Energy Institute Hrvoje Požar

UNCERTAINTIES IN THE SEE TRANSMISISON NETWORK AND EVALUATION OF RISK FOR FUTURE INFRASTRUCTURE INVESTMENTS

- EXECUTIVE SUMMARY-

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CONTENTS

TERMS OF REFERENCE

1. BACKGROUND

Several facts strongly influence a transmission system planning process in an open market environment:

- Significant uncertainties that appear in an deregulated environment,
- Lack of data needed for planning process,
- Different view on transmission development from influential parties (producers, traders, suppliers, consumers, regulators),
- Disproportion between technical, economical, environmental and social requests.

Although transmission planners were faced to different uncertainties before introduction of market conditions in power system, existing and new uncertainties make transmission planning even more difficult. Locations and capacities of new power plants, their biding behaviour, existence of the present ones in the future, consumer's reaction on instantaneous electricity price (price elasticity), electricity and power trading, regulatory aspects etc., are hard to be predicted even for the purpose of short-term planning. Network development based on deterministic power flow analyses of several possible system conditions will not give the clear picture of future transmission system operating conditions and transmission system investments will not be satisfactory evaluated especially concerning a risk that is caused due to some uncertainties. Incorporation of multi-scenario analyses in a transmission system planning process, defining as much as possible scenarios that will comprise different uncertainties, is necessary in order to have a better view on transmission system development and investments. Possible scenarios concerning power plants construction and dispatch, load growth, market transactions, etc. have to be carefully defined and coordinated between different parties like transmission grid owners, system operators, market operators and regulators. An example how different uncertainties influence a transmission system planning and cause additional risk for the new investments is given in Appendix 2 of the study of *Transmission Network Investment Criteria* [3].

The existence of different market players (producers, traders, suppliers), eventually separated ownership and control responsibilities on transmission assets (TSO vs. ISO model) and separated companies (production, transmission, distribution, supply) caused the lack of data needed for a adequate transmission network planning. Confidentiality of some data and the lack of willingness to share them between different parties additionally stress the problem of planning.

Each market player has different view on transmission adequacy and reliability today. Producer wants to give energy to a network without any limitations and he is not interested in what happens after his unit transformers or power plant busbars trip, trader wants to buy wherever he finds energy and to sell it to someone without any restrictions, supplier wants to buy energy as cheaper as possible, system operator has to allow all this keeping the appropriate level of network security and Regulator has to define that level and to prepare an infrastructure for market transactions in order to reduce or eliminate market power. Achieving an optimal solution for everybody is impossible, so Regulator's obligation is to define unique target function that has to be met during transmission network planning.

Transmission network have to satisfy different requests based on technical, economical, environmental and social perceiving. Technical requests are usually hard to meet satisfying economical requests at the same time. Possible technical and economical solutions are restricted by environmental aspects. Social aspects has to be met (consumers have to be supplied) balancing economical considerations in transmission network operation and development. It is clear that optimal solution should represent a combination of socio-economical, technical and environmental requests.

2. UNCERTAINTIES RELEVANT FOR THE SEE TRANSMISSION NETWORK DEVELOPMENT

Significant uncertainties appear in an open market environment that will exist in the SEE. The most important uncertainties for the SEE region with respect to transmission system development have been identified in [3]. They are:

- new power plants size and locations,
- hydrological conditions,
- generators bids,
- load prediction,
- regional power balance,
- branches and generators availability.
- New interconnection lines and internal lines which have an impact on parallel operation

Some of these uncertainties were included in the study for *Evaluation of investments in transmission network to sustain generation and market development in SEE* [2]. Based on three scenarios of power plants construction plan from *updated GIS*, two hydrological scenarios and three regional balance scenarios, overall of 12 scenarios were analyzed to evaluate the investments in the SEE transmission system. Transmission investments were evaluated for two time frames (2010 and 2015).

3. OBJECTIVE

The main objective of this Study is to expand analyses from [2] taking into account the most important uncertainties listed in chapter 1.2 in order to have a better view on the planned transmission investments in the SEE region and to analyze and evaluate the impact of different uncertainties on the planned transmission investments and the SEE transmission system. This analysis may assist the EC, WB, USAID and other donors to identify the risk of transmission system development related to future market activities.

The following transmission system development scenarios will be analyzed related to the most important uncertainties:

<u>Scenarios related to the power plants construction plan</u>
Different scenarios will be defined based on the GIS and updated GIS findings, and TSOs representatives' updated knowledge. For the countries which were not analyzed in GIS study, TSO's knowledge should be used. Analysis will also comprise larger penetration of renewable energy sources in the SEE, especially wind turbines.

Scenarios related to the connection of Italian market with SEE market
Different scenarios will be defined depending on the HVDC link between Italy and SEE region (Croatia, Montenegro, Albania) and its capacity. Transmission system will be analyzed for different energy paths feeding this link.

Scenarios related to the connection of Turkish market with SEE market
Different scenarios will be defined depending on the connection of Turkish market to SEE market. HVDC link between Turkey and Romania (600 MW) should also have been taken into account when building up the scenarios.

Scenarios related to the individual countries power balance
Due to uncertain generation construction plans and market development, individual countries within the SEE region may become net power importers or net power exporters in the future. Several scenarios will be analyzed based on the countries power balance.

Scenarios related to the branches and generators availability
All analyses will be performed assuming full network topology and (n-1) topology.

Scenarios related to the planning time frame
Two time frames will be analyzed (2015 and 2020).

4. 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 the analyses. With a participation of all transmission system operators in South-Eastern Europe, the Project Group will use the verified PSS/E RTSM for winter peak conditions in 2015 and 2020. Analyses on the PSS/E RTSM should provide insight to transmission network adequacy under different uncertainties.

Total number of scenarios that will be analyzed is set to 73 scenarios (excluding the scenarios related to the branches and generators availability).

Special attention on analysis of overloadings and voltage profile in the region should be given with respect to different uncertainties. Possible network congestions and significance of new interconnection and internal lines candidates under different future conditions should be identified. All investments in interconnection and internal lines which have an impact on parallel operation should be analyzed under different scenarios and the impact of uncertainties on each transmission infrastructure investment has to be evaluated and described.

5. DELIVERABLES AND DEADLINES

The study report is to be based upon finalized regional power system model for 2020 that is under preparation. Consequently, the pdf final report is expected to be finalized 4 months upon power system model finalization and contract signing[1].

[1] 1 * Note: power system model was finalized in July 2009, while Study draft was released in September 2009

6. STUDY CONTENTS

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Export Serbia (with UNMIK) →Montenegro+Albania+Macedonia+Greece

4.2 Impact of the Krško NPP 2 construction on SEE transmission system

Scenarios (4):
2015, 2020 (winter peak)
Pq=1080 MW
Export Slovenia→Italy (without HVDC)
Export Slovenia→Albania+Montenegro+Macedonia+Greece+ Serbia+UNMIK

4.3 Impact of the Kozjak PSHPP construction on SEE transmission system

Scenarios (4):
2015, 2020 (winter peak)
Pq=440 MW
Export Slovenia→Italy (without HVDC)
Export Slovenia→Albania+Montenegro+Macedonia+Greece+Serbia+UNMIK

4.4 Impact of possible large penetration of Wind power plants

Scenarios (2):
2015, 2020 (winter peak)
PWPPinst SEE= 4600 MW
SECI Region:

Croatia 1000 MW
BiH 500 MW
Montenegro 100 MW
Bulgaria 1500 MW
*Romania 1000 MW**
Serbia 500 MW
Export SECI Region→Italy (without HVDC)+Turkey+CENTREL
** Note: Models of Romania and Bulgaria already include some WPPs installed in base case models, so additional power installed in WPPs should be analyzed here*

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Export 1000 MW
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1. INTRODUCTION

Transmission system operator (TSO) is responsible for operation, maintenance and development of the high voltage power grid, with two main objectives: to sustain system security and to allow free market transactions. Power sector liberalization and electricity market development assume that the number of market participants and market transactions would increase. At the same time TSO is asked to minimize costs and to justify it in a transparent way.

In this context, transmission system planning process tends to become more difficult, mainly due to the highly uncertain operating conditions. The main sources of uncertainties in transmission system planning are:

- Unpredictable load demand growth,
- Increase of power exchanges with neighbouring systems,
- Operation of the existing generation plants,
- Decommissioning of generation units,
- Location of future power plants,
- Hydrological conditions.

All aforementioned possible sources of uncertainties concerning power plants construction and dispatch, load growth, market transactions, etc. have to be carefully defined and coordinated between different parties like transmission grid owners, system operators, market operators and regulators.

