation units in the SEE region in accordance with findings and conclusions from updated GIS.

Due to unknown location of several thousands of MWs in a number of scenarios (Table 1), transmission system adequacy will be analyzed for three scenarios only, assuming that it will be possible to determine locations of new power plants for these scenarios:

- Base case with official rehabilitation program (GIS sc1);
- Base case with justified rehabilitation program (GIS sc2); and
- Hydro power plants and high fuel price scenario (GIS sc8);

3. TRANSMISSION NETWORK PLANNING UNCERTAINTIES

Significant uncertainties have appeared due to a deregulated market environment. The most important uncertainties for the SEE region with respect to transmission system development have been identified in [2]. They are:

- new power plants sizes and locations;
- hydrological conditions;
- generators bids;
- branches and generators availability;
- load prediction; and
- regional power balance.

Transmission network planning scenarios should be related to:

- updated GIS results for scenarios 1, 2 and 8 (GIS sc1, GIS sc2, GIS sc8);
- hydrological conditions (dry, wet);
- branches availability (n available branches, n-1 available branches); and
- regional power balance (import, export, zero balance – related to GIS countries).

Transmission planning scenarios based on the three scenarios from updated GIS are presented in Figure 2 and Table 2.

It is assumed, based on the existing situation and related predictions, that the most probable export paths lead to Italy and western UCTE countries (Germany, Austria), and import paths from CENTREL and Ukraine.

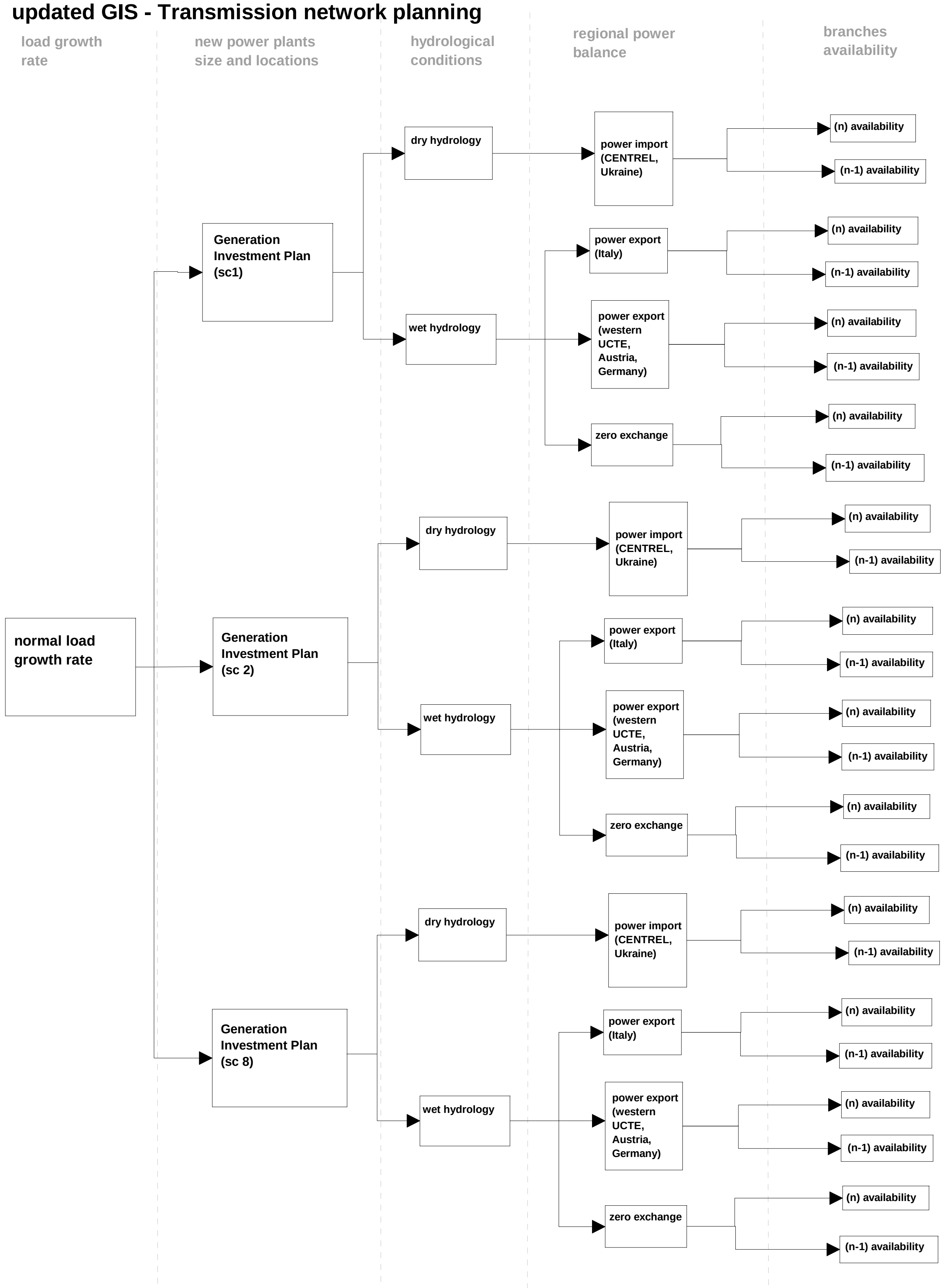


Figure 2 Transmission network planning scenarios

Table 2 Transmission network planning scenarios

GIS scenario	Hydrology	Regional balance	Identification
Base case with official rehabilitation program (sc1)	Dry	Import (CENTREL, Ukraine)	sc1 - 1
	Wet	Export to Italy	sc1 - 2
		Export to Western UCTE (Germany, Austria)	sc1 - 3
		Zero Balance	sc1 - 4
Base case with justified rehabilitation program (sc2)	Dry	Import (CENTREL, Ukraine)	sc2 - 1
	Wet	Export to Italy	sc2 - 2
		Export to Western UCTE (Germany, Austria)	sc2 - 3
		Zero Balance	sc2 - 4
Hydro power plants and high fuel price scenario (sc8)	Dry	Import (CENTREL, Ukraine)	sc8 - 1
	Wet	Export to Italy	sc8 - 2
		Export to Western UCTE (Germany, Austria)	sc8 - 3
		Zero Balance	sc8 - 4

4. TRANSMISSION NETWORK PLANNING CRITERIA AND METHODOLOGY FOR PROJECT PRIORITIZATION

SECI (South East Europe Cooperative Initiative) Project Group on the Regional Transmission System Planning prepared the study titled *Transmission network investment criteria* [2], with the aim to define transmission investment criteria from regional prospective and uniform methodology for project prioritization. Candidate transmission projects have to be evaluated by using predefined regional investment criteria and predefined prioritization methodology developed in the aforementioned study.

4.1 Planning criteria

Planning criteria for transmission system planning are divided into technical and economic criteria. Separate application of technical and economic criteria in transmission system development evaluation and projects prioritization is suggested here concerning availability of appropriate software tools and input data. SEE TSOs are currently equipped and trained to use technical criteria only.

Technical criteria for SEE transmission system planning are used for technical evaluation of the candidate projects for transmission network reinforcements. Technical criteria include:

1) Security (n-1) criterion;
2) Voltage and reactive power criterion;
3) Short-circuit criterion; and
4) Stability criterion.

For the long term planning, such as in this study, only the security (n-1) criterion should be used.

Economic criterion for transmission system planning is related to the profitability index. The profitability index is defined as the ratio between expected annual benefit from candidate project and the annuity of its expected costs. Candidate project is economically profitable if its profitability index is larger than 1 within planning period. The following types of benefit from construction of candidate projects may be estimated for the purpose of economic evaluation:

- benefit due to reduction of expected annual undelivered electricity costs;
- benefit due to annual losses reduction;
- benefit due to reduction of annual re-dispatching costs; and
- benefit due to annual congestion costs reduction.

The following types of costs from construction of candidate projects may be estimated for the purpose of the economic evaluation:

- investment costs; and
- operation and maintenance costs.

4.2 Methodology for prioritization of candidate projects

Only candidate projects with possible regional significance should be evaluated at the SEE regional level, while transmission projects with local significance, nominated by TSOs, have to be included into base case network topology.

Load flow and security analysis should be performed for all planning scenarios and network constraints should be recorded. List of recorded network constraints for all analyzed planning scenarios in a studied year is the basis for candidate projects' technical and economical evaluations that follow.

Starting from the common list of candidate projects, nominated by SEE TSOs as "projects with possible regional significance", and conducted analyses of load flows and security (n-1) analysis, candidate projects should be included into network topology one by one, and new load flow and security analysis has to be performed for all analyzed planning scenarios in a studied year. New list of network constraints has to be created, and constraints which are removed when new project is included into network topology have to be highlighted.

Candidate projects which are included in the reviewed list of candidate projects are technically prioritized according to network constraints which are removed by candidate projects:

- the first group contains candidate projects that remove network constraints with (n) available branches (the highest level of technical prioritization); and
- the second group contains projects that remove network constraints with (n-1) available branches (lower level of technical prioritization).

Inside these two groups of candidate projects, further technical prioritization is made according to:

- the number of planning scenarios in which candidate project removes network constraints (more planning scenarios with network constraints that are removed by candidate project, more technically significant is a project);
- voltage level of overloaded transmission lines (removal of overloading on 400 kV level are more significant than on 220 kV); and
- the number of network constraints that are removed by a candidate project (more constraints are removed, more technically significant is a project).

Candidate projects which are included in the reviewed list of candidate projects and prioritized according to the technical criteria should be further evaluated and prioritized according to the economic criteria based on the highest profitability indexes.

5. SCOPE OF WORK

- PSS/E RTSM (Regional Transmission System Model) which was created by SECI Project Group on the Regional Transmission System Planning, sponsored by USAID, has to be used for analyses. With a participation of all power system utilities in South East Europe, the Project Group finalized the PSS/E RTSM for 2010 and 2015, suitable for load flow, short-circuit and dynamic analysis. Besides the GIS countries, the RTSM also comprises models of Greece, Turkey, Slovenia, Burstyn (Ukraine), Italy, Hungary and Austria, with aim to have adequate network representation for all types of network analyses. Two models were created, one for winter maximum and the other for summer minimum demand in 2010 and 2015. Analyses on the PSS/E RTSM should provide insight to transmission network adequacy and determine what transmission reinforcements or additional priorities are eventually required to meet updated GIS 2015 generation dispatch under normal and (n-1) operating conditions.

- To analyze transmission network for investigated scenarios and in accordance with findings and conclusions from updated GIS. For three scenarios from updated GIS, and four sub-scenarios for each GIS scenario, steady-state load flows have to be calculated and contingency (n-1) analyses performed. Security criterion has to be based on lines overloading and voltage profile, and checked for each analyzed scenario. Special attention should be directed to existing and planned interconnectors between different SEE power systems (countries), as well as to internal lines with strong influence on regional flows. Total number of scenarios is 12.

- Special attention should be given to analysis of overloading and voltage profile in the region. Possible network bottlenecks should be identified and some solutions for transmission system relief should be described. The significance of new interconnection and internal lines candidates should be evaluated. Candidate transmission projects should be evaluated using predefined regional transmission investment criteria and technically prioritized according to the previously described prioritization methodology. Economic criteria evaluation and prioritization are not envisaged to be analyzed here due to the lack of appropriate model and input data at this moment.

- The following issues should be analyzed:
    - Load flow calculations
      To identify low, medium and high loaded elements in transmission network, (low to 20%, medium 20-60% and highly loaded over 60% of current limit)
    - Security (n-1) analysis
      The system adequacy is checked for operating conditions using “n-1” contingency criterion. List of contingencies includes:
        - all interconnection lines;
        - all 400 and 220 kV lines, except lines which outages cause “island” operation (in case of parallel lines and double circuit lines, outage of one line-circuit is considered);
        - all transformers 400/220 kV (in case of parallel transformers, outage of one transformer is considered).

- Voltage profile, for all voltage level 220 kV and above
  Voltage limits are given according to the operational and planning standards used in the monitored region, and they will be used for full topology and "n-1" analyses. Although, in emergency conditions for some voltage levels wider voltage limits are allowed, these are not taken into consideration.

- For all calculations, professional software package PSS/E™ (Power System Simulator for Engineering) version 30 should be used.

- PSS/E RTSM should be adjusted to updated GIS concerning network topology, demand, production and exchange data.

6. REFERENCES

[1] *Southeastern Europe Power Generation Investment Study (GIS) Update*, presentation on 9th Athens Forum, Varadan Atur, World Bank, October 2006

[2] *Transmission network investment criteria*, Report prepared by Energy Institute Hrvoje Pozar – EIHP and Electricity Coordinating Centre – EKC, March 2007

1. EXECUTIVE SUMMARY

Region of South East Europe (SEE) has experienced an ongoing process of changes in energy sector in areas of power generation, power transmission and power distribution. These changes are reflected in each country through reorganization of vertically integrated electric power utilities, followed by functional separation of transmission from generation and distribution. Changes in energy sector have also affected the planning philosophy of generation and transmission since most of SEE countries are transition countries. All generation and transmission plans and perspectives were summoned and analyzed in the "*Generation Investment Study*" in 2004. Its aim was to provide the list of most perspective generation units from regional perspective, to check the connection possibilities of these power plants to SEE transmission grid and eventually needed transmission system reinforcements in order to sustain new power generation.

However, since 2004, a number of significant changes emerged, mainly concerning gas and coal price changes which required updating of original GIS. Accordingly, generation development plans (until year 2015) were modified throughout "Update of GIS" study (commissioned in 2007) which yielded 10 different scenarios of generation upgrades and rehabilitation programs depending on benefits, fuel prices, emission quotes, hydrology states etc. On the other hand, new transmission projects emerged through South East Europe Cooperation Initiative (SECI) Regional Transmission System Planning working group. Another contribution of this working group was definition of transmission planning criteria in "*Transmission Network Investment Criteria*" study commissioned in 2007, which could be used for selection of a single transmission line candidate, amongst many other ones, as the most suitable one for high voltage transmission grid.

All these novelties implicated the conduction of an update of the original GIS study with the aim similar to the previous study, but reflecting a new moment as well: to generate a list of priorities of transmission line candidates, which should be built in order to reinforce the transmission grid in the SEE.

The present study was conducted on the premises of 3 generation patterns (taken from the update of GIS), with 4 exchange scenarios for each generation pattern, and with 8 transmission line candidates which influence was investigated (96 cases in total). Amongst these transmission line candidates, there are: one double OHL, two OHL triangles (loops) and two submarine HVDC cables. These 8 transmission line candidates were adopted with a planned special purpose, but each of them was analyzed from a regional point of view. All analyses were performed on the basis of the modified SECI load flow model for entire SEE. The analyses consisted of load flow and contingency (n-1) calculations.

After performing all calculations and assembling all results, the process of prioritization was conducted according to the "*Transmission Network Investment Criteria*". This process included sorting of transmission line candidates by numbers of system cases with contributions and obstructions for each candidate in the SEE regional transmission grid.

Overall conclusions of the analysis can be stated as follows:

1) According to *Transmission Network Investment Criteria*, none of observed interconnection candidate lines bring significant improvement to exchange possibilities in the region. In other words, the SEE transmission grid in 2015 can support planned injection of power from new power plants even without any interconnection transmission line candidate.
2) Exchange possibilities in the region are limited by the bottlenecks in internal networks, mainly in Albania, Romania and Bulgaria. Some of these bottlenecks can be removed by applying operational and dispatching control remedial measures.
3) As the final outcome, comparison of impacts of candidate interconnection lines resulted with a priority list - the highest priority was allocated to OHL 2x400 kV Ernestinovo (HR) – Pecs (HU).

Having this in mind, eight transmission line candidates were identified first and then their impacts to load flows in GIS countries were sorted for the scenario with maximum load in winter 2015. Load flow and contingency analyses produced results which were used to compare the impact of each candidate through a number of benefits or violations in regional power system. According to the methodology defined in *Transmission Network Investment Criteria* these benefits were analyzed statistically and sorted in order to select the transmission line with the highest priority for upgrading the existing regional transmission grid.

Final outcome of the prioritization was the following list of ranked transmission lines:

1. OHL 400 kV Ernestinovo (HR) – Pecs (HU) (double line)
2. OHL 400 kV Ernestinovo (HR) – Sombor (RS) – Pecs (HU) (triangle)
3. OHL 400 kV Kashar (AL) – Kosovo B (RS-UNMIK)
4. OHL 400 kV Zerjavinec (HR) – Cirkovce (SI) – Hevitz (HU) (triangle)
5. OHL 400 kV Marica Istok I (BG) – Nea Santa (GR)
6. OHL 400 kV Novi Sad (RS) – Timisoara (RO)
7. HVDC 400 kV Konjsko (HR) – Candia (IT)
8. HVDC 400 kV Durres (AL) – Foggia (IT) + OHL 400 kV Bitola (MK) – Elbasan (AL)

In order to provide comments for each of these transmission line candidates and their positions in the list of priorities, some important facts must be mentioned. In relation to load flow power balance for GIS countries in 2015, control areas of UCTE and IPS/UPS have an excess of power while power systems of Italy, Greece and Turkey were defined as importing regions with high amounts of imported power. Imports of Greece and Turkey were fixed to 2000 MW (1200 MW is import of Turkey, 400 MW is import of Greece and 400 MW is transit of power over HVDC Arachtos (GR) – Galatina (IT) to Italy). This high power import routed all power flow from GIS countries toward south of SEE in all cases (even when GIS countries exported power to western UCTE). High amount of power flows from IPS/UPS (Ukraine) and CENTREL (Slovakia) in all operating regimes due to the high import of Hungary (-1200 MW) and Italy (-9250 MW).

Generally, although there are three defined directions of power flow (from IPS/UPS to GIS countries, from GIS countries to western UCTE and from GIS countries to Italy), power flow does not follow the defined direction of exchange in any of these cases because of mixture of exporting and importing GIS countries, as well as because of importing countries to the north and south of GIS ones.

OHL 2x400 kV Ernestinovo (HR) – Pecs (HU) is ranked as the first one in the list of priorities. Among all candidates this line brings the highest contribution to the regional power flows in regimes of low water inflow when GIS region imports power from IPS/UPS and in regimes when GIS region is balanced. Large amounts of power always flow from Hungary toward Turkey and Greece, over Romania, Serbia and Bulgaria - part of this flow is diverted to the western part of GIS region. In case of presence of double OHL Ernestinovo – Pecs, a path of power is shortened - instead of flowing from Hungary over Romania and Serbia, power directly flows from Hungary to Croatia.

OHL 400 kV Ernestinovo (HR) – Sombor (RS) – Pecs (HU) (triangle) is the second one in the list of priorities. This transmission line candidate is a modification of the first ranked candidate since one of the transmission lines is fed into S/S 400 kV Sombor in Serbia. It is mentioned in Chapter 6 that effects of operation of this triangle are slightly worse than the effects of above mentioned double circuit line Ernestinovo (HR) – Pecs (HU).

OHL 400 kV Kashar (AL) – Kosovo B (RS-UNMIK) is the third one in the list of priorities. Reason for having this OHL candidate on the third place is to be found in its extremely beneficial effect to neighboring Albania in all regimes of operation or exchange. Conceptually, 400 kV grid of Albania consists of single backbone connection from Montenegro to Greece without any generation connected to this voltage level. In case of any heavy power transfer this candidate provides needed voltage support maintaining steady state security in this part of GIS region. It is considered that this candidate should not be treated as a separate transmission line candidate, but with an HVDC candidate which might lead from Albania. Another supporting reason for this conclusion is related to connection of new power generation in UNMIK (Kosovo B and C) until 2015.

OHL 400 kV Zerjavinec (HR) – Cirkovce (SI) – Heviz (HU) (triangle) is the fourth candidate in the list of priorities. Situated in the far north-west of GIS region, this transmission line candidate is actually an upgrade of existing double interconnection line 400 kV Zerjavinec (HR) – Heviz (H) (one of lines is fed into S/S 400 kV Cirkovce in Slovenia). Benefits of this OHL loop are not fully expressed in defined scenarios of the present study due to the position and direction of exchanges. This triangle, combined with double OHL 400 kV Okroglo (SI) – Udine (IT), might contribute more to power transfers from IPS/UPS directly to UCTE and Italy.

OHL 400 kV Marica Istok I (BG) – Nea Santa (GR) is the fifth candidate in the list of priorities. On the contrary to the previous candidate, this line is situated at the far south-east of GIS region. In comparison to other candidates, this line does not bring many differences in situations related to the middle of GIS region due to its position and already defined power flow direction from Bulgaria to Turkey. Since the existing two lines (to Babaeski and Hamitabat in Turkey) already have enough reserve transmission capacity, operation of the new candidate from Marica Istok I to Nea Santa only redistributes the power flow by diverting one part over Greece. Much higher contribution of this candidate could be noticed in scenarios with much higher power import of Turkey and Greece or export of Turkey to UCTE.

OHL 400 kV Novi Sad (RS) – Timisoara (RO) is the sixth candidate in the list of priorities. Contribution of this candidate is neutral in comparison to other candidates since there are no much gains and losses with its operation. This is a consequence of predefined power flows from north to south of GIS region over Serbia and Romania simultaneously, so there are no significant changes in line flows in presence of this line.

HVDC 400 kV Konjsko (HR) – Candia (IT) is the seventh candidate in the list of priorities. The main purpose of this candidate is 500 MW power transfer toward Italy. Although the amount of power is not critical (natural power of 400 kV transmission line), operation of this submarine cable brings more problems to GIS transmission grid due to the weak connection point in Konjsko. Main conclusion for this cable is that the connection at Konjsko must be reinforced.

Combination of HVDC 400 kV Durres (AL) – Foggia (IT) and OHL 400 kV Bitola (MK) – Elbasan (AL) is the eighth candidate in the list of priorities. These two elements present an essential part of the Corridor 8 energy connection from Black Sea to the Ionian Sea. Once again, like in case of previous candidate, 500 MW power transfer toward Italy causes overloads and low voltages in Albania due to undeveloped 400 kV grid in this part of GIS region. However, these problems could be solved effectively with inclusion of OHL 400 kV Kashar – Kosovo B which may bring higher voltage support to 400 kV grid and power transfer from TPP situated in UNMIK.

As stated before, overall conclusion of the present study is the following: the transmission grid of the SEE region and the GIS one in particular, can sustain envisioned generation development and power injection until 2015. The existing transmission grid with already presumed interconnection lines enables secure power transfer without any overloaded branches or voltage magnitudes lower than the limit defined by Grid Codes of participating TSOs. Presence of the new transmission line candidates does not bring too many changes in power flow composition from the planning viewpoint, but in a way contributes to certain exchange scenarios.

2. INTRODUCTION

The main objective of the original Generation Investment Study (GIS) was to assist the European Commission (EC), International Financial Institutions (IFIs) and donors to identify an indicative priority list of investments in power generation and related electricity infrastructure from the regional perspective and in line with the objectives of South East Europe Regional Electricity Market (SEE REM). The study determined the optimal timing, size and location for construction of future generating capacity in the region over the 15 year period (2005 – 2020). It also identified priority investments in main transmission interconnections between the countries and sub-regions to help optimize investment requirements in power generation over the study horizon. The following were investigated in the project: Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Macedonia, Montenegro, Romania, Serbia and UNMIK. Fourteen load flow regional transmission system models (RTSM) were created by SECI (South East Europe Cooperative Initiative) Project Group and developed in PSS/E software format. Input data for these models in terms of generation and load prediction in the SEE REM conditions were obtained by using additional software, WASP and GTMax, namely. Regional Balkans Infrastructure Study (REBIS) – Electricity and Generation Investment Study (GIS) was finished and issued on December 31, 2004 by PWC and MWH.

Since 2004, a number of significant changes emerged concerning primarily gas price growth and decrease in price of imported coal which required updating of original GIS. The aim of the new project was the updating of Generation Investment Study (updated GIS) with some altered fuel prices, according to market development, as well as with some revised constraints to the power system development. Load prediction for the 15 year period (2005 – 2020) was taken from the original GIS on the basis of GTMax calculations. The update of GIS has been performed and issued on January 9, 2007 by WB and SEEC [3] with the following development scenarios:

- Base case with official rehabilitation program (GIS sc1);
- Base case with justified rehabilitation program (GIS sc2);
- High fuel price scenario (GIS sc3);
- Low fuel price scenario (GIS sc4);
- €20/t CO_2 scenario (GIS sc5);
- €30/t CO_2 scenario (GIS sc6);
- High electricity import scenario (GIS sc7);
- Hydro power plants and high fuel price scenario (GIS sc8);
- Hydro power plants with €20/t CO_2 scenario (GIS sc9); and
- Hydro power plants with €30/t CO_2 scenario (GIS sc10).

It should be stressed out that updated GIS gives only types and sizes of new power plants for different planning scenarios, without their location and market engagement, unlike original GIS from 2004. The reason for that is the usage of WASP model only, while in the previous stage GTMax was also used. Main results from update of GIS are generation expansion plans followed by rehabilitation of existing TPPs. These expansion plans are given for each analyzed scenario.

Update of GIS was used as a starting condition for performing the present study, whose main objective remains the same, as it was in original GIS from 2004, but with updated and revised data. For starting conditions three characteristic scenarios were taken from update of GIS (these being estimated as the most probable ones):

- Base case with official rehabilitation program (GIS sc1);
- Base case with justified rehabilitation program (GIS sc2); and
- Hydro power plants and high fuel price scenario (GIS sc8).

As in original GIS, with participants from all power system utilities in South East Europe, the SECI Project Group finalized the PSS/E RTSM for 2015 for load flow analyses [4]. The following were involved in creation of the PSS/E RTSM: Albania – KESH; Bosnia and Herzegovina – NOS, EPBiH, EPRS, EPHZHB; Bulgaria – NEK/ESO; Croatia – HEP, EIHP; Macedonia – ESM/MEPSO; Greece – PPC/HTSO; Hungary – MVM; Romania – Transelectrica; Serbia – EPS/EMS, EKC; Montenegro – EPCG; Slovenia – ELES; Turkey – TEAS and Italy – TERNA. This model also contains reduced day-ahead congestion forecast (DACF) model of Austria in order to equivalent the influence of western UCTE grid.

Winter maximum regime was chosen as far most critical for the SEE region because of similar load profiles in almost all analyzed power systems. Countries which were analyzed in original GIS (Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Macedonia, Montenegro, Romania, Serbia and UNMIK) were analyzed in the present study as well from the regional aspect as a single GIS region. This approach was adopted from *Transmission Network Investment Criteria* released in March 2007, by EIHP and EKC [5].

For each of the three chosen scenarios from update of GIS the four exchange scenarios were analyzed:

- Zero balance of GIS region (wet hydrology situation);
- Export to western UCTE from GIS region (wet hydrology situation);
- Export to Italy from GIS region (wet hydrology situation); and
- Import from Ukraine and CENTREL to GIS region (dry hydrology situation).

Engagement of generation units for each scenario and each hydrological condition (12 models in total) was taken from original GIS and updated recently by SECI in the RTSM.

Analysis conducted on the PSS/E RTSM provided an insight to transmission network adequacy and determined what transmission reinforcements or additions priorities are eventually required to meet 2015 generation dispatch under normal and (n-1) operating conditions.

The PSS/E RTSM was adjusted according to GTMax model from original GIS, concerning network topology, demand, production and exchange data from recent collection of SECI working group. For each scenario, steady-state load flows were calculated and contingency (n-1) analyses performed. Security criterion based on voltage profile and lines congestions (thermal overloading) were checked for each analyzed scenario. Special attention was directed to group of planned interconnection lines between different SEE power systems (countries). According to the principles from *Transmission Network Investment Criteria*, prioritization of these transmission line candidates was performed on the basis of load flow and (n-1) calculations.
The final outcome of the present study is the identification of possible network bottlenecks and evaluation of the role of new interconnection line candidates in removal of the bottlenecks.

3. METHODOLOGY

3.1 Short Description of PSS/E Model

For all calculations performed in the present study, Siemens PTI PSS/E (Power System Simulator for Engineering) is used. It is a system of computer programs and structured data files designed to handle the basic functions of power system performance simulation work, namely:

- Data handling, updating, and manipulation;
- Power flow;
- Optimal power flow;
- Fault analysis;
- Dynamic simulations + Extended term dynamic simulations;
- Open network access and price calculation; and
- Equivalent Construction.

Current version of this software package used for calculations here is version 30.3. PSS/E is comprised of the following modules:

PSS/E Power Flow: This module is basic PSS/E program module and it is a powerful and easy-to-use for basic power flow network analysis. Besides analysis tool this module is also used for data handling, updating, and manipulation.

PSS/E Optimal Power Flow (PSS/E OPF): PSS/E Optimal Power Flow (PSS/E OPF) is a powerful and easy-to-use network analysis tool that goes beyond traditional load flow analysis to fully optimize and refine a transmission system. This task is achieved with the integration of PSS/E OPF into the PSS/E load flow program. PSS/E OPF improves the efficiency and throughput of power system performance studies by adding intelligence to the load flow solution process. PSS/E OPF directly changes controls to quickly determine the best solution.

PSS/E Balanced or Unbalanced Fault Analysis: The PSS/E Fault Analysis (short circuit) program is fully integrated with the power flow program. The system model includes exact treatment of transformer phase shift, and the voltage profile from the solved power flow case.

PSS/E Dynamic Simulation: PSS/E models system disturbances such as faults, generator tripping, motor starting and loss of field. The program contains an extensive library of generator, exciter, governor, and stabilizer models as well as relay model including underfrequency, distance and overcurrent relays to accurately simulate disturbances.

3.2 Network Investment Criteria

The SEE TSOs are obliged to plan transmission systems under their control. Their plans will include new facilities and objects, but planned primarily to satisfy their national requirements, obligations and criteria. Regional and market significance of these projects may be invisible or not estimated and taken into account. Unique list of candidate projects in the SEE region should be determined and each of the SEE TSOs should define candidate projects according to their national plans and considerations. This list has to include technical and economic parameters of candidate projects. The list of candidate projects prepared by each SEE TSO shall be divided into two parts: 1) candidate projects with local significance, and 2) candidate projects with possible regional significance.

Only candidate projects with possible regional significance should be evaluated at the SEE regional level, examined according to pre-defined technical and economic criteria and prioritized according to the methodology described in *Transmission Network Investment Criteria*.

Load flow and security analyses have to be conducted within planning time-horizon in order to examine future network operation and identify possible constraints that might occur. Network modeling for load flow and security analyses shall be prepared by SEE TSOs, representing a network on the territory of their control. Models shall be merged and one official model of the SEE transmission network shall be prepared for each studied year within the planning horizon. Network shall be modeled in the PSS/E format (Power System Simulator for Engineers, Siemens PTI) that is used by all SEE TSOs. Concerning analyzed demand situations, three load levels shall be modeled: 1 - winter peak load; 2 - summer maximum load; and 3 - summer minimum load. Initial models should be used to create different models representing future uncertainties. Load flow and security analyses should be performed for all future scenarios and network constraints should be recorded. List of recorded network constraints for all analyzed planning scenarios in a studied year is the base for project candidates' technical and economic evaluation.

For the purpose of economic evaluation of candidate projects, declared by SEE TSOs as "projects with possible regional significance", and their prioritization, probabilistic analysis offers the best performance. Probabilistic analysis should be conducted for different demand (load) levels. Probabilistic analysis should be performed for all planning scenarios defined according to future uncertainties. For each planning scenario benefits from candidate projects should be evaluated.

Separate application of technical and economic criteria in transmission system development evaluation and projects prioritization procedures should be allowed, depending on readiness and availability of software tools. Starting from the common list of candidate projects, nominated by SEE TSOs as "projects with possible regional significance", and conducted analyses of load flows and (n-1) security, candidate projects should be included into network topology one by one, and new load flow and security analysis have to be performed for all analyzed planning scenarios in a studied year. New list of network constraints has to be created, and constraints that are removed when new project is included into network topology have to be highlighted.

Candidate projects which are included in the reviewed list of candidate projects are technically prioritized according to network constraints that are removed by candidate projects:

- the first group contains candidate projects which remove network constraints with (n) available branches (the highest level of technical prioritization); and
- the second group contains projects which remove network constraints with (n-1) available branches (lower level of technical prioritization).

In these two groups of candidate projects, further technical prioritization is made according to:

- the number of planning scenarios in which a candidate project removes network constraints (more planning scenarios with network constraints which are removed by a candidate project, more technically significant is a project);

- voltage level of overloaded transmission lines (removal of overloading on 400 kV lines are more significant than on 220 kV lines); and
- the number of network constraints that are removed by a candidate project (more constraints are removed, more technically significant is a project).

Candidate projects which are included in the reviewed list of candidate projects and prioritized according to the technical criteria should be further evaluated and prioritized according to the economic criterion, which is not part of the present study as mentioned before.

Technical criteria for the SEE transmission system planning are used for technical evaluation of the candidate projects for transmission network reinforcements. Table 3.1 presents the summary of suggested SEE transmission system technical planning criteria.

The technical criteria include:

1) Security (n-1) criterion;
2) Voltage and reactive power criterion;
3) Short-circuit criterion; and
4) Stability criterion.

Transmission network investment criteria also include the economic one (the profitability index), but it is not evaluated within the present study due to the lack of input data and appropriate model. It should be evaluated in future work in order to get a better view over economic considerations of network investments.

Table 3.1 Technical criteria for the SEE transmission system planning

Planning time-frame	Topology	Analyzed operating conditions	Technical criteria satisfaction	Permitted corrective actions
Short	All branches and generators available **(n)**	SEE peak load SEE minimum load (1-3 year horizon)	$I_{lines} < I_{max\ lines}^{*}$ $U_{min} < U_{node} < U_{max}$ Stability criteria Short-circuit criteria	automatic transformers regulation switching of compensation devices network sectioning
	One branch (line, transformer) or generator or compensation device unavailable **(n-1)**	SEE peak load (1-3 year horizon)	$I_{lines} < I_{max\ lines}^{**}$ $U_{min} < U_{node} < U_{max}$	generators re-dispatching*** automatic and manual transformers regulation switching of compensation devices network sectioning
Mid	All branches and generators available **(n)**	SEE peak load SEE minimum load (5 year horizon)	$I_{lines} < I_{max\ lines}^{*}$ $U_{min} < U_{node} < U_{max}$ Stability criteria Short-circuit criteria	automatic transformers regulation switching of compensation devices network sectioning
	One branch (line, transformer) or generator or compensation device unavailable **(n-1)**	SEE peak load (5 year horizon)	$I_{lines} < I_{max\ lines}^{**}$ $U_{min} < U_{node} < U_{max}$	generators re-dispatching*** automatic and manual transformers regulation switching of compensation devices network sectioning
Long	All branches and generators available **(n)**	SEE peak load SEE minimum load (10 year horizon)	$I_{lines} < I_{max\ lines}^{*}$ $U_{min} < U_{node} < U_{max}$	automatic transformers regulation switching of compensation devices network sectioning
	One branch (line, transformer) or generator or compensation device unavailable **(n-1)**	SEE peak load (10 year horizon)	$I_{lines} < I_{max\ lines}^{**}$ $U_{min} < U_{node} < U_{max}$	generators re-dispatching*** automatic and manual transformers regulation switching of compensation devices network sectioning

* may be defined separately for winter and summer operation
** may be defined assuming permitted short time overloading (within 30 minutes)
*** power plants with fast regulation only (within 30 minutes)

4. PREREQUISITES AND ASSUMPTIONS

4.1 Introduction

SECI Regional Transmission System Model (RTSM), made in PSS/E, is used to provide more detailed view on the SEE regional transmission network operation under realistic market conditions. Figure 4.1 shows which countries and their transmission systems were modeled. High voltage transmission network of 750 kV, 400 kV, 220 kV, 150 kV (present Greece and Turkey), and 110 kV voltage levels is implemented in the model. Moreover, all new substations and lines which are expected to be operational till 2015 (according to the long term development plans) are modeled as well.