The main objective of this Study is to analyse the most important uncertainties in order to have a better view on the planned transmission investments in the SEE region and to analyze and evaluate the impact of different uncertainties on the planned transmission investments and the SEE transmission system. This study is one of the most detailed studies ever taken in this region on possible impact of different uncertainties on the future planning and operation of transmission network. This analysis may assist the EC, WB, USAID and other donors to identify the most probable bottlenecks and the risk of transmission system development related to future market activities in SEE.

The need for such kind of the study is even clearer after natural gas crises that Europe has been facing last few years. Uncertainty of natural gas supply reduction automatically assumes different power plants engagement and consequently power flow changes that has to be sustained by transmission network in order to insure security of electricity supply of all its customers.

Also, actual moment for this Study can be viewed through the electricity consumption changes due to global economic crises. Almost none of energy sector planners predicted such a steep drop of economic activity, energy prices and power consumption. It is even harder to predict future developments in that sense. All of that will surely have impact on country power balances that is also analyzed in this Study.

Not to forget that European policy targets on CO_2 emission reduction, as well as expecting global post-Kyoto obligations will also have significant influence on power generation mix and the role of transmission network in the near future.

That's why at the beginning of this Study the Authors prepared Questionnaire for regional TSO with detailed set of 14 questions on uncertainty definitions, ranges and its treatment in the network planning process. All 12 regional TSO responded to the Questionnaire. The TSOs' Questionnaire responses prove that the treatment of uncertainties in the transmission planning process is generally poor in this region. Also, none of the regional TSOs is taking into account impact of neighbouring systems' uncertainties. In accordance to TSOs' responses set of 73 regional uncertainty scenarios was defined, combining actual official transmission network development plans till 2020 (described as base cases) and candidate projects and other uncertainties in the region. So, the main idea of this Study is to evaluate the impact of the most important uncertainties in the region on all regional power systems in terms of security assessment, power exchanges, element loadings, power losses etc.

Besides Executive Summary the Study consists of three parts: study body text, Appendix I and Appendix II. Due to large number of scenarios that have been analyzed here (73 scenarios), study body text comprises of more than 200 pages, with additional several hundreds of pages of detailed reports given in Appendices. Appendix I gives detailed TSO answers on the above mentioned Questionnaire, while on the Appendix II detailed calculation results are presented.

Knowing that all input data, analyzed scenarios and detailed models were defined and harmonized by the responsible TSOs for the given timeframe of 2020, this Study can be taken as one of the most detailed study on common transmission system development in South East Europe so far.

2. SEE TRANSMISSION SYSTEM

Region of South East Europe (SEE) has been experiencing an ongoing process of changes in energy sector. Moreover, three important sets of changes have been taking place practically at the same time: deregulation, restructuring and privatization. In all three processes transmission system is playing important role. These changes are reflected in each country through reorganization of vertically integrated electric power utilities, followed by functional separation of transmission from generation, distribution and supply business and occasionally ended up with privatization. Changes in energy sector have also affected the planning philosophy of generation and transmission since most of SEE countries are having economies in transition. In order to establish and harmonize common regional and wider European electricity market lot of study activities have been taken in last few years. The most important regional generation and transmission studies that were presented and discussed at different occasions on the regional level (Athens Fora, conferences, workshops, web sites etc.) are referred in [1, 2, 3]. The main aim of the studies was to assist the European Commission (EC), the World Bank (WB) and donors in identifying indicative priority list of investments in power generation and related transmission infrastructure from the regional perspective and in line with the objectives of SEE regional electricity market.

The Study presented in this document is launched as the continuation of transmission planning activities in the region. Although transmission planners were faced to different uncertainties before, introduction of market conditions in power system makes transmission planning even more difficult. Accordingly, the main goal of this Study is to point out and evaluate the most influential uncertainties and critical elements in transmission planning proposed by the relevant system operators.

2.1.Existing situation

Till October 2004 South East European (SEE) power system has never been connected in unified parallel operation. Until 1995 Hungary, Slovakia, Czech Republic and Poland (CENTREL) as well as Romania and Bulgaria were not part of the UCTE grid at all. Due to war damages in the region in 1991, Serbian, Montenegrin, part of BiH, Macedonian, Albanian, Greek and Kosovo power systems, in addition to Romanian and Bulgarian, were separated from UCTE and in island operation (so called 2nd synchronous UCTE zone). In October 2004 UCTE reconnection was done and power system conditions in SEE dramatically changed. At the same time power utilities in the region enter deregulation and privatization process. Due to post-socialistic collapse of industrial consumption, SEE was initially characterized by surplus of installed generation capacities and power generation. Relatively cheap electricity from SEE became a great market opportunity. In that sense it has been very challenging to analyze creation of the energy market in SEE region.

Since October 10, 2004 at 10:00 hours, when UCTE grid reconnection process was completed, for the first time in the history all of continental Europe including whole SEE has become a single synchronous electricity area with 450 million people in 22 countries, and annual consumption of electricity of approx. 2.300 TWh, being one of the two biggest synchronous electricity areas in the world.

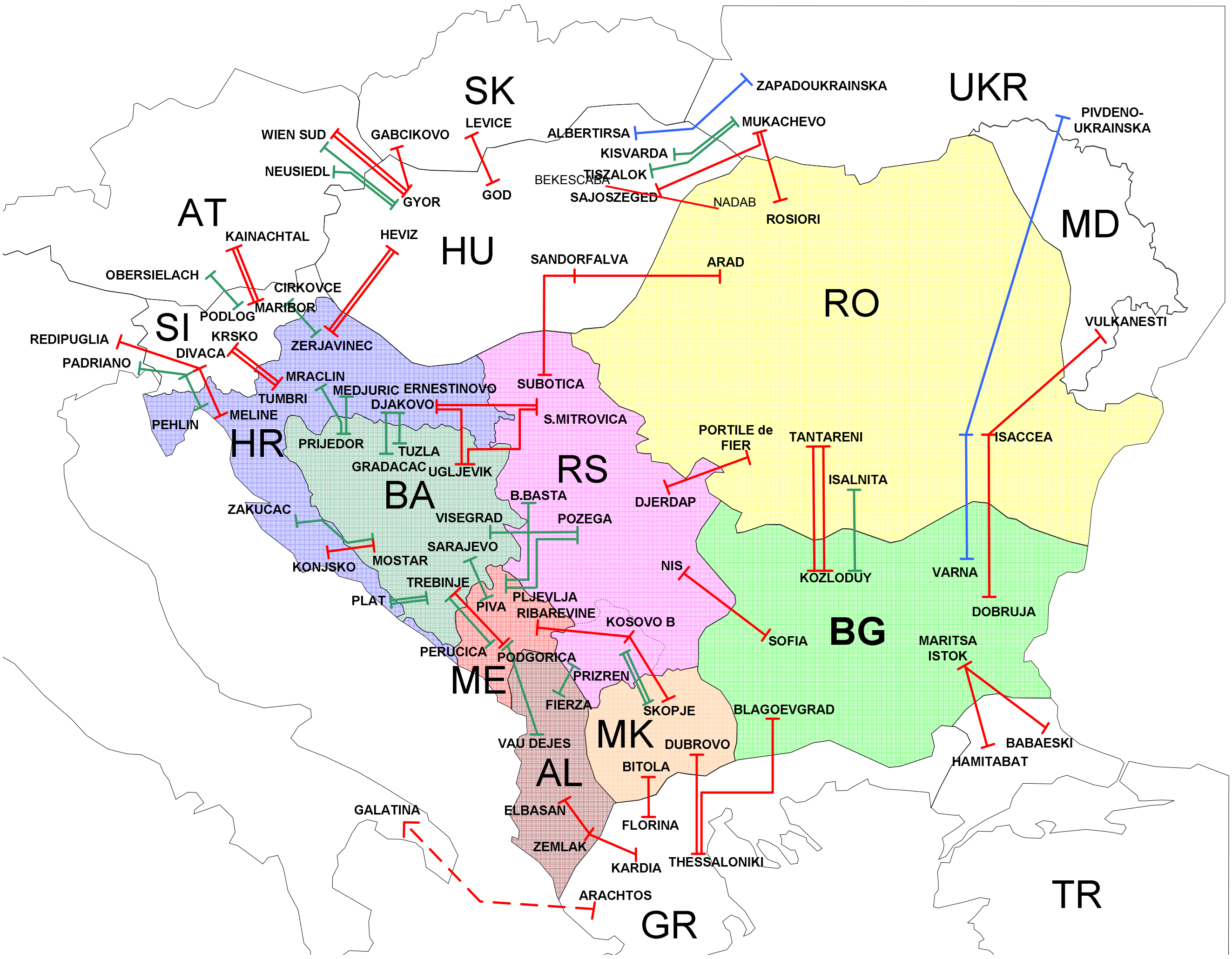
In parallel with UCTE reconnection, after decade of political and economical turbulence regional countries in SEE agreed to create a stable common regulatory and market framework capable of attracting investment in gas networks, power generation and transmission networks, so that all countries have access to the stable and continuous gas and electricity supply that is essential for economic development and social stability. Due to numerous discrepancies in energy sectors among the countries, the mission of common regional energy market is facing lot of challenges. A year later, after few years of preparation [4, 5] in October 2005 the first multilateral and binding treaty was signed – Treaty Establishing the Energy Community [6].