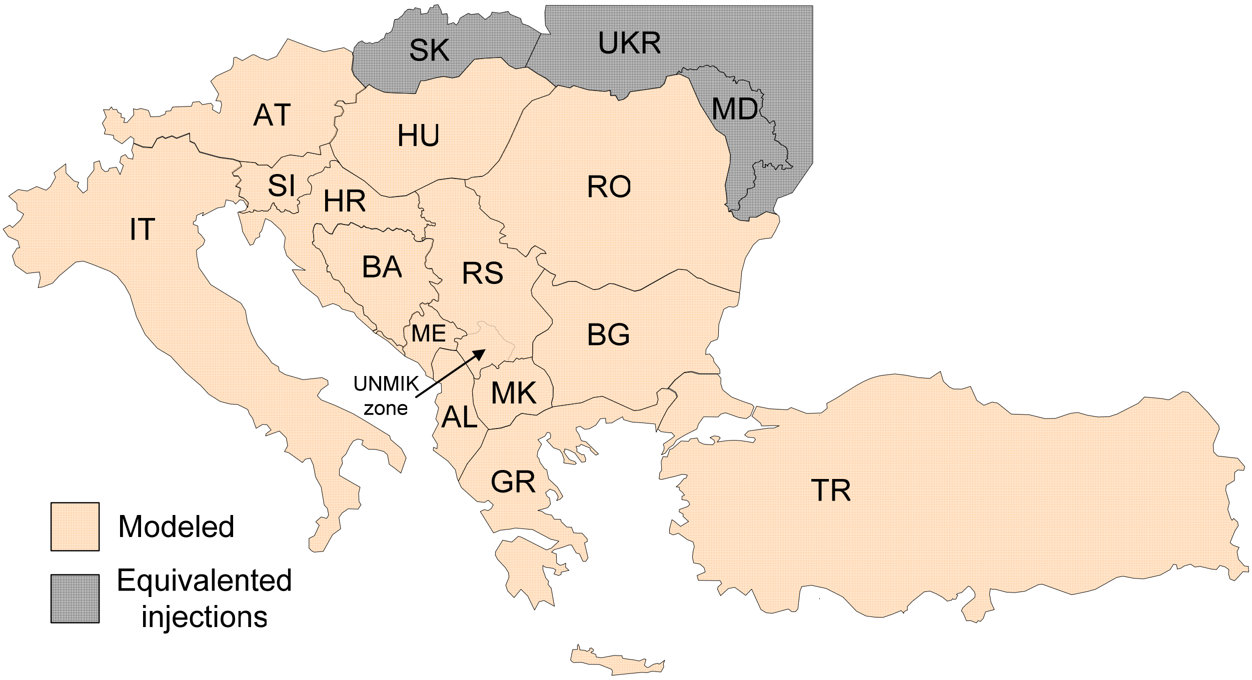


Figure 4.1 Modeled countries in the SECI regional transmission system model

All generation units that are connected to the transmission voltage level are modeled as they are in reality (with step-up transformers). Planned generation units (according to update of GIS) are modeled with step up transformers or as plant bus injections on the basis of available data. Model is designed for load-flow calculations and analysis, but with adequate data input (already developed and tested) it can be used for other types of analysis too:

- Short-circuit calculations; and
- Dynamics (transient stability assessment).

In the models, the whole 110 kV and above network is included. Each interconnection line has assigned an X node which is placed at border of each country (not in the middle of tie line). The model for 2015 is obtained by introducing consumption of each electric power system according to results from GTmax calculation in original GIS. Generation in each power system was introduced as a combination of data obtained from original GIS (GTMax results) and recent data obtained from SECI RTSM for winter 2015 scenario. By using the SECI RTSM as the basis for development of GIS models, all planned network topology changes in SEE were automatically introduced.

Voltage level limits are presented in the **Error! Reference source not found.**4.1. These limits are used in load flow calculations as well as in contingency analysis.

Table 4.1 Defined limits for voltage levels

	Defined voltage levels											
	750 kV		400 kV		220 kV		150 kV		110 kV		Generator	
	min	max	min	max	min	max	min	max	min	max	min	max
kV	712	787	380	420	198	242	135	165	99	121		
p.u.	0,95	1,05	0,95	1,05	0,90	1,10	0,90	1,10	0,90	1,10	0,95	1,05

These limits are defined according to the operational and planning standards used in the monitored region, and they are used for full topology and "n-1" analyses. Although wider voltage limits are allowed in emergency conditions for some voltage levels, these are not taken into consideration.

The system adequacy is checked for operating conditions using (n-1) contingency criterion. It must be stated that common practice in UCTE, nowadays, is to consider 110 kV grid as a part of distribution system, while 400 kV and 220 kV networks are ranked as transmission system. From this point of view, in almost all countries of GIS region and in the SECI RTSM, 110 kV grid can be treated as distribution network (except in Montenegro and Macedonia). For this reason the list of contingencies includes:

- all interconnection 400 and 220 kV lines;
- all internal 400 and 220 kV lines, except lines which outage cause “island” operation; and
- all transformers 400/220 kV (in case of parallel transformers, outage of one transformer is considered).

Current thermal limits are used as rated limits for lines and transformers. These limits are established on the basis of a temperature to which conductor is heated by current above which either the conductor material would start being softened or the clearance from conductor to ground would drop beyond permitted limits. In these analyses, conductor current must not reach limits imposed by thermal limit defined for conductors material and cross-section according to the IEC standard (50) 466: 1995 – International Electrotechnical Vocabulary - Chapter 466: Overhead Lines. For transformers, installed rated MVA power is used as thermal limit. Every branch with current above its thermal limit is treated as overloaded.

All system states in which voltage level is outside permitted limits or branches are loaded beyond thermal limit (overloaded), by full topology or (n-1) contingency analyses, are treated as "insecure states" and referenced as such in the present study.

4.2 Generation and Demand

This section hereafter shortly describes analyzed generation and demand which were forecasted in original GIS and update of GIS (WASP and GTMax calculations) and explains how they are implemented in PSS/E. In the present study, total number of 12 scenarios were analyzed from transmission network perspective (Table 4.2). These scenarios were developed on the basis of different power plant rehabilitation programs, different fuel prices and expected hydrological situations. Three scenarios from update of GIS are taken into consideration as the base cases and four different exchange programs are defined for each scenario.

Table 4.2 Definition of analyzed scenarios for the GIS countries

GIS scenario	Hydrology	Regional balance
Base case with official rehabilitation program (sc 1)	Dry	Import (CENTREL, Ukraine)
	Wet	Export to Italy
		Export to western UCTE (Germany, Austria)
		Zero balance
Base case with justified rehabilitation program (sc 2)	Dry	Import (CENTREL, Ukraine)
	Wet	Export to Italy
		Export to western UCTE (Germany, Austria)
		Zero balance
Hydro power plants and high fuel price scenario (sc 8)	Dry	Import (CENTREL, Ukraine)
	Wet	Export to Italy
		Export to western UCTE (Germany, Austria)
		Zero balance

Demand forecast for winter regime in 2015 is taken consequently from original GIS and update of GIS, since this value was calculated and given as a reference for all calculations. Total demand for GIS region (Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Macedonia, Montenegro, Romania, Serbia and UNMIK) is 33151 MW. This consumption was used in modeling of the Base Case Official Scenario (Table 4.2), while slightly increased values of demand were used for the Base Case Justified Scenario (33188 MW) and High Gas Price & Hydro Scenario (33193 MW). This increase of demand originates from addition of self consumption for new TPP generation units, which were added according to update of GIS. Particular demands of each power system in GIS region are taken from original GIS base case for 2015 and introduced into PSS/E load flow models.

Generation in GIS countries was defined on the basis of generation from the original GIS and data obtained from the SECI RTSM. Since the present study has to be in concordance with previous stages of GIS, some planned power plants were not taken into consideration, although they existed in the SECI RTSM (because they were not in any stage of GIS). Further engagement of any unit was enabled as a cross section of generation data from the original GIS and the SECI RTSM. Generation of all units depends on the regimes analyzed in the present study.

Exchange regimes were defined for each scenario, on the basis of hydrology situation, namely:

- Zero balance - wet hydrology (generation in GIS region covers its own demand);
- Wet hydrology (export from GIS region to UCTE or Italy particularly); and
- Dry hydrology (import of GIS region from CENTREL and Ukraine).

Zero balance regime presents a generation pattern in which GIS region is self sustainable in terms of power generation and consumption. Generation of TPPs is taken from the original GIS and update of GIS, while generation of HPPs is derived from comparison of data from the original GIS (average hydrology scenario) and the SECI winter RTSM. It must be pointed out that the SECI RTSM for winter 2015 is a “wet hydrology” model. Since the aim was to get the reduced generation of HPPs (with high water inflows), least value of generation was taken for each generator in this comparison. This way, more average hydrology scenario with zero balance exchange program was obtained.

Low water inflows (often marked as “dry hydrology”), which are considered to be the same for entire GIS region, affect the engagement of HPPs. In this regime, GIS region has a generation deficiency due to much lower generation of HPPs. While engagement of TPPs in this regime remains the same as it is in the zero balance regime, engagement of HPPs is completely taken from the original GIS dry hydrology scenario.

High water inflows (often marked as “wet hydrology”), which are also considered to be the same for entire GIS region, affect the engagement of HPPs in opposite manner. In this regime, GIS region has a generation surplus due to much higher generation of HPPs. Engagement of TPPs in this regime remains the same as it is in the zero balance regime, but engagement of HPPs is taken to be at a higher value of generation for each unit compared between the original GIS and the SECI RTSM.

According to update of GIS, ten scenarios for generation structure, rehabilitation and expansion were given based upon most probable fuel reserves, fuel prices, ecological impacts and common practice. Since all of these scenarios were analyzed in WASP software with the same consumption at regional level (33151 MW, taken from the original GIS), it can be concluded that any of them is concurrent in means of power balance. Three scenarios were chosen for further analyses in the present study since they have the highest compatibility with situation in analyzed region (Table 4.1):

- Base case with official rehabilitation program (Base Case Official Scenario);
- Base case with justified rehabilitation program (Base Case Justified Scenario); and
- Hydro power plants and high fuel price (High Gas Price & Hydro Scenario).

All prerequisites and assumptions from update of GIS for these selected scenarios were taken into account regarding the number and engagement of TPPs. New planned TPPs, OCGTs and CCGTs are also taken into account and implemented in period from 2005 till 2015 (Table 4.3). All generation unit output values are given as grid output values (nominal power of generator reduced by generation block self consumption). Self consumption of standard TPPs may vary from 5% to 10%, while for OCGT or CCGT it goes up to 5% of installed capacity depending of processes covered with this supply. Since the self consumption of HPPs is usually less than 1%, nominal power for each generator presents at the same time the grid output.

Nevertheless, since all analyses in update of GIS were performed with WASP software, result outputs for three selected scenarios contain some generic power plants (lignite, imported coal or gas power plants) with respective generation, but without given exact location, or way of connection to power system. In such cases, replacement power plants were chosen from group of power plants with similar or same installed power which are not considered in GIS, but are present in the SECI RTSM (Table 4.4). This way, consistency with previous GIS studies is maintained and updates, given in the SECI RTSM for 2015, were implemented.

Table 4.3 New generation units planned in update of GIS from 2005 till 2015.

	Base Case Official		Base Case Justified		High Gas Price & Hydro	
Area	Power Plant	Installed power [MW]	Power Plant	Installed power [MW]	Power Plant	Installed power [MW]
Albania	TPP Vlora(2010)	132	TPP Vlora(2010)	132	TPP Vlora(2010)	132
Bulgaria	TPP Maritsa Istok I	2x275	TPP Maritsa Istok I	2x275	TPP Maritsa Istok I	2x275
	NPP Belene	1x930	NPP Belene	1x930	NPP Belene	1x930
Bosnia & Herzegovina					HPP Buk Bijela	3x150
					HPP Srbinje/Foca	3x18,5
					HPP Glavaticevo	172
					HPP Dabar	160
Croatia						
Macedonia						
Montenegro					HPP Komarnica	168
					HPP Zlatica	3x18.5
					HPP Kostanica	552
					HPP Andrijevo	200
Serbia (with UNMIK)	TPP Kosovo C (UNMIK) 1-1	1x450	TPP Kosovo C (UNMIK) 1-5	1x450		
	TPP Kolubara B	2x320	TPP Kolubara B	2x320	TPP Kolubara B	2x320
	TPP Kosovo B (UNMIK) 3-5	3x275	TPP Kosovo B (UNMIK) 3-8	4x275		
					HPP Zhur (UNMIK)	293
Romania	GTPP Bucuresti sud 1	100	GTPP Bucuresti sud 1	100	GTPP Bucuresti sud 1	100
	GTPP Bucuresti sud 2	100	GTPP Bucuresti sud 2	100	GTPP Bucuresti sud 2	100
	GTPP Bucuresti west 1	100	GTPP Bucuresti west 1	100	GTPP Bucuresti west 1	100
	GTPP Bucuresti west 2	100	GTPP Bucuresti west 2	100	GTPP Bucuresti west 2	100
	NPP Cerna Voda 2	664	NPP Cerna Voda 2	664	NPP Cerna Voda 2	664
	NPP Cerna Voda 3	664	NPP Cerna Voda 3	664	NPP Cerna Voda 3	664
GIS total	BCO new generation	5255	BCJ new generation	5530	HGPH new generation	6086

Table 4.4 Unknown generic power plants in GIS and their replacement candidates

Scenario	Unknown power plant	Installed power [MW]	Replacement candidate
Base Case Official	Combined Cycle	288	CCGT Skopje (MK)
	Combined Cycle	480	CCGT Sisak+CCGT Osijek (HR)
Total generation with unknown location		768	
Base Case Justified	Combined Cycle	288	CCGT Skopje (MK)
	Combined Cycle	480	CCGT Sisak+CCGT Osijek (HR)
	Combined Cycle	480	CCGT Novi Sad (RS)
	Imported coal	470	TPP Plomin G3 (HR)
Total generation with unknown location		1718	
High Gas Price&Hydro	Combined Cycle	288	CCGT Skopje (MK)
	Combined Cycle	480	CCGT Sisak+CCGT Osijek (HR)
	Lignite subcritical	275	TPP Kosovo B G3 (RS/Unmik)
	Lignite subcritical	275	TPP Kosovo B G4 (RS/Unmik)
	Lignite subcritical	275	TPP Kosovo B G5 (RS/Unmik)
	Lignite subcritical	450	TPP Kosovo C G1 (RS/Unmik)
	Imported coal Supercritical	470	TPP Plomin G3 (HR)
	Imported coal Supercritical	470	TPP Maritsa Istok III G5 (BG)
	Imported coal Supercritical	470	TPP Maritsa Istok III G6 BG)
Total generation with unknown location		3453	

Besides new conventional fossil fuel fired power plants, new 1000 MW nuclear reactor in NPP Belene (Bulgaria) and two new 700 MW reactors in NPP Cherna Voda (Romania) were also taken into consideration according to update of GIS. Other than that, in the High Gas Price & Hydro Scenario, due to increased fuel price, much higher development of HPPs is expected and introduced in the models accordingly.

All new power plants are modeled in the power systems according to information gathered from corresponding electric power utilities and TSOs. In some cases when the means of connection of power plant was unknown, it was connected to the nearest substation with a capability to accept the additional power injection (i.e. HPP Dabar and HPP Glavaticevo).

In the process of determination of locations for new power plants, the regional gas network development plans were also respected (Figure 4.2).

Geographical positions of new and assigned power plants until 2015 are shown in Figures 4.3 – 4.5.

Figure 4.2 Gas network development plans in the region (including PEOP oil pipeline)

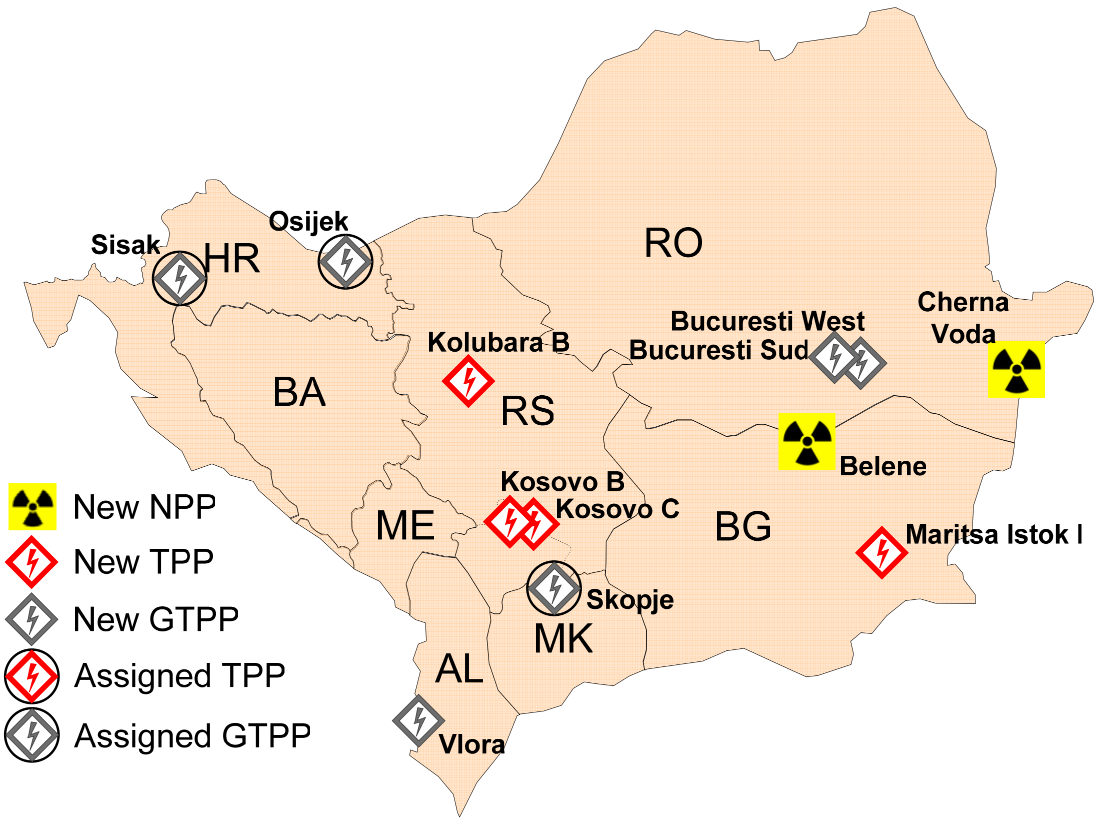


Figure 4.3 Base Case Official
- Location of new power plants in GIS and assigned locations for power plants with previously unknown location -

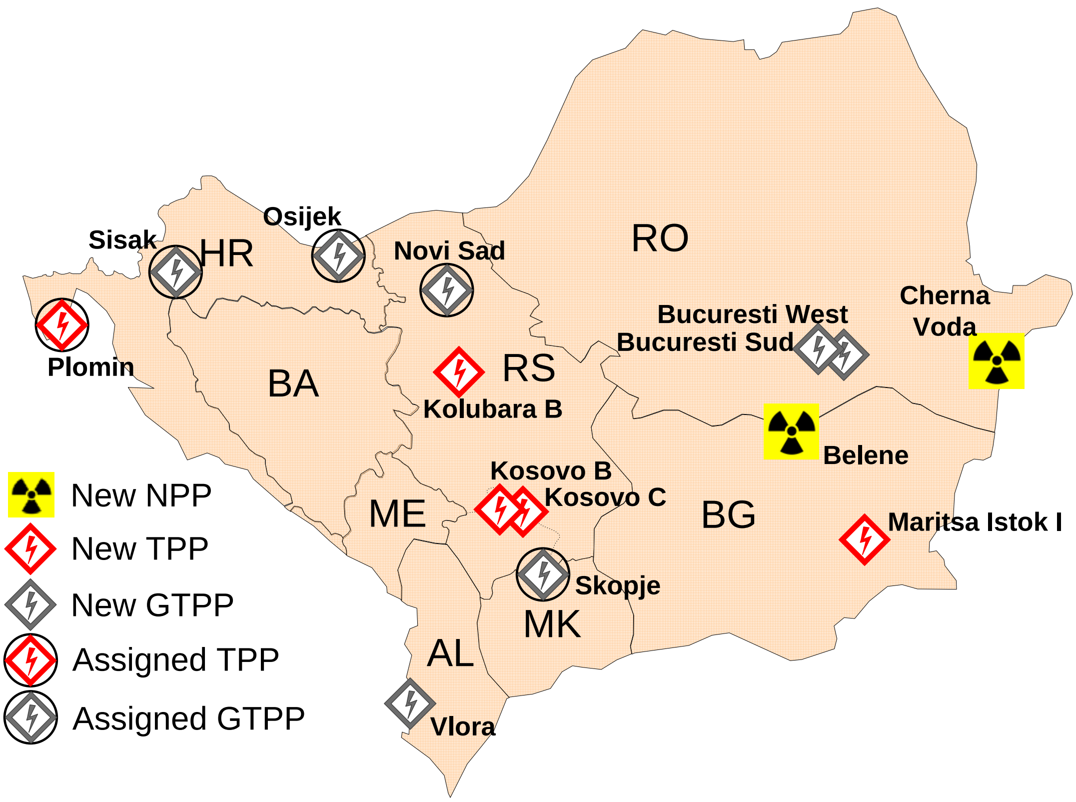


Figure 4.4 Base Case Justified
- Location of new power plants in GIS and assigned locations for power plants with previously unknown location -

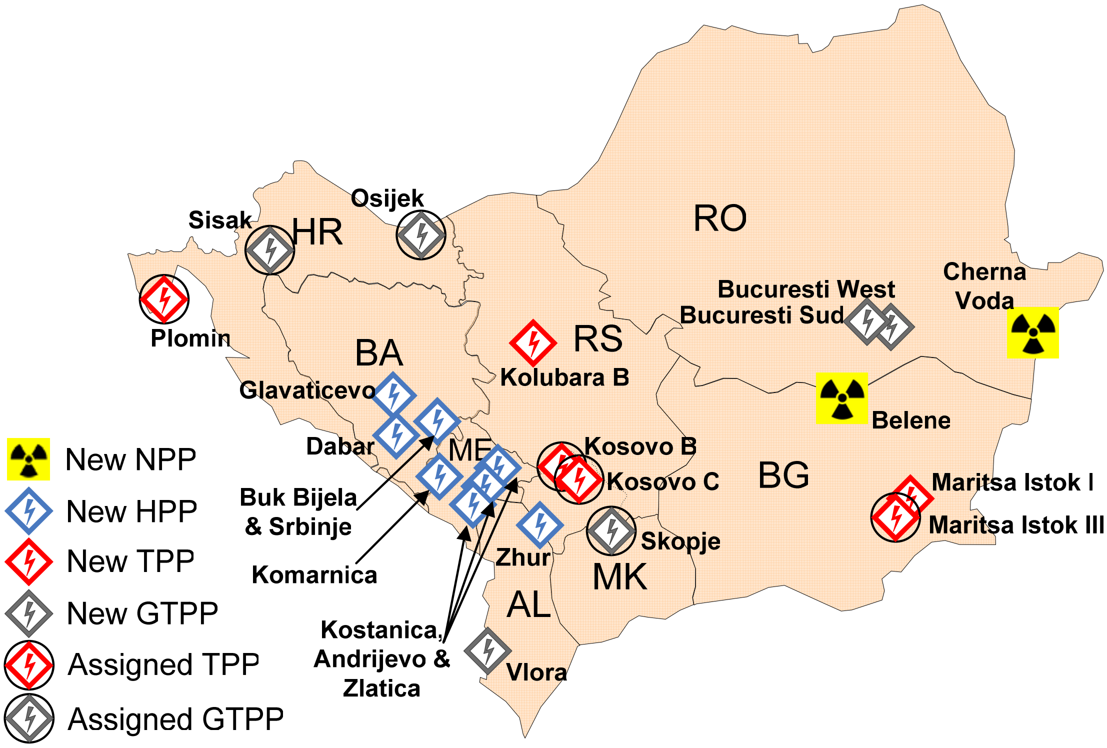


Figure 4.5 High Gas Price & Hydro
- Location of new power plants in GIS and assigned locations for power plants with previously unknown location -

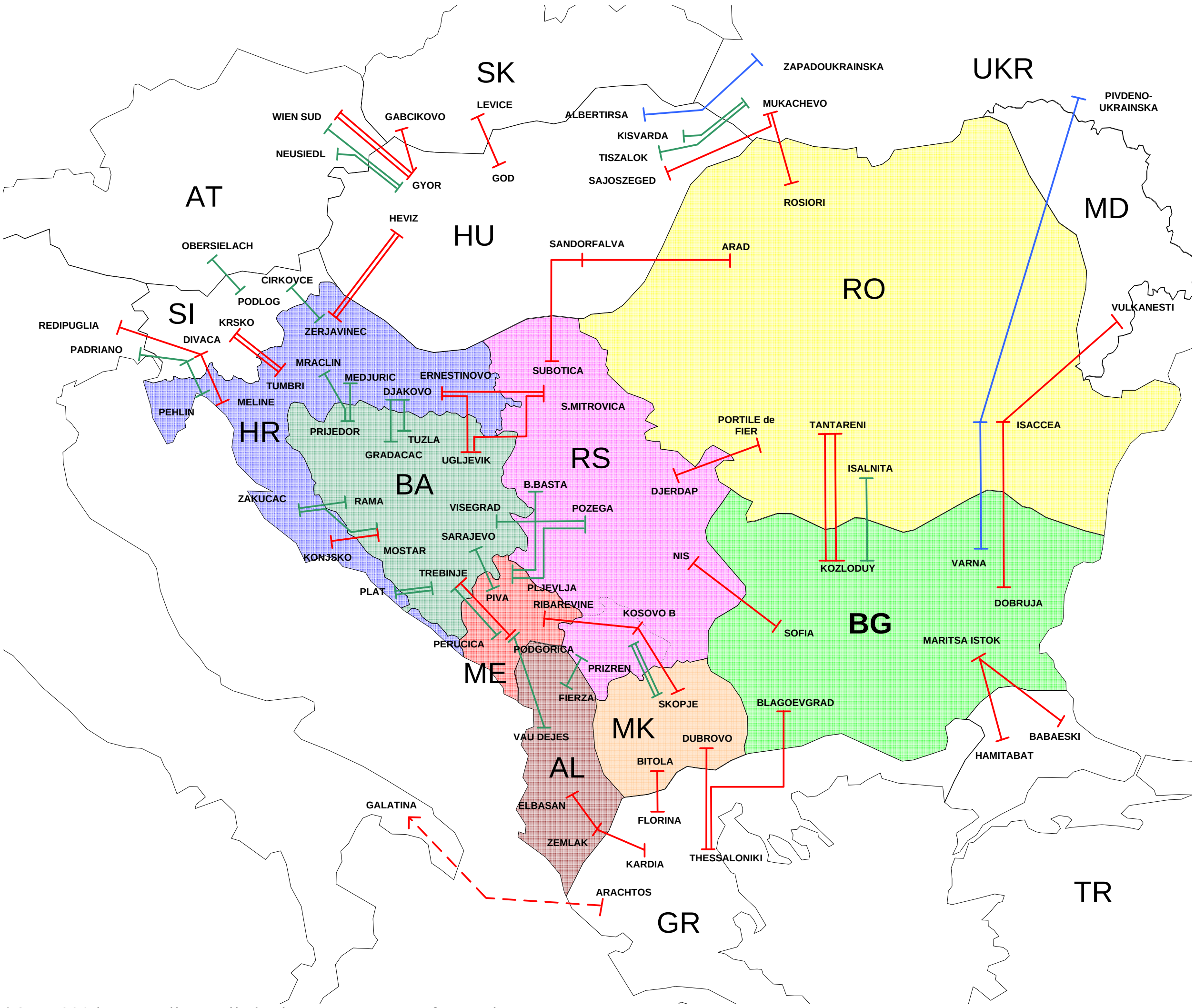
4.3 Model and Network Topology

Network topology for load flow model is completely adopted from the SECI RTSM for winter regime in 2015. Several modifications that were introduced are related to connection of new power plants, planned in update of GIS. Table 4.5 and Figure 4.6 show existing interconnection lines in the SEE (2007), as well as lines which are at the moment under construction. This topology is upgraded for 2015 by adding several planned interconnection lines. Planned interconnection lines which were considered as definitely present in 2015 are given in Table 4.6 and in Figure 4.7. Based on information collected from neighboring TSOs and *UCTE System Adequacy Forecast* it was possible to determine the years of planned commissioning for each OHL from the list. All these assumed transmission lines provide a substantial reinforcement to actual transmission network of the SEE region. Submarine HVDC cable 400 kV Arachtos (GR) – Galatina (IT) is considered to be in operation in 2015 with set direction of power flow of 400 MW from Greece to Italy.

Transmission lines 400 kV S. Mitrovica (RS) – Ugljevik (BA) and Bitola (MK) – Florina (GR) were treated as planned transmission lines in original GIS, but during the period from the original GIS to update of GIS, these lines became actual (construction and erection were completed). Other than that, OHLs 400 kV Kashar – Durres and Kashar - Elbasan (Albania) were treated as a necessary internal grid reinforcement, for inclusion of further transmission line candidates. Although, OHL 220 kV Kashar – Durres already exists, transformation 400/220 kV in Durres is not modeled in order to avoid unnecessary parallel flow through 400 kV and 220 kV grid. Tie lines 400 kV Issacea (RO) – Vulcanesti (MD) and 750 kV Zahidoukrainskaya (UA)-Isaccea (RO) were considered to be out of operation.

Table 4.5 List of interconnection lines in South East Europe in 2007

Interconnection line	Interconnected countries	Voltage level (kV)	Conductors			Transfer Capacity (MVA)	Lenght (km)		
			Type	Size (mm2)	Number per phase		I to border	border to II	Total
Varna - Isaccea	BG - RO	750	ACSR	300	5	2390	150	85	235
Albertirsa - Zapadoukrainska	HU - UA	750	ACSR	400	5	5360	268	254	522
Isaccea - Pivdenoukrainska	RO - UA	750	ACSR	400	5	5360	5	395	400
God - Levice	HU - SK	400	ACSR	500/350	2/3	1440	88	36	124
Gyor - Gabcikovo	HU - SK	400	ACSR	500/450	2/3	1440	29	15	44
Zemlak - Kardia	AL - GR	400	ACSR	500	2	1309	21	80	101
Mostar4 - Konjsko	BA - HR	400	ACSR	490	2	1318	41	69	110
Ugljevik - Ernestinovo	BA - HR	400	ACSR	490	2	1318	39	53	92
Blagoevgrad - Thessaloniki	BG - GR	400	ACSR	500	2	1309	72	102	174
Dobrudja - Isaccea	BG - RO	400	ACSR	400	3	1715	81	150	231
Maritsa Istok - Hamitabat	BG - TR	400	ACSR	400	3	1715	59	90	149
Isaccea - Vulcanesti	RO - MOLD	400	ACSR	400	3	1715	5	54	59
Kozloduy - Tantareni (double)	BG - RO	400	ACSR	500/300	2/3	2490	14	102	116
Sofia West - Nis	BG - RS	400	ACSR	500	2	1330	37	86	123
Maritsa Istok - Babaeski	BG - TR	400	ACSR	500	2	1309	50	77	127
Zerjavinec - Heviz (double)	HR - HU	400	ACSR	490	2	1318	99	69	168
Dubrovo - Thessaloniki	MK - GR	400	ACSR	490	2	1330	55	60	115
Skopje - Kosovo B	MK - RS	400	ACSR	490	2	1330	36	68	104
Arachtos - Galatina HVDC	GR - IT	400	HVDC	1250	/	500	/	/	313
Gyor - Wien Sud (double)	HU - AT	400	ACSR	500	2	2563	59	63	122
Podgorica - Trebinje	ME - BA	400	ACSR	490	2	1330	60	21	81
Arad - Sandorfalva	RO - HU	400	ACSR	450/500	2	1212	5	52	57
Portile De Fier - Djerdap	RS - RO	400	ACSR	967	2	1330	1	2	3
Rosiori - Mukacevo	RO - UA	400	ACSR	450	2	1212	39	36	75
Ernestinovo - S. Mitrovica	HR - RS	400	ACSR	490	2	1330	52	41	93
Subotica - Sandorfalva	RS - HU	400	ACSR	490	2	1330	27	21	48
Maribor - Keinachtal (double)	SI - AT	400	ACSR	490	2	1330	26	37	63
Melina - Divaca	HR - SI	400	ACSR	490	2	1318	26	41	67
Tumbri - Krsko (double)	HR - SI	400	ACSR	490	2	1318	32	16	48
Divaca - Redipuglia	SI - IT	400	ACSR	490	2	1330	39	10	49
Mukachevo - Sajoszeged	UA - HU	400	ACSR	400	2	1386	8	142	150
Bitola - Florina	MK - GR	400	ACSR	490	2	1312	20	13	33
Ribarevine - Kosovo B	RS - ME	400	ACSR	490	2	2000	50	73	123
Ugljevik - S. Mitrovica	BA - RS	400	ACSR	490	2	1920	46	34	80
Vau Dejes - Podgorica	AL - ME	220	ACSR	360	1	301	47	21	68
Fierze - Prizren	AL - RS	220	ACSR	360	1	301	26	45	71
Pljevlja - Bajina Basta	ME - RS	220	ACSR	360	1	720	15	82	97
Pljevlja - Pozega	ME - RS	220	ACSR	360	1	1000	14	78	92
Gradacac - Djakovo	BA - HR	220	ACSR	360	1	300	19	27	46
Prijedor -Mraclin	BA - HR	220	ACSR	360	1	300		66	66
Mostar4 - Zakucac	BA - HR	220	ACSR	360	1	300	49	50	99
Prijedor2 - Medjuric	BA - HR	220	ACSR	360	1	300	34	32	66
TE Tuzla - Djakovo	BA - HR	220	ACSR	360	1	300	65	27	92
Trebinje - HE Dubrovnik (Plat)	BA - HR	220	ACSR	240	2	491	7	5	12
Trebinje - HE Dubrovnik (Plat)	BA - HR	220	ACSR	240	2	491	7	5	12
Trebinje - HE Perucica	BA - ME	220	ACSR	360	1	301	20	42	62
Sarajevo20 - Piva	BA - ME	220	ACSR	490	2/1	366	61	23	84
Visegrad - Pozega	BA - RS	220	ACSR	360	1	301	18	51	69
Zerjavinec - Cirkovce	HR - SI	220	ACSR	360	1	300	19	51	70
Skopje - Kosovo A	MK - RS	220	ACSR	360	1	301	18	65	83
Skopje - Kosovo A	MK - RS	220	ACSR	360	1	301	18	65	83
Gyor - Wien Sud	HU - AT	220	ACSR	360	1	305	59	63	122
Gyor - Neusiedl	HU - AT	220	ACSR	360	1	305	55	27	82
Podlog - Obersielach	SI - AT	220	ACSR	490	1	366	46	20	66
Pehlin - Divaca	HR - SI	220	ACSR	490	1	350	6	47	53
Divaca - Padricano	SI - IT	220	ACSR	490	1	366	10	2	12
Mukachevo - Kisvarda	UA - HU	220	ACSR	400	1	308	54	10	64
Mukachevo - Tiszalok	UA - HU	220	ACSR	400	1	308	97	35	132



*OHL 220 kV Mraclin – Prijedor is temporary out of operation

Figure 4.6 Interconnection lines in South East Europe in 2007

Table 4.6 List of transmission lines considered to be in operation in the SEE region until 2015

Type of element	Voltage [kV]	From	To	Conductors			Total length	Transfer capacity
				Type	Size (mm2)	Number per phase	km	MVA
OHL	400	Stip (MK)	Chervena Mogila (BU)	ACSR	490	2	146	1420
OHL	400	Podgorica 2 (ME)	Kashar (AL)	ACSR	490	2	144.2	1350
OHL	400	N.Santa (GR)	Babaeski (TR)	ACSR	400	3	180	1500
OHL	400	Nis-Leskovac-Vranje (RS)	Skopje 1 (MK)	ACSR	490	2	95	1330
OHL	400	Bekescsaba (HU)	Nadab (RO)	ACSR	500/300	2 / 3	54	1211
OHL (double)	400	Okroglo (SI)	Udine (IT)	ACSR	400	2	113	1163
OHL	400	Sajovanka (HU)	Rimavska Sobota (SK)	ACSR	500	1	40	554.3
OHL	220	Imotski (HR)	Rama (BiH)	ACSR	360	1	75	300

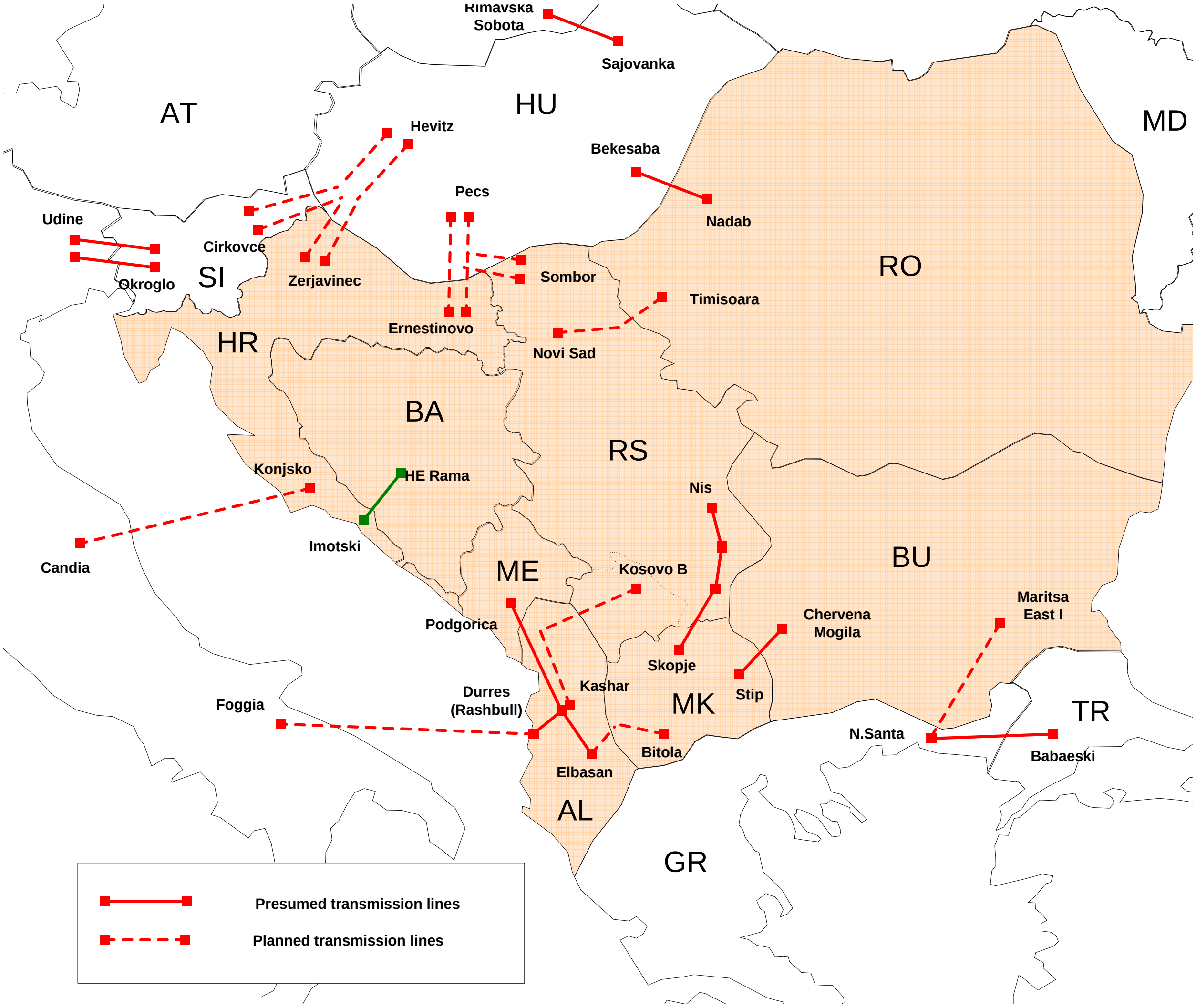


Figure 4.7 Planned interconnection line candidates and presumed interconnection lines in 2015

Beside the lines given in Table 4.6, another group of transmission line candidates was investigated, one by one. These planned interconnection line candidates in South East Europe until 2015 are shown in Table 4.7. Although term “candidate” may have a meaning that only one transmission line is under consideration, the present study refers “candidates” even to a group of elements which are implicitly going to be put in operation together. In some cases, group of two or three elements (OHL or cable) present one transmission candidate for analysis (i.e. candidate 6, OHL 400 kV Bitola - Elbasan and HVDC 400 kV Durres – Foggia).

Table 4.7 List of transmission line candidates for operation in the SEE region until 2015

Candidate No	Type of element	Voltage [kV]	From	To	Conductors			Total length	Transfer capacity
					Type	Size (mm2)	Number per phase	km	MVA
1	OHL	400	Kashar(AL)	Kosovo B (UNMIK)	ACSR	490	2	240	1330
2	OHL	400	N.Santa (GR)	Maritsa Istok 1 (BU)	ACSR	400	3	180	1715
3	OHL (double)	400	Ernestinovo (HR)	Pecs (HU)	ACSR	490/500	2	87	2x1330
4	OHL	400	Zerjavinec (HR)	Hevitz (HU)	ACSR	490	2	181	1386
	OHL	400	Hevitz (HU)	Cirkovce (SI)	ACSR	490	2	162	1386
	OHL	400	Cirkovce (SI)	Zerjavinec (HR)	ACSR	490	2	140	1386
5	OHL	400	Novi Sad (RS)	Timisoara (RO)	ACSR	490	2	128	1330
6	OHL	400	Bitola 2 (MK)	Elbasan (AL)	ACSR	490	2	125	1330
	HVDC	400	Durres (AL)	Foggia (IT)	DC cable	1250	/	250	500
7	HVDC	400	Konjsko (HR)	Candia (IT)	DC cable	1250	/	200	500
8	OHL	400	Ernestinovo (HR)	Pecs (HU)	ACSR	490/500	2	87	1330
	OHL	400	Pecs (HU)	Sombor (RS)	ACSR	500/490	2	115	1330
	OHL	400	Ernestinovo (HR)	Sombor (RS)	ACSR	490	2	115	1330

Comments for transmission line candidates:

- Interconnection line 400 kV Kashar (AL) – Kosovo B (RS/UNMIK)
  This tie line should increase system stability, security and transmission capacity between north and south region of Albania and between Albania and UNMIK. The most significant impact should be to voltage profile in Albanian consumption area in the south. Another future purpose of this interconnection is to evacuate large amount of power from power plants which are planned to be constructed in UNMIK until 2020.
- Interconnection line 400 kV Nea Santa (GR) – Maritsa East 1 (BG)
  There were many versions of new connection between Bulgaria and Greece and this is the latest planned interconnection line. It is expected, for this line, not just to increase the transfer capacity from Bulgaria to Greece, but also to increase power system security and stability with respect to future connection of Turkey to UCTE.
- Interconnection line 400 kV Ernestinovo (HR) – Pecs (HU) (double line)
  Double tie line between Croatia and Hungary is expected to increase steady state security in the SEE region. The importing capability of Croatia and surrounding countries from CENTREL and Ukraine is expected to be increased as well. The contract for its construction is already signed by both sides, HEP OPS (Croatian TSO) and MAVIR (Hugarian TSO), and line construction is expected to start soon.
- Interconnection line 400 kV Zerjavinec (HR) – Cirkovce (SI) – Hevitz (HU) (triangle)
  This loop or triangle of transmission lines is supposed to be the final stage in connecting of Slovenia to Croatia and Hungary by building a double OHL and leading it into existing double OHL 400 kV Zerjavinec (HR) – Hevitz (HU). Triangle connection would be formed near Pince in Hungary. Purpose of this loop of OHLs is to interconnect neighboring three countries.
- Interconnection line 400 kV Novi Sad (RS) – Timisoara (RO)
  This tie line should increase system stability, security and transmission capacity between north and west regions of Serbia and Romania. Feasibility studies are yet to

be performed by EMS (TSO of Sebia) and TRANSELECTRICA (TSO of Romania).

- Interconnection line 400 kV Bitola (MK) – Elbasan (AL) (OHL) and HVDC Durres (AL) – Foggia (IT)

  These two elements are supposed to be a backbone of Corridor 8 (EBRD – gas, oil and energy connection of Bulgarian coast at Black Sea and Albanian coast at Ionian Sea). Coastal part of Corridor 8 would be finalized by inclusion of OHLs 400 kV Chervena Mogila (BG) – Stip (MK) and 400 kV Bitola (MK) – Elbasan (AL). Final outcome would be the possibility to export power to Italy through submarine HVDC cable to Foggia. Several feasibility and technical studies are ongoing, but transmission capacity of this cable is still under question mark due to many necessary reinforcements in transmission system of Albania in case of its realisation. In the present study, its transfer capacity is reduced to 500 MW.

- Interconnection HVDC Konjsko (HR) – Candia (IT)

  Constant deficit of power in Italy leads to exploration of new possible ways to import energy through new tie lines. One such possible line is a submarine HVDC cable from Croatia to Italy over the Adriatic Sea. It is expected that it would reduce the transfer path of energy from the SEE to Italy, due to high loading of existing tie lines in northern region of Italy and neighboring countries. Transfer capacity is to be determined. In the present study, its transfer capacity is set to 500 MW.

- Interconnection line 400 kV Ernestinovo (HR) – Sombor (RS) – Pecs (HU) (triangle)

  This loop (triangle) of OHLs is an alternative to double OHL 400 kV Ernestinovo – Pecs. Double OHL would be conducted from Sombor (Serbia) into one of two lines Ernestinovo – Pecs. This way transfer capacities from Hungary (CENTREL) to Croatia and Serbia would be significantly increased. This configuration is only considered as an option by corresponding TSOs.

4.4 Power Balance and Exchanges

Generation and demand in each country, analyzed as a part of GIS region, were determined according to data from original GIS, update of GIS and methodology explained in Chapter 4.1. After introduction of these in the SECI RTSM load flow models for 2015, twelve new GIS models for load flow calculations were obtained (three scenarios with four exchange patterns per each scenario). Exchange programs in several countries surrounding GIS region were kept at the same value (for Turkey -1200MW, for Greece -400 MW with transfer of additional 400 MW to Italy, and for Hungary -1200 MW). However, for areas which are parts of large interconnections (UCTE, CENTREL, IPS/UPS) their exchange programs depend on suficit or deficit of power in GIS region. It is also important to point out that power system of Ukraine is seen as a part of eastern IPS/UPS interconnection which is ought to be in synchronous operation with UCTE in 2015. Under this assumption it was possible to set such high exports of power toward SEE because of high energy reserves in IPS/UPS (i.e. in the Base Case Official Scenario – Dry Hydrology, export of CENTREL is 2070MW and export of Ukraine is 2630 MW). Export from IPS/UPS is realised over power system of Ukraine which is the reason why this exchange is seen as import from Ukrainian grid. Although there are several connection points between IPS/UPS and UCTE around Central and South East Europe, import of power was modeled only for tie lines from western Ukraine (Burshtin and Mukachevo) to Hungary and north of Romania. This direction of import from Ukraine is considered to be more critical than combined import from

Mukachevo on one side and Moldovan and Ukrainian Black Sea Region on another side.

Demand, generation and exchange patterns in GIS region for each scenario of the present study are given in Tables 4.8 - 4.19 (given as outputs from PSS/E Area/Owner/Zone query).

Table 4.8 Demand, generation and exchanges in GIS region for scenario Base Case with Official Rehabilitation – Zero Balance –

PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E TUE, JUL 17 2007 8:51
GIS REGIONAL MODEL - BASE CASE OFFICIAL AREA TOTALS
MAXIMUM LOAD - WINTER 2015 ZERO BALANCE IN MW/MVAR

X-- AREA --X	FROM GENERATION	TO LOAD	TO BUS SHUNT	TO LINE SHUNT	FROM CHARGING	TO NET INT	LOSSES	DESIRED NET INT
10	1047.3	1614.0	0.0	0.0	0.0	-620.0	53.3	-620.0
AL	576.6	707.2	-186.1	0.0	390.1	8.7	437.1	
20	7432.2	6688.0	0.0	14.3	0.0	600.0	129.9	600.0
BG	1616.8	2174.9	0.0	123.1	3041.9	491.4	1869.5	
30	2461.0	2410.0	0.0	0.0	0.0	0.0	51.0	0.0
BA	850.2	924.4	0.0	0.0	872.3	234.6	563.5	
40	2658.4	3752.0	0.0	0.0	0.0	-1150.0	56.4	-1150.0
HR	600.4	1074.2	0.0	0.0	1323.8	197.3	652.8	
60	1461.7	1438.0	0.0	0.1	0.0	0.0	23.6	0.0
MK	431.3	529.8	-32.9	1.3	399.5	64.3	268.4	
70	8917.5	9056.0	0.0	83.2	0.0	-460.2	238.4	-460.0
RO	2086.1	3892.6	104.9	258.1	5127.6	89.7	2868.4	
90	9402.4	7499.0	0.0	17.5	0.0	1710.0	175.9	1710.0
RS	2645.4	2708.8	0.0	74.8	1696.2	-512.6	2070.6	
91	640.7	694.0	0.5	1.6	0.0	-80.0	24.5	-80.0
ME	248.6	281.5	-34.2	10.9	221.8	-42.5	254.7	
TOTALS	34021.1	33151.0	0.5	116.7	0.0	-0.2	753.0	0.0
	9055.6	12293.4	-148.4	468.2	13073.3	530.7	8985.0	

Table 4.9 Demand, generation and exchanges in GIS region for scenario Base Case with Official Rehabilitation – Wet hydrology, Export to western UCTE –

PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E TUE, JUL 17 2007 8:46
GIS REGIONAL MODEL - BASE CASE OFFICIAL AREA TOTALS
MAXIMUM LOAD - WINTER 2015 WET SCENARIO EXPORT TO UCTE IN MW/MVAR

X-- AREA --X	FROM GENERATION	TO LOAD	TO BUS SHUNT	TO LINE SHUNT	FROM CHARGING	TO NET INT	LOSSES	DESIRED NET INT
10	1184.9	1614.0	0.0	0.0	0.0	-479.9	50.9	-480.0
AL	569.6	707.2	-190.3	0.0	398.5	23.5	427.8	
20	7572.5	6688.0	0.0	14.5	0.0	740.1	129.8	740.0
BG	1617.0	2174.9	0.0	124.6	3046.2	500.0	1863.8	
30	2862.4	2410.0	0.0	0.0	0.0	390.0	62.4	390.0
BA	906.2	924.4	0.0	0.0	869.7	156.9	694.5	
40	2880.3	3752.0	0.0	0.0	0.0	-949.9	78.2	-950.0
HR	677.5	1074.2	0.0	0.0	1312.7	69.3	846.7	
60	1482.0	1438.0	0.0	0.1	0.0	20.1	23.9	20.0
MK	427.9	529.8	-33.0	1.3	399.9	61.7	268.0	
70	9378.0	9056.0	0.0	83.3	0.0	-10.1	248.8	-10.0
RO	2197.2	3892.6	105.0	258.6	5131.4	39.4	3033.0	
90	9837.3	7499.0	0.0	17.5	0.0	2130.0	190.8	2130.0
RS	2757.8	2708.8	0.0	74.7	1692.5	-610.3	2277.1	
91	727.9	694.0	0.6	1.8	0.0	10.1	21.5	10.0

X-- AREA --X	FROM GENERATION	TO LOAD	TO BUS SHUNT	TO LINE SHUNT	FROM CHARGING	TO NET INT	LOSSES	DESIRED NET INT
ME	264.3	281.5	-35.3	11.9	225.8	6.5	225.5	
TOTALS	35925.4	33151.0	0.6	117.2	0.0	1850.2	806.4	1850.0
	9417.5	12293.4	-153.6	471.1	13076.7	246.9	9636.4	

Table 4.10 Demand, generation and exchanges in GIS region for scenario Base Case with Official Rehabilitation – Wet hydrology, Export to Italy –

PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E TUE, JUL 17 2007 8:48
GIS REGIONAL MODEL - BASE CASE OFFICIAL AREA TOTALS
MAXIMUM LOAD - WINTER 2015 WET SCENARIO EXPORT TO ITALY IN MW/MVAR

X-- AREA --X	FROM GENERATION	TO LOAD	TO BUS SHUNT	TO LINE SHUNT	FROM CHARGING	TO NET INT	LOSSES	DESIRED NET INT
10	1184.8	1614.0	0.0	0.0	0.0	-479.9	50.7	-480.0
AL	571.1	707.2	-190.3	0.0	398.3	26.0	426.6	
20	7572.7	6688.0	0.0	14.5	0.0	740.1	130.1	740.0
BG	1620.0	2174.9	0.0	124.6	3045.9	499.5	1867.0	
30	2864.0	2410.0	0.0	0.0	0.0	390.0	64.0	390.0
BA	945.1	924.4	0.0	0.0	864.3	173.3	711.7	
40	2892.6	3752.0	0.0	0.0	0.0	-950.1	90.7	-950.0
HR	843.2	1074.2	0.0	0.0	1284.7	99.1	954.5	
60	1482.0	1438.0	0.0	0.1	0.0	20.1	23.9	20.0
MK	428.2	529.8	-32.9	1.3	399.9	62.3	267.7	
70	9377.6	9056.0	0.0	83.3	0.0	-9.9	248.2	-10.0
RO	2196.4	3892.6	105.0	258.6	5131.4	44.9	3026.6	
90	9837.9	7499.0	0.0	17.5	0.0	2130.0	191.5	2130.0
RS	2780.2	2708.8	0.0	74.7	1691.2	-597.4	2285.3	
91	728.1	694.0	0.6	1.8	0.0	10.0	21.7	10.0
ME	269.4	281.5	-35.2	11.9	225.5	8.9	227.8	
TOTALS	35939.7	33151.0	0.6	117.2	0.0	1850.2	820.8	1850.0
	9653.6	12293.4	-153.5	471.1	13041.0	316.6	9767.1	

Table 4.11 Demand, generation and exchanges in GIS region for scenario Base Case with Official Rehabilitation – Dry hydrology, Import from CENTREL and Ukraine –

PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E THU, AUG 09 2007 10:01
GIS REGIONAL MODEL - BASE CASE OFFICIAL AREA TOTALS
MAXIMUM LOAD - WINTER 2015 DRY SCENARIO IN MW/MVAR

X-- AREA --X	FROM GENERATION	TO LOAD	TO BUS SHUNT	TO LINE SHUNT	FROM CHARGING	TO NET INT	LOSSES	DESIRED NET INT
10	932.5	1614.0	0.0	0.0	0.0	-730.0	48.5	-730.0
AL	622.3	707.2	-195.1	0.0	399.4	112.5	397.1	
20	7436.9	6688.0	0.0	14.2	0.0	600.0	134.7	600.0
BG	1728.7	2174.9	0.0	122.6	3029.0	525.6	1934.6	
30	2110.5	2410.0	0.0	0.0	0.0	-360.0	60.5	-360.0
BA	971.0	924.4	0.0	0.0	857.7	301.6	602.7	
40	2090.6	3752.0	0.0	0.0	0.0	-1750.1	88.6	-1750.0
HR	724.6	1074.2	0.0	0.0	1293.3	46.8	897.0	
60	1339.5	1438.0	0.0	0.1	0.0	-120.0	21.4	-120.0
MK	436.6	529.8	-32.9	1.3	398.5	83.3	253.7	
70	8683.9	9056.0	0.0	81.5	0.0	-720.0	266.5	-720.0
RO	2378.1	3892.6	103.7	252.8	5008.7	29.7	3108.0	
90	8554.0	7499.0	0.0	17.4	0.0	850.0	187.7	850.0
RS	2730.1	2708.8	0.0	74.2	1678.2	-486.6	2112.0	
91	498.4	694.0	0.5	1.6	0.0	-220.0	22.2	-220.0
ME	231.1	281.5	-34.4	10.9	221.3	-30.3	224.7	

TOTALS	31646.2	33151.0	0.5	114.7	0.0	-2450.1	830.1	-2450.0
	9822.6	12293.4	-158.5	461.8	12886.1	582.5	9529.6	

Table 4.12 Demand, generation and exchanges in GIS region for scenario Base Case with Justified Rehabilitation – Zero Balance –

PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E TUE, JUL 17 2007 8:59
GIS REGIONAL MODEL - BASE CASE JUSTIFIED AREA TOTALS
MAXIMUM LOAD - WINTER 2015 ZERO BALANCE IN MW/MVAR

X-- AREA --X	FROM GENERATION	TO LOAD	TO BUS SHUNT	TO LINE SHUNT	FROM CHARGING	TO NET INT	LOSSES	DESIRED NET INT
10	1048.1	1614.0	0.0	0.0	0.0	-620.0	54.1	-620.0
AL	578.9	707.2	-185.9	0.0	389.6	5.2	442.0	
20	7282.0	6688.0	0.0	14.3	0.0	450.0	129.8	450.0
BG	1608.0	2174.9	0.0	123.1	3041.3	503.1	1848.2	
30	2310.2	2410.0	0.0	0.0	0.0	-150.0	50.2	-150.0
BA	845.7	924.4	0.0	0.0	872.4	254.0	539.7	
40	3016.3	3752.0	0.0	0.0	0.0	-800.0	64.3	-800.0
HR	616.1	1074.2	0.0	0.0	1318.3	88.3	771.9	
60	1413.2	1438.0	0.0	0.1	0.0	-50.0	25.1	-50.0
MK	433.3	529.8	-32.9	1.3	399.1	55.2	279.1	
70	8546.1	9056.0	0.0	83.1	0.0	-830.0	237.0	-830.0
RO	2035.7	3892.6	104.8	258.0	5122.8	92.3	2810.8	
90	9829.8	7536.7	0.0	17.9	0.0	2100.0	175.1	2100.0
RS	2688.7	2742.7	0.0	77.0	1704.0	-494.0	2066.9	
91	620.6	694.0	0.5	1.6	0.0	-100.0	24.4	-100.0
ME	243.5	281.5	-34.2	10.9	221.9	-45.2	252.3	
TOTALS	34066.3	33188.7	0.5	117.0	0.0	0.0	760.0	0.0
	9049.8	12327.3	-148.2	470.3	13069.4	458.9	9010.9	

Table 4.13 Demand, generation and exchanges in GIS region for scenario Base Case with Justified Rehabilitation – Wet scenario, Export to western UCTE –

PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E TUE, JUL 17 2007 8:55
GIS REGIONAL MODEL - BASE CASE JUSTIFIED AREA TOTALS
MAXIMUM LOAD - WINTER 2015 WET SCENARIO EXPORT TO UCTE IN MW/MVAR

X-- AREA --X	FROM GENERATION	TO LOAD	TO BUS SHUNT	TO LINE SHUNT	FROM CHARGING	TO NET INT	LOSSES	DESIRED NET INT
10	1185.7	1614.0	0.0	0.0	0.0	-480.0	51.7	-480.0
AL	572.6	707.2	-190.2	0.0	398.2	21.4	432.4	
20	7421.9	6688.0	0.0	14.5	0.0	590.0	129.4	590.0
BG	1599.9	2174.9	0.0	124.6	3046.6	508.3	1838.7	
30	2792.2	2410.0	0.0	0.0	0.0	319.9	62.2	320.0
BA	901.6	924.4	0.0	0.0	870.1	163.1	684.2	
40	3255.5	3752.0	0.0	0.0	0.0	-580.2	83.7	-580.0
HR	700.3	1074.2	0.0	0.0	1307.5	-31.3	965.0	
60	1433.5	1438.0	0.0	0.1	0.0	-30.0	25.4	-30.0
MK	429.0	529.8	-32.9	1.3	399.6	52.4	278.1	
70	9072.0	9056.0	0.0	83.5	0.0	-310.0	242.6	-310.0
RO	2111.2	3892.6	105.0	259.0	5139.2	51.0	2942.8	
90	10396.0	7536.7	0.0	17.9	0.0	2649.9	191.5	2650.0
RS	2812.2	2742.7	0.0	76.9	1701.2	-599.7	2293.4	
91	728.2	694.0	0.6	1.8	0.0	10.0	21.9	10.0
ME	262.9	281.5	-35.2	11.9	225.8	2.8	227.7	

X-- AREA --X	FROM GENERATION	TO LOAD	TO BUS SHUNT	TO LINE SHUNT	FROM CHARGING	TO NET INT	LOSSES	DESIRED NET INT
TOTALS	36285.0	33188.7	0.6	117.7	0.0	2169.6	808.4	2170.0
	9389.7	12327.3	-153.3	473.7	13088.2	167.9	9662.3	

Table 4.14 Demand, generation and exchanges in GIS region for scenario Base Case with Justified Rehabilitation – Wet scenario, Export to Italy –

PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E   TUE, JUL 17 2007   8:57
GIS REGIONAL MODEL - BASE CASE JUSTIFIED   AREA TOTALS
MAXIMUM LOAD - WINTER 2015   WET SCENARIO EXPORT TO ITALY   IN MW/MVAR

X-- AREA --X	FROM GENERATION	TO LOAD	TO BUS SHUNT	TO LINE SHUNT	FROM CHARGING	TO NET INT	LOSSES	DESIRED NET INT
10	1185.5	1614.0	0.0	0.0	0.0	-480.0	51.5	-480.0
AL	574.4	707.2	-190.1	0.0	398.0	24.5	430.9	
20	7422.2	6688.0	0.0	14.5	0.0	590.0	129.7	590.0
BG	1603.1	2174.9	0.0	124.6	3046.3	507.8	1842.0	
30	2794.1	2410.0	0.0	0.0	0.0	320.0	64.1	320.0
BA	947.6	924.4	0.0	0.0	863.7	183.5	703.4	
40	3268.6	3752.0	0.0	0.0	0.0	-580.0	96.6	-580.0
HR	914.5	1074.2	0.0	0.0	1274.1	35.0	1079.4	
60	1433.4	1438.0	0.0	0.1	0.0	-30.0	25.3	-30.0
MK	429.2	529.8	-32.9	1.3	399.6	53.2	277.5	
70	9071.7	9056.0	0.0	83.5	0.0	-310.0	242.2	-310.0
RO	2111.5	3892.6	105.0	259.0	5138.8	54.7	2938.9	
90	10396.7	7536.7	0.0	17.9	0.0	2650.0	192.2	2650.0
RS	2838.5	2742.7	0.0	76.9	1699.8	-582.8	2301.3	
91	728.4	694.0	0.5	1.8	0.0	10.0	22.1	10.0
ME	268.9	281.5	-35.2	11.9	225.4	5.6	230.5	
TOTALS	36300.6	33188.7	0.5	117.7	0.0	2170.0	823.6	2170.0
	9687.5	12327.3	-153.2	473.6	13045.6	281.5	9804.0	

Table 4.15 Demand, generation and exchanges in GIS region for scenario Base Case with Justified Rehabilitation – Dry scenario, Import from CENTREL and Ukraine –

PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E   TUE, JUL 17 2007   8:53
GIS REGIONAL MODEL - BASE CASE JUSTIFIED   AREA TOTALS
MAXIMUM LOAD - WINTER 2015   DRY SCENARIO   IN MW/MVAR

X-- AREA --X	FROM GENERATION	TO LOAD	TO BUS SHUNT	TO LINE SHUNT	FROM CHARGING	TO NET INT	LOSSES	DESIRED NET INT
10	933.8	1614.0	0.0	0.0	0.0	-730.0	49.8	-730.0
AL	642.8	707.2	-195.8	0.0	400.2	125.9	405.6	
20	7285.7	6688.0	0.0	14.2	0.0	450.0	133.5	450.0
BG	1703.7	2174.9	0.0	122.7	3030.2	538.4	1898.0	
30	2081.1	2410.0	0.0	0.0	0.0	-390.0	61.1	-390.0
BA	922.2	924.4	0.0	0.0	854.7	261.4	591.0	
40	2487.6	3752.0	0.0	0.0	0.0	-1360.1	95.7	-1360.0
HR	743.1	1074.2	0.0	0.0	1288.5	-40.5	997.9	
60	1291.0	1438.0	0.0	0.1	0.0	-170.0	22.9	-170.0
MK	437.2	529.8	-32.9	1.3	398.2	71.9	265.3	
70	8409.6	9056.0	0.0	81.6	0.0	-990.0	262.0	-990.0
RO	2303.6	3892.6	103.9	253.4	5022.7	34.9	3041.5	
90	9162.5	7536.7	0.0	17.8	0.0	1420.0	188.0	1420.0
RS	2836.9	2742.7	0.0	76.5	1688.8	-424.9	2131.3	
91	499.3	694.0	0.5	1.6	0.0	-220.0	23.1	-220.0

ME	231.1	281.5	-34.2	10.9	221.0	-37.1	231.1	
TOTALS	32150.6	33188.7	0.5	115.4	0.0	-1990.2	836.2	-1990.0
	9820.4	12327.3	-159.0	464.7	12904.3	530.1	9561.7	

Table 4.16 Demand, generation and exchanges in GIS region for scenario Hydro Power Plants with High Gas Price – Zero Balance –

PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E TUE, AUG 14 2007 8:48
GIS REGIONAL MODEL - HIGH GAS PRICE & HYDRO AREA TOTALS
MAXIMUM LOAD - WINTER 2015 ZERO BALANCE IN MW/MVAR

X-- AREA --X	FROM GENERATION	TO LOAD	TO BUS SHUNT	TO LINE SHUNT	FROM CHARGING	TO NET INT	LOSSES	DESIRED NET INT
10	926.6	1614.0	0.0	0.0	0.0	-740.0	52.6	-740.0
AL	509.6	707.2	-185.0	0.0	388.7	-44.2	420.4	
20	7966.4	6729.7	0.0	16.0	0.0	1100.0	120.6	1100.0
BG	1485.3	2206.5	0.0	135.6	3049.6	427.4	1765.5	
30	2539.8	2410.0	0.0	0.0	0.0	80.0	49.8	80.0
BA	790.9	924.4	0.0	0.0	894.6	215.4	545.7	
40	2791.8	3752.0	0.0	0.0	0.0	-1019.9	59.7	-1020.0
HR	613.3	1074.2	0.0	0.0	1314.5	121.1	732.5	
60	1198.7	1438.0	0.0	0.1	0.0	-260.0	20.6	-260.0
MK	402.2	529.8	-33.0	1.5	401.2	74.6	230.6	
70	8433.2	9056.0	0.0	83.5	0.0	-930.2	223.8	-930.0
RO	1931.0	3892.6	105.3	259.2	5151.1	136.9	2688.0	
90	9039.1	7499.0	0.0	17.6	0.0	1370.0	152.4	1370.0
RS	2472.6	2708.8	0.0	75.1	1704.0	-454.4	1847.0	
91	1116.3	694.0	0.5	1.6	0.0	400.0	20.1	400.0
ME	158.6	281.5	-34.6	11.0	264.2	-34.2	199.0	
TOTALS	34011.9	33192.8	0.5	118.9	0.0	0.0	699.7	0.0
	8363.5	12325.0	-147.4	482.4	13167.9	442.6	8428.7	

Table 4.17 Demand, generation and exchanges in GIS region for scenario Hydro Power Plants with High Gas Price – Wet scenario, Export to western UCTE –

PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E TUE, AUG 14 2007 8:48
GIS REGIONAL MODEL - HIGH GAS PRICE & HYDRO AREA TOTALS
MAXIMUM LOAD - WINTER 2015 WET SCENARIO EXPORT TO UCTE IN MW/MVAR

X-- AREA --X	FROM GENERATION	TO LOAD	TO BUS SHUNT	TO LINE SHUNT	FROM CHARGING	TO NET INT	LOSSES	DESIRED NET INT
10	1186.2	1614.0	0.0	0.0	0.0	-480.0	52.2	-480.0
AL	566.8	707.2	-190.5	0.0	398.7	18.5	430.3	
20	8236.3	6729.7	0.0	16.1	0.0	1370.0	120.4	1370.0
BG	1512.2	2206.5	0.0	136.0	3051.0	438.5	1782.2	
30	3281.8	2410.0	0.0	0.0	0.0	770.2	101.6	770.0
BA	1082.2	924.4	0.0	0.0	865.6	79.0	944.3	
40	3167.2	3752.0	0.0	0.0	0.0	-739.4	154.6	-740.0
HR	1045.3	1074.2	0.0	0.0	1261.8	-275.3	1508.2	
60	1280.4	1438.0	0.0	0.1	0.0	-180.0	22.2	-180.0
MK	403.9	529.8	-33.0	1.5	401.5	67.4	239.7	
70	8884.9	9056.0	0.0	83.4	0.0	-499.9	245.5	-500.0
RO	2130.9	3892.6	105.0	258.6	5132.9	47.5	2960.1	
90	9828.5	7499.0	0.0	17.4	0.0	2120.1	192.0	2120.0
RS	2841.9	2708.8	0.0	74.5	1687.7	-510.5	2256.7	

91	1377.4	694.0	0.5	1.6	0.0	660.0	21.2	660.0
ME	128.3	281.5	-35.0	11.1	265.2	-70.5	206.4	
TOTALS	37242.6	33192.8	0.5	118.7	0.0	3020.9	909.8	3020.0
	9711.5	12325.0	-153.5	481.8	13064.4	-205.3	10327.9	

Table 4.18 Demand, generation and exchanges in GIS region for scenario Hydro Power Plants with High Gas Price – Wet scenario, Export to Italy –

PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E TUE, AUG 14 2007 8:47
GIS REGIONAL MODEL - HIGH GAS PRICE & HYDRO AREA TOTALS
MAXIMUM LOAD - WINTER 2015 WET SCENARIO EXPORT TO UCTE IN MW/MVAR

X-- AREA --X	FROM GENERATION	TO LOAD	TO BUS SHUNT	TO LINE SHUNT	FROM CHARGING	TO NET INT	LOSSES	DESIRED NET INT
10	1186.1	1614.0	0.0	0.0	0.0	-480.0	52.1	-480.0
AL	570.6	707.2	-190.4	0.0	398.3	22.2	429.9	
20	8236.4	6729.7	0.0	16.1	0.0	1370.0	120.5	1370.0
BG	1512.8	2206.5	0.0	136.0	3051.0	437.2	1784.0	
30	3287.3	2410.0	0.0	0.0	0.0	770.4	107.0	770.0
BA	1221.4	924.4	0.0	0.0	850.5	159.0	988.5	
40	3201.3	3752.0	0.0	0.0	0.0	-739.3	188.5	-740.0
HR	1506.6	1074.2	0.0	0.0	1176.4	-209.6	1818.4	
60	1280.3	1438.0	0.0	0.1	0.0	-180.0	22.2	-180.0
MK	404.0	529.8	-33.0	1.5	401.5	68.0	239.2	
70	8883.3	9056.0	0.0	83.4	0.0	-499.9	243.8	-500.0
RO	2122.4	3892.6	105.0	258.7	5134.7	56.7	2944.1	
90	9828.3	7499.0	0.0	17.4	0.0	2120.2	191.6	2120.0
RS	2878.9	2708.8	0.0	74.5	1685.3	-477.9	2258.8	
91	1378.1	694.0	0.5	1.6	0.0	660.1	21.7	660.0
ME	149.9	281.5	-34.8	11.0	264.5	-53.9	210.6	
TOTALS	37281.1	33192.7	0.5	118.7	0.0	3021.6	947.9	3020.0
	10366.0	12325.0	-153.3	481.7	12962.2	1.7	10673.5	

Table 4.19 Demand, generation and exchanges in GIS region for scenario Hydro Power Plants with High Gas Price – Dry scenario, Import from CENTREL and Ukraine –

PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS/E TUE, AUG 14 2007 8:45
GIS REGIONAL MODEL - HIGH GAS PRICE & HYDRO AREA TOTALS
MAXIMUM LOAD - WINTER 2015 DRY SCENARIO IN MW/MVAR

X-- AREA --X	FROM GENERATION	TO LOAD	TO BUS SHUNT	TO LINE SHUNT	FROM CHARGING	TO NET INT	LOSSES	DESIRED NET INT
10	811.8	1614.0	0.0	0.0	0.0	-850.0	47.8	-850.0
AL	586.1	707.2	-195.9	0.0	401.2	92.4	383.6	
20	7969.7	6729.7	0.0	16.0	0.0	1100.0	124.0	1100.0
BG	1568.3	2206.5	0.0	135.3	3041.1	456.4	1811.2	
30	2191.7	2410.0	0.0	0.0	0.0	-270.0	51.7	-270.0
BA	793.4	924.4	0.0	0.0	880.6	210.5	539.1	
40	2339.2	3752.0	0.0	0.0	0.0	-1490.1	77.3	-1490.0
HR	714.6	1074.2	0.0	0.0	1294.5	69.7	865.3	
60	1097.7	1438.0	0.0	0.1	0.0	-360.0	19.6	-360.0
MK	407.5	529.8	-33.0	1.5	400.3	85.7	223.7	
70	8229.3	9056.0	0.0	82.2	0.0	-1150.3	241.3	-1150.0
RO	2141.9	3892.6	104.5	255.1	5060.0	110.6	2839.0	
90	8519.5	7499.0	0.0	17.5	0.0	839.9	163.1	840.0
RS	2551.7	2708.8	0.0	74.6	1690.2	-441.2	1899.8	
91	795.6	694.0	0.5	1.6	0.0	80.0	19.4	80.0

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ME          162.6    281.5    -34.8     11.0    263.2    -22.0    190.1

TOTALS    31954.4  33192.8      0.5    117.4      0.0  -2100.5    744.2  -2100.0
           8926.2  12325.0   -159.1    477.5  13031.1    562.2   8751.6
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Exchange programs of GIS region which can be read from the previous PSS/E outputs are summoned in Table 4.20. Negative sign in front of exchange power means that that area or region is importing energy.