The Energy Community Parties are European Community on the one hand and the Contracting Parties on the other hand. The Contracting Parties are The Republic of Albania, the Republic of Bulgaria, Bosnia and Herzegovina, the Republic of Croatia, the Former Yugoslav Republic of Macedonia, the Republic of Montenegro, Romania, the Republic of Serbia and Kosovo. Initially, Austria, Italy, Hungary and Slovenia as neighbouring and influenced countries to this region had a status of Participant. Turkey is still in negotiation process. Several countries have a status of Observer. Development of the Regional Energy Market is coordinated by the European Commission.

The task of the Energy Community is to organize the relations between the countries in the region and create a legal and economic framework in relation to Network Energy in order to:

(a) create a stable regulatory and market framework capable of attracting investment in gas networks, power generation, and transmission and distribution networks, so that all parties have access to the stable and continuous energy supply that is essential for economic development and social stability,
(b) create a single regulatory space for trade in Network Energy that is necessary to match the geographic extent of the concerned product markets,
(c) enhance the security of supply of the single regulatory space by providing a stable investment climate in which connections to Caspian, North African and Middle East gas reserves can be developed, and indigenous sources of energy such as natural gas, coal and hydropower can be exploited,
(d) improve the environmental situation in relation to Network Energy and related energy efficiency, foster the use of renewable energy, and set out the conditions for energy trade in the single regulatory space,
(e) develop Network Energy market competition on a broader geographic scale and exploit economies of scale.

Improving the balance between energy supply and demand is crucial to boost and sustain economic development in SEE. It also means that countries should be prepared to draw fully on the substantial gains which can result from energy trading among themselves and with their neighbours. This requires a strong commitment by the countries of the region towards market oriented reforms in order to: improve overall energy conservation and efficiency, reduce an excessively high energy intensity of production compared to international standards, strengthen national institutional capacities and adapt legislation and regulation to EU norms and practices. All of this is having substantial impact to the regional transmission network operation and development. Transmission system in SEE today is relatively well developed. Comparing to the other regions in Europe, SEE is characterized by the large number (58) of interconnection capacities on 220 kV voltage level and above, as given in the following Table and Figure.



*OHL 220 kV Mraclin – Prijedor was temporary out of operation till 2009

** OHL 400 kV Bekescaba (H) - Nadab (RO) was put in operation in December 2008

Figure 2.1.1. Interconnection lines in South East Europe in 2008

One of the reasons for that is the fact that lot of interconnection lines were initially built as internal lines. For example, during 90's after separation of the former federal republics within Ex - Yugoslavia into 6 independent states, some former internal lines became interconnection lines. I.e. between Croatia and BiH there are 20 interconnection lines today (400, 220 and 110 kV) with total installed capacity of 5500 MVA that is more than a sum of the both countries peak loads.

Table 2.1.1. List of interconnection lines in South East Europe in 2008

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

Moreover, according to the studies [2, 3], none of observed new 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 new interconnection transmission line. **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. This is the most indicative proof that **existing level of interconnections in the region is satisfactory high** for future and foreseen generation investments and exchange patterns.

2.2.Development (2015 and 2020)

Within the Regional Transmission Planning Project under umbrella of SECI and financial support of USAID common regional transmission system development was analyzed since 2001. Official transmission development plans of each TSO in the region is merged and continuously updated and harmonized. So far, common transmission system planning models have been prepared for the time horizons of 2005, 2010, 2015 and 2020. Planned and candidate interconnection lines which were considered in different studies as definitely present in 2015/2020 are given in
Table ***2.2.1*** and on Figure 2.2.1. Based on the information collected from neighbouring 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. Within this Study timeframe of 2015 and 2020 is analyzed. Accordingly, comparing to the current network topology the following table shows the list of new interconnection lines included in the model of 2015 and 2020. Existing submarine HVDC cable 400 kV Arachtos (GR) – Galatina (IT) is considered to be in operation with set direction of power flow of 400 MW from Greece to Italy.

Table 2.2.1. List of transmission lines considered to be in operation in the SEE region until 2020

From		To		No. of elements	Voltage [kV]	Length [km]	Modelled in
Nea Santa	GR	Babaeski	TR	1	400	**180**	**2015**
Nis-Leskovac-Vranje	RS	Stip	MK	1	400	**220**	**2015**
Podgorica 2	ME	Kashar (Tirana)	AL	1	400	**144.2**	**2015**
Wien SO	AT	Gyor	HU	2nd	400		**2015**
Ernestinovo	HR	Pecs	HU	**2**	400	**87.1**	**2015**
Fillipoi/Nea Santa	GR	Maritsa Istok	BG	1	400	**180**	**2015**
Pancevo	RS	Resita	RO	1	400	**124**	**2015**
Kashar (Tirana)	AL	Kosovo C/Gen. Jankovic	RS	1	400	**239/174**	**2015/2020**
Hevitz	HU	Cirkovce(-Pince-)	SI	1	400	**162.3**	**2015**
Cirkovce(-Pince-)	SI	Zerjavinec	HR	1	400	**140**	**2015**
Imotski/Zagvozd	HR	Rama	BA	1	220	**75**	**2015/2020**
Okroglo	SI	Udine	IT	1	400	**113**	**2020**
Avce	SI	Udine	IT	1	400	**75.1**	**2020**

* There are two lines Zerjavinec(HR)-Hevitz(HU). Intention is to cut one of those, and to connect it with the node Pince in SI, thus making Zerjavinec-Pince-Hevitz. Also, Pince is radially connected to Cirkovice(SI)