Table 4.20 Exchange programs of GIS region for each scenario

Scenario	Zero Balance	Export to UCTE (Wet hydrology)	Export to Italy (Wet hydrology)	Import from CENTREL and Ukraine (Dry hydrology)
Base Case Official	0 MW	1850 MW	1850 MW	-2450 MW
Base Case Justified	0 MW	2170 MW	2170 MW	-1990 MW
High Gas Price&Hydro	0 MW	3020 MW	3020 MW	-2100 MW

4.5 Criteria for Analyses

The basic assumption underlying the work conducted within the present study is that the SEE regional electricity market will exist in the near future at the territory of South East Europe. Planning criteria and methodology are thus suggested to be respected by the SEE TSOs. Well defined planning criteria and methodology at the regional level may help the SEE countries to develop their power systems and infrastructure that will serve common electricity market in accordance with the Energy Policy for Europe (EPE). Meeting the objectives from the EPE related to sustainability, competitiveness and security of supply will surely help the SEE countries to better integrate into future common European electricity market.

The SEE transmission network planning criteria and methodology are proposed by observing national networks at the territory of the SEE region, under the responsibility of the SEE TSOs, as unique network, with the aim to promote and ensure market activities inside the Energy Community. Planning criteria and methodology are defined by taking into account national requests defined by national grid codes as much as possible, but suited to the SEE regional electricity market needs. They serve primarily to support market activities at satisfactory level of overall system adequacy and security, based on technical and economic considerations. They also serve to estimate the level of future SEE power system reliability and to identify and prioritize transmission investment candidates from a regional point of view. In other words, the SEE region is observed as one power system with same obligations and rights for all market participants and transmission network planning criteria and methodology are set to keep the overall system adequacy and security in the most economic way.

Important assumption for the effective usage of proposed planning criteria and methodology which will lead to transmission network investments with regional significance is an acceleration of authorization procedures. Dynamic and fast development of the SEE transmission system will support predicted fast growth of trading activities inside the electricity market and fast integration of renewable energy sources (construction period for a new wind power plant is up to three years), which will be impossible if complicated authorization procedures remain unchanged. Environmental aspects in the SEE transmission system development have to be observed and respected in the most efficient manner. This will help to speed up the construction of transmission facilities by making them more acceptable for the public. Private initiatives and public-private partnership in the SEE transmission system planning and development should be stimulated by market oriented signals. Private interest is important aspect with respect to economic rationalization of network investments and need to be respected and promoted.

The SEE transmission system planning should include the most important uncertainties that may arise in the future. According to the planning horizons (short, medium, long term), there are different types of uncertainties which have to be included in analyses. The most important uncertainties which should be observed in the network planning are:

- new power plants sizes and locations;
- hydrological conditions;
- generators bids;
- branches and generators availability;
- load prediction; and
- regional power balance.

Transmission network has to be designed to serve the needs of its consumers. Connection of new power plants brings probably the largest uncertainty in network development. As many scenarios as necessary concerning Generation Investment Plan have to be analyzed. In accordance to the European Energy Policy special attention should be directed to the integration of renewable sources into the grid. One generation investment scenario may be defined assuming high integration of renewable sources at distribution (small wind power plants, fuel cells, small hydro etc.) and transmission level (large wind power plants).

Transmission system investments are financed by the SEE TSOs through transmission fees and loans according to national legislation. National regulatory authorities have to approve network investments and allow the inclusion of investment costs into transmission fees. The present study does not observe the problem of investments financing. Problems may arise if some SEE TSO is not satisfied with the SEE transmission system development plan, made according to the criteria and methodology defined here, and rejects to invest in some new line with a regional market significance (with not so obvious benefit for national network and system under control of that TSO). Some mechanism for investments financing on the territory of one TSO but beneficiary for other TSOs or market players/participants has to be found at least in the framework of the Energy Community. Otherwise, the adoption of proposed planning criteria and methodology will be more complicated, if not impossible. Private investments should also be stimulated by the SEE TSOs, regulatory authorities and respective EU bodies.

With the market development it is expected that congestion costs will become a very influential factor for construction of interconnection lines. Nevertheless, transfer limits on interconnection lines in the SEE are often related to some internal network problems, and rationalization of some investments in new interconnection capacity may cause that internal problems stay hidden. Furthermore, the SEE TSOs may declare lower values of Net Transfer Capacity in order to protect domestic power producers from market activities or to keep unnecessary high level of security of a system under their control because of various reasons.

Having in mind that proposed planning criteria and methodology are related to the SEE region as a whole, the treatment of interconnection lines and internal national lines should be the same. It means that suggested criteria and methodology have to be applied equally to interconnection lines between different SEE TSOs and to internal power lines inside national networks. Planning criteria for power lines between the SEE TSOs and other markets and power systems should be based on economical rationales, taking into account possibilities for expanding market activities (power import, export) and differences in electricity prices on different markets.

4.6 Cost/Investment Estimation

Electricity towers, and the wires and conductors that they support, are the major way of transmitting electricity. They are generally a lattice steel structure with a number of cross arms. The type, size, height and spacing of towers are determined by geographical, operational, safety and environmental considerations. A typical OHL route will involve three types of tower:

- suspension (used for straight lines);
- deviation (where the route changes direction); and
- terminal (where the lines connect with substations or underground cables).

A suspension tower is typically between 40 to 60 meters in height with a phase to phase spacing of between 7 and 25 meters, depending on the type of tower. The two principal types are the "pine" which narrows at the top and the Y shaped "delta". The width of the tower right of way will depend on the level of power to be transmitted but typically range between 30 and 50 meters for 400 kV. For 400 kV, towers are usually spaced around 350 to 450 meters apart and provide ground clearance of at least seven meters in all weather conditions. Higher clearances usually apply if the route crosses motorways or high-pressure water hoses and minimum clearance for trees and public street lighting also apply. Towers for 400 kV are typically made from steel.

In the absence of a defined methodology to calculate capital charges and costs, and in order to evaluate investments, unit price method is implemented in following review. Given unit price related to construction costs take into consideration configuration of terrain (flat land, medium mountain, high mountain). Total investment costs (in EUR) for lines and corresponding elements construction till 2010 is presented in Table 4.21 (values should be used only as the last mean for prioritization of candidate lines). The investments cover total length of transmission lines and construction of 400 kV transmission line bays in appropriate substations. Total investment costs of transmission line bays include costs of the following elements:

- construction of 400 kV transmission line itself; and
- construction of 400 kV transmission line bays (breakers, disconnectors with and without blades ground, current and voltage measuring transformers, lightning arrester).

These total price values do not take into consideration lease of land or other additional upgrades of power system. Investment values of HVDC submarine cables consist of converter substation total prices (190-350 €/kVA), and cable+cable laying prices (720000 €/km + 20% risk).

Table 4.21 Total investment sum of interconnection lines in South East Europe planned in 2010

Candidate No	Type of element	Voltage [kV]	From	To	Lines			TL bays (S/S)			Total price [M€]
					Length [km]	Unit price [€/km]	Total price [M€]	Unit price [€]	Number of bays	Total price [M€]	
1	OHL	400	Kashar(AL)	Kosovo B (RS/UNMIK)	240	235000	56.40	650000	2	1.3	57.70
2	OHL	400	N.Santa (GR)	Maritsa Istok 1 (BU)	180	235000	42.30	650000	2	1.3	43.60
3	OHL (double)	400	Ernestinovo (HR)	Pecs (HU)	87	240000	41.81	650000	4	2.6	44.41
4	OHL	400	Cirkovce (SI)	Pince (Hevitz (HU))	80	240000	19.20	650000	1	0.65	19.85
	OHL	400	Cirkovce (SI)	Pince (Zerjavinec (HR))	80	240000	19.20	650000	1	0.65	19.85
5	OHL	400	Novi Sad (RS)	Timisoara (RO)	128	200000	25.60	650000	2	1.3	26.90
6	OHL	400	Bitola 2 (MK)	Elbasan (AL)	125	235000	29.33	650000	2	1.3	30.63
	HVDC	400	Durres (AL)	Foggia (IT)	250	864000	216.00	125000000	2	125	341.00
7	HVDC	400	Konjsko (HR)	Candia (IT)	200	864000	172.80	125000000	2	125	297.80
8	OHL	400	Ernestinovo (HR)	Pecs (HU)	87	240000	20.90	650000	2	1.3	22.20
	OHL	400	Pecs (HU)	Sombor (RS)	115	240000	27.60	650000	2	1.3	28.90
	OHL	400	Ernestinovo (HR)	Sombor (RS)	115	240000	27.60	650000	2	1.3	28.90

5. ANALITICAL RESULTS

5.1 Introduction

This Chapter describes results of load flow and security (n-1) analyses for cases defined in Chapter 3. The load flow analysis includes line loading and voltage profile analysis, analysis of losses and also analysis of power flows through interconnection lines.

Monitored elements are branches that belong to GIS countries and interconnection lines from GIS countries to the neighboring systems. Monitored lines assume 400 and 220 kV lines while monitored transformers assume 400/220, 400/110 kV and 220/110 kV transformers.

The system reliability and adequacy is checked by using (n-1) contingency criterion. List of contingencies includes:

- all interconnection lines;
- all 400 and 220 kV lines, except lines which outage cause “island” operation (in case of parallel lines and double circuit lines, outage of one line-circuit is considered); and
- all transformers 400/220 kV (in case of parallel transformers, outage of one transformer is considered).

Voltage profile is analyzed for voltage levels of 220 kV and above. Voltage limits are given according to the operational and planning standards used in the monitored region, and they will be used for full topology and (n-1) analyses. Although wider voltage limits are allowed in emergency conditions for some voltage levels, these facts are not taken into consideration.

Thermal current limits are used for rated limits of lines and rated installed capacity of transformers, as described in Chapter 4. Voltage limits are also defined in Chapter 4. Every branch with current above its thermal limit is treated as overloaded. States with overloaded branches and/or voltages below or above defined voltage limits are treated as "insecure".

Results of load flow and contingency analyses are given in separate Annex of the present study. All explanations and interpretations are in concordance with the Annex. Annex is organized in sub-chapters relating to each generation and exchange scenario - results are given then for each transmission line candidate (96 sets of results in total). Each set of results contains:

- load flow report in terms of element loading and voltage profile histograms;
- table of elements loaded over 80%;
- comparison table of critically loaded elements in base case and with candidate in operation (loading over 60% of MVA rate);
- single line diagram for graphical representation of load flows; and
- contingency analysis report.

Before the thorough analysis of calculation results, some notifications must be pointed out since they are repeated from case to case due to the nature of the problem.

Detected branch overloading in (n-1) analysis in Romania are related to 220 kV loop (triangle) from S/S Fundeni to S/S Bucuresti Sud A & B. According to the information from TRANSELECTRICA there are possibilities in operational practice to remove this bottleneck by changing a switching status of some elements. This is the reason why this overloading is noted but not considered as critical as they do not require network reinforcements.

Loss of 400 kV line in Albania, between the Zemlak and Elbasan substations can cause decrease of voltages in 400 kV substations Kashar, Fier, Elbasan and Rashbull due to usually high import of reactive power from Greece to support voltages in 400 kV and 220 kV grids in southern Albania. Opposite situation is detected in central Bulgaria in region where HPPs are concentrated. Because of large number of power plants, radial connection to main 400 kV/220kV ring and low consumption, voltages in this part of grid are extremely high (in some cases over 1.1 pu). These violations will not be considered as critical as they present a regular feature of Bulgarian transmission grid.

Most of other contingency voltage depressions were detected on radially connected substations from 400 kV or 220 kV to lower voltage level. Loss of single HV branch that connects this S/S causes voltage drop due to inability of 110 kV grid to provide reactive support to higher voltage level. These problems were identified in Serbia (S/S Sombor), Romania (S/S L. Sarat), Bulgaria (S/S O. Chiflik) and Bosnia (S/S Banja Luka).

To provide deeper insight into the voltage problems which are obviously present in the analyzed scenarios, it is necessary to conduct more comprehensive and thorough analysis. It is assumed that the utilization of existing devices, such as transformer automatic tap changers and switchable shunts, or the generation re-dispatch may mitigate these voltage problems without a need to construct new lines.

Figures in the following sections of this Chapter show geographical positions of critical contingency elements within the analyzed scenarios. They also exhibit which transmission line candidate removes these critical ones or adds a new one. Green color reveals 220 kV elements (line 220 kV or transformer 220/x kV), while red one reveals 400 kV elements (line 400 kV or transformer 400/x kV). Addition or removal of new critical contingency elements is shown with arrows pointing to X (for removal) and O (for addition). Dashed arrow is used only in cases of missing convergence (partial or total blackout of power system) for some heavy outages.

Critical elements presented in the following Figures are elements that become overloaded in case of single (n-1) outage in GIS region. The same element may be critical in cases of different single outages. If transmission line candidate removes critical line overload for all problematic single outages, it is assumed that such candidate line releases critical element. If it is not the case for all problematic outages, such critical element is still considered as critical one.

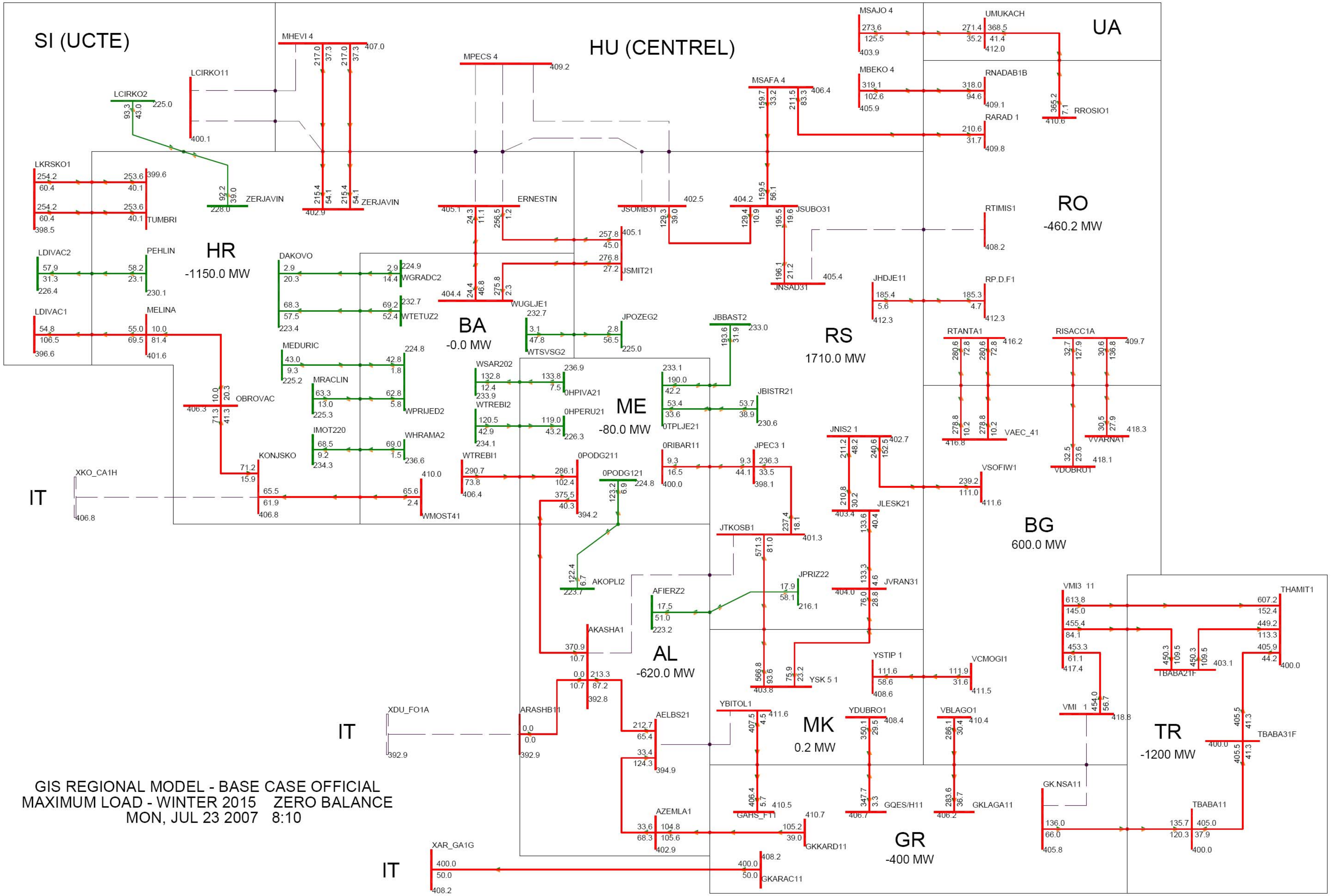

Figure 5.1 Example of power flows along interconnection lines in the region for 2015 Base Case with Official Rehabilitation Program - Zero Balance scenario

5.2 Scenario 1 – Base Case with Official Rehabilitation Program

This part of the present study describes results of static load flow and voltage profile analyses which are conducted for complete network topology and (n-1) contingencies in the scenario denoted as Scenario 1 – Base Case with Official Rehabilitation Program. Three levels of regional power balance are observed, depending on the hydrological conditions (dry and wet hydrology):

- power import in GIS countries (during dry hydrological conditions);
- zero balance of GIS countries (during wet hydrological conditions); and
- power export from GIS countries (during wet hydrological conditions).

Concerning the import/export cases, the simulated regime means the following:

- Zero Balance – Wet Hydrology;
- Export to western UCTE (Germany, Austria) – Wet Hydrology;
- Export to Italy – Wet Hydrology; and
- Import from CENTREL and Ukraine – Dry Hydrology.

5.2.1 Zero Balance – Wet Hydrology

Load Flow Analysis

Power exchanges over the country borders for 2015, Base Case with Official Rehabilitation - Zero Balance scenario, are shown in Figure 5.2.

Power flows along regional interconnection lines and system balances, as well as tie line loadings, branch loadings, transformer loadings and bus voltages are shown in Figures 1.1.1 – 1.1.5 of Annex (Chapter 1). According to these results it can be seen that the tie lines in the region are mostly loaded less than 60% of their thermal limits for the analyzed scenario in 2015. Among total number of forty seven 400 kV and 220 kV interconnection lines in the region twenty are loaded between 20% and 60% of their thermal ratings. There is only one tie line which is loaded more than 60% of its thermal limit; 220 kV Pljevlja (ME) – B.Basta (RS) is loaded with 62.3%. This is direct consequence of engagement of HPP B. Basta (RS) and RHPP B. Basta (RS) as well as of power transfer from north to south of the SEE.

Table 1.1.1 of Annex (Chapter 1) lists all network elements loaded over 80% of their thermal limits (PSS/E output). As it can be seen from this output list, most of the elements loaded over 80% are transformers. Thus, certain internal network reinforcements are necessary to sustain given load demand level and generation pattern. These overloads are detected in Albania in 220 kV grid and in planned S/S 400/110 kV Pec in Serbia/UNMIK.

The most of observed elements are loaded below 60%. There are 38 branches loaded between 60% and 100% (33 transformers and 5 transmission lines). Most of these transformers are connected to 110 kV grid which is considered to operate as a part of distribution and for that reason they are not analyzed. It can be noticed that interconnection lines are not jeopardized since they are loaded far below their thermal ratings. This is the consequence of small exchanges between the countries in the analyzed region since there is an overall balance between generation and consumption in GIS region. It should be emphasized that these results represent only a situation when additional devices (transformer automatic tap changers, switchable shunts, etc.) are not used for voltage regulation. Impacts of such devices, which exist in many points of the SEE regional transmission network, need more comprehensive and thorough analysis.

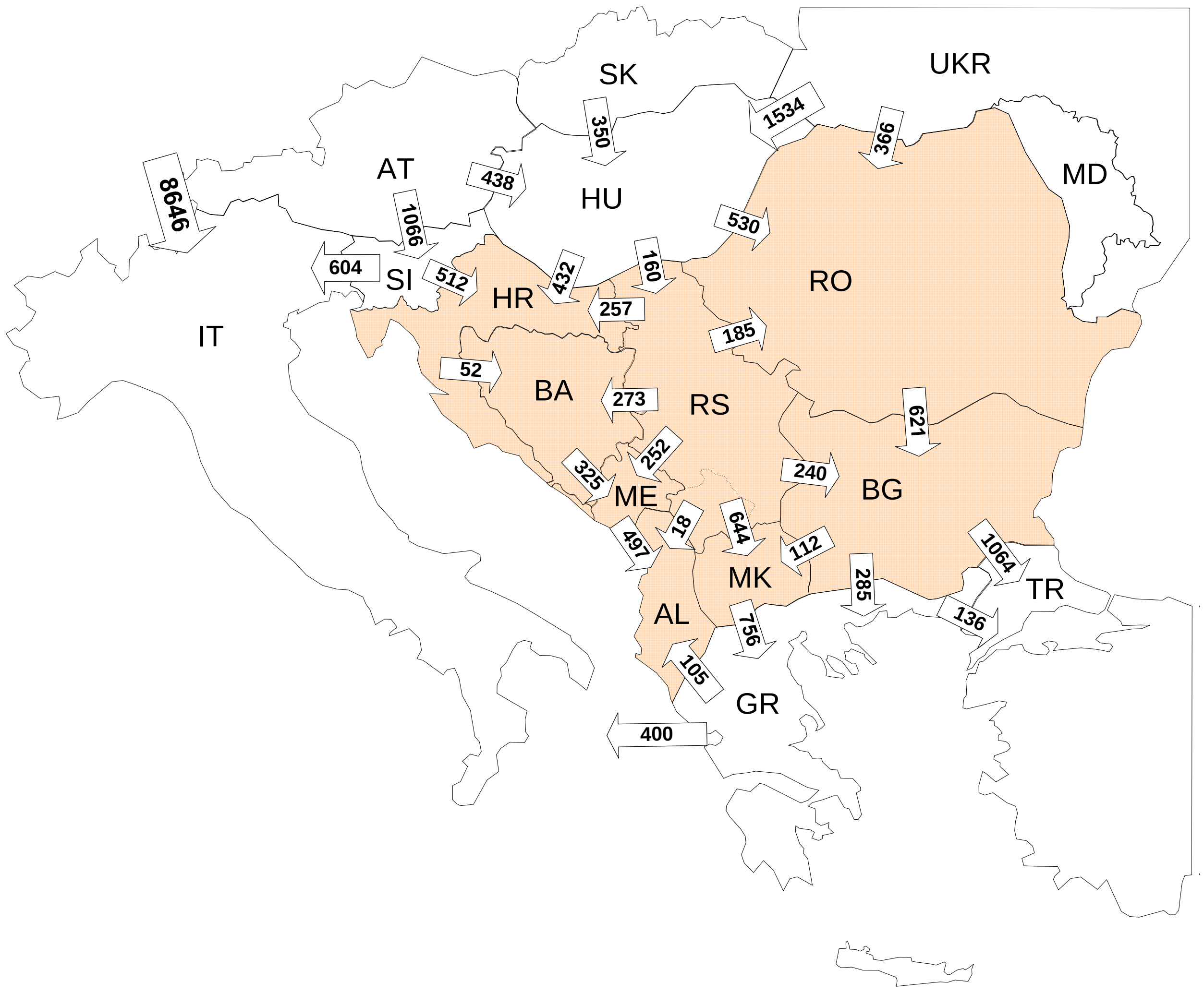

Figure 5.2 Area (border) exchanges for Base Case with Official Rehabilitation
– Zero Balance –

Security (n-1) Analysis

Results of security (n-1) analysis for Base Case with Official Rehabilitation Program - Zero Balance scenario are presented in Table 1.1.2 of Annex (Chapter 1). Insecure system situations for given generation pattern and power exchanges are detected in the power systems of Albania and Romania.

Figure 5.3 gives the geographical positions of critical elements in GIS region which are detected in contingency states of GIS power grid. Candidate line impact to steady state security is summoned and presented in Figure 5.4. Detailed results for each transmission line candidate are given in sub-chapters 1.1.1-1.1.8 of Annex.

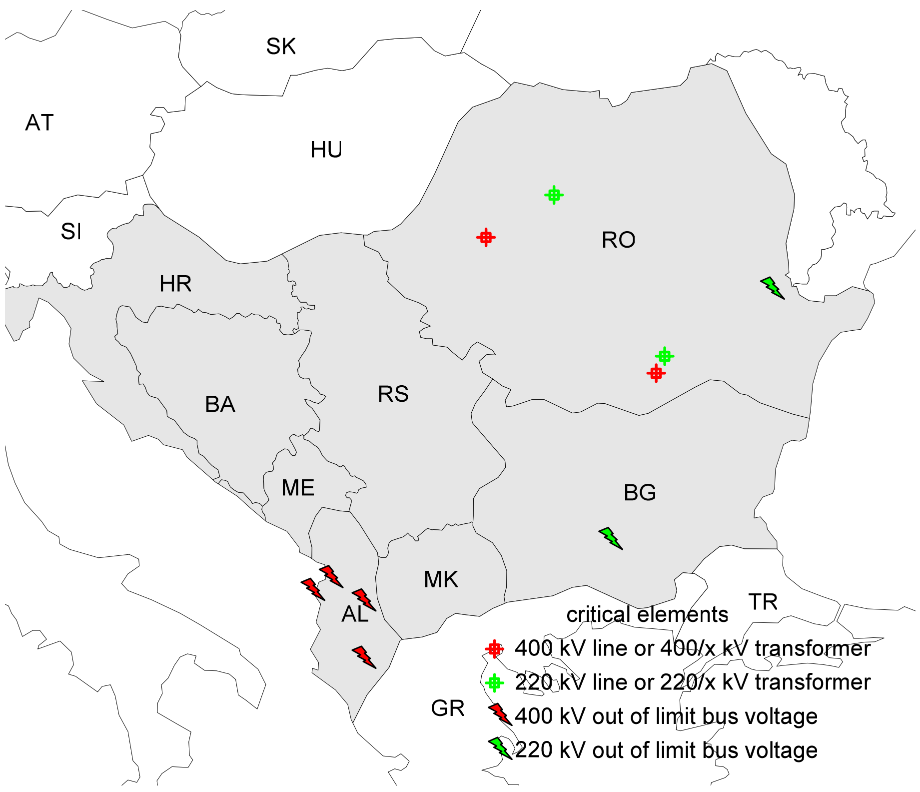

Figure 5.3 Geographical positions of the critical elements for Base Case with Official Rehabilitation – Zero Balance –

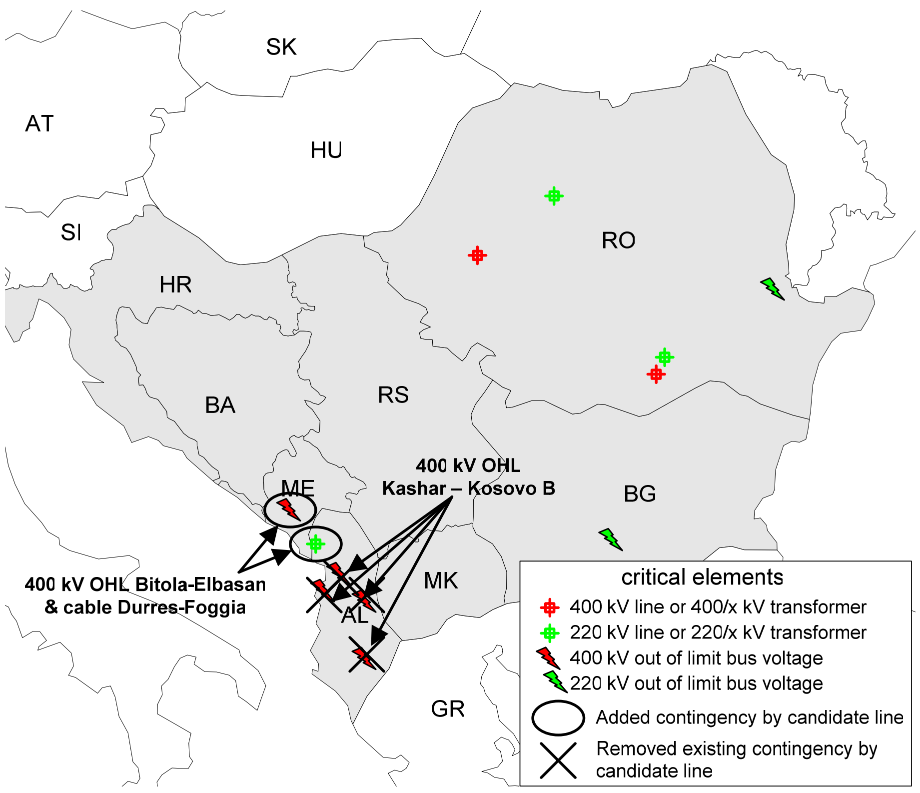

Figure 5.4 Overall view of geographical positions of the critical elements for Base Case with Official Rehabilitation – Zero Balance scenario, with influence of each transmission line candidate to power system security – (X for removal and O for addition of contingency)

It can be seen that in Zero Balance scenario with no significant exchange between countries of GIS region there is no many problems in steady state, neither in contingency states. Because of this reason, impact of transmission line candidates cannot be expressed fully.

There are only two transmission line candidates which bring contributions and obstructions to the power transfer in this case (Figure 5.4). First one is OHL 400 kV Kashar – Kosovo B which removes voltage problems in 400 kV level in Albania. Second one (combination of HVDC 400 kV Durres – Foggia + OHL 400 kV Bitola – Elbasan) overloads 220 kV OHL Podgorica (ME) – Vau Dejes (AL), and depresses voltage in S/S 400 kV Podgorica 2. This is a consequence of power transfer of toward Italy over a transmission grid with low voltage support on 400 kV level.

5.2.2 Export to Western UCTE (Germany, Austria) – Wet Hydrology

Load Flow Analysis

Power exchanges over the borders in 2015, Base Case with Official Rehabilitation program - Export to western UCTE scenario are shown in Figure 5.5.

Power flows along regional interconnection lines and system balances, as well as tie line loadings, branch loadings, transformer loadings and bus voltages are shown in Figures 1.2.1 – 1.2.5 of Annex (Chapter 1). According to these results it can be seen that the tie lines in the region are mostly loaded less than 60% of their thermal limits in the analyzed scenario for 2015. Among total number of forty seven 400 kV and 220 kV interconnection lines in the region 23 are loaded between 20% and 60% of their thermal ratings. There are no tie lines loaded more than 60% of its thermal limit. Table 1.2.1 of Annex (Chapter 1) lists all network elements loaded over 80% of their thermal limits (PSS/E output). As it can be seen from this output list, most of the elements loaded over 80% are transformers.

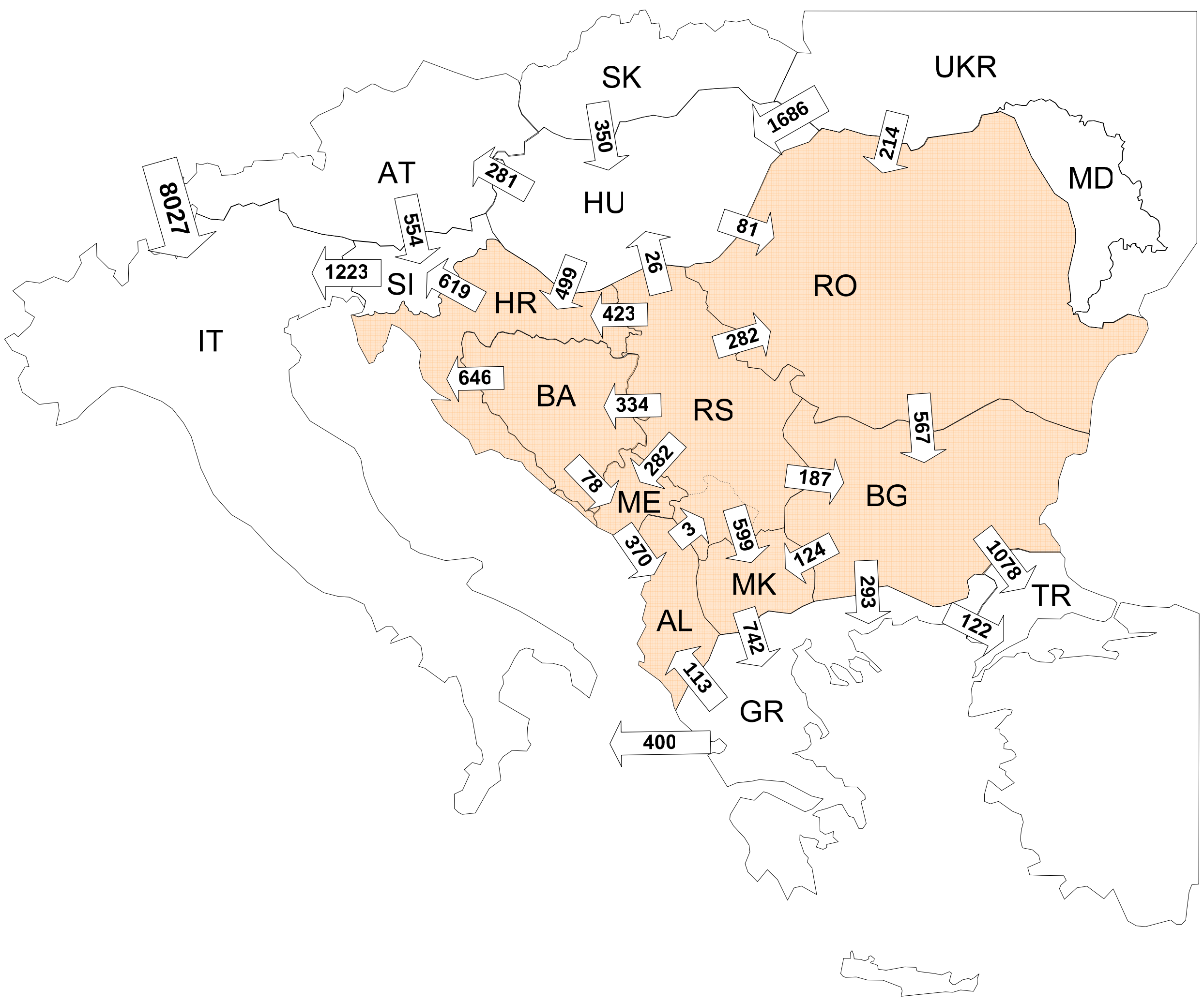

Figure 5.5 Area (border) exchanges for Base Case with Official Rehabilitation
– Export to western UCTE –

Most of observed elements are loaded below 60%. There are 40 branches loaded between 60% and 100% (34 transformers and 6 transmission lines). Most of these transformers are connected to 110 kV grid which is considered to operate as a part of distribution and for that reason not analyzed here. Although GIS countries have a surplus of 1850 MW, general direction of power flow is from north to south.

It can be noticed that interconnection lines are not jeopardized since they are loaded far below their thermal ratings. This is the consequence of small exchanges between the countries in the analyzed region since there is an overall balance between generation and consumption in GIS region.

It should be emphasized that these results represent only a situation where additional devices (transformer automatic tap changers, switchable shunts, etc.) are not used for voltage regulation. Impacts of such devices, which exist in many points of the SEE regional transmission network, need more comprehensive and thorough analysis.

Security (n-1) Analysis

Results of security (n-1) analysis for Base Case with Official Rehabilitation program- Export to western UCTE scenario are presented in Table 1.2.2 of Annex (Chapter 1). Insecure system situations for given generation pattern and power exchanges are detected in the power system of Romania. Figure 5.6 shows geographical positions of critical elements in GIS region. Their influence on steady state security is summoned and presented in Figure 5.7. Detailed results for each transmission line candidate are given in sub-chapters 1.2.1-1.2.8 of Annex.

It can be seen that in Export to UCTE scenario, with significant power export from the countries of GIS region, there is not many problems in steady state, neither in contingency states. Because of this reason, impact to transmission line candidates cannot be expressed fully, or it had even opposite effect.

There are only two transmission line candidates who brought obstructions to the power transfer in this case (Figure 5.7). First one is HVDC 400 kV Durres – Foggia + OHL 400 kV Bitola – Elbasan which added voltage depression problems in S/S 400 kV Kashar and Rashbull in Albania. This is a consequence of transfer of power toward Italy over a transmission grid with low voltage support at 400 kV level. Second one is HVDC 400 kV Konjsko – Candia which brings an overload to 220 kV OHL Zakucac – Konjsko (HR) in contingency state due to the power transfer of 500 MW through the weak meshed grid in coastal region of Adriatic Sea with existing loading of transmission lines.

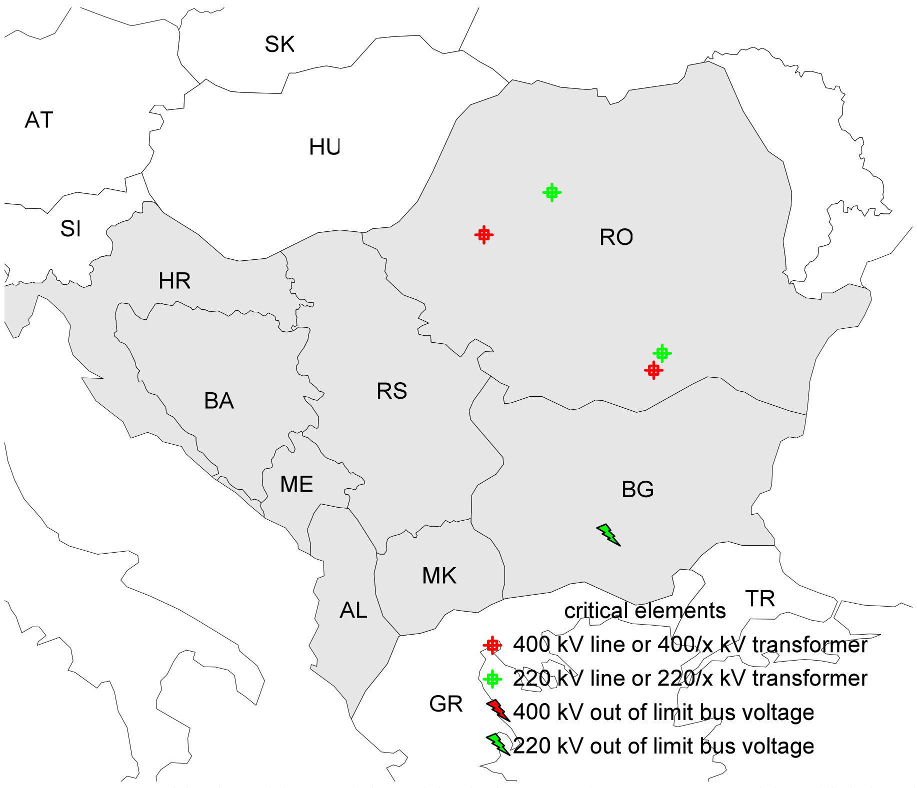

Figure 5.6 Geographical positions of the critical elements for Base Case with Official Rehabilitation – Export to western UCTE –

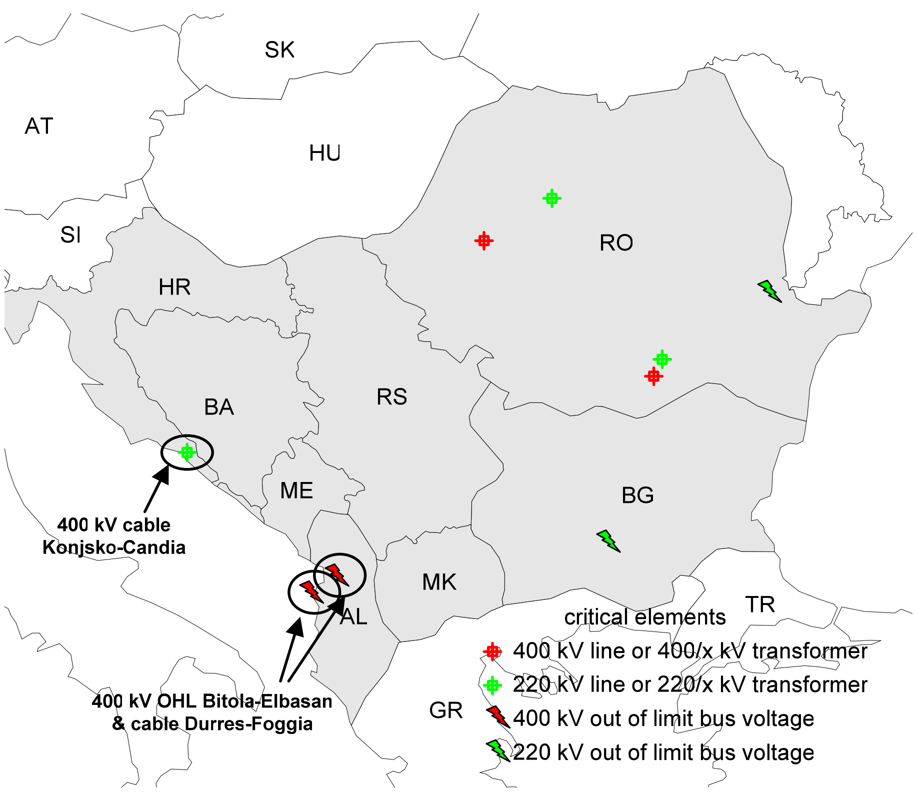

Figure 5.7 Overall view of geographical positions of critical elements for Base Case with Official Rehabilitation – Export to western UCTE scenario, with influence of each transmission line candidate to power system security – (X for removal and O for addition of contingency)

5.2.3 Export to Italy – Wet Hydrology

Load Flow Analysis

Power exchanges over the borders for 2015, Base Case with Official Rehabilitation program - Export to Italy scenario are shown in Figure 5.8.

Power flows along regional interconnection lines and system balances, as well as tie line loadings, branch loadings, transformer loadings and bus voltages are shown in Figures 1.3.1 – 1.3.5 of Annex (Chapter 1). According to these results it can be seen that the tie lines in the region are mostly loaded less than 60% of their thermal limits for the analyzed scenario in 2015. Among total number of forty seven 400 kV and 220 kV interconnection lines in the region 27 are loaded between 20% and 60% of their thermal ratings. Table 1.3.1 of Annex (Chapter 1) lists all network elements loaded over 80% of their thermal limits (PSS/E output). As it can be seen from this output list, most of the elements loaded over 80% are transformers.

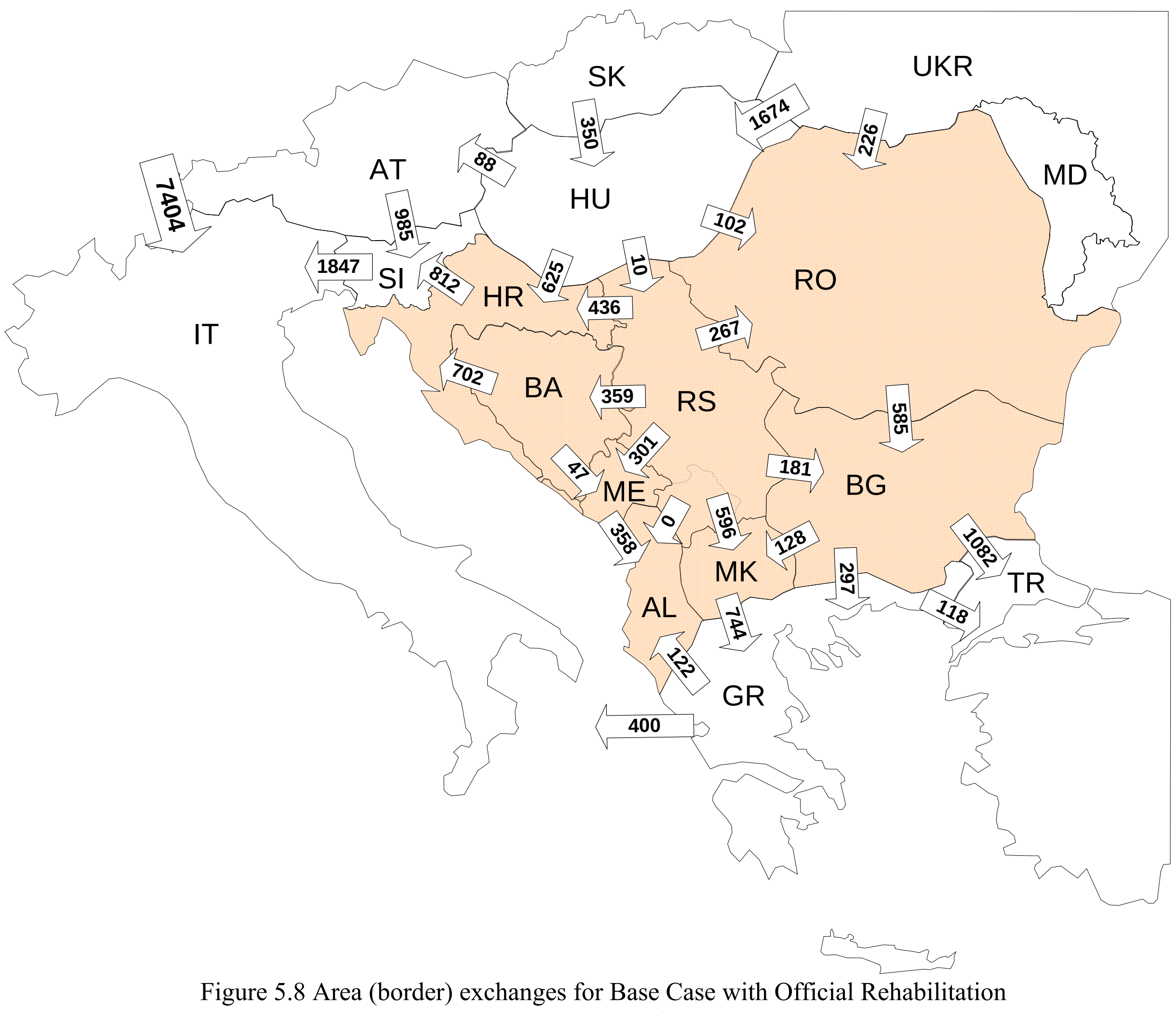

Figure 5.8 Area (border) exchanges for Base Case with Official Rehabilitation
– Export to Italy –

Total number of branches (lines and transformers) loaded between 60% and 100 % is 41. Most of these branches are transformers 400/110 kV and 220/110 kV. Due to the fact that 110 kV grid is not analyzed in GIS, loading of these branches is not of interest.

It can be noticed that interconnection lines are not jeopardized since they are loaded far below their thermal ratings. General direction of power flow remains from north to south (2000 MW towards Greece and Turkey) although there is a high export of power in GIS region scheduled for Italy.

Security (n-1) Analysis

Results of security (n-1) analysis for Base Case with Official Rehabilitation program- Export to Italy scenario are presented in Table 1.3.2 of Annex (Chapter 1). Insecure system situations for given generation pattern and power exchanges are detected in the power systems of Croatia and Romania. Figure 5.9 gives geographical positions of critical elements in GIS region detected in contingency states of GIS power grid. According to the results from sub-chapters 1.3.1-1.3.8 of Annex, influence on steady state security is summoned and presented in Figure 5.10 for each transmission line candidate.

It can be seen that in export to Italy scenario, where there is significant export of power from the countries of GIS region, problems were detected near the border of Slovenia and Croatia on OHL 220 kV line Pehlin (HR) – Divaca (SI) and in S/S 400 kV Meline (voltage violation).

There are two transmission line candidates which brought contributions and obstructions to the power transfer in this case (Figure 5.10). First one is HVDC 400 kV Durres – Foggia + OHL 400 kV Bitola – Elbasan which added voltage depression problems in S/S 400 kV Kashar, Rashbull and S/S 220 kV Rashbull in Albania. This is a consequence of transfer of power toward Italy over a transmission grid with low voltage support on 400 kV level.

Second HVDC 400 kV Konjsko – Candia brought complete removal of base case contingency problems (one overload and one voltage violation) at border with Slovenia, but an overload on 220 kV OHL Zakucac – Konjsko (HR) in contingency state was added. This addition of new critical element is a consequence of the power transfer of 500 MW through weakly meshed grid in coastal region of Adriatic Sea with existing loading of transmission lines.

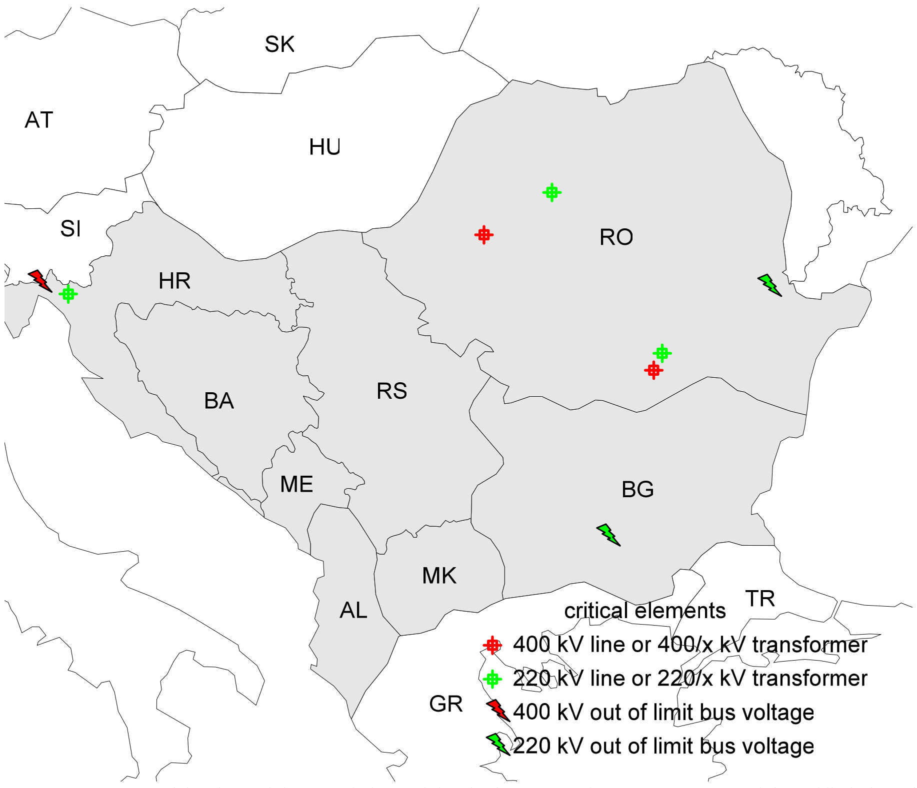

Figure 5.9 Geographical positions of the critical elements for Base Case with Official Rehabilitation – Export to Italy –

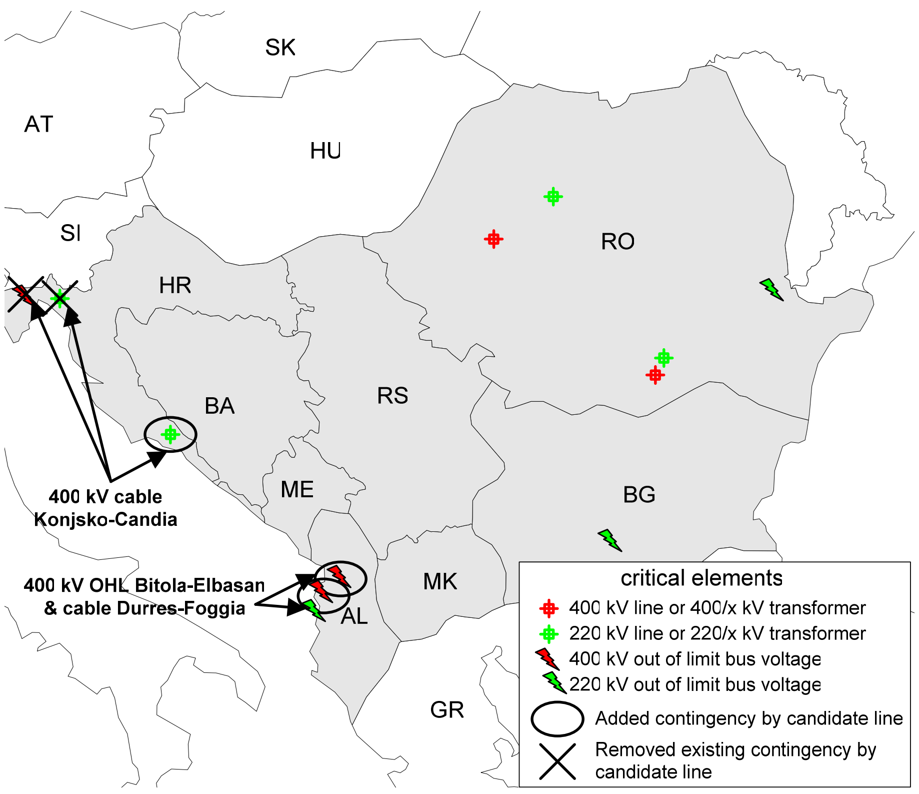

Figure 5.10 Overall view of geographical positions of critical elements for Base Case with Official Rehabilitation – Export to Italy scenario, with influence of each transmission line candidate to power system security – (X for removal and O for addition of contingency)

5.2.4 Import from CENTREL and Ukraine – Dry Hydrology

Load Flow Analysis

Power exchanges over the borders for 2015, Base Case with Official Rehabilitation program - Import from CENTREL and Ukraine scenario are shown in Figure 5.11.

Power flows along regional interconnection lines and system balances, as well as tie line loadings, branch loadings, transformer loadings and bus voltages are shown on Figures 1.4.1 – 1.4.5 of Annex (Chapter 1). According to these results it can be seen that the tie lines in the region are mostly loaded less than 60% of their thermal limits in the analyzed scenario for 2015. There are only two tie lines which are loaded more than 60% of its thermal limit; 220 kV Prijedor (BA) – Mraclin (HR) is loaded with 66% and OHL 400 kV Mukachevo (UA) – Rosiori (RO) with 84.9%. This is direct consequence of high import from 400 kV grid of Ukraine. Table 1.4.1 of Annex lists all network elements loaded over 80% of their thermal limits (PSS/E output). As it this output list shows, most of the elements loaded over 80% are transformers.

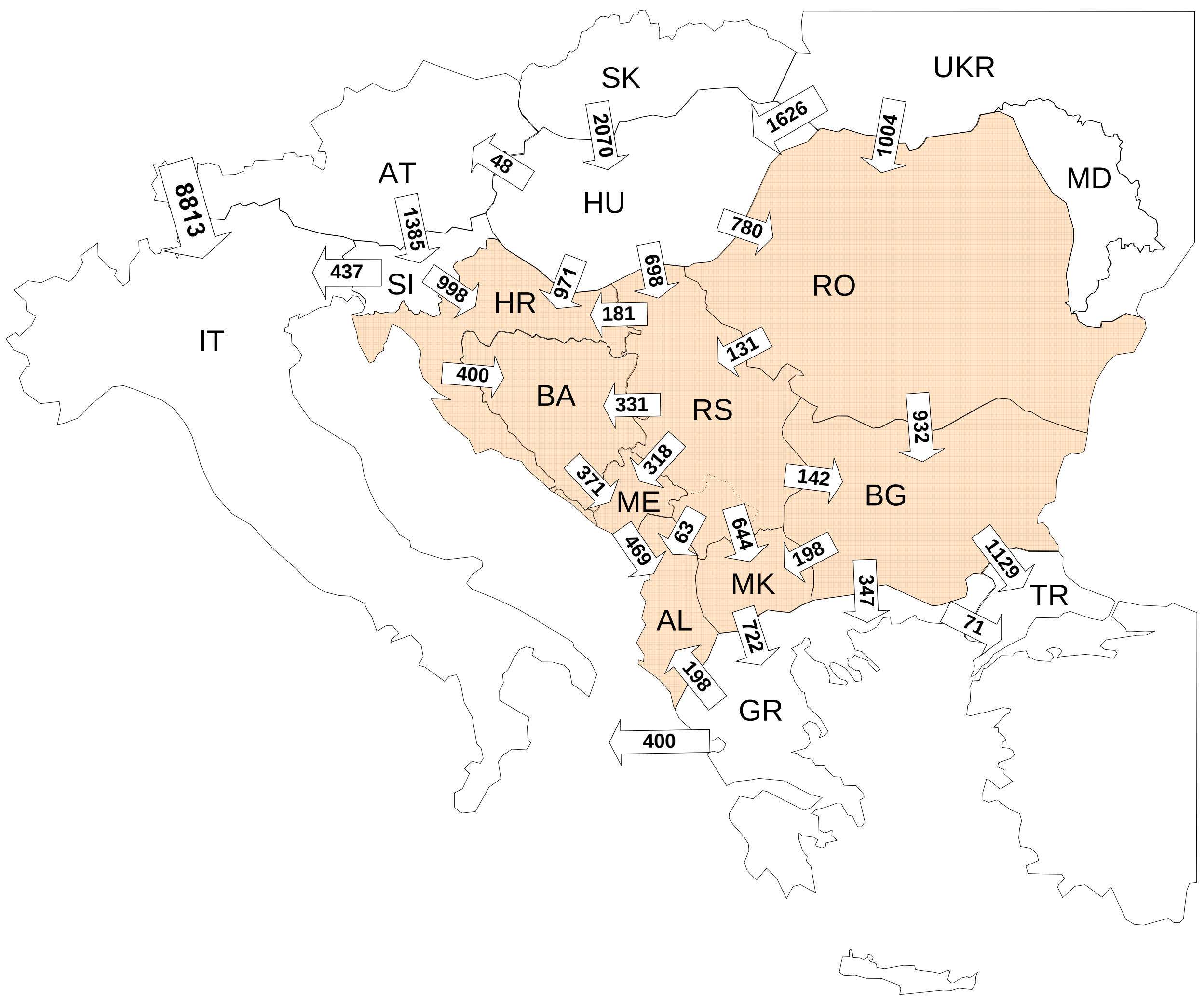

Figure 5.11 Area (border) exchanges for Base Case with Official Rehabilitation
– Import from CENTREL and Ukraine –

Thus, certain internal network reinforcements are necessary to sustain given load demand level and generation pattern, since, for instance, OHL 220 kV Mraclin – Zerjavinec is loaded 94% of thermal rating.

Total number of branches (lines and transformers) loaded between 60% and 100% is 53. Most of these branches are interconnection transformers 400/110 kV and 220/110 kV. Due to the fact that 110 kV grid is not analyzed in GIS, loading of these branches is not of interest.

It can be noticed that interconnection lines are not jeopardized since they are loaded far below their thermal ratings. The general direction of power flow remains from north to south (2000 MW towards Greece and Turkey) although there is a high import of 2450 MW from IPS/UPS to GIS region.

Security (n-1) Analysis

Results of security (n-1) analysis for Base Case with Official Rehabilitation program- Import from CENTREL and Ukraine scenario are presented in Table 1.4.2 of Annex. Insecure system situations for given generation pattern and power import are detected in the power systems of Albania, Croatia and Romania. Figure 5.12 gives geographical positions of critical elements in GIS region detected in contingency states of GIS power grid. According to the results from sub-chapters 1.4.1-1.4.8 of Annex, impact to steady state security is summoned and presented in Figure 5.13 for each transmission line candidate.

Problems identified in Albania (and Podgorica in Montenegro) at 400 kV level are a consequence of weak voltage support of the rest of their power systems. Loss of many 400 kV and 220 kV elements connected to or inside of power system of Albania can cause a voltage collapse in southern part of Albania. Steady state security of Croatia is reduced with base case loading of OHL 220 kV Mraclin – Zerjavinec of 94%. North and west parts of Romania are affected by high inflow of power from CENTREL and Ukraine. Transformer 400/220 kV at S/S 400 kV Rosiori and OHL 220 kV Baia – Rosiori become overloaded for several contingencies.

When transmission candidate OHL 400 kV Kashar – Kosovo B is in operation, it removes voltage problems in contingency states in Albania and Montenegro. Double OHL 400 kV Ernestinovo – Pecs and OHL triangle 400 kV Ernestinovo – Sombor – Pecs have the same effect when each of these candidates is in operation. Critical contingencies in Croatia (OHL 220 kV Mraclin – Zerjavinec) and in Romania (OHL 220 kV Baia – Rosiori) are removed, but new critical element is added (OHL 220 kV Beograd 3 – Obrenovac).

Submarine cables (Durres – Foggia and Konjsko – Candia) add a number of new critical elements and voltage violations. Two 220 kV interconnecting OHLs became overloaded; Podgorica – Vau Dejes (ME - AL) and Prijedor – Mraclin (BA – HR). Voltage violations are mostly situated in S/S 400 kV in western Romania (Oradea, Nadab, Arad, Rosiori), but there are some also in Croatia (S/S 400 kV Konjsko and Obrovac).

The most important annotation is that for certain outages, with HVDC 400 kV Konjsko-Candia in operation, voltage collapse occurs in Albania. Since there were no dynamic stability analyses performed in the present study it is impossible to foresee the course of events in this part of transmission system of GIS region.

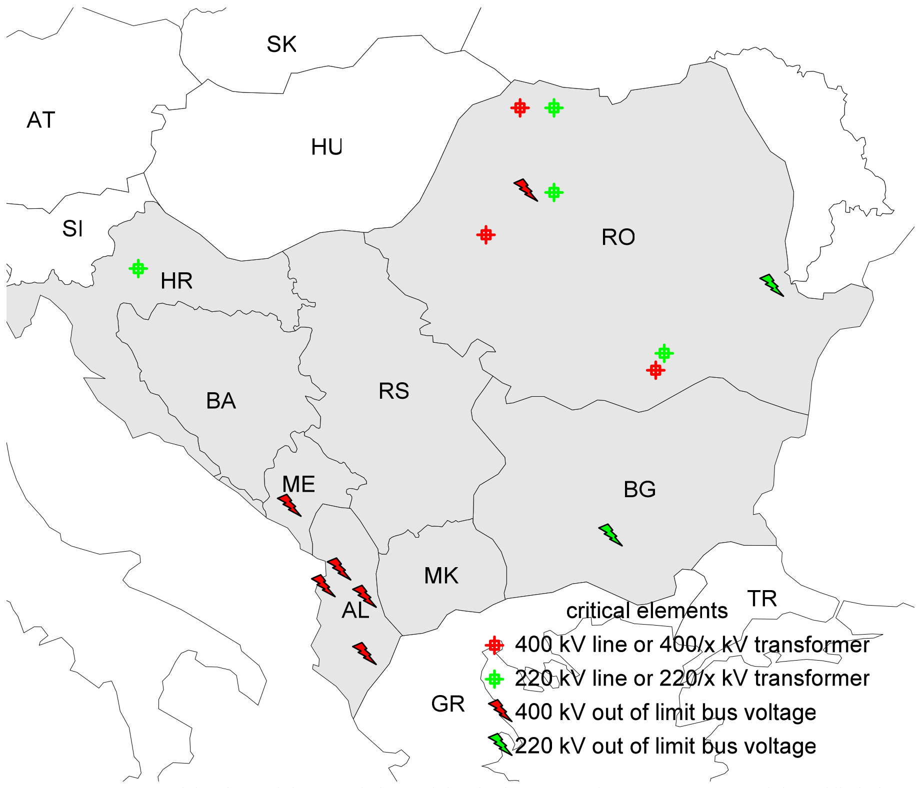

Figure 5.12 Geographical positions of the critical elements for Base Case with Official Rehabilitation – Import from CENTREL and Ukraine –

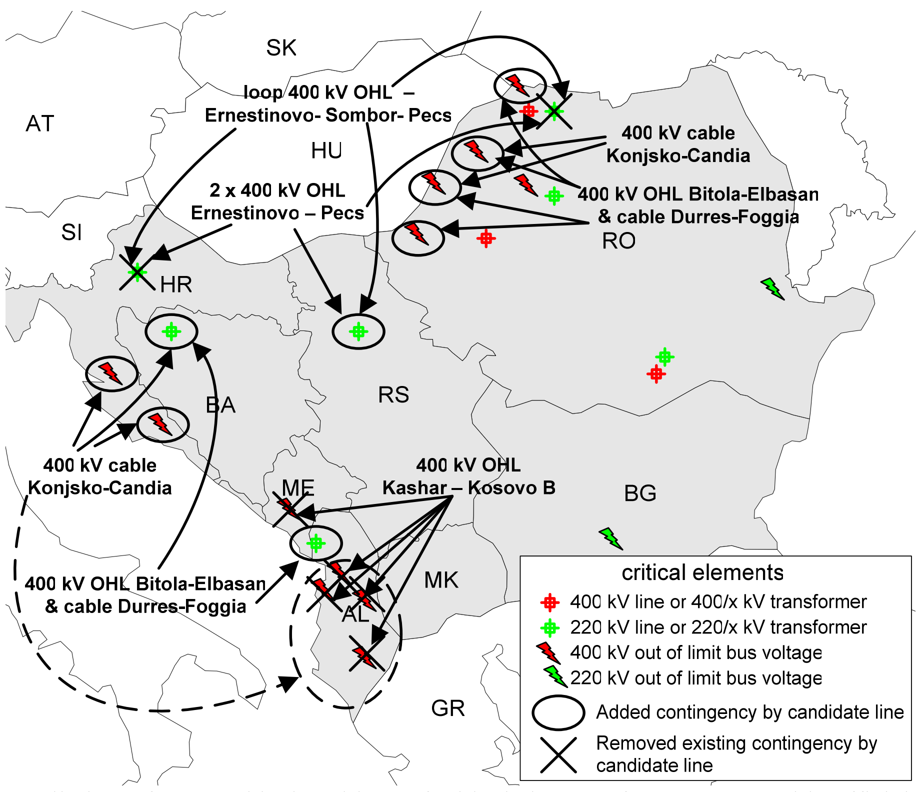

Figure 5.13 Overall view of geographical positions of critical elements for Base Case with Official Rehabilitation – Import from CENTREL and Ukraine scenario, with influence of each transmission line candidate to security – (X for removal and O for addition of contingency)

5.3 Scenario 2 - Base Case with Justified Rehabilitation Program

This part of the present study describes results of static load flow and voltage profile analyses conducted for complete network topology and (n-1) contingencies in the scenario which is denoted as Scenario 1 – Base Case with Justified Rehabilitation program. Three levels of regional power balance are observed, depending on the hydrological conditions (dry and wet hydrology):

- power import in GIS countries (during dry hydrological conditions);
- zero balance of GIS countries (during wet hydrological conditions); and
- power export from GIS countries (during wet hydrological conditions).

Concerning the import/export cases, the simulated regime means the following:

- Zero Balance – Wet Hydrology;
- Export to western UCTE (Germany, Austria) – Wet Hydrology;
- Export to Italy – Wet Hydrology; and
- Import from CENTREL and Ukraine – Dry Hydrology.

5.3.1 Zero Balance – Wet Hydrology

Load Flow Analysis

Power exchanges over the borders for 2015, Base Case with Official Rehabilitation program - Zero Balance scenario are shown in Figure 5.14. Power flows along regional interconnection lines and system balances, as well as tie line loadings, branch loadings, transformer loadings and bus voltages are shown in Figures 2.1.1 – 2.1.5 of Annex (Chapter 2). According to these results it can be seen that the tie lines in the region are mostly loaded less than 60% of their thermal limits in the analyzed scenario for 2015. Among total number of forty seven 400 kV and 220 kV interconnection lines in the region 20 are loaded between 20% and 60% of their thermal ratings.

There is only one tie-line which is loaded more than 60% of its thermal limit; 220 kV Pljevlja (ME) – B.Basta (RS) is loaded with 64%. This is direct consequence of full engagement of HPP B. Basta (RS) and RHPP B. Basta (RS). Table 2.1.1 of Annex (Chapter 2) lists all network elements loaded over 80% of their thermal limits (PSS/E output). As it can be seen from this output list, most of the elements loaded over 80% are transformers. Most of observed elements are loaded below 60%. There are 41 branches loaded between 60% and 100% (36 transformers and 5 transmission lines). Most of these transformers are connected to 110 kV grid which is considered to operate as a part of distribution and for that reason not analyzed. It can be noticed that interconnection lines are not jeopardized since they are loaded far below their thermal ratings. This is a consequence of small exchanges between the countries in the analyzed region since there is an overall balance between generation and consumption in GIS region. It should be emphasized that these results represent only a situation when additional devices (transformer automatic tap changers, switchable shunts, etc.) are not used for voltage regulation. Impacts of such devices, which exist in many points of the SEE regional transmission network, need more comprehensive and thorough analysis.

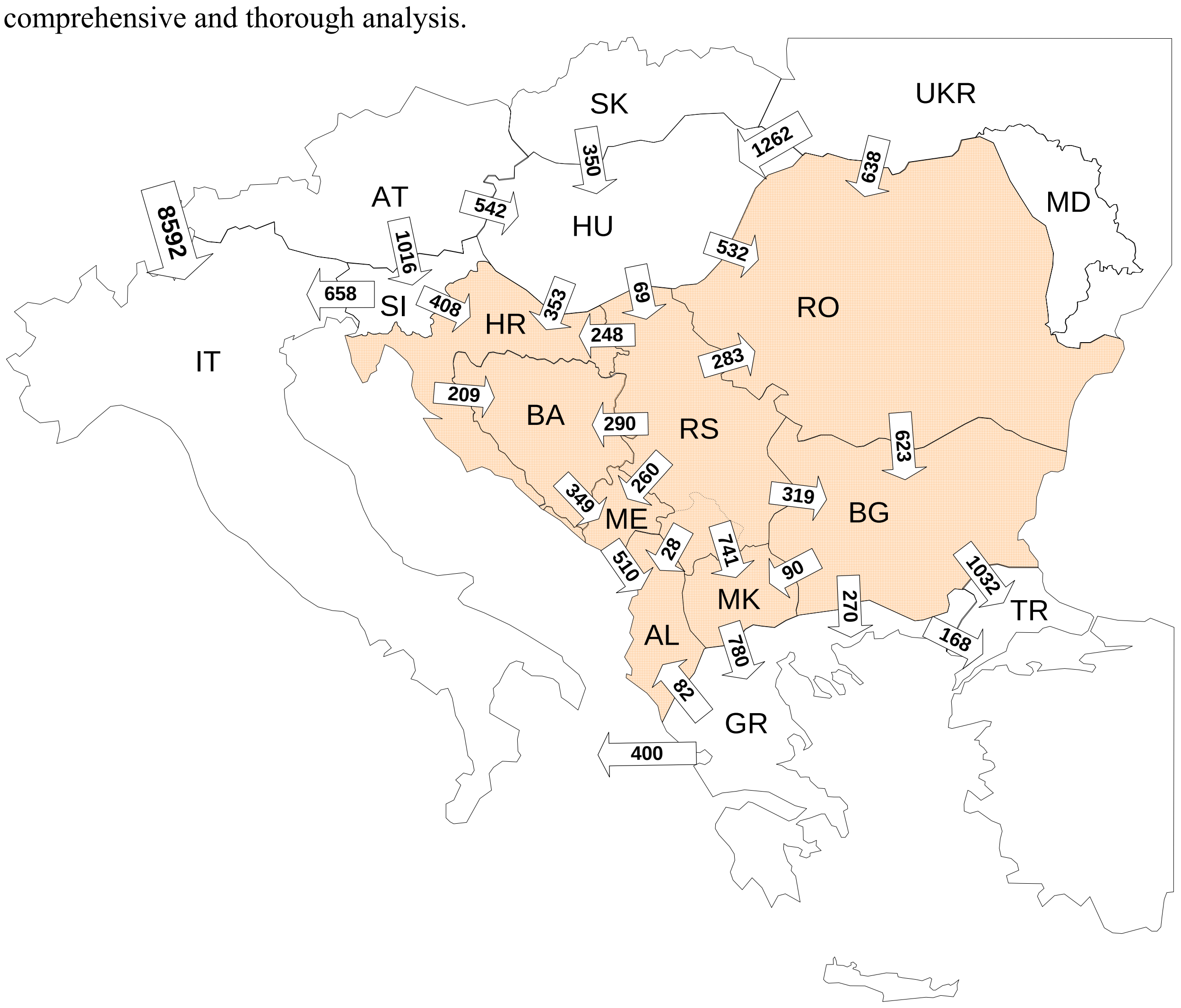

Figure 5.14 Area (border) exchanges for Base Case with Justified Rehabilitation
– Zero Balance –

Security (n-1) Analysis

Results of security (n-1) analysis for Base Case with Justified Rehabilitation program - Zero Balance scenario are presented in Table 2.1.2 of Annex. Insecure system situations for given generation pattern and power import are detected in the power systems of Albania, BiH, Bulgaria and Serbia. Figure 5.15 shows geographical positions of critical elements in GIS region. According to the results from sub-chapters 2.1.1-2.1.8 of Annex, influence on steady state security is summoned and presented in Figure 5.16 for each transmission line candidate. It can be seen that in Zero Balance scenario with no significant exchange between countries of GIS region there is not many problems in steady state, neither in contingency states. Because of this reason, influence of transmission line candidates cannot be expressed fully. There are three transmission line candidates which bring contributions and obstructions to the power transfer in this case (Figure 5.16). First one is OHL 400 kV Kashar – Kosovo B which removes voltage problems in 400 kV level in Albania. Second one (combination of HVDC 400 kV Durres – Foggia + OHL 400 kV Bitola – Elbasan) brings an overload to 220 kV OHL Podgorica (ME) – Vau Dejes (AL), and voltage drop in S/S 400 kV Podgorica 2. This is a consequence of power transfer toward Italy over transmission grid with low voltage support at 400 kV level. Third one which affects the steady state security with its operation is OHL 400 kV Novi Sad – Timisoara. Presence of this line removes overload of OHL 220 kV Beograd 3 - Obrenovac in contingency states.