** OHL 2x 400 kV Ernestinovo (HR) – Pecs (H) will probably be in operation 2010 - 2011

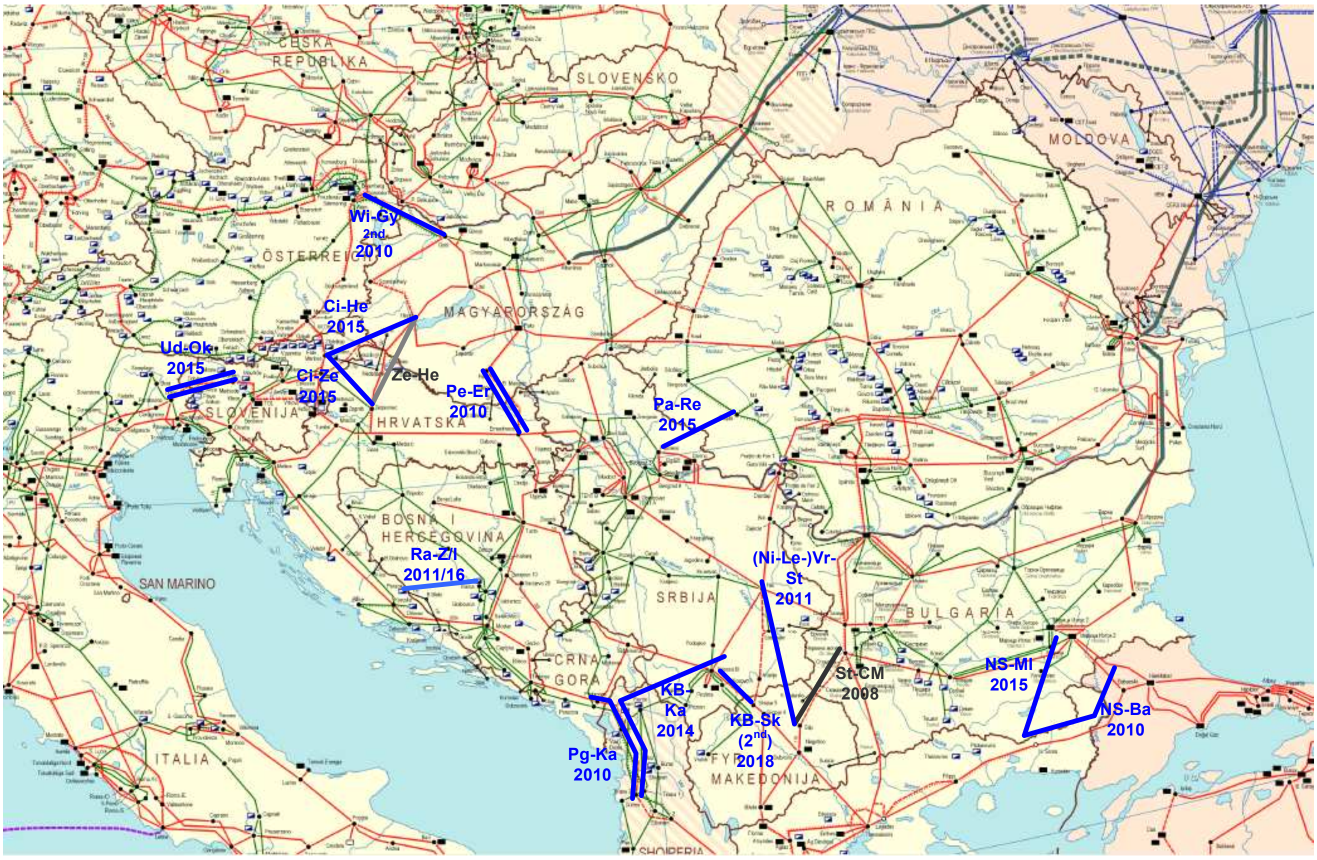


Figure 2.2.1. Planned interconnection lines until 2020

In addition to the existing power plants in the region in 2009 new power plants planned to be commissioned till the target years of 2015 and 2020 are also added, as shown in the Table 2.2.2.

Significant part of this region is Turkey. With its 44 000 MW of currently installed generation capacity and around 30 000 MW of the peak load together with 10-year average load growth of around 7%, Turkey is as large as the whole SEE region. Currently, power system of Turkey is not in synchronous operation with the rest of Europe, but the preparation process is underway. With its connection to the European power system, significant impact on SEE power system operation and development can be expected. Just for illustration, expected level of wind power plant integration in Turkish system till 2013 is around 12 000 MW[2], more than all new power plants in the SEE.

[2] Gul Okan (TEIAS): Integrating Renewables and The Smart Grid in Turkey, Regional Transmission Network Development, Istanbul 11-12 November 2009

Table 2.2.2. List of new power plants in SEE countries

ALB - new generation

Plant name	Plant type		Capacity (MW) Pinstalled		P net output[1]		Modelled in
	HPP/TPP/ NPP/other	Details	per Unit	plant	per Unit	plant	
TPP Fieri new	TPP	CCGT	300	300	290	290	2010
HPP Ashta (former Bushati project)	HPP	RoR hydro		48		48	2015
HPP Kalivaci (Vjosa river)	HPP	RoR Hydro		390		390	2015
TPP Vlora 1	TPP	CCGT		100		90	2015
HPP Graboves (Devoll cascade)	HPP	Res Hydro	2*150	300	2*150	300	2020
HPP Cekin (Devoll cascade)	HPP	Res Hydro	2*65	130	2*65	130	2020
HPP Banje (Devoll cascade)	HPP	Res Hydro	3*17	51	3*17	51	2020
Porto Romano	TPP	Coal		800		800	2020

BIH - new generation

Plant name	Plant type		Capacity (MW) Pinstalled		P net output[1]		Modelled in
	HPP/TPP/ NPP/other	Details	per Unit	plant	per Unit	plant	
HPP Mostarsko Blato	HPP	RoR Hydro	2x31.5	63	2x31.5	63	2015
TPP Stanari	TPP	Lignite	1x420	420	388	388	2015
WPP Mesihovina	other	Wind		44		44	2015
WPP Kamena	other	Wind		42		42	2015
WPP Merdzan Glava	other	Wind		60		60	2020

BUL - new generation

Plant name	Plant type		Capacity (MW) Pinstalled		P net output[1]		Modelled in
	HPP/TPP/ NPP/other	Details	per Unit	plant	per Unit	plant	
Maritsa East 1, new1	TPP	Lignite	1*335	330	1*318	318	2010
Maritsa East 1, new2	TPP	Lignite	1*335	330	1*318	318	2010
Maritsa East 3, new1	TPP	Lignite	1*400	400	1*375	375	2015
Maritsa East 3, new2	TPP	Lignite	1*400	400	1*375	375	2015
Belene G1	NPP	Nuclear	1*1000	1000	1*900	900	2015
Belene G2	NPP	Nuclear	1*1000	1000	1*900	900	2015
WPP Majak	other	Wind		300/360		300/360	2015/2020
WPP Vidno	other	Wind		280/530		280/530	2015/2020
WPP Valtchi Dol	other	Wind		200		200	2015
WPP Kavarna	other	Wind		80/200		80/200	2015/2020
WPP Baltchik	other	Wind		45		45	2015
WPP Gen. Toshevo	other	Wind		50		50	2020
WPP Shabla	other	Wind		160		160	2020
WPP Svoboda	other	Wind		600		600	2020

CRO - new generation

Plant name	Plant type		Capacity (MW) Pinstalled		P net output[1]		Modelled in
	HPP/TPP/ NPP/other	Details	per Unit	plant	per Unit	plant	
Zagreb new block CC	TPP	CCGT	75+40	115	73+38	110	2010
Sisak new block CC	TPP	CCGT	156+79	235	150+75	225	2010
Osijek new block CC	TPP	CCGT	156+79	235	150+75	225	2010
Lesce	HPP	RoR Hydro	2*21	42	2*21	42	2010
Podsused	HPP	RoR Hydro		43		43	2010
Dubrovnik g3	HPP	Res Hydro	1*108	108	1*105	105	2015
Plomin g3 new	TPP	Lignite	573	573	521	521	2015
WPP Vratarusa	other	Wind		62		62	2020
WPP Rudine	other	Wind		63		63	2020
WPP Ponikve	other	Wind		34		34	2020
WPP Krs-Padjene	other	Wind		100		100	2020
WPP Bruska	other	Wind		60		60	2020
Dubrovnik g5	HPP	Res Hydro	1*108	108	1*105	105	2020
HTEZATG1				400		400	2020
HTESLAG1				400		400	2020

HUN - new generation

Plant name	Plant type: HPP/TPP/NPP/other	Plant type: Details	Capacity (MW): Pinstalled per Unit	Capacity (MW): Pinstalled plant	Capacity (MW): P net output[1] per Unit	Capacity (MW): P net output[1] plant	Modelled in
Mátra Power Plant Generation	TPP	Lignite		485		436	2015
Dunamenti	TPP	CCGT	1x260	260		252.2	2015
E.ON Gonyu 1	TPP	CCGT		430		417.1	2015
E.ON Gonyu 2	TPP	CCGT		430		417.1	2015

MKD - new generation

Plant name	Plant type: HPP/TPP/	Plant type: Details	Capacity (MW): Pinstalled per Unit	Capacity (MW): Pinstalled plant	Capacity (MW): P net output[1] per Unit	Capacity (MW): P net output[1] plant	Modelled in
Matka 2 (Sv.Petka)	HPP	Res Hydro	30	30	30	30	2010
Boskov Most g1	HPP	Res Hydro	35	35	35	35	2010
Gasna Skoplje	TPP	CCGT	250	250	242	242	2010
Boskov Most g2	HPP	Res Hydro	35	35	35	35	2020
HPP Cebren	HPP	PSPP	3*110	330	3*110	330	2020
HPP Galiste	HPP	Res Hydro	3*65	195	3*65	195	2020
HPP Gradec	HPP	Res Hydro	2*27	54	2*27	54	2020
HPP Veles	HPP	Res Hydro	3*31	93	3*31	93	2020
HPP Spilje 2	HPP	Res Hydro		73	73	73	2020
Gasna Zelezara	TPP	CCGT				100	2020

MNE - new generation

Plant name	Plant type: HPP/TPP/NPP/other	Plant type: Details	Capacity (MW): Pinstalled per Unit	Capacity (MW): Pinstalled plant	Capacity (MW): P net output[1] per Unit	Capacity (MW): P net output[1] plant	Modelled in
Komarnica	HPP	Res Hydro	2x56	112	2x56	112	2015
Andrijevo	HPP	Res Hydro	2x64	128	2x64	128	2015
Raslovici	HPP	RoR Hydro	2x18,5	37	2x18,5	37	2015
Milunovici	HPP	RoR Hydro	2x18,5	37	2x18,5	37	2015
Zlatica	HPP	RoR Hydro	2x18,5	37	2x18,5	37	2015
Pljevlja II	TPP	Lignite	1*225	225	1*191	191	2015
Berane	TPP	Lignite	1*125	125	1*110	110	2020

ROM - new generation(PPs >100 MW)