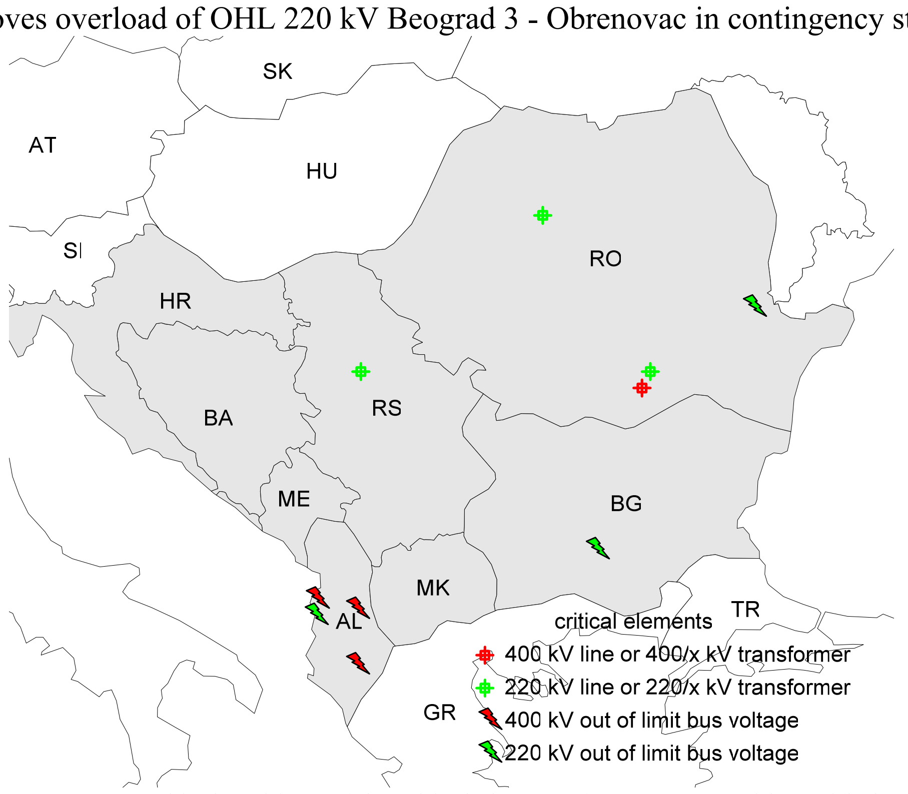

Figure 5.15 Geographical positions of the critical elements for Base Case with Justified Rehabilitation – Zero Balance –

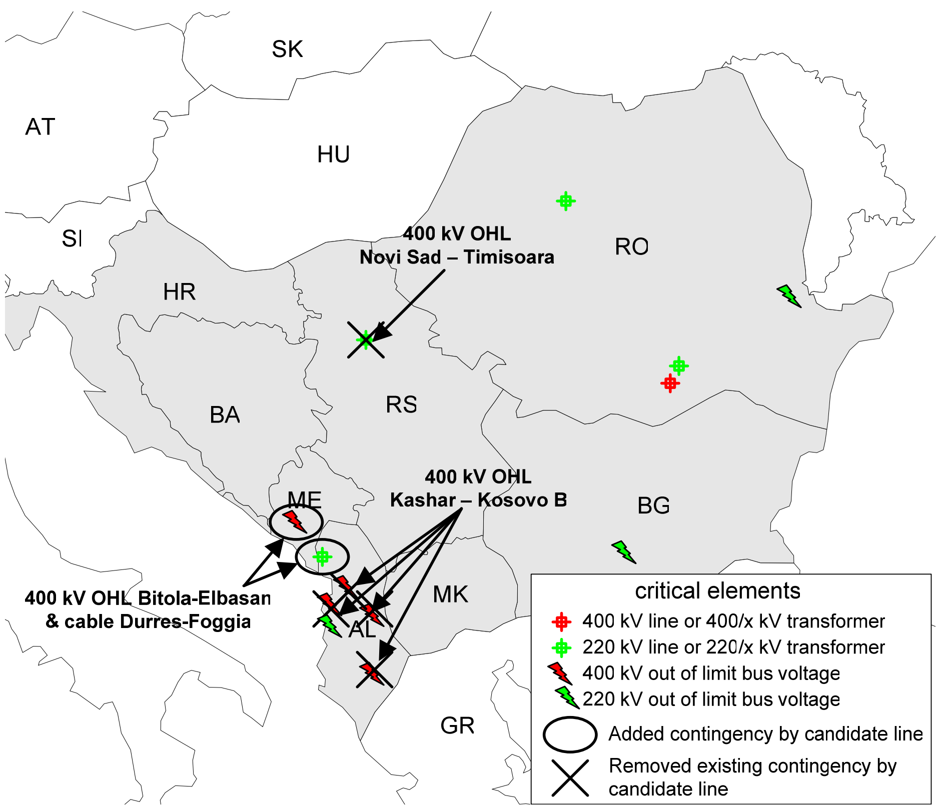

Figure 5.16 Overall view of geographical positions of critical elements for Base Case with Justified Rehabilitation – Zero Balance scenario, with influence of each transmission line candidate to power system security – (X for removal and O for addition of contingency)

5.3.2 Export to western UCTE (Germany, Austria) – Wet Hydrology

Load Flow Analysis

Power exchanges over the borders for 2015, Base Case with Justified Rehabilitation program - Export to western UCTE scenario are shown in Figure 5.17.

Power flows along regional interconnection lines and system balances, as well as tie line loadings, branch loadings, transformer loadings and bus voltages are shown in Figures 2.2.1 – 2.2.5 of Annex (Chapter 2). According to these results it can be seen that the tie lines in the region are mostly loaded less than 60% of their thermal limits in the analyzed scenario for 2015. Among total number of forty seven 400 kV and 220 kV interconnection lines in the region 24 are loaded between 20% and 60% of their thermal ratings. There is only one tie line loaded more than 60% of its thermal limit; 220 kV Divaca (SI) – Pehlin (HR) is loaded with 63.1%. Table 2.2.1 of Annex lists all network elements loaded over 80% of their thermal limits. As it can be seen from this output list, most of the elements loaded over 80% are transformers. These transformers are situated in Albania and Serbia.

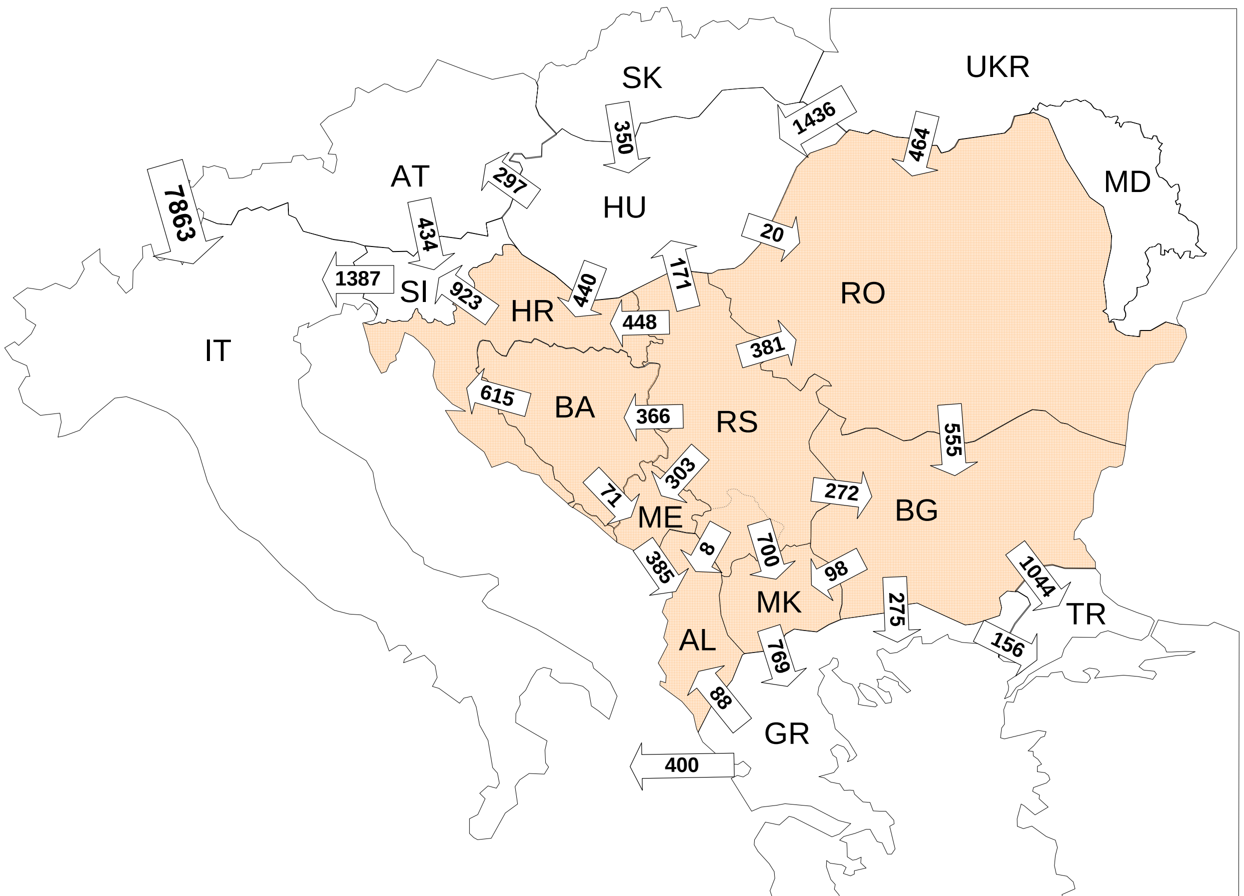

Figure 5.17 Area (border) exchanges for Base Case with Justified Rehabilitation
– Export to western UCTE –

Most of observed elements are loaded below 60%. There are 45 branches loaded between 60% and 100% (39 transformers and 6 transmission lines). Most of these transformers are connected to 110 kV grid which is considered to operate as a part of distribution and for that reason not analyzed here. Although GIS countries have a surplus of 2170 MW, general direction of power flow is from north to south.

It can be noticed that interconnection lines are not jeopardized since they are loaded far below their thermal ratings. This is the consequence of small exchanges between the countries in the analyzed region since there is an overall balance between generation and consumption in GIS region.

It should be emphasized that these results represent only a situation when additional devices (transformer automatic tap changers, switchable shunts, etc.) are not used for voltage regulation. Impacts of such devices, which exist in many points of the SEE regional transmission network, need more comprehensive and thorough analysis.

Security (n-1) Analysis

Results of security (n-1) analysis for Base Case with Justified Rehabilitation program- Export to western UCTE scenario are presented in Table 2.2.2 of Annex (Chapter 2). Insecure system situations for given generation pattern and power import are detected in the power systems of Albania, Bulgaria and Romania.

Figure 5.18 gives geographical positions of critical elements in the GIS region, which are detected in contingency states of GIS power grid. According to the results from sub-chapters 2.2.1-2.2.8 of Annex, influence on steady state security is summoned and presented in Figure 5.19 for each transmission line candidate.

It can be seen that in Export to UCTE scenario, where there is significant power export from the GIS countries, there is not many problems in steady state, neither in contingency states. Because of this reason, impact to transmission line candidates cannot be expressed fully, or it had even opposite effect.

Only one transmission line candidate brought obstructions to the power transfer in this case (Figure 5.19). Submarine HVDC 400 kV Durres – Foggia + OHL 400 kV Bitola – Elbasan added voltage depression problems in S/S 400 kV Kashar, Rashbull, Elbasan and Zemlak in Albania. This is a consequence of power transfer toward Italy over a transmission grid with low voltage support at 400 kV level.

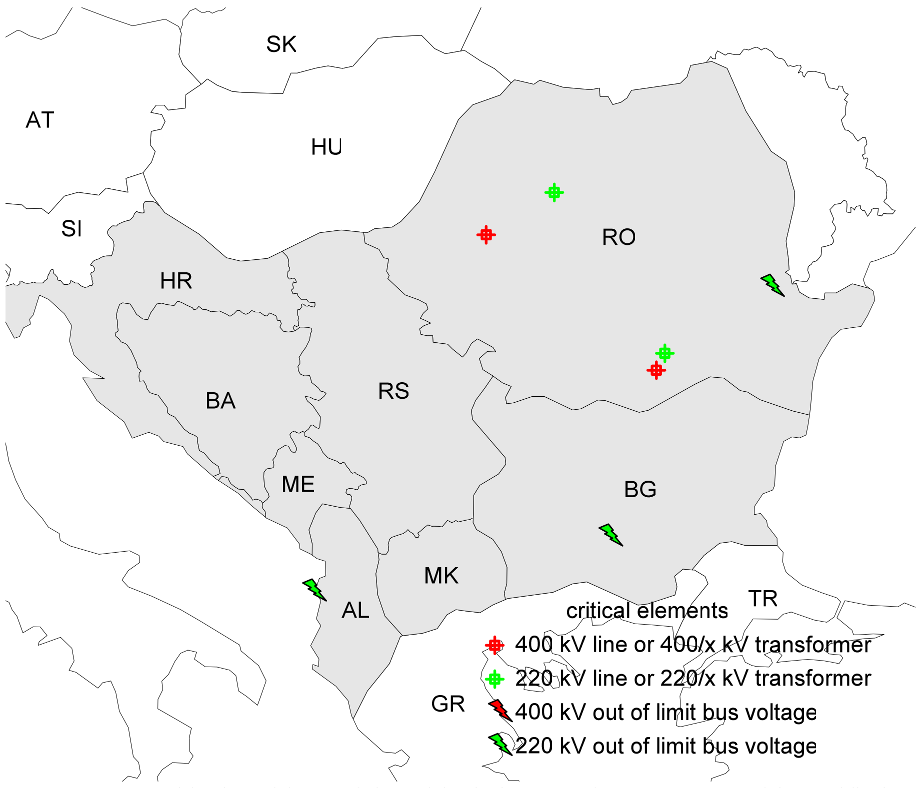

Figure 5.18 Geographical positions of the critical elements for Base Case with Justified Rehabilitation
– Export to western UCTE –

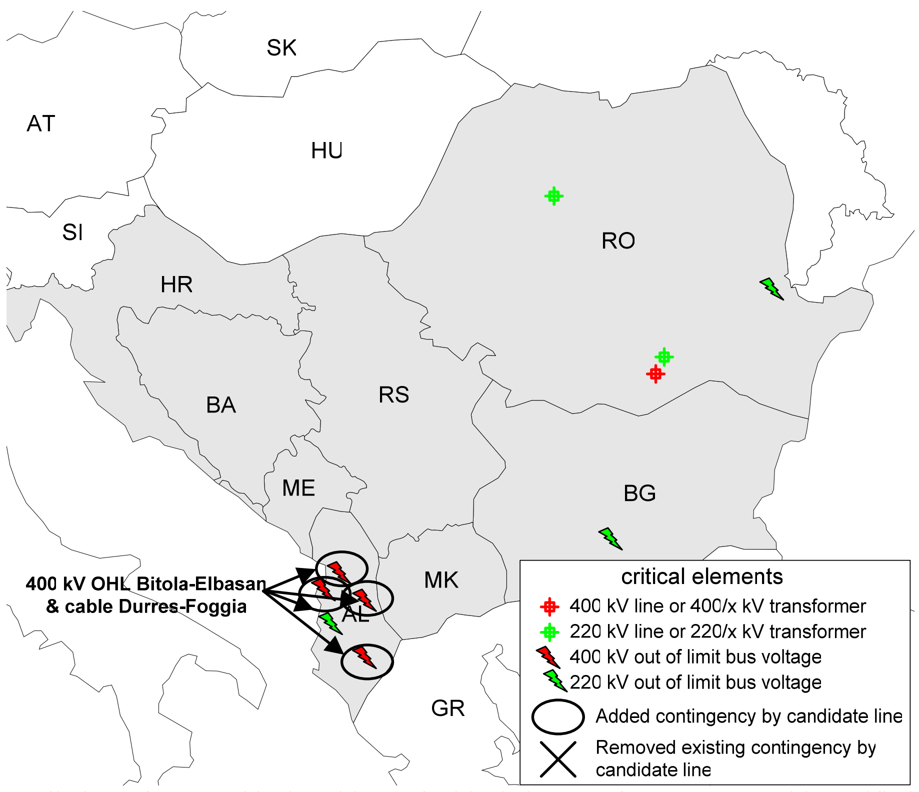

Figure 5.19 Overall view of geographical positions of critical elements for Base Case with Justified Rehabilitation
– Export to western UCTE scenario, with influence of each transmission line candidate to security –
(X for removal and O for addition of contingency)

5.3.3 Export to Italy – Wet Hydrology

Load Flow Analysis

Power exchanges over the borders for 2015, Base Case with Justified Rehabilitation program - Export to Italy scenario are shown in Figure 5.20.

Power flows along regional interconnection lines and system balances, as well as tie line loadings, branch loadings, transformer loadings and bus voltages are shown in Figures 2.3.1 – 2.3.5 of Annex (Chapter 2). According to these results it can be seen that the tie lines in the region are mostly loaded less than 60% of their thermal limits in the analyzed scenario for 2015. Among total number of forty seven 400 kV and 220 kV interconnection lines in the region 20 are loaded between 20% and 60% of their thermal ratings. There is only one tie line loaded more than 60% of its thermal limit; 220 kV Pehlin (HR) – Divaca (SI) is loaded with 86.1 %. This is direct consequence of power export toward Italy. Table 2.3.1 of Annex lists all network elements loaded over 80% of their thermal limits (PSS/E output). As it can be seen from this output list, most of the elements loaded over 80% are transformers.

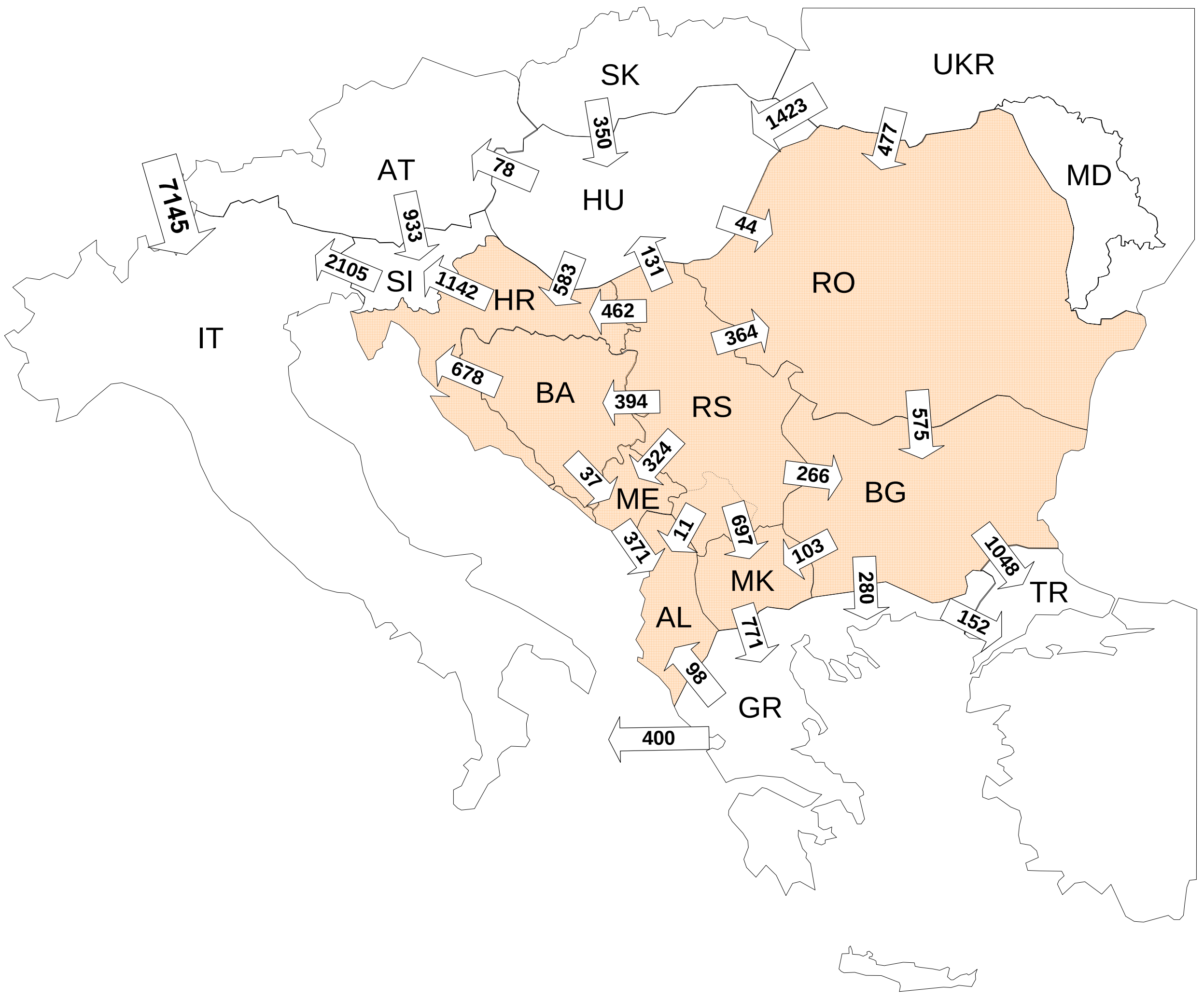

Figure 5.20 Area (border) for Base Case with Justified Rehabilitation
– Export to Italy –

Total number of branches (lines and transformers) loaded between 60% and 100% is 44 (38 transformers and 6 lines). Most of these branches are transformers 400/110 kV and 220/110 kV. Due to the fact that 110 kV grid is not analyzed in GIS, loading of these branches is not of interest here.

It can be noticed that interconnection lines are not jeopardized since they are loaded far below their thermal ratings. General direction of power flow remains from north to south (2000 MW towards Greece and Turkey) although there is a high power export in the GIS region scheduled for Italy (2170 MW).

Security (n-1) Analysis

Results of security (n-1) analysis for Base Case with Justified Rehabilitation program- Export to Italy scenario are presented in Table 2.3.2 of Annex. Insecure system situations for given generation pattern and power exchanges are detected in the power systems of Croatia and Romania.

Figure 5.21 gives geographical positions of critical elements in the GIS region, which are detected in contingency states of GIS power grid. According to the results from sub-chapters 2.3.1-2.3.8 of Annex, impact to steady state security is summoned and presented in Figure 5.22 for each transmission line candidate.

It can be seen that in Export to Italy scenario with significant power export from the GIS countries, problems were detected near border between Slovenia and Croatia; OHL 220 kV Pehlin (HR) – Divaca (SI) and in S/S 400 kV Meline (voltage violation).

There are two transmission line candidates who brought contributions and obstructions to the power transfer in this case (Figure 5.22). First one is HVDC 400 kV Durres – Foggia + OHL 400 kV Bitola – Elbasan which added voltage depression problems in S/S 400 kV Kashar, Rashbull and S/S 220 kV Rashbull in Albania. This is a consequence of power transfer toward Italy over a transmission grid with low voltage support at 400 kV level. Second HVDC 400 kV Konjsko – Candia brought complete removal of base case contingency problems (one overload and one voltage violation) near border with Slovenia, but overload of 220 kV OHL Zakucac – Konjsko (HR) was added in contingency state. This addition of new critical element is a consequence of 500 MW power transfer through weakly meshed grid in coastal region of Adriatic Sea with existing loading of transmission lines.

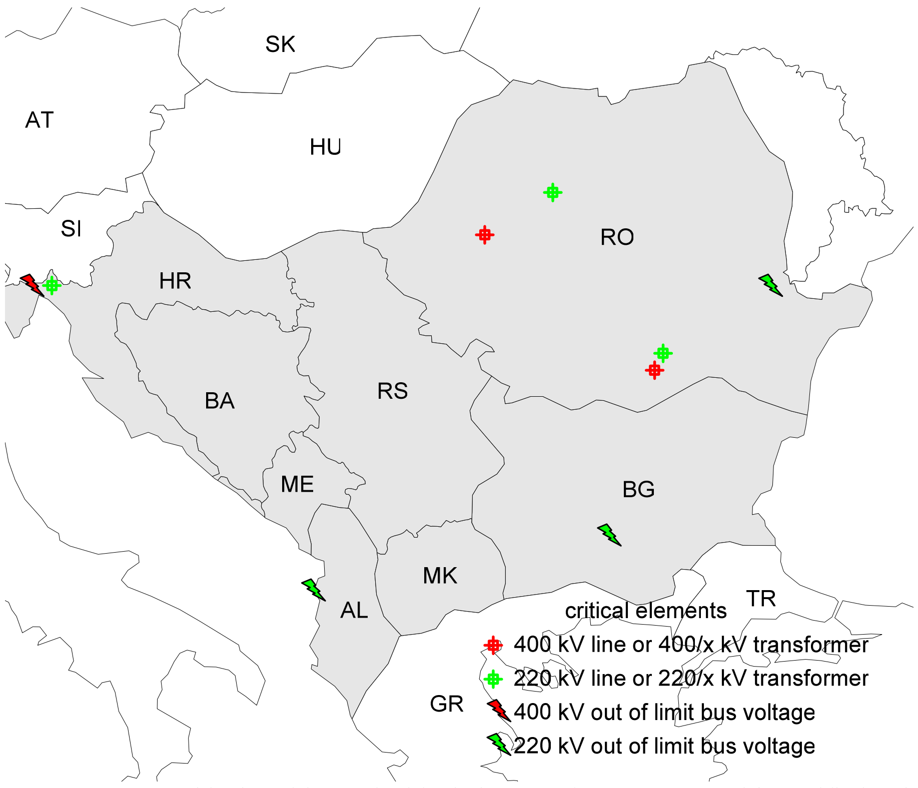

Figure 5.21 Geographical positions of critical elements for Base Case with Justified Rehabilitation – Export to Italy –

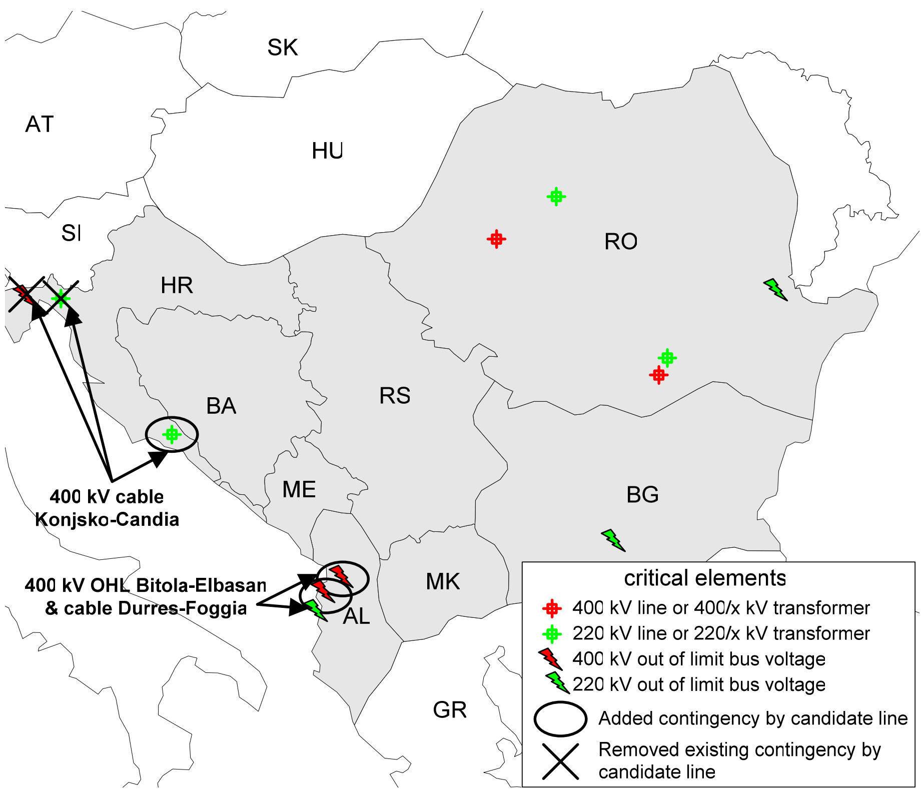

Figure 5.22 Overall view of geographical positions of critical elements for Base Case with Justified Rehabilitation – Export to Italy scenario, with influence of each transmission line candidate to power system security – (X for removal and O for addition of contingency)

5.3.4 Import from CENTREL and Ukraine – Dry Hydrology

Load Flow Analysis

Power exchanges over the borders for 2015, Base Case with Justified Rehabilitation program - Import from CENTREL and Ukraine scenario are shown in Figure 5.23.

Power flows along regional interconnection lines and system balances, as well as tie line loadings, branch loadings, transformer loadings and bus voltages are shown in Figures 2.4.1 – 2.4.5 of Annex (Chapter 2). According to these results it can be seen that the tie lines in the region are mostly loaded less than 60% of their thermal limits in the analyzed scenario for 2015. Among total number of 47 400 kV and 220 kV interconnection lines in the region 20 are loaded between 20% and 60% of their thermal ratings. There are two tie lines loaded more than 60% of their thermal limit; 220 kV Prijedor (BA) – Mraclin (HR) is loaded with 68.6% and OHL 400 kV Mukachevo (UA) – Rosiori (RO) with 72.7%. Table 2.4.1 of Annex lists all network elements loaded over 80% of their thermal limits (PSS/E output). As it can be seen from this output list, most of the elements loaded over 80% are transformers.

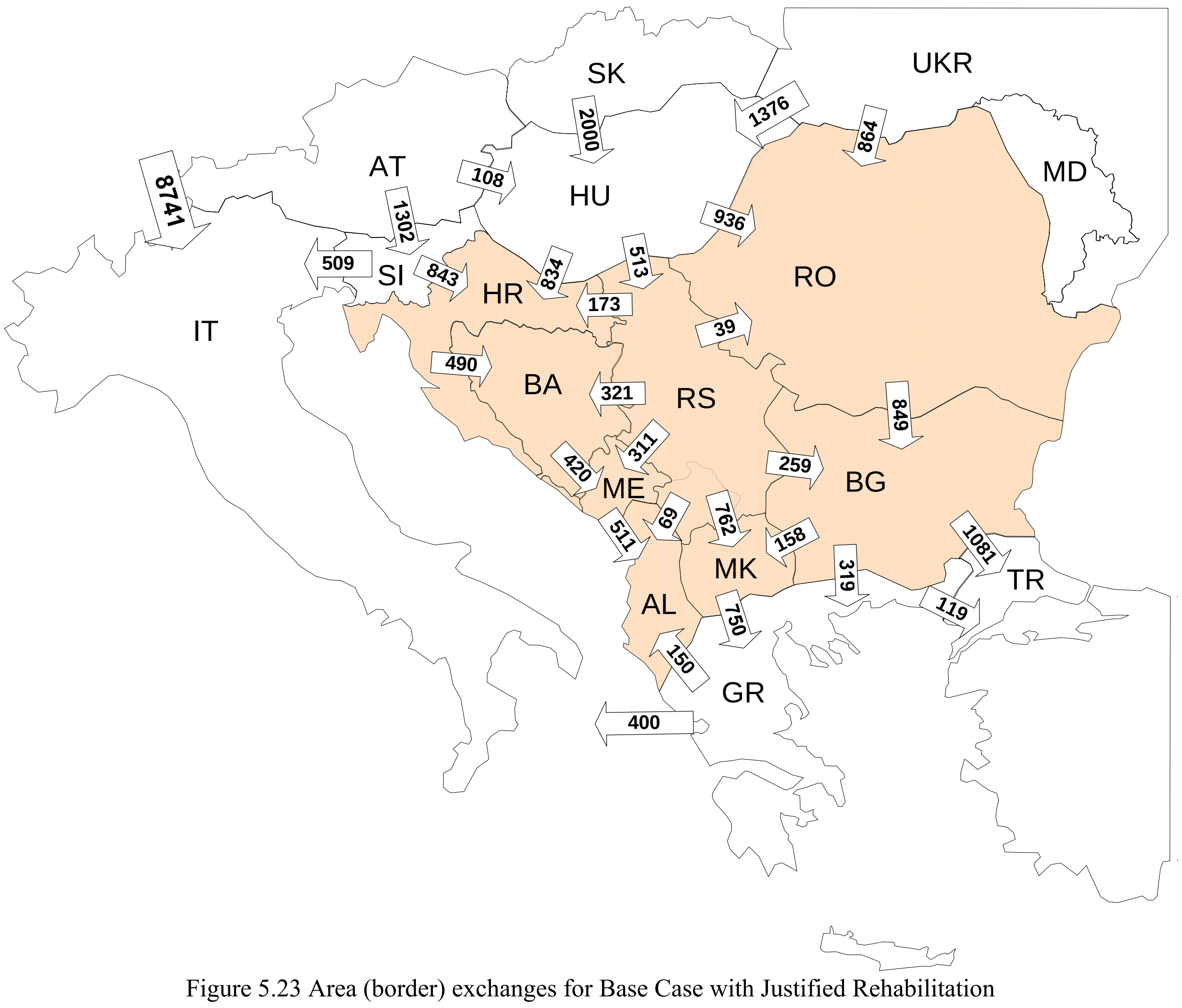

Figure 5.23 Area (border) exchanges for Base Case with Justified Rehabilitation
– Import from CENTREL and Ukraine –

Thus, certain internal network reinforcements are necessary to sustain given load demand level and generation pattern, since, for instance, OHL 220 kV Mraclin – Zerjavinec is loaded 88.5% of its thermal rating. Total number of branches (lines and transformers) loaded between 60% and 100% is 53 (47 transformers and 6 lines). Most of these branches are transformers 400/110 kV and 220/110 kV. Due to the fact that 110 kV grid is not analyzed in GIS, loading of these branches is not of interest here.

It can be noticed that interconnection lines are not jeopardized since they are loaded far below their thermal ratings. General direction of power flow remains from north to south (2000 MW towards Greece and Turkey) although there is a high import of 1990 MW from IPS/UPS to GIS region.

Security (n-1) Analysis

Results of security (n-1) analysis for Base Case with Justified Rehabilitation program- Import from CENTREL and Ukraine scenario are presented in Table 2.4.2 of Annex. Insecure system situations for given generation pattern and power import are detected in the power systems of Albania, Croatia and Romania. Figure 5.24 gives geographical positions of critical elements in the GIS region, which are detected in contingency states of GIS power grid. According to the results from sub-chapters 2.4.1-2.4.8 of Annex, impact to steady state security is summoned and presented in Figure 5.25 for each transmission line candidate.

Problems identified in Albania (and Podgorica in Montenegro) at 400 kV level are consequence of weak voltage support from the rest of their power systems. Loss of many 400 kV and 220 kV elements connected to or inside of power system of Albania can cause a voltage collapse in southern part of Albania. Steady state security of Croatia is reduced with base case loading of OHL 220 kV Mraclin – Zerjavinec of 88.5%. North and west parts of Romania are affected by high inflow of power from CENTREL and Ukraine. Transformer 400/220 kV at S/S 400 kV Rosiori and OHL 220 kV Baia – Rosiori become overloaded for several contingencies.

If candidate OHL 400 kV Kashar – Kosovo B is in operation, it removes voltage problems in contingency states in Albania and Montenegro. Double OHL 400 kV Ernestinovo – Pecs and OHL triangle 400 kV Ernestinovo – Sombor – Pecs have the same effect if each of these candidates is in operation. Critical contingency in Croatia (OHL 220 kV Mraclin – Zerjavinec) is removed, but new critical element is added (OHL 220 kV Podgorica – Vau Dejes). Triangle OHL 400 kV Zerjavinec – Cirkovce – Hevitz and OHL 400 kV Kashar – Kosovo B also remove single critical contingency in Croatia.

Submarine HVDC cables (Durres – Foggia and Konjsko – Candia) add many new critical elements and voltage violations. Two interconnection OHLs 220 kV became overloaded; Podgorica – Vau Dejes (ME - AL) and Prijedor – Mraclin (BA – HR). Voltage violations are mostly situated in S/S 400 kV in western Romania (Oradea, Nadab, Arad, Rosiori), but there are some in Croatia also (S/S 400 kV Konjsko and Obrovac).

The most important annotation is that for certain outages, with HVDC 400 kV Konjsko – Candia in operation, voltage collapse might occur in Albania. Since there were no dynamic stability analyses performed in the present study it is impossible to foresee the course of events in this part of transmission system of GIS region.

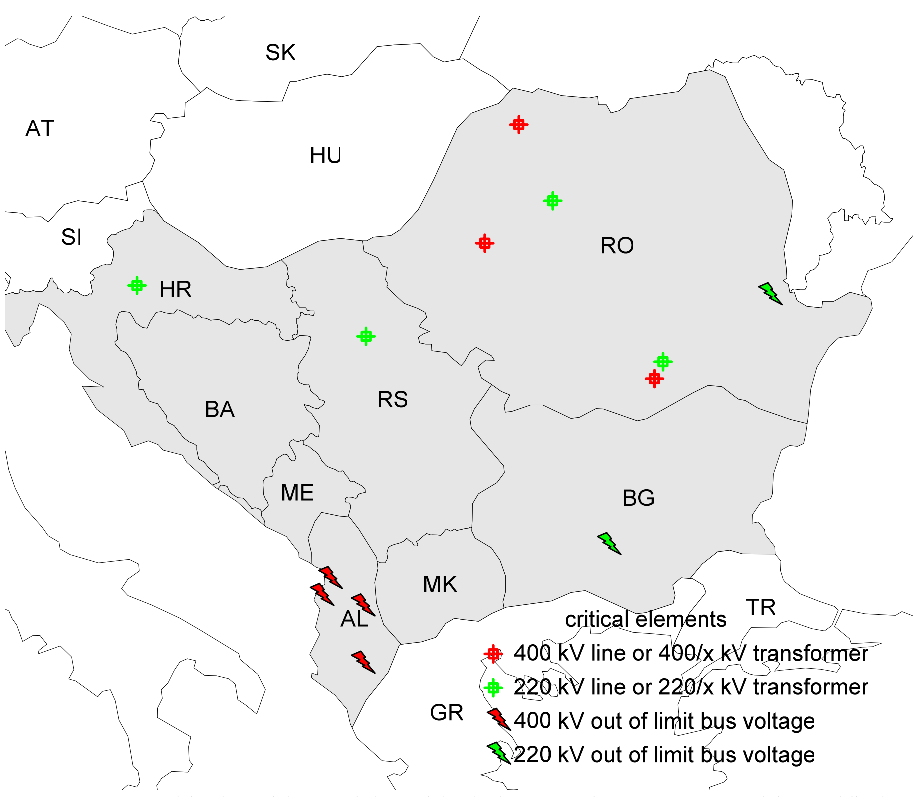

Figure 5.24 Geographical positions of the critical elements for Base Case with Justified Rehabilitation – Import from CENTREL and Ukraine –

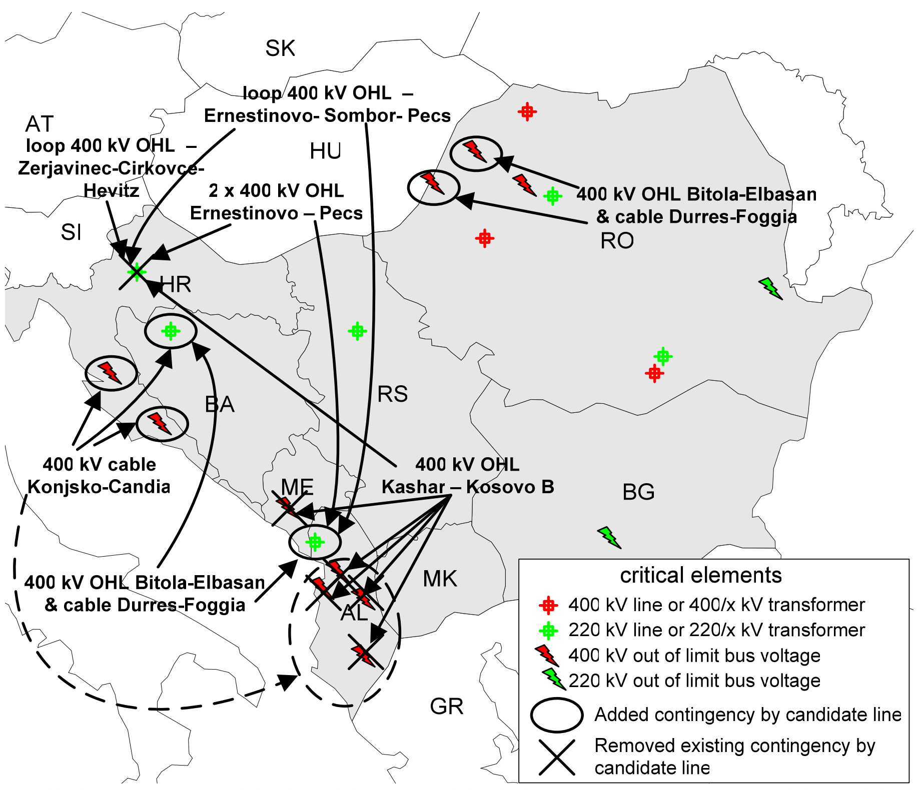

Figure 5.25 Overall view of geographical positions of critical elements for Base Case with Justified Rehabilitation – Import from CENTREL and Ukraine scenario, with influence of each transmission line candidate to security – (X for removal and O for addition of contingency)

5.4 Scenario 3 – Hydro Power Plants and High Fuel Price

This part of the present study describes results of static load flow and voltage profile analyses which are conducted for complete network topology and (n-1) contingencies in the scenario denoted as Scenario 8 – Hydro power plants and high fuel price. Three levels of regional power balance are observed, depending on the hydrological conditions (dry and wet hydrology):

- power import in the GIS countries (during dry hydrological conditions);
- zero balance of the GIS countries (during wet hydrological conditions); and
- power export from GIS countries (during wet hydrological conditions).

Concerning the import/export case, the simulated regime means the following:

- Zero Balance – Wet Hydrology;
- Export to Italy – Wet Hydrology;
- Export to Western UCTE (Germany, Austria) – Wet Hydrology; and
- Import from CENTREL, Ukraine – Dry Hydrology.

5.4.1 Zero Balance – Wet Hydrology

Load Flow Analysis

Power exchanges over the borders for 2015, Hydro power plants and high fuel price - Zero Balance scenario are shown in Figure 5.26.

Power flows along regional interconnection lines and system balances, as well as tie line loadings, branch loadings, transformer loadings and bus voltages are shown in Figures 3.1.1 – 3.1.5 of Annex (Chapter 3). According to these results it can be seen that the tie lines in the region are mostly loaded less than 60% of their thermal limits in the analyzed scenario for 2015. Among total number of 47 400 kV and 220 kV interconnection lines in the region none of them is loaded more than 60%, and 20 are loaded between 20% and 60% of their thermal ratings.

Table 3.1.1 of Annex (Chapter 3) lists all network elements loaded over 80% of their thermal limits (PSS/E output). As it can be seen from this output list, most of the elements loaded over 80% are transformers.

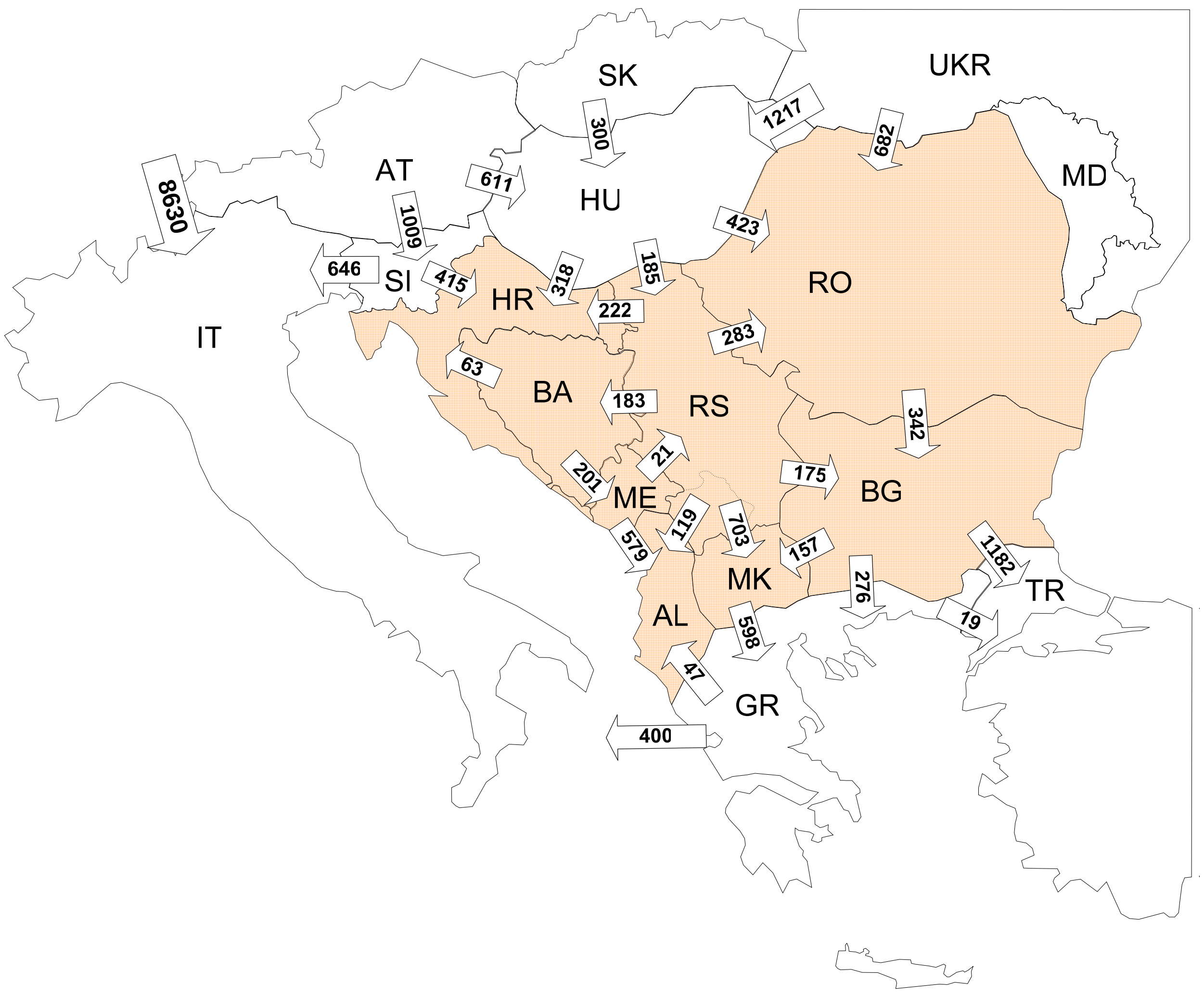

Figure 5.26 Area exchanges for Hydro power plants and high fuel price
– Zero Balance –

The most of observed elements are loaded below 60%. There are 48 branches loaded between 60% and 100% (34 transformers and 4 transmission lines). Most of these transformers are connected to 110 kV grid which is considered to operate as a part of distribution and for that reason they not analyzed here. It can be noticed that interconnection lines are not jeopardized since they are loaded far below their thermal ratings. This is the consequence of small exchanges between the countries in the analyzed region since there is an overall balance between generation and consumption in GIS region. These results represent only a situation when additional devices (transformer automatic tap changers, switchable shunts, etc.) are not used for voltage regulation. Impacts of such devices need more comprehensive and thorough analysis.

Security (n-1) Analysis

Results of security (n-1) analysis for Hydro power plants and high fuel price - Zero Balance scenario are presented in Table 3.1.2 of Annex. Insecure system situations for given generation pattern and power import are detected in the power systems of Albania, Romania, Bulgaria and Serbia. Figure 5.27 gives geographical positions of critical elements in GIS region which are detected in contingency states of GIS power grid. According to the results from sub-chapters 3.1.1-3.1.8 of Annex, impact to steady state security is summoned and presented in Figure 5.28

for each transmission line candidate.

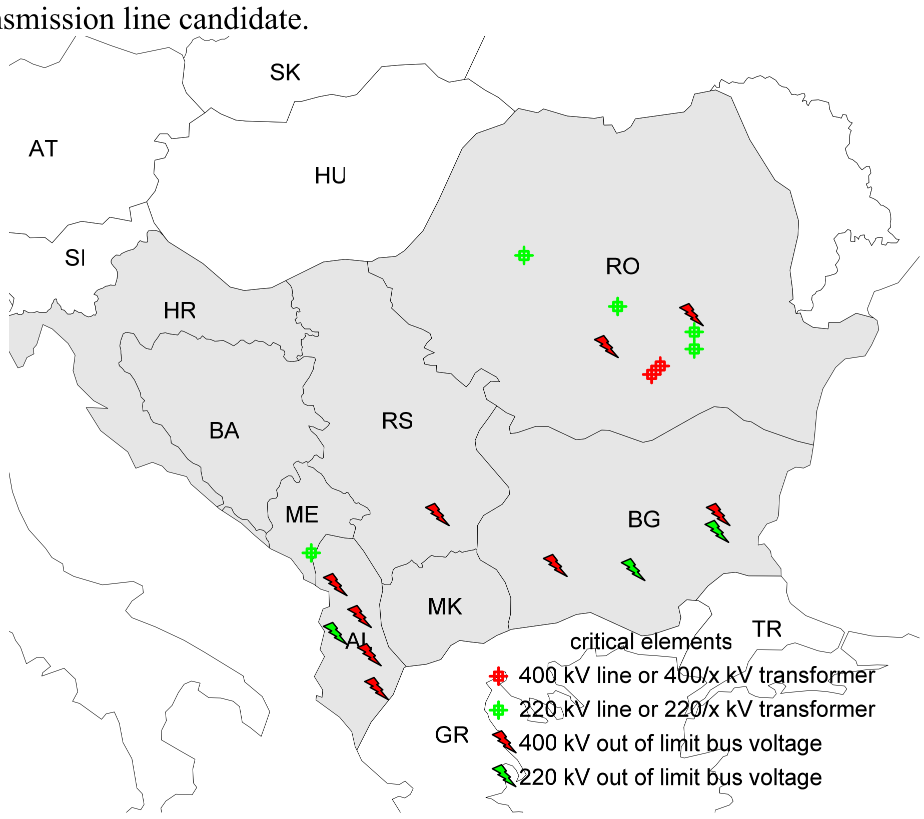

Figure 5.27 Geographical positions of the critical elements for Hydro power plants and high fuel price – Zero Balance –

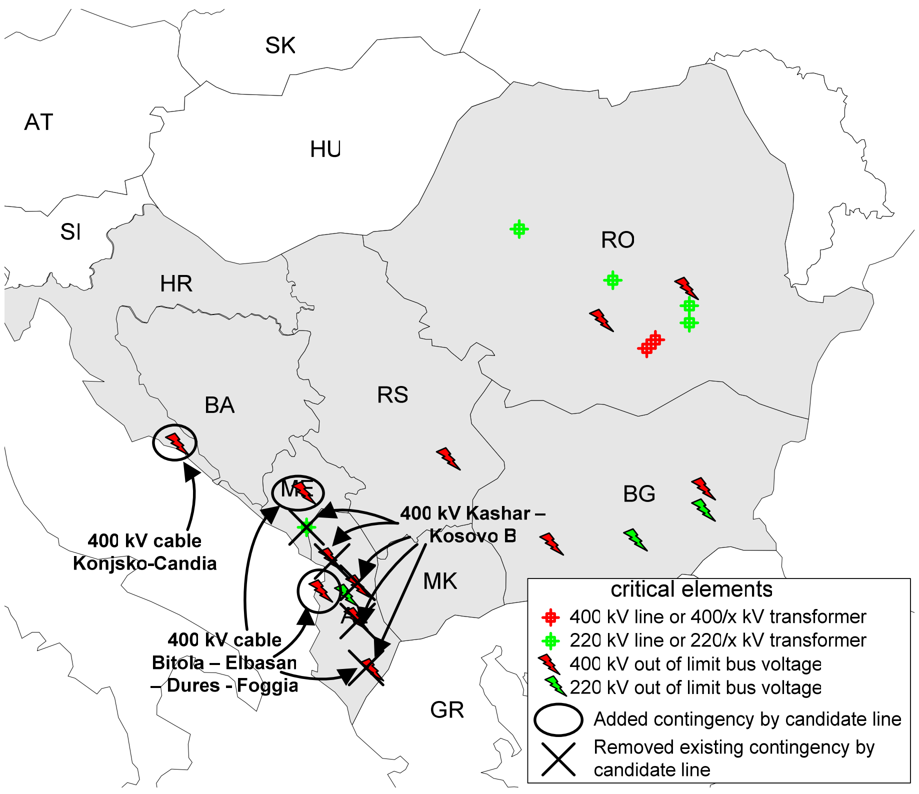

Figure 5.28 Overall view of geographical positions of critical elements for Hydro power plants and high fuel price – Zero Balance scenario, with influence of each transmission line candidate to power system security – (X for removal and O for addition of contingency)

It can be seen that in Zero Balance scenario with no significant exchanges between the GIS countries there is not many problems in steady state, neither in contingency states. Because of this reason, influence of transmission line candidates cannot be expressed fully. There are three transmission line candidates which bring contributions and obstructions to the power transfer in this case (Figure 5.28). First one is OHL 400 kV Kashar – Kosovo B which removes voltage problems in 400 kV level in Albania and contingency overload of OHL 220 kV Podgorica – Vau Dejes. Second one (combination of HVDC 400 kV Durres – Foggia + OHL 400 kV Bitola – Elbasan) brings voltage depressions in S/S 400 kV Podgorica 2 (ME) and S/S Rashbull 400 kV (AL). This is a consequence of power transfer toward Italy over a transmission grid with low voltage support at 400 kV level. Third one is HVDC 400 kV Konjsko – Candia which brings voltage depression in S/S 400 kV Konjsko.

5.4.2 Export to UCTE – Wet Hydrology

Load Flow Analysis

Power exchanges over the borders for 2015, Hydro power plants and high fuel price – Export to UCTE scenario are shown in Figure 5.29.

Power flows along regional interconnection lines and system balances, as well as tie line loadings, branch loadings, transformer loadings and bus voltages are shown in Figures 3.2.1 – 3.2.5 of Annex (Chapter 3). According to these results it can be seen that the tie lines in the region are mostly loaded less than 60% of their thermal limits in the analyzed scenario for 2015. Among total number of 47 400 kV and 220 kV interconnection lines in the region 22 are loaded between 20% and 60% of their thermal ratings.

Table 3.2.1 of Annex (Chapter 3) lists all network elements loaded over 80% of their thermal limits (PSS/E output). As it can be seen from this output list, most of the elements loaded over 80% are transformers.

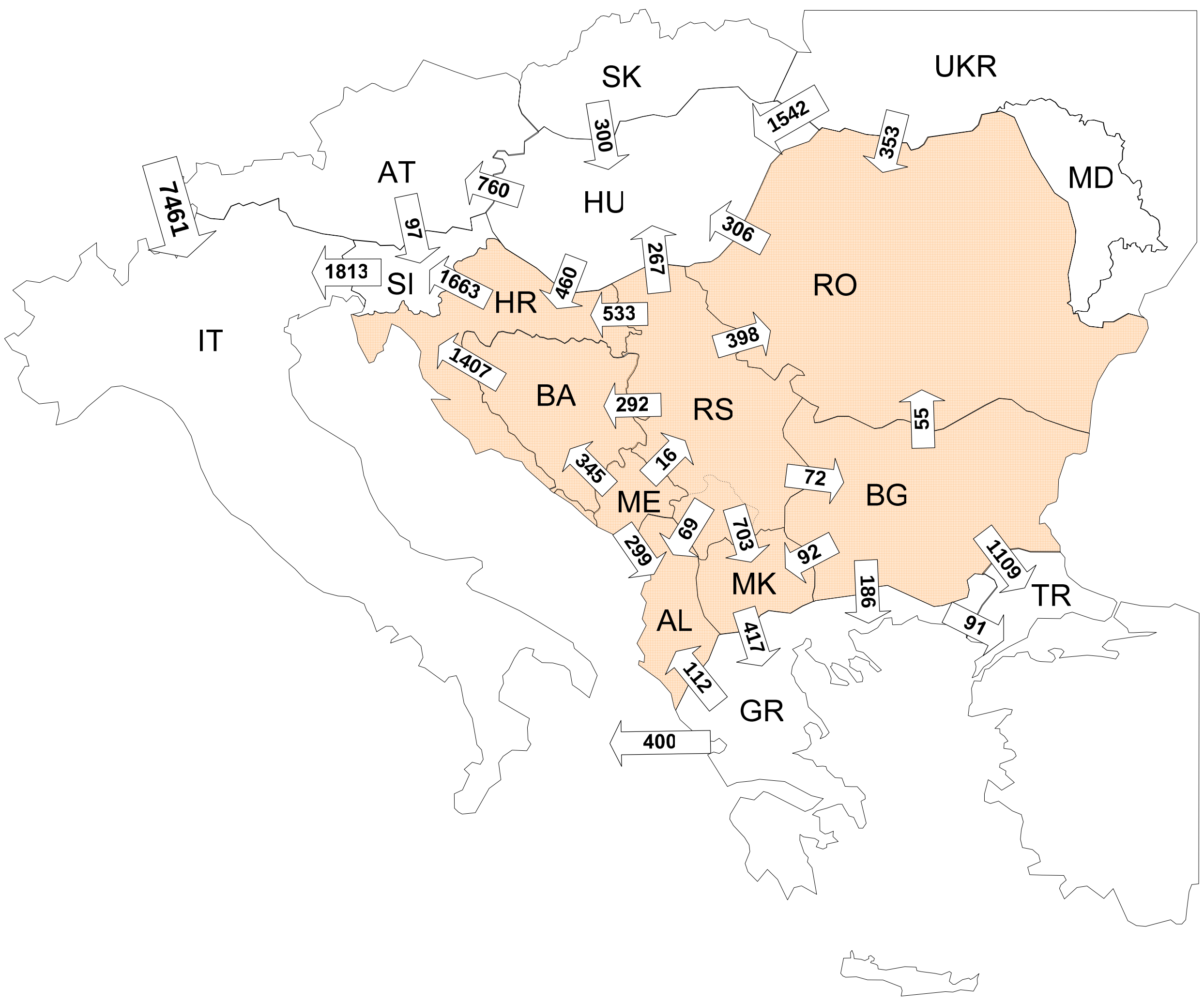

Figure 5.29 Area exchanges for Hydro power plants and high fuel price
– Export to UCTE –

Most of observed elements are loaded below 60%. There are 45 branches loaded between 60% and 100% (36 transformers and 9 transmission lines). Most of these transformers are connected to 110 kV grid which is considered to operate as a part of distribution and for that reason not analyzed here.

It can be noticed that interconnection lines are not jeopardized since they are loaded far below their thermal ratings. This is the consequence of small exchanges between the countries in the analyzed region since there is an overall balance between generation and consumption in the GIS region.

It should be emphasized that these results represent only a situation when additional devices (transformer automatic tap changers, switchable shunts, etc.) are not used for voltage regulation. Impacts of such devices, which exist in many points of the SEE regional transmission network, need more comprehensive and thorough analysis.

Security (n-1) Analysis

Results of security (n-1) analysis for Hydro power plants and high fuel price - Export to UCTE scenario are presented in Table 3.2.2 of Annex. Insecure system situations for given generation pattern and power import are detected in the power systems of Albania, Romania, Bulgaria and Croatia.

Figure 5.30 gives geographical positions of critical elements in the GIS region which are detected in contingency states of GIS power grid. According to the results from sub-chapters 3.2.1-3.2.8 of Annex, impact to steady state security is summoned and presented in Figure 5.31 for each transmission line candidate.

There are several transmission line candidates who bring contributions and obstructions to the power transfer in this case (Figure 5.31).

First one is OHL 400 kV Kashar – Kosovo B which removes voltage problems in 400 kV level in Albania and Romania and it also removes contingency overload of OHL 220 kV Podgorica – Andrijevo. This 220 kV OHL is also removed as critical contingency element in case of operation of candidates OHL 400 kV Marica Istok 1 -Nea Santa, double OHL 400 kV Ernestinovo – Pecs and triangle OHL 400 kV Ernestinovo – Sombor - Pecs, respectively.

Transmission candidate (combination of HVDC 400 kV Durres – Foggia + OHL 400 kV Bitola – Elbasan) brings voltage depressions in S/S 400 kV in Albania, but it removes contingency overloads of OHL 220 kV Imotski – Zakucac and OHL 220 kV Divaca - Pehlin.

Submarine cable HVDC 400 kV Konjsko – Candia also brings voltage depression in S/S 400 kV Konjsko and Obrovac with addition of contingency overload of OHL 220 kV Konjsko – Brinje.

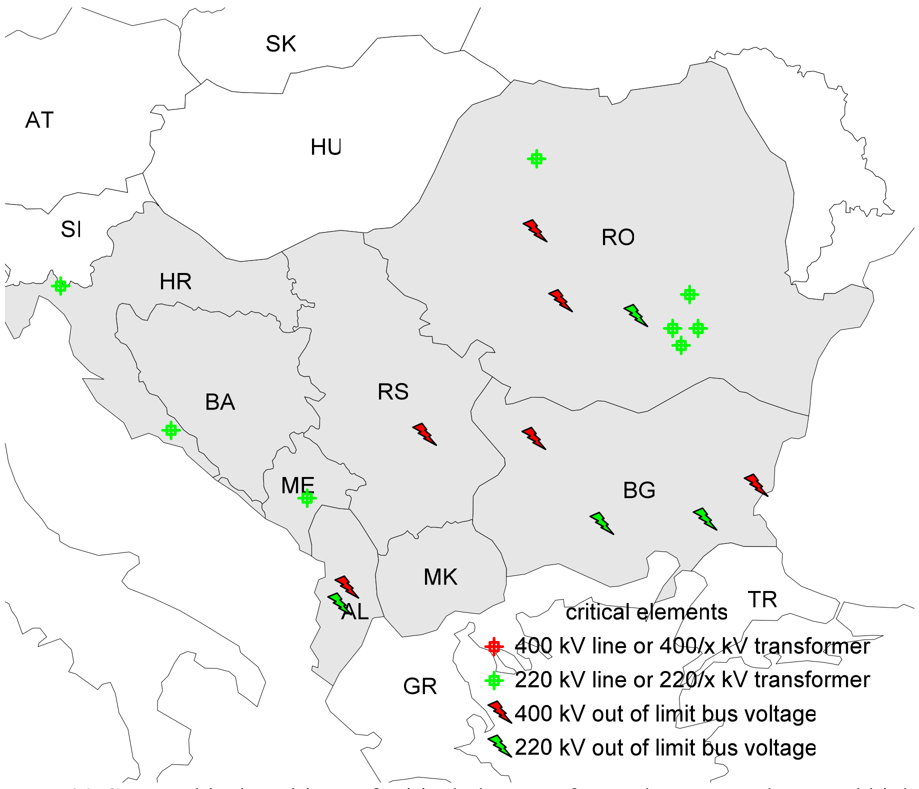

Figure 5.30 Geographical positions of critical elements for Hydro power plants and high fuel price
– Export to UCTE Base Case –

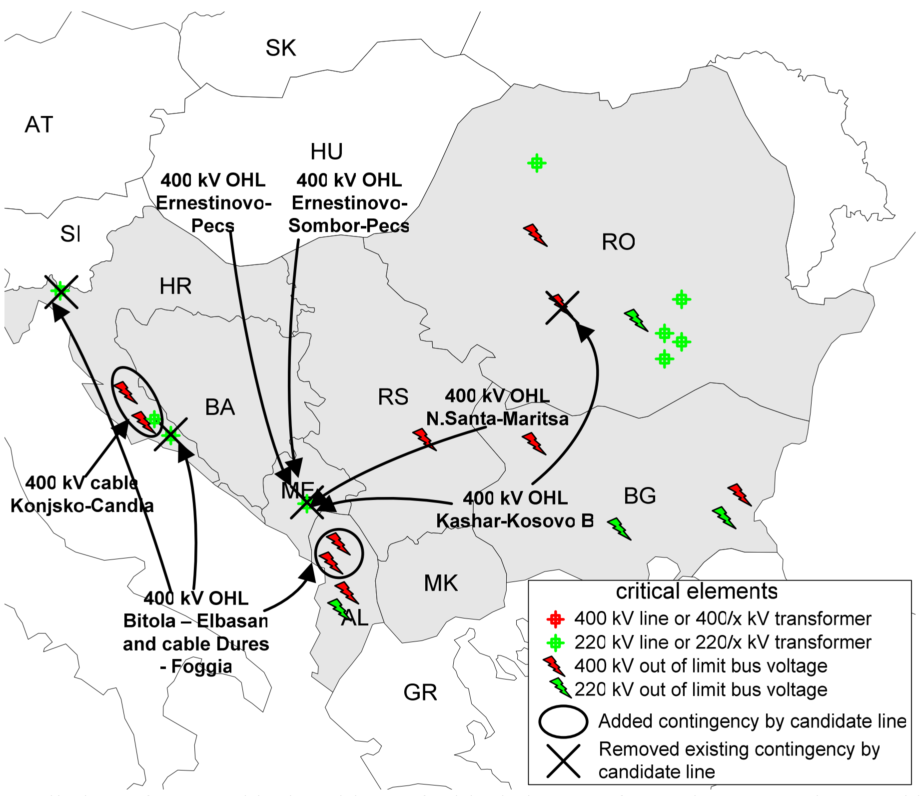

Figure 5.31 Overall view of geographical positions of critical elements for Hydro power plants and high fuel price
– Zero Balance scenario, with influence of each transmission line candidate to power system security –
(X for removal and O for addition of contingency)

5.4.3 Export to Italy – Wet Hydrology

Load Flow Analysis

Power exchanges Hydro power plants and high fuel price - Export to Italy scenario for 2015 are shown in Figure 5.32.

Power flows along regional interconnection lines and system balances, as well as tie line loadings, branch loadings, transformer loadings and bus voltages are shown in Figures 3.3.1 – 3.3.5 of Annex (Chapter 3). According to these results it can be seen that the tie lines in the region are mostly loaded less than 60% of their thermal limits in the analyzed scenario for 2015. Among total number of 47 400 kV and 220 kV interconnection lines in the region 22 are loaded between 20% and 60% of their thermal ratings. Table 3.3.1 of Annex lists all network elements loaded over 80% of their thermal limits (PSS/E output). As it can be seen from this output list, most of the elements loaded over 80% are transformers.

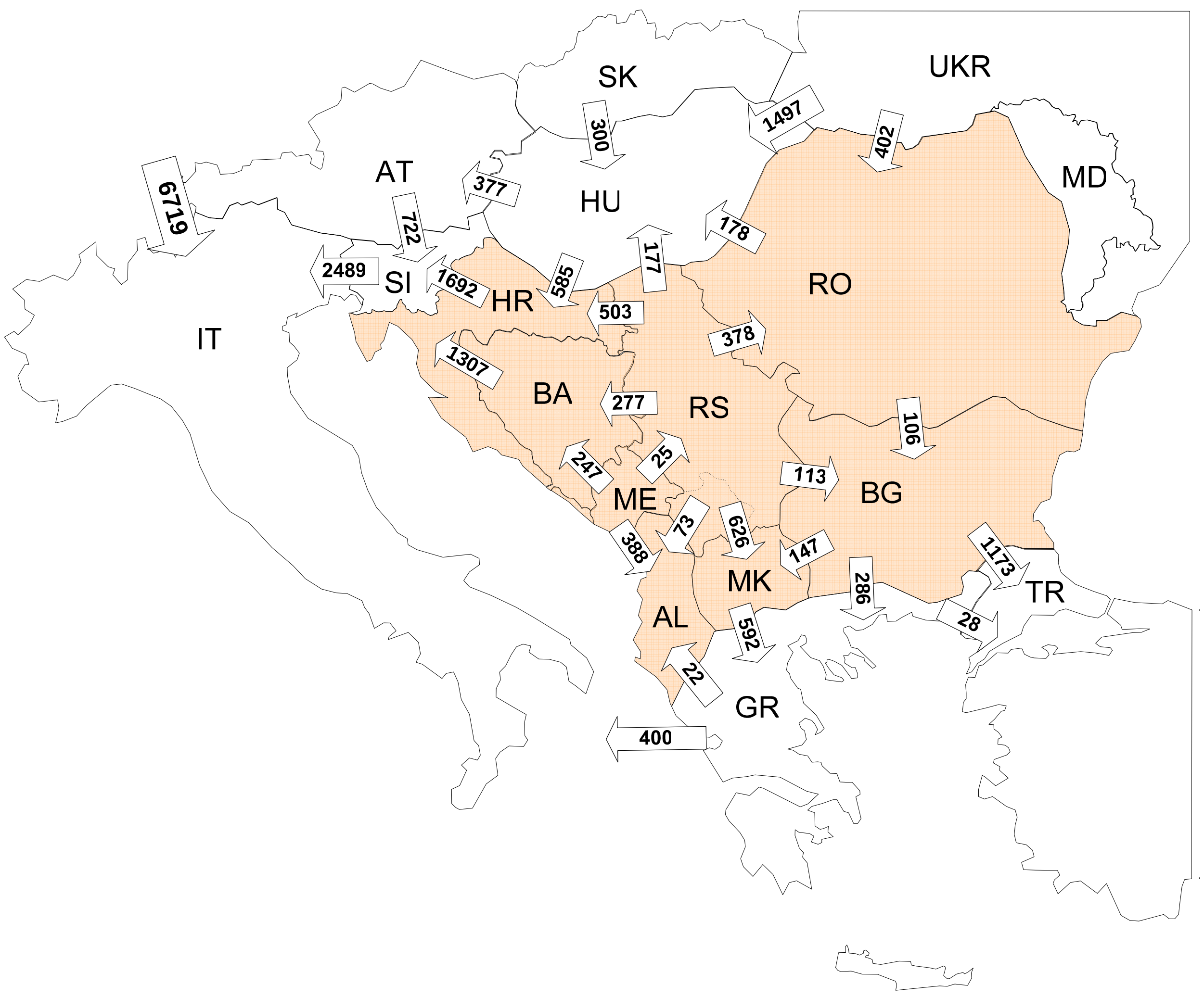

Figure 5.32 Area exchanges for Hydro power plants and high fuel price
– Export to Italy –

Most of observed elements are loaded below 60%. There are 45 branches loaded between 60% and 100% (36 transformers and 9 transmission lines). Most of these transformers are connected to 110 kV grid which is considered to operate as a part of distribution and for that reason not analyzed here.

It can be noticed that interconnection lines are not jeopardized since they are loaded far below their thermal ratings. This is the consequence of small exchanges between the countries in the analyzed region since there is an overall balance between generation and consumption in the GIS region.

It should be emphasized that these results represent only a situation when additional devices (transformer automatic tap changers, switchable shunts, etc.) are not used for voltage regulation. Impacts of such devices, which exist in many points of the SEE regional transmission network, need more comprehensive and thorough analysis.