Plant name	Plant type: HPP/TPP/NPP/other	Plant type: Details	Capacity (MW): Pinstalled per Unit	Capacity (MW): Pinstalled plant	Capacity (MW): P net output[1] per Unit	Capacity (MW): P net output[1] plant	Modelled in
Tarnita-Lapustesti	HPP	PS Hydro	4*250	1000	4*250	1000	2015
Braila new	TPP	CCGT	2*330	660	2*285	570	2010
Bucuresti sud new1	TPP	CCGT	108	108	104	104	2010
Iernut g78	TPP	CCGT	123+247	369.77	119+240	359	2010
Rovinari new (AFBed)	TPP	Lignite	1*330	330	1*285	285	2010
Doicesti new (AFBed)	TPP	Lignite	2*200	2*200	2*180	360	
Cernavoda 3	NPP	Nuclear	720	720	676	676	2010
Cernavoda 4	NPP	Nuclear	720	720	676	676	2015
WPP Tariverde	other	Wind		350/830		350/830	2015/2020
WPP Vant	other	Wind		300		300	2020
RCULDAB1 400.00	other	Wind		870		870	2020
RADJUD1 400.00	other	Wind		538		538	2020
RGAROAF1 400.00	other	Wind		400		400	2020
RTATARU1 400.00	other	Wind		240		240	2020
RMIRCE51 110.00	other	Wind		138		138	2020
RTULCE5A 110.00	other	Wind		210		210	2020

SRB - new generation(PPs >100 MW)

Plant name	Plant type: HPP/TPP/NPP/other	Plant type: Details	Capacity (MW): Pinstalled per Unit	Capacity (MW): Pinstalled plant	Capacity (MW): P net output[1] per Unit	Capacity (MW): P net output[1] plant	Modelled in
Djerdap I upgrade (phase 1)	HPP	RoR Hydro	4*25	100	4*25	100	2015
Kolubara B	TPP	Lignite	2x350	700	2x315	630	2015
Kosovo C	TPP	Lignite	4*530	2120	4*500	2000	2015
Zhur	HPP	RoR Hydro	246+46.8	292.8	246+46.8	292.8	2020
Djerdap I upgrade (phase 2)	HPP	RoR Hydro	2*25	50	2*25	50	2020

1 - if $P_{installed}$ is available, net output is estimated according to typical percentages for self consumption

3. IDENTIFICATION OF THE MOST IMPORTANT UNCERTAINTIES IN THE SEE TRANSMISSION SYSTEM

Along with the power sector deregulation and market opening the role of TSO significantly changed. In old monopolistic environment TSO was having the function of power system monitoring and control of the power system elements trying to reach "*optimum of the sum*". At that time generation, transmission, distribution and supply were vertically integrated and coordinated where:

1. TSO was involved in defining power units engagement (dispatching),
2. power supply was centralized and predictable to the TSO,
3. TSO was negotiating and realizing cross-border exchanges,
4. TSO was actively participating in definition of type, size and location of new generation units.

In a new market environment:

1. future generation dispatch is not known to the TSO (only partially predictable),
2. TSO is not defining power units market engagement and commitment,
3. power supply is not centralized and it is only partially predictable to the TSO,
4. TSO is monitoring and managing cross-border exchanges,
5. TSO is only approving grid connection for new generation units with no impact to a decision making process of the generation investment.

Nowadays, generators, TSOs, DSOs, suppliers, traders and customers are of disintegrated roles and interests with its own particular optimums. Generators are independent, trying to sell its production as more expensive as possible, suppliers are independent, trying to purchase cheap electricity, traders are independent, trying to earn on power exchanges, while customers are interested in cheap electricity of reasonable quality. TSO must guarantee non-discriminatory third party access to the grid and power system security and reliability that would result in non-discriminatory combination of all above mentioned interests. In other words it can be illustratively called as "*sum of optimums*".

In order to minimize all above mentioned uncertainties TSOs must act pro-actively and should make different types of analysis that would predict eventual transmission network weaknesses. One of the analyses of that kind on the regional level is presented in this Study.

This Study is commissioned in order to identify and evaluate the most important uncertainties in the regional power system that could effect the development of electricity market. Accordingly, the basic purpose for the work conducted within this Study assumes that regional electricity market will be established and put in operation in the near future at the territory of South East Europe according to the Energy Community Treaty signed in 2005 by Albania, Bosnia and Herzegovina, Bulgaria, Croatia, FYR of Macedonia, Montenegro, Romania, Serbia and UNMIK. Otherwise, all power systems could operate, analyze and plan its own network with no any concerns about other system's uncertainties.

Well identified and evaluated uncertainties on the regional level may help 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 EPE of sustainability, competitiveness and security of supply will surely help SEE countries to better integrate into future common European electricity market.

Basic assumption for the work to be conducted after this Study is that stable regulatory framework and the necessary degree of co-ordination between SEE TSOs in terms of operational, planning and market standards and rules will be achieved in the near future. More sufficient unbundling of TSOs from production and supply companies may lead to more incentives to develop the network and minimize negative impact of uncertainties in the overall interest of the market and the region as a whole.

SEE transmission network planning criteria and methodology are defined observing national networks at the territory of SEE, under the responsibility of SEE TSOs, as unique network, with the aim to promote and ensure market activities within the Energy Community. Planning criteria and methodology are defined taking into account national requests defined in national Grid Codes as much as possible, but suited to the regional electricity market needs. They serve primarily to support market activities with satisfactory level of overall system adequacy and security, based on technical and economical considerations. They also serve to estimate the level of future SEE power system reliability and to identify and prioritize transmission investment candidates from regional point of view.

In other words, SEE region is observed as one power system with the same obligations and rights for all market participants. Transmission network planning criteria and methodology are set to keep the overall system adequacy and security on the most economical way at the regional level [3].

Important assumption for the effective usage of transmission planning criteria and methodology proposed in [3] which will lead to transmission network investments with regional significance is acceleration of Authorization procedures (according to existing practice construction of a new transmission line may last for more than 10 years). Dynamic and fast development of SEE transmission system should support predicted fast growth of trading activities on the electricity market and fast integration of renewable energy sources (construction period for a new wind power plant is up to three years), which is impossible if complicated Authorization procedures stay unchanged.

Environmental aspects in 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 in SEE transmission system planning and development should be regulated and stimulated by adequate market oriented signals. Private interest is important aspect concerning economical rationalization of network investments and has to be respected and promoted in a proper way.

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 planning), there are different types of uncertainties that have to be included in analyses.

Generally speaking, the most important uncertainties that should be observed in network planning are:

- new power plants size and locations,
- hydrological conditions,
- generators bids,
- branches and generators availability,
- load prediction,
- regional and national power balance.

Transmission network has to be designed to serve the needs of its consumers. Connection of new power plants probably brings the largest uncertainty in network development, especially taking into account eligible producers that are of highest investors' interest. As many as necessary scenarios concerning generation investment variations have to be analyzed. Construction of new generating facilities is left to the market (at least till security of supply is not jeopardized). So, country balances will strongly depend on the generation investors' activities. That is something that can not be easily predicted by the TSOs who should develop the network to sustain generation development. Besides that, all other well known uncertainties from the monopolistic era remain the same, such as load prediction, consumer price elasticity, branches and generators availability etc. Also, due to large share of hydro power plants in the generation mix, this region is additionally highly dependent on the hydrological conditions. Accordingly, every single power system development analysis should also take that into account. Market environment assume that every generating company will have its own bidding strategy, based on its own profit target not a social welfare or something else.

In accordance to the European Energy Policy special attention should be directed on the integration of renewable sources into the grid. One generation investment scenario may be defined assuming high integration of renewable sources, especially wind power plants in the power system. At this moment, developers' interest in WPPs in the region is huge due to promising wind potential and high European renewables integration targets.

Transmission system investments are financed by SEE TSOs through transmission fees and loans according to national legislative frameworks. National Regulatory Authorities have to approve network investments that are technically and economically justified and to allow the inclusion of investment costs into transmission fees. This Study didn't observe the problem of project financing or the problem of internal, local network strengthening for the third countries needs. Problems may arise if some of the SEE TSOs is not satisfied with SEE transmission system development plan and rejects to invest in new line with 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 has to be found in the separate framework of the Energy Community. Otherwise, the adoption of planning criteria and methodology suggested and applied in [2, 3] will be more complicated, if not impossible. Private investments should be stimulated also by SEE TSOs, national regulatory Authorities, future pan-European agency for cooperation of energy regulators and other relevant EU bodies.

With the market development it is expected that congestion costs will become very influential factor for interconnection lines construction. Nevertheless, transfer limits on interconnection lines in SEE are often limited and related to some internal network problems, and rationalization of some investments in new interconnection capacity may cause that internal problems stay hidden. Furthermore, SEE TSOs may declare lower values of Net Transfer Capacity in order to protect domestic power producers from market activities or to keep unnecessary level of system security under their control because of different reasons. This Study is not dealing with these types of problems, as well. It is just study on the technical aspects of given uncertainties.

Having in mind that the regional power system modelled in this Study considers whole SEE region as a unified, common power system, the treatment of interconnection lines and internal national lines is the same.

For the purpose of the study "*Transmission Network Investment Criteria*" [3] the Authors prepared questionnaire for the relevant TSOs in the SEE region. The TSOs answers were checked once again for the purpose of this Study, and checked once again during the SECI Regional Transmission System Planning Working Group meeting in March 2009 in Istanbul. It comprises of 14 questions related to the network planning and uncertainties. All 12 TSOs responded: UNMIK, Macedonia, Turkey, Albania, BIH, Serbia, Slovenia, Romania, Croatia, Italy, Bulgaria and Montenegro.

Generally, none of the regional TSOs consider uncertainties in transmission network planning as not important. On the contrary, nine TSOs are considering it very influential (UNMIK, Macedonia, Turkey, BIH, Serbia, Slovenia, Romania, Croatia, Italy), while three TSOs consider it moderately infuential (Albania, Bulgaria, Montenegro), as given on the following figure.

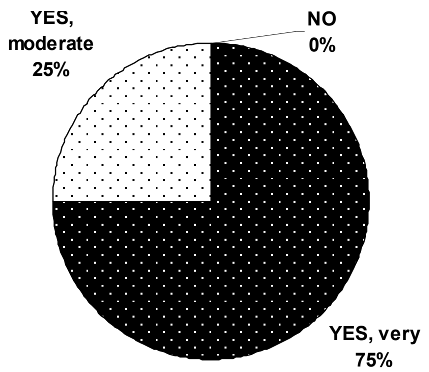


Figure 2.2.1. Would you say that uncertainties in the future are influential to a transmission network planning in your country? – Answers of 12 regional TSOs

In the following subchapter the summarized treatment of uncertainties in transmission system planning are given by the TSOs, while complete questionnaire responses are presented in Appendix I.

3.1. Summarized treatment of uncertainties

In order to get a clear picture, in this subchapter summarized TSOs' responses are given. The following table shows the most important uncertainties in transmission system planning as seen from TSOs point of view.

Table 3.1.1. The most important uncertainties in transmission system planning

Country	new power plants size and location	generators engagement	hydrological conditions	existing power plants decommissioning	load prediction	branches availability	regulatory and market issues	market transacti ons	country power balance
Albania	√	√	√			√		√	√
Bosnia and Herzegovina	√	√	√	√					√
Bulgaria	√	√	√			√		√	√
Croatia	√	√	√			√		√	√
FYR of Macedonia	√	√	√						√
Montenegro			√						
Romania	√	√	√	√	√	√	√	√	√
Serbia	√	√	√					√	√
Slovenia	√	√	√		√			√	√
Turkey	√	√	√	√	√	√	√	√	√
UNMIK	√	√	√	√		√		√	√

The following figure gives the distribution of different uncertainties treatment in the region. Obviously, power plant size and location is taken as the most common uncertainty in 11 countries. Uncertainties in load prediction are taken as important one in 9 out of 14 countries, while country power balance is critical in 8 countries. All other uncertainties are taken as critical in less than 5 countries.

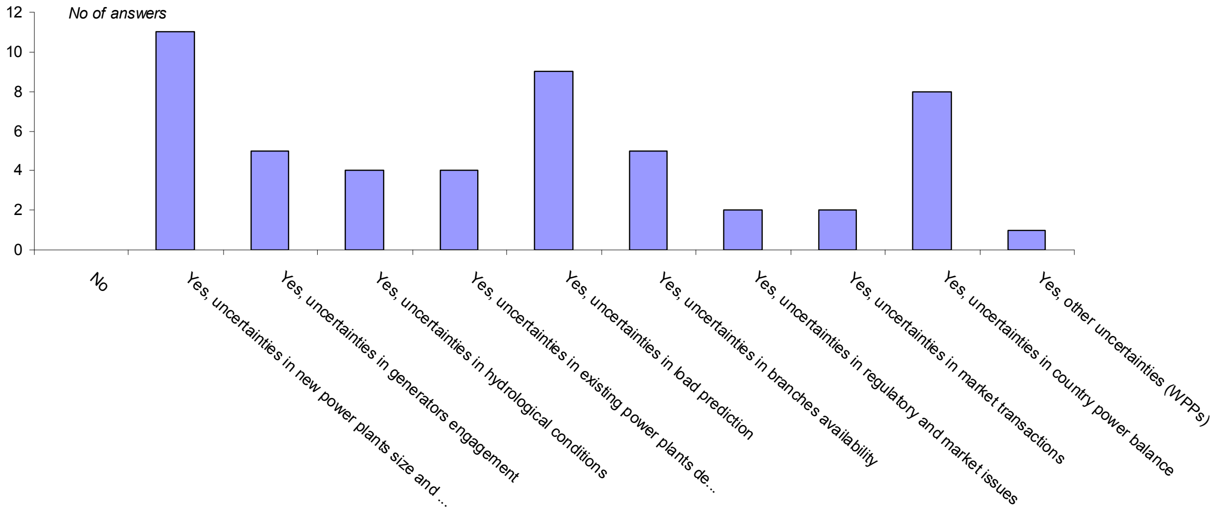


Figure 3.1.1. Do you take into account uncertainties during transmission network planning and which ones?

Due to transmission network planning uncertainties all TSOs use multi-scenario analyses, while probabilistic calculations are sometimes used only in Macedonia, Slovenia and Croatia. Very indicative answers are given on wrong transmission investments. None of these TSOs is estimating wrong transmission investments.

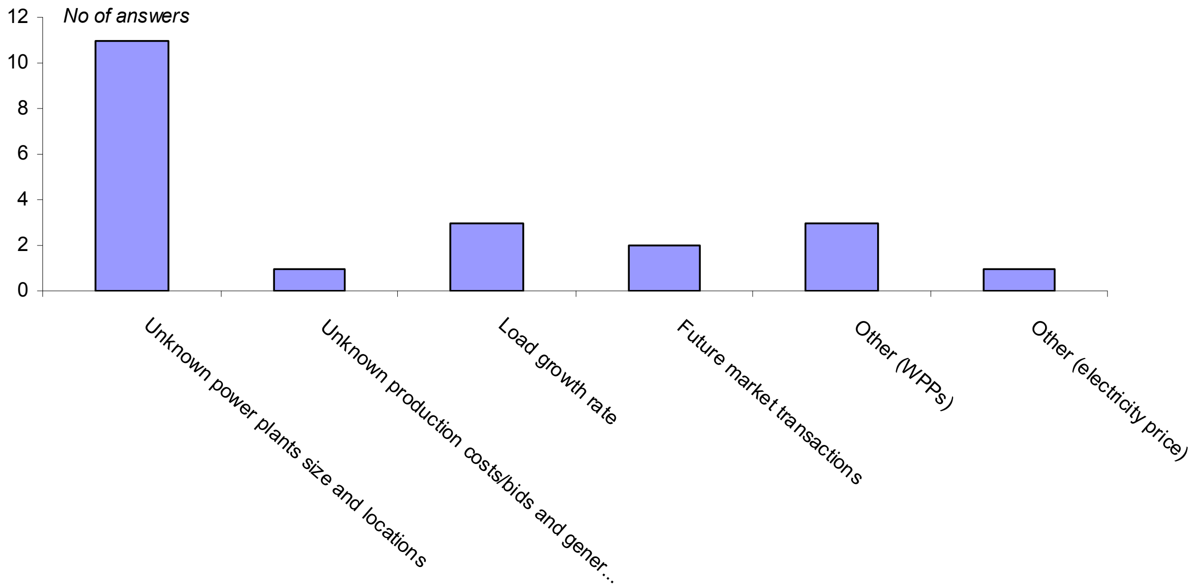


Figure 3.1.2. What is the most influential uncertainty in your country related to a transmission network planning?

Most of the regional TSOs found potential connection to the Italian market most influential uncertainty out of their direct scope. Significant influence is given also to the connection of the Turkish system to the UCTE grid, as shown on the following Figure.