Security (n-1) Analysis

Results of security (n-1) analysis for Hydro power plants and high fuel price – Export to Italy scenario are presented in Table 3.3.2 of Annex. Insecure system situations for given generation pattern and power import are detected in the power systems of Albania, Romania, Bulgaria and Croatia.

Figure 5.33 gives geographical positions of critical elements in the GIS region which are detected in contingency states of GIS power grid. According to the results from sub-chapters 3.3.1-3.3.8 of Annex, impact to steady state security is summoned and presented in Figure 5.34 for each transmission line candidate.

There are several transmission line candidates who bring contributions and obstructions to the power transfer in this case (Figure 5.34).

The first one is OHL 400 kV Kashar – Kosovo B which removes voltage problems at 400 kV level in Albania and it also removes contingency overload of OHL 220 kV Podgorica – Andrijevo. Triangle OHL 400 kV Zerjavinec – Cirkovce – Hevitz, if in operation, removes contingency overloads of OHL 220 kV Meline – Pehlin and OHL 220 kV Podgorica – Andrijevo.

Transmission candidate (combination of HVDC 400 kV Durres – Foggia + OHL 400 kV Bitola – Elbasan) brings voltage depressions in S/S 400 kV in Albania, but it removes contingency overloads of OHL 220 kV Imotski – Zakucac.

Submarine cable HVDC 400 kV Konjsko – Candia also removes voltage depression in S/S 400 kV Meline and it removes contingency overload of OHL 220 kV Divaca – Pehlin.

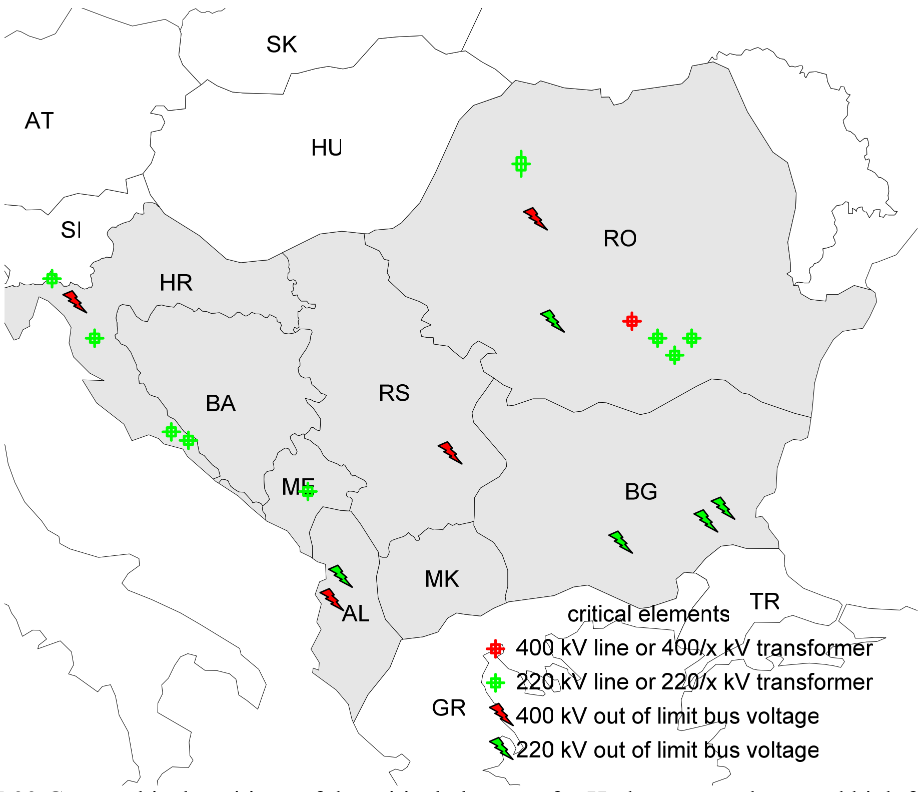

Figure 5.33 Geographical positions of the critical elements for Hydro power plants and high fuel price
– Export to Italy –

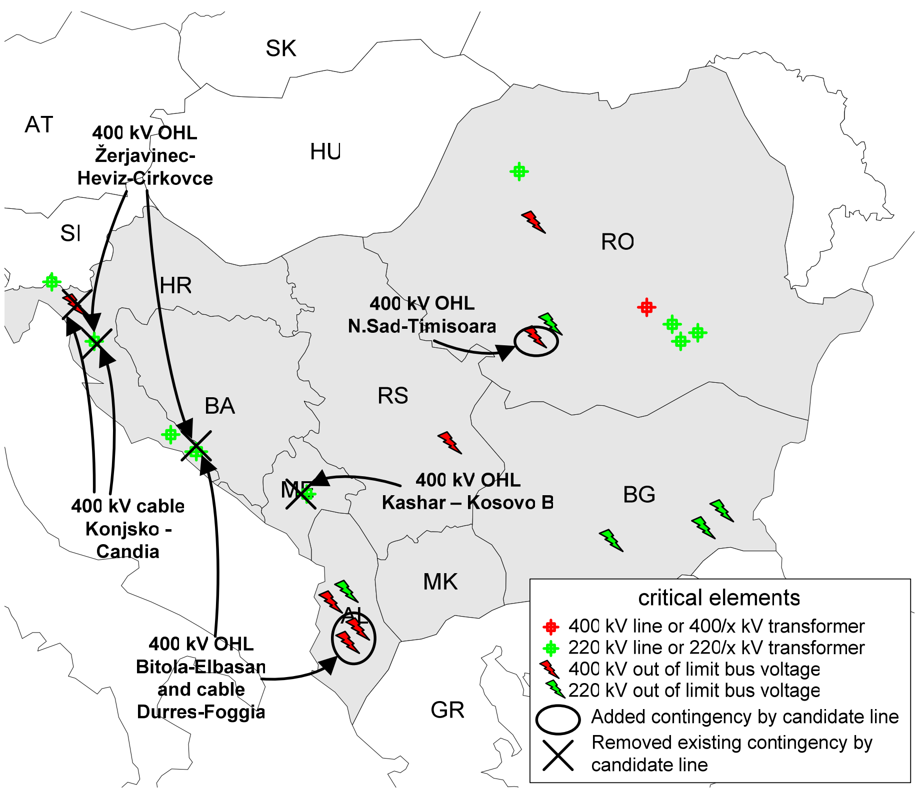

Figure 5.34 Overall view of geographical positions of critical elements for Hydro power plants and high fuel price
– Export to Italy scenario, with influence of each transmission line candidate to power system security –
(X for removal and O for addition of contingency)

5.4.4 Import from CENTREL and Ukraine – Dry Hydrology

Load Flow Analysis

Power exchanges for Hydro power plants and high fuel price - Import from CENTREL and Ukraine scenario for 2015 are shown in Figure 5.35.

Power flows along regional interconnection lines and system balances, as well as tie line loadings, branch loadings, transformer loadings and bus voltages are shown in Figures 3.4.1 – 3.4.5 of Annex (Chapter 3). According to these results it can be seen that the tie lines in the region are mostly loaded less than 60% of their thermal limits in the analyzed scenario for 2015. Among total number of 37 400 kV and 220 kV interconnection lines in the region 22 are loaded between 20% and 60% of their thermal ratings. Table 3.4.1 of Annex lists all network elements loaded over 80% of their thermal limits (PSS/E output). As it can be seen from this output list, most of the elements loaded over 80% are transformers.

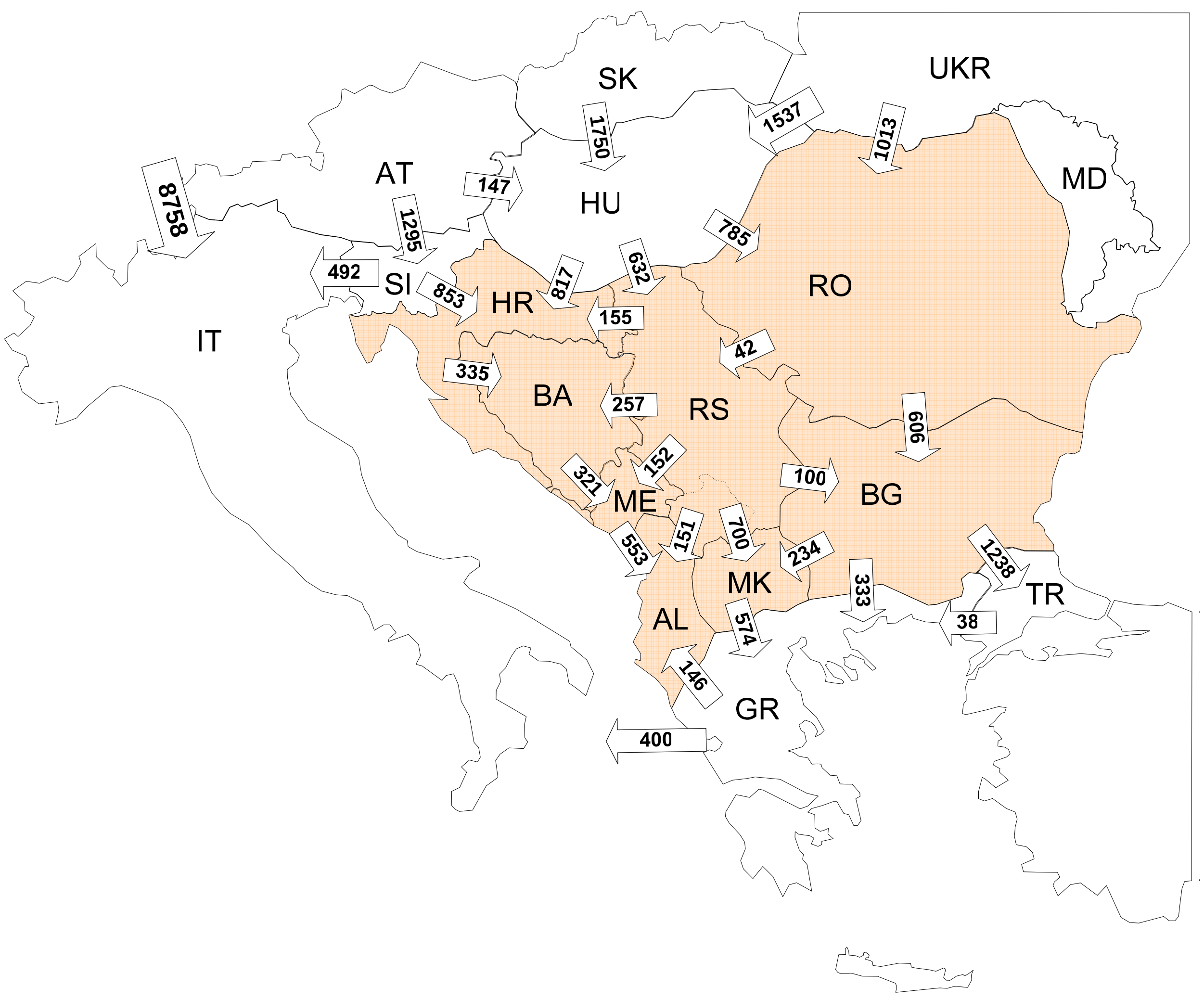

Figure 5.35 Area exchanges for Hydro power plants and high fuel price
– Import from CENTREL and Ukraine –

Most of observed elements are loaded below 60%. There are 45 branches loaded between 60% and 100% (36 transformers and 9 transmission lines). Most of these transformers are connected to 110 kV grid which is considered to operate as a part of distribution and for that reason not analyzed here.

It can be noticed that interconnection lines are not jeopardized since they are loaded far below their thermal ratings. This is the consequence of small exchanges between the countries in the analyzed region since there is an overall balance between generation and consumption in the GIS region.

It should be emphasized that these results represent only a situation when additional devices (transformer automatic tap changers, switchable shunts, etc.) are not used for voltage regulation. Impacts of such devices, which exist in many points of the SEE regional transmission network, need more comprehensive and thorough analysis.

Security (n-1) Analysis

Results of security (n-1) analysis for Hydro power plants and high fuel price - Import from CENTREL and Ukraine scenario are presented in Table 3.4.2 of Annex. Insecure system situations for given generation pattern and power import are detected in the power systems of Albania, Croatia and Romania. Figure 5.36 gives geographical positions of critical elements in GIS region, which are detected in contingency states of GIS power grid. According to the results from sub-chapters 3.4.1-3.4.8 of Annex, impact to steady state security is summoned and presented in Figure 5.37 for each transmission line candidate.

Problems identified in Albania (and Podgorica in Montenegro) at 400 kV level are consequence of weak voltage support of the rest of their power systems. Loss of many 400 kV and 220 kV elements connected to or inside of power system of Albania can cause a voltage collapse in southern part of Albania. Steady state security of Croatia is reduced with base case loading of OHL 220 kV Mraclin – Zerjavinec of 85%. North and west parts of Romania are affected by high inflow of power from CENTREL and Ukraine. Transformer 400/220 kV at S/S 400 kV Rosiori and OHL 220 kV Baia – Rosiori become overloaded for several contingencies.

If transmission candidate OHL 400 kV Kashar – Kosovo B is in operation, it removes voltage problems in contingency states in Albania and contingency overload of OHL 220 kV Podgorica – Vau Dejes. Double OHL 400 kV Ernestinovo – Pecs and OHL triangle 400 kV Ernestinovo – Sombor – Pecs remove voltage violations and mentioned contingency overloads in Romania (transformers and lines connected to Rosiori). Voltage violations in Bulgaria are removed with operation of OHL 400 kV Marica Istok – Nea Santa.

Critical contingency in Croatia (OHL 220 kV Mraclin – Zerjavinec) is added, by operation of submarine cables (Durres – Foggia and Konjsko – Candia) along with voltage violations which are mostly situated in S/S 400 kV in western and central Romania (Oradea, Nadab, Arad, Rosiori, Bucuresti), but there are also some in Croatia (S/S 220 kV Konjsko, Imotski and Zakucac). The most important annotation is that for certain outages, with HVDC 400 kV Konjsko – Candia in operation, voltage collapse occurs in Albania. Since there were no dynamic stability analyses performed in the present study it is impossible to foresee the course of events in this part of transmission system of GIS region.

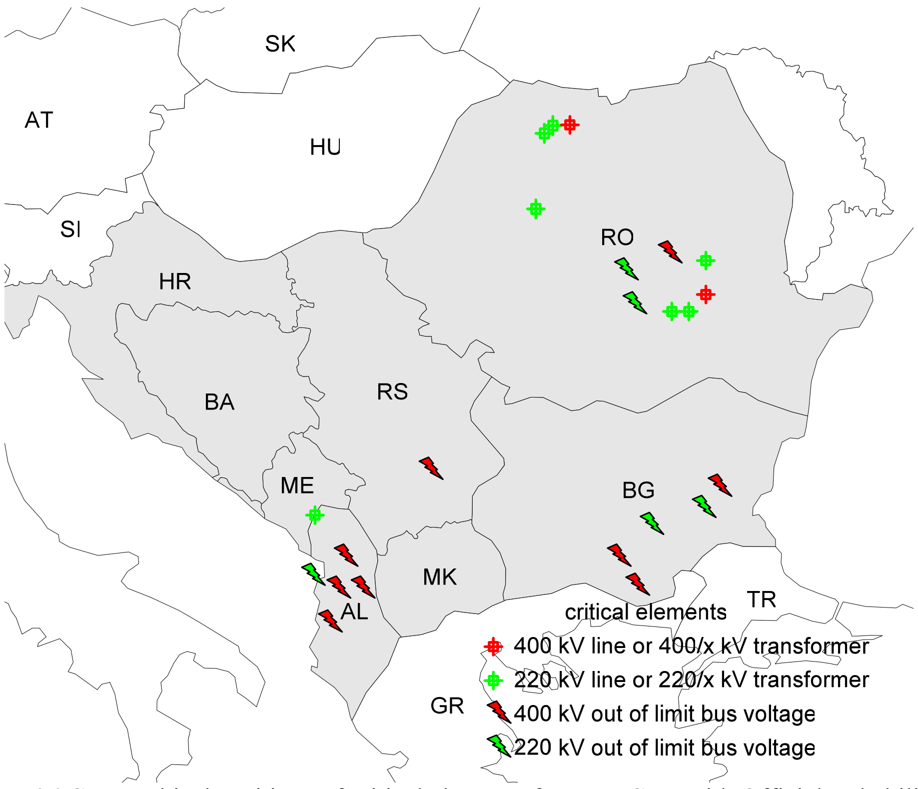

Figure 5.36 Geographical positions of critical elements for Base Case with Official Rehabilitation
– Import from CENTREL and Ukraine Base Case –

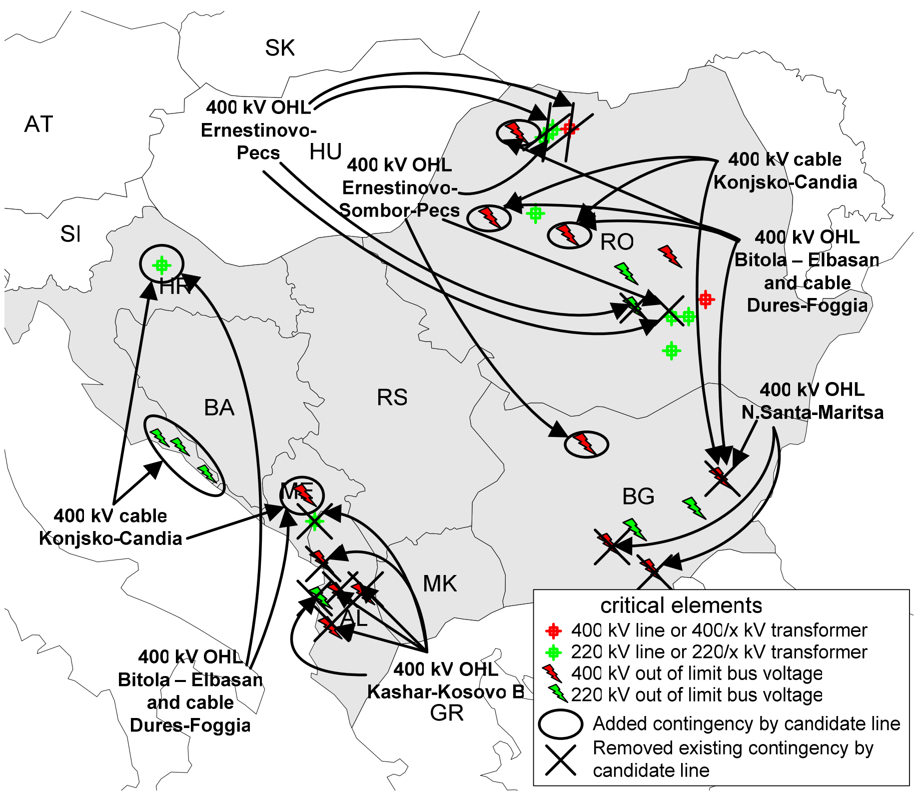

Figure 5.37 Overall view of geographical positions of critical elements, for Hydro power plants and high fuel price
– Import from CENTREL and Ukraine Base Case, with influence of each transmission line candidate to security –
(X for removal and O for addition of contingency)

6. PRIORITIZATION

Process of load flow and contingency analyses is followed by processing calculated results in order to determine which transmission line candidate has the most positive influence on regional transmission grid of the GIS countries. This process is regarded in this Chapter as prioritization. According to the methodology from *Transmission Network Investment Criteria*, statistical approach shall be applied to examine all results from load flow and contingency analyses. Statistical approach is based on counting influences in terms of:

- Number of added or removed overloads in base case (loaded over 100%);
- Number of added or removed contingency critical elements;
- Number of added or removed contingency voltage violations; and
- Number of relieved or loaded elements for more than 2% of MVA rate (additional set of data).

It must be pointed out that in all cases (with and without candidates) there are no loadings of transmission elements higher than 100%, so there are no added or removed bottlenecks to be numbered. This is the reason why a more relaxed approach was applied by observing the list of critically loaded elements which are actually loaded more than 60% (Annex).

A number of influences appeared in each load flow case (12 cases in total); these being assembled in Table 6.1. In order to prioritize transmission line candidates, it is necessary to simplify the sorting out of 8 sets of data (from Table 6.1).

Table 6.1 Total numbers of positive and negative influences of transmission candidates

		Load Flow (n)				Contingency analysis (n-1)			
		Total (in/out)		Total (delta>2%)		Total (n-1) overload		Total (n-1) voltages	
No.	Candidates	removed	added	relieved	loaded	removed	added	removed	added
1	Kashar-Kosovo B	2	1	4	1	5	0	28	0
2	Maritsa Istok-Nea Santa	0	0	0	0	1	0	4	0
3	Ernestinovo-Pecs	3	1	16	0	9	2	1	0
4	Zerjavinec-Cirkovce-Hevitz	1	0	10	0	3	0	0	0
5	Novi Sad-Timisoara	0	0	3	0	1	0	1	0
6	Bitola-Elbasan&Durres-Foggia	7	15	27	29	3	7	1	29
7	Konjsko-Candia	7	22	11	36	4	6	3	22
8	Ernestinovo-Sombor-Pecs	3	1	15	0	8	2	1	1

The easiest way to quantify the effectiveness of presence of transmission line candidate in some base case is to subtract the number of "obstructions" from the number of "contributions" and the result could be proclaimed to be a *benefit coefficient*. If this coefficient is higher, it means that some particular transmission line (with this coefficient) is bringing benefit to power system with its operation (with more removed overloading or voltage violations). In case when the coefficient is less than zero, this particular candidate brings more unwanted effects to some power system.

Prioritization of transmission line candidates is conducted by sorting out the benefit coefficients corresponding to each transmission line. According to the methodology of transmission investment criteria (Chapter 3), removal of bottlenecks from base case has the most important influence on prioritization. Then, contingency events have come as the second criterion for sorting out (overloading and voltage violations). At the last place, as the least important criterion, there is the change of current flow for more than 2% of MVA rate. This criterion is added to the standard methodology in order to make the sorting out more correct. If these criterions are applied in this order to the calculated benefit coefficients, the priority list of candidates is obtained and given in Table 6.2. It is obvious that there are all zeros in the first column because of application of the strict methodology for prioritization. Since by the first criterion all candidates are of the same importance, the sorting out was completed through the next three criterions.

Table 6.2 List of transmission candidates after ranking according to the original *Transmission Network Investment Criteria* methodology

	Candidates	in/out	n-1 over	n-1 volt	delta>2%
1	Ernestinovo-Pecs	0	7	1	16
2	Ernestinovo-Sombor-Pecs	0	6	0	15
3	Kashar-Kosovo B	0	5	28	3
4	Zerjavinec-Cirkovce-Hevitz	0	3	0	10
5	Maritsa Istok-Nea Santa	0	1	4	0
6	Novi Sad-Timisoara	0	1	1	3
7	Konjsko-Candia	0	-2	-19	-25
8	Bitola-Elbasan&Durres-Foggia	0	-4	-28	-2

For the purpose of checking the result of prioritization, more relaxed approach was used by counting the number of addition or removal of elements which are loaded more than 60%. With the usage of this criterion as the first one in front of contingency analysis criterions, the prioritization produces the candidate list given in Table 6.3. It can be seen from Table 6.3 that the list of candidates differs only at the last two places which are replaced (HVDC cables), but since both of these candidates have negative benefit coefficients, this difference does not affect the position of candidates in the first three places.

Table 6.3 List of transmission candidates after ranking according to the modified (relaxed) *Transmission Network Investment Criteria* methodology

	Candidates	in/out	n-1 over	n-1 volt	delta>2%
1	Ernestinovo-Pecs	2	7	1	16
2	Ernestinovo-Sombor-Pecs	2	6	0	15
3	Kashar-Kosovo B	1	5	28	3
4	Zerjavinec-Cirkovce-Hevitz	1	3	0	10
5	Maritsa Istok-Nea Santa	0	1	4	0
6	Novi Sad-Timisoara	0	1	1	3
7	Bitola-Elbasan&Durres-Foggia	-8	-4	-28	-2
8	Konjsko-Candia	-15	-2	-19	-25

Some transmission candidates have extreme benefits to contingency voltages, for instance such as OHL 400 kV Kashar - Kosovo B. Some other candidates have extremely bad influence which is presented by large negative coefficient. Just by looking at the benefit coefficients, it could be concluded if an element has a good or bad influence on power transfer at the regional level, but in order to really identify how a transmission line candidate affects electrical quantities in the power system, each load flow and contingency result must be analyzed thoroughly.

After performing all load flow and contingency analyses, and after using the methodology (Chapter 3) for prioritization from *Transmission Network Investment Criteria*, the list of priorities for new transmission lines in the GIS region emerges in this order (Figure 6.1):

1. OHL 400 kV Ernestinovo (HR) – Pecs (HU) (double line)

2. OHL 400 kV Ernestinovo (HR) – Sombor (RS) – Pecs (HU) (triangle)

3. OHL 400 kV Kashar (AL) – Kosovo B (RS-UNMIK)

4. OHL 400 kV Zerjavinec (HR) – Cirkovce (SI) – Hevitz (HU) (triangle)

5. OHL 400 kV Marica Istok I (BG) – Nea Santa (GR)

6. OHL 400 kV Novi Sad (RS) – Timisoara (RO)

7. HVDC 400 kV Konjsko (HR) – Candia (IT)

8. HVDC 400 kV Durres (AL) – Foggia (IT) + OHL 400 kV Bitola (MK) – Elbasan (AL)

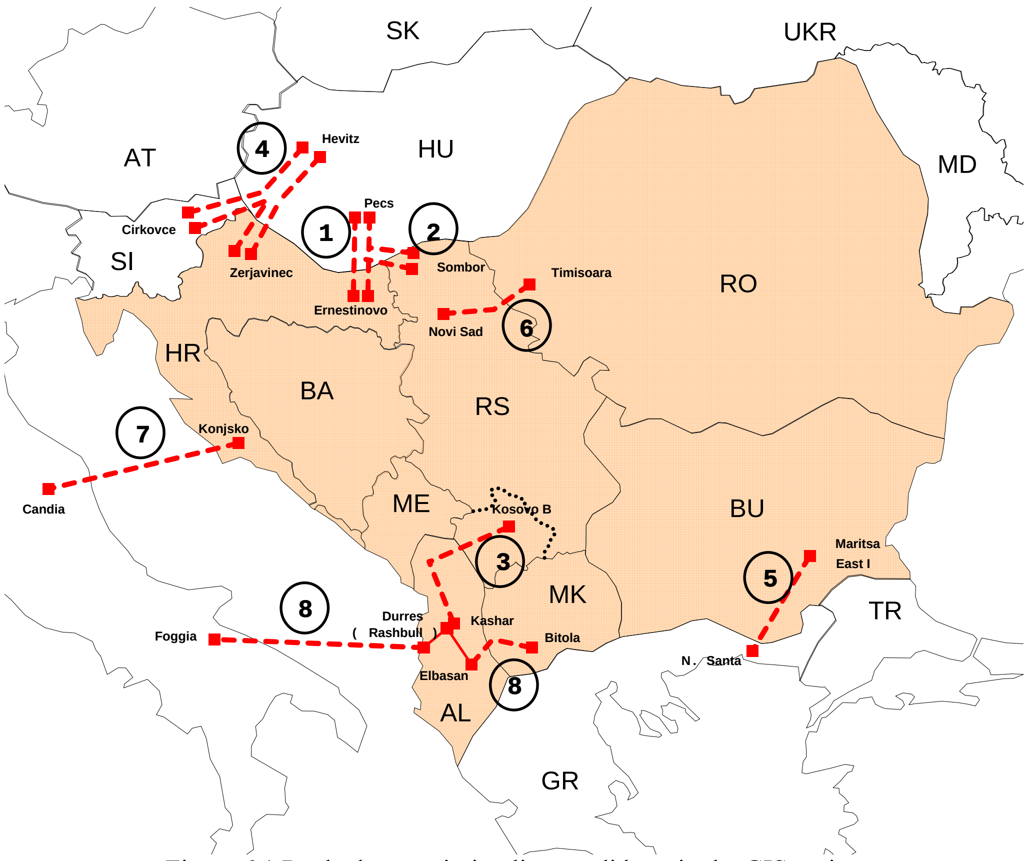

Figure 6.1 Ranked transmission line candidates in the GIS region

Double OHL Ernestinovo – Pecs yields the best effects in the SEE transmission grid, while HVDC 400 kV Durres – Foggia + OHL 400 kV Bitola – Elbasan has the lowest beneficial effects. From the Tables 6.2 and 6.3 it is obvious that there is very small, but distinctive difference in benefits of double OHL 400 kV Ernestinovo – Pecs and OHL 400 kV triangle Ernestinovo – Sombor – Pecs.

7. CONCLUSIONS

Since the completion of the original GIS study in 2004, many changes in transmission system planning and generation investment occurred in the SEE region. These changes were reflected in terms of new transmission line candidates which were supposed to contribute to sustaining new generation patterns, planned for 2015. New planned generation in the region of the GIS countries was defined in the update of GIS study. This update of generation pattern required the update of transmission development plans as well. Further transmission development was emphasized through analysis of influence of several new transmission line candidates on regional power system of the GIS countries and UNMIK (Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Macedonia, Montenegro, Romania, Serbia and UNMIK).

Eight transmission line candidates were identified and their influence on load flows in the GIS region was analyzed in scenario of maximum load in winter 2015. Load flow and contingency analyses produced results which were used to qualify the influence of each candidate through a number of benefits or violations in the SEE regional power system. According to the methodology defined in *Transmission Network Investment Criteria* these numbers were analyzed in statistical manner and than sorted out in order to select the transmission line with the highest priority for upgrading the existing regional transmission grid. The final outcome of the prioritization was the list of ranked transmission lines as follows:

1. OHL 400 kV Ernestinovo (HR) – Pecs (HU) (double line)
2. OHL 400 kV Ernestinovo (HR) – Sombor (RS) – Pecs (HU) (triangle)
3. OHL 400 kV Kashar (AL) – Kosovo B (RS-UNMIK)
4. OHL 400 kV Zerjavinec (HR) – Cirkovce (SI) – Hevitz (HU) (triangle)
5. OHL 400 kV Marica Istok I (BG) – Nea Santa (GR)
6. OHL 400 kV Novi Sad (RS) – Timisoara (RO)
7. HVDC 400 kV Konjsko (HR) – Candia (IT)
8. HVDC 400 kV Durres (AL) – Foggia (IT) + OHL 400 kV Bitola (MK) – Elbasan (AL)

In order to comment on each of these transmission line candidates and related position in the list of priorities some important facts must be mentioned first. In load flow power balance for the GIS region in 2015, control areas of UCTE and IPS/UPS have an excess of power while systems of Italy, Greece and Turkey were defined as importing ones with high amounts of import. Import of Greece and Turkey was fixed at 2000 MW (1200 MW is import of Turkey, 400 MW is import of Greece and 400 MW is power transit over HVDC Arachtos (GR) – Galatina (IT) to Italy). Such high power import routed all power flow from the GIS toward south of the SEE in all cases (even when the GIS region is exporting power to west of UCTE). High amount of power flows from IPS/UPS (Ukraine) and CENTREL (Slovakia) in all operating regimes due to high power import of Hungary (-1200 MW) and Italy (-9250 MW).

Generally, although there are three pre-defined directions of power flow (from IPS/UPS to GIS, from GIS to western UCTE and from GIS to Italy) the power flow does not follow the pre-defined direction of exchange in any of these cases because of mixture of exporting and importing countries inside the GIS region, as well as because of importing countries to the north and south of the GIS ones.

OHL 400 kV Ernestinovo (HR) – Pecs (HU) (double line) is the first one on the list of priorities. This line brings the highest contribution to the regional power flows in regimes of low water inflow when the GIS region imports power from IPS/UPS and in regimes when the GIS region is balanced. Large amounts of power flow from Hungary toward Turkey and Greece, over Romania, Serbia and Bulgaria, and part of this flow is diverted to the western part of the GIS region. In case of presence of double OHL Ernestinovo – Pecs, the path of power is shortened, and instead of flowing from Hungary over Romania and Serbia, power flows directly from Hungary to Croatia.

OHL 400 kV Ernestinovo (HR) – Sombor (RS) – Pecs (HU) (triangle) is the second one on the list of priorities. This transmission candidate is a possible modification of the first ranked candidate since one of transmission lines is fed into S/S 400 kV Sombor in Serbia. It was mentioned in Chapter 6 of the present study that effects of operation of this triangle are slightly worse than the effects of the double transmission line.

OHL 400 kV Kashar (AL) – Kosovo B (RS-UNMIK) is the third one on the list of priorities. Reason for having this OHL candidate at the third place is found in its extremely beneficial effect to power system of neighboring Albania in all operation or exchange regimes. Conceptually, 400 kV grid of Albania consists of single backbone connection from Montenegro to Greece without any generation connected to this voltage level. In case of any heavy power transfer this line candidate provides needed voltage support and maintains steady state security of this part of the GIS region. It is considered that this line candidate should not be considered as separate transmission line candidate, but in combination with any HVDC candidate which may lead from Albania. Another supporting reason for this conclusion is found in expected new power generation in UNMIK (Kosovo B and C) until 2015.

OHL 400 kV Zerjavinec (HR) – Cirkovce (SI) – Hevitz (HU) (triangle) is the fourth candidate on the list of priorities. Situated in the far north of the GIS region, this transmission line candidate is actually an upgrade of existing double interconnection line OHL 400 kV Zerjavinec – Hevitz (one of lines is fed into S/S 400 kV Cirkovce in Slovenia). Benefits of this candidate loop are not fully expressed in defined scenarios of the present study due to position and direction of exchanges. This triangle, combined with double OHL 400 kV Okroglo (SI) – Udine (IT) might bring high contribution to power transfer from IPS/UPS directly to UCTE and Italy.

OHL 400 kV Marica Istok I (BG) – Nea Santa (GR) is the fifth candidate on the list of priorities. On the contrary to the previous candidate, this one is situated in the far south of the GIS region. In comparison to other candidates, this one does not introduce much difference in the middle of the GIS region due to its position and already defined power flow direction from Bulgaria to Turkey. Since the existing two lines (to Babaeski and Hamitabat in Turkey) already have enough reserve transmission capacity, operation of new candidate from Marica Istok I to Nea Santa only redistributes the power flow by diverting one part over Greece. Much higher contribution of this candidate could be noticed in scenarios with significantly higher power import of Turkey and Greece or export of Turkey to UCTE.

OHL 400 kV Novi Sad (RS) – Timisoara (RO) is the sixth candidate on the list of priorities. Contribution of this candidate is neutral in comparison to other candidates since there are no many gains and losses with operation of this line. This is a consequence of pre-defined power flows from north to south of the GIS region over Serbia and Romania simultaneously, so there are no significant changes in the line flows in presence of this line.

HVDC 400 kV Konjsko (HR) – Candia (IT) is the seventh candidate on the list of priorities. The main purpose of this candidate is 500 MW power transfer toward Italy. Although the amount of power is not critical (natural power of 400 kV transmission line), operation of this candidate brings more problems to the GIS transmission grid due to weak connection point in Konjsko (HR). The main conclusion for this candidate is that connection at Konjsko (HR) must be reinforced (with another 400 kV OHL from some other S/S) or the connection point should be moved to another point of more meshed grid (such as S/S Mostar 4 in Bosnia and Herzegovina).

Combination of HVDC 400 kV Durres (AL) – Foggia (IT) and OHL 400 kV Bitola (MK) – Elbasan (AL) is the eighth candidate on the list of priorities. These two elements present an essential part of the Corridor 8 energy connection from Black Sea to the Ionian Sea. Once again, as in case of previous candidate, 500 MW power transfer toward Italy brings overloads and low voltages in Albania due to undeveloped 400 kV grid in this part of the GIS region. However, these problems are solved effectively with inclusion of OHL 400 kV Kashar – Kosovo B which might provide higher voltage support to 400 kV grid and power transfer from TPP expected in UNMIK.

Overall conclusion of the present study is that the SEE regional transmission grid and the GIS region in particular can sustain generation development and injection of power until 2015. Existing transmission grid with presumed interconnection lines enables a secure power transfer without any overloaded branches or voltage magnitudes lower than the limits defined by Grid Codes of participating TSOs. Presence of new transmission line candidates does not bring many changes in power flow composition, but in a way contributes in certain exchange scenarios.

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