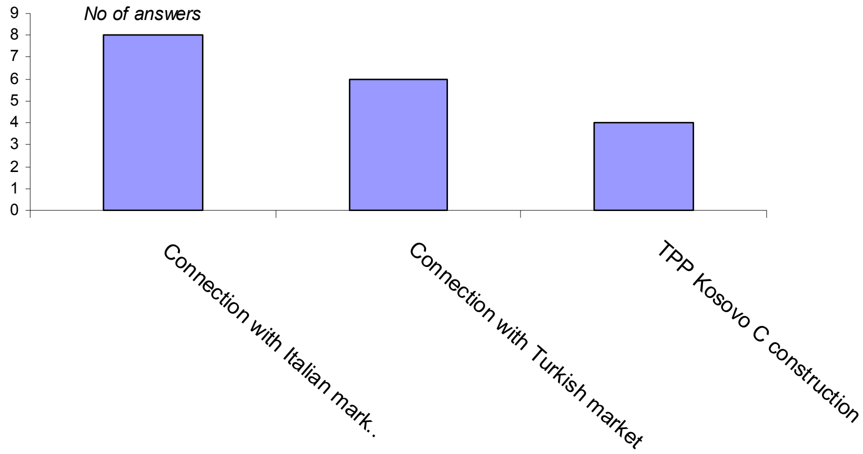


Figure 3.1.3. What is the most influential uncertainty, among those listed below, on your transmission development plan?

Finally, all TSOs gave their "wish list", meaning the list of scenarios that they would like to be analyzed in this Study. As stated before, scenarios related to the power plants location and size are the most important ones.

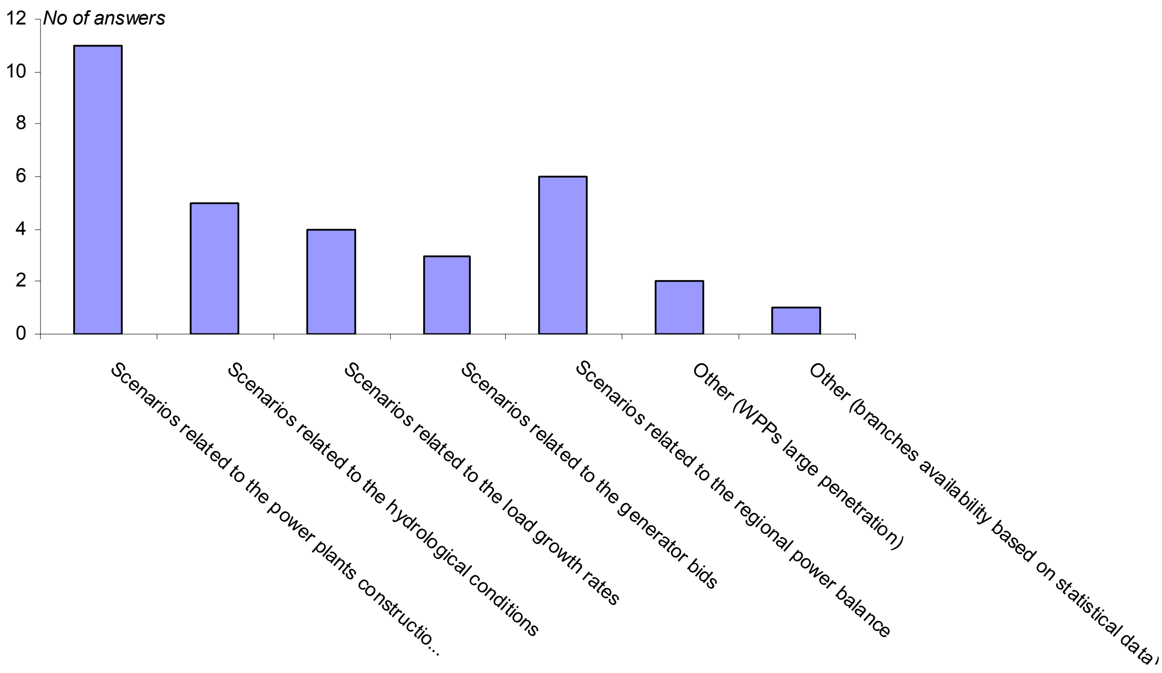


Figure 3.1.4. What uncertainties (scenarios) would you like to be analyzed in the Study?

Finally, the main problem in detailed analysis of given uncertainties is related to input data comprising of production costs, load growth and hydrological conditions. TSOs declared relatively low ability to share these data, as described in the following Table.

Table 3.1.2. TSO's ability to share input data

Answer (able to share data)	**No**	**%**
Production costs	4	33
Load growth	9	75
Hydrological data	5	42

Accordingly, the Authors were forced to use existing power system models verified by each TSO in the region as the main reference. Additional sensitivity analysis is left to Author's estimation.

In the following chapters the Authors performed calculations of 73 different power system scenarios that include different uncertainties. In that way the most critical part of the SEE network will be detected, as well as their dependency on every single uncertainty in the analyzed timeframe of 2015 and 2020.

4. BASE CASE SCENARIOS

Base case scenarios for 2015 and 2020 are described in this chapter, representing official power system developments. All other power system development scenarios described in the chapter 5 are addendum to the base case models and are compared to the base case results. In that way it is easy to define what kind of changes every single uncertainty is introducing in the network.

4.1. Winter MAXIMUM 2015, base case scenario

Winter maximum regime for 2015 assumes no additional power plants, DC cables or additional power interchanges in comparison to the merged official power system development plans.

Aggregated physical exchanges among analyzed countries are shown in the Figure 4.1.1. Negative exchange values assume that the power flow direction is opposite than the arrow.

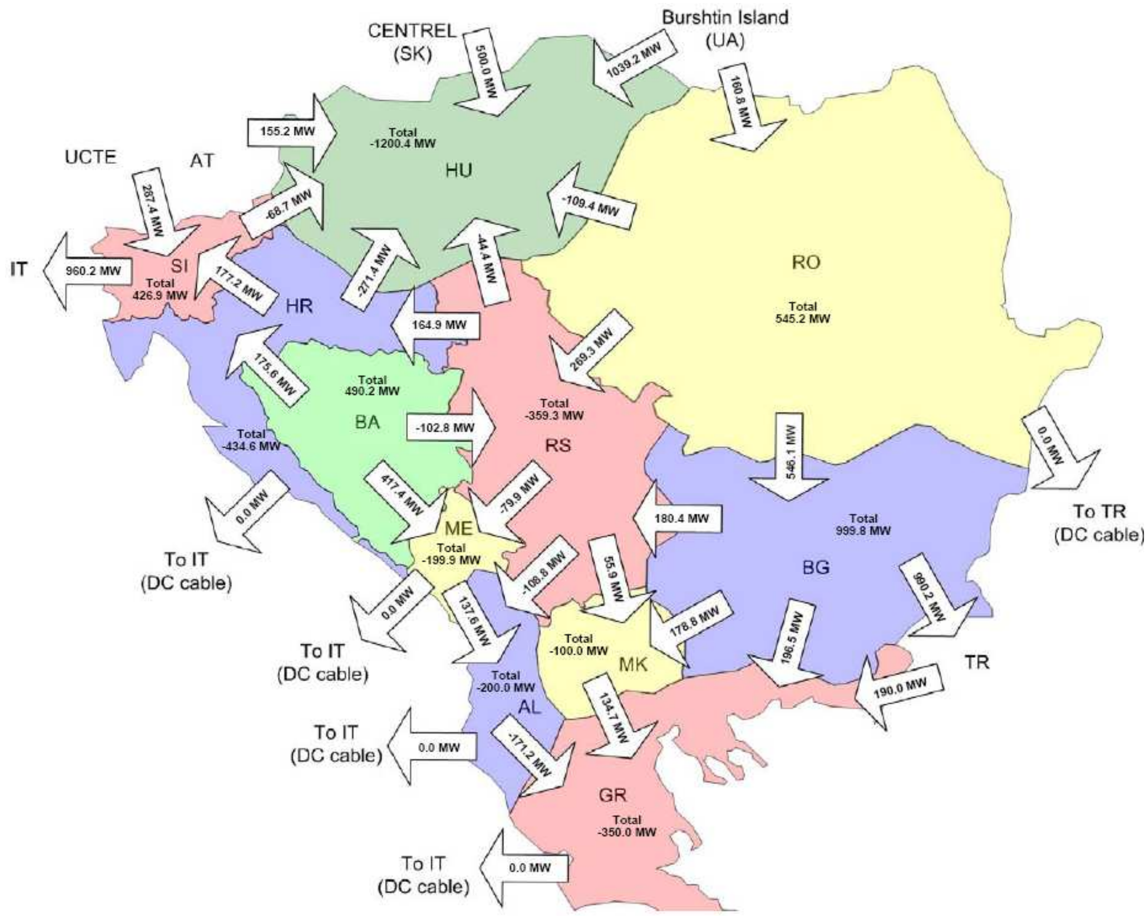


Figure 4.1.1. Aggregated border flows in the area of SEE in winter maximum 2015, base case scenario

Aggregated border flows given in the Figure 4.1.1. are the consequence of production, demand and exchange programs given in Table 4.1.1. For each area, the first line in the table represents the active power (MW) and the second line the reactive power (Mvar).

Table 4.1.1. Area totals (MW/Mvar) in area of SEE in winter maximum 2015, base case scenario

X-- AREA --X	FROM GENERATION	TO LOAD	TO BUS SHUNT	TO LINE SHUNT	FROM CHARGING	TO NET INT	LOSSES	DESIRED NET INT
10	1338.4	1491.9	0.0	0.0	0.0	-200.0	46.5	-200.0
AL	476.1	689.7	-199.8	0.0	458.9	27.4	417.7	
20	8805.2	7603.7	0.0	14.4	0.0	999.8	187.2	1000.0
BG	2901.9	3045.8	-44.9	120.9	2996.2	320.9	2455.4	
30	3148.0	2610.1	0.0	0.0	0.0	490.2	47.6	490.0
BA	698.4	724.5	0.0	0.0	911.2	322.4	562.6	
35	40263.7	49222.0	0.0	1.1	0.0	-9401.3	441.9	-9400.0
IT	7040.4	10816.5	0.0	-157.0	12570.0	-541.1	9492.0	
40	3099.9	3483.0	0.0	0.0	0.0	-434.6	51.5	-435.0
HR	359.2	1074.2	0.0	0.0	1408.5	18.7	674.9	
45	5391.3	6500.0	0.1	0.0	0.0	-1200.4	91.6	-1200.0
HU	960.2	1926.6	178.2	-29.6	2423.8	95.6	1213.2	
50	10298.1	10371.1	0.0	0.0	0.0	-350.0	277.0	-350.0
GR	2144.6	5312.0	170.2	9.3	6613.0	111.9	3140.4	
55	4395.3	-4593.5	0.0	4.8	0.0	8883.6	100.3	8886.0
UX	-4.0	637.5	0.0	12.8	2320.7	380.3	1286.2	
60	1501.6	1577.0	0.0	0.0	0.0	-100.0	24.6	-100.0
MK	453.1	573.6	-31.4	0.0	403.6	49.4	265.1	
65	1207.1	0.0	0.0	0.0	0.0	1200.0	7.1	1200.0
UA	-196.3	0.0	0.0	0.0	653.8	345.6	111.9	
70	10254.2	9416.9	0.0	88.4	0.0	545.2	203.8	545.0
RO	2511.6	4075.6	512.8	273.9	4616.7	-234.1	2500.0	
75	2997.1	2514.0	0.0	8.8	0.0	426.9	47.4	424.0
SI	982.5	811.0	0.0	54.0	608.4	177.8	548.1	
80	54592.6	54622.1	0.0	0.0	0.0	-800.1	770.7	-800.0
TR	4578.4	7792.0	1175.4	0.0	17195.6	-131.6	12938.2	
90	7714.0	7871.1	0.0	17.8	0.0	-359.3	184.4	-360.0
RS	2620.3	2853.5	0.0	76.6	1729.8	-642.9	2063.1	
91	628.7	805.2	0.5	1.9	0.0	-199.9	20.9	-200.0
ME	297.9	299.2	-35.0	10.9	239.5	60.4	201.9	
95	501.4	0.0	0.0	0.0	0.0	500.0	1.4	500.0
SK	-384.9	0.0	0.0	0.0	40.0	-360.8	15.9	
TOTALS	156136.5	153494.7	0.6	137.2	0.0	0.0	2504.0	0.0
	25439.4	40631.6	1725.5	371.9	55189.9	0.0	37886.4	

The same data for two zones in Serbia (UNMIK and EMS are treated as the zones in the area 90) are given in Table 4.1.2.

Table 4.1.2. Totals (MW/Mvar) of zones in Serbia in winter maximum 2015, base case scenario

X-- ZONE --X	FROM GENERATION	TO LOAD	TO BUS SHUNT	TO LINE SHUNT	FROM CHARGING	TO NET INT	LOSSES
90	6892.0	6567.2	0.0	13.7	0.0	151.0	160.2
EMS	2220.4	2379.7	0.0	55.6	1470.9	-567.3	1823.2
901	822.0	1303.9	0.0	4.1	0.0	-510.3	24.2
UNMIK	399.9	473.7	0.0	21.0	259.0	-75.7	239.8
TOTALS	7714.0	7871.1	0.0	17.8	0.0	-359.3	184.4
	2620.3	2853.5	0.0	76.6	1729.8	-642.9	2063.1

Figure 4.1.2 shows histogram of branch loadings in the transmission grid of SECI countries. All lines 220 kV, 400 kV and 750 kV in these countries are taken into consideration as well as transformers 750/400 kV and 400/220 kV. Power network on 110 kV and 150 kV voltage level is not analyzed in details in this Study (although it was monitored during power flows and n-1 calculations) since it is taken as of local importance. It can be noticed that all observed elements are loaded below 70% of their thermal limits.

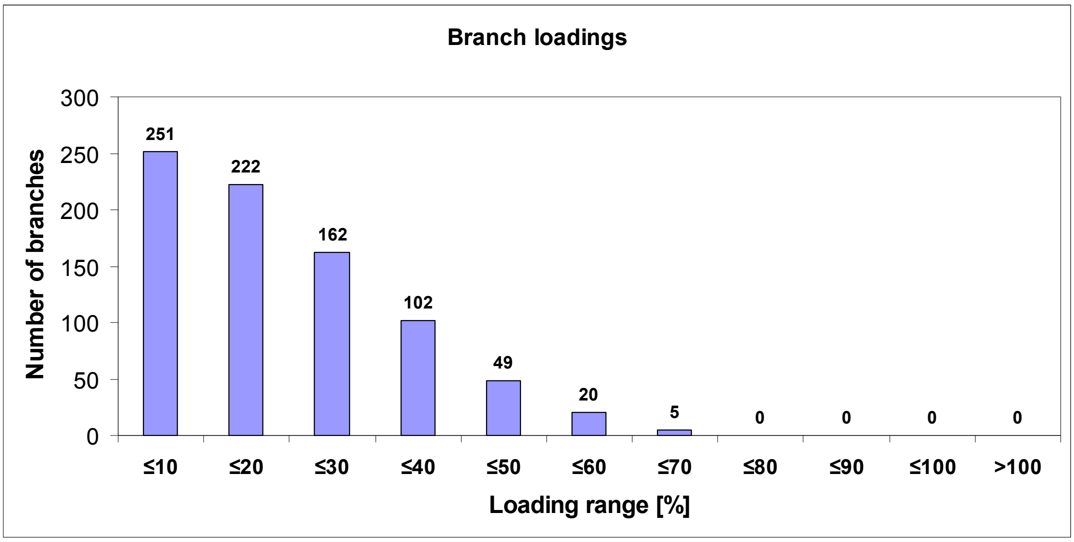
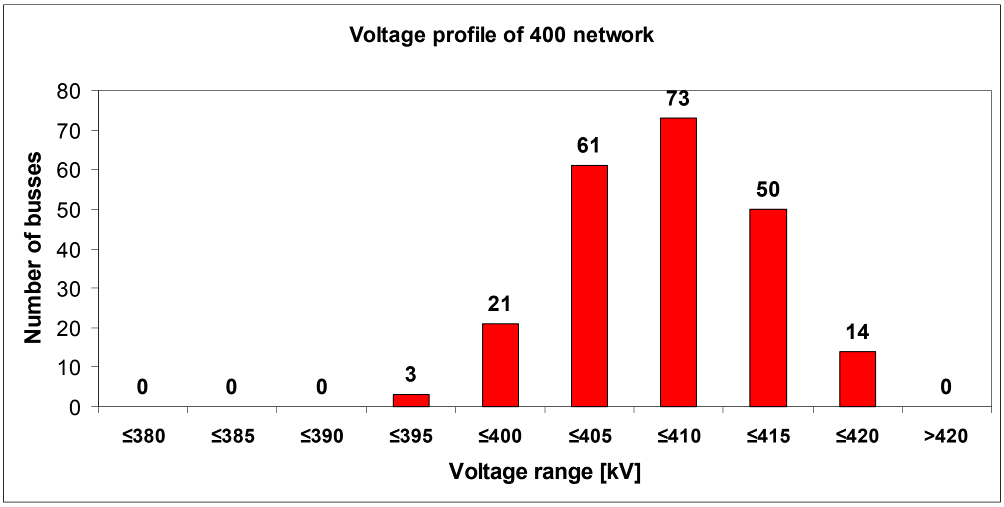


Figure 4.1.2. Histogram of branch loadings in monitored grid in winter maximum 2015, base case topology

It should be noted that there are no lines and transformers which are loaded more than 80% of their thermal limits. Consequently, there are no element overloadings in the area of interest.

Figure 4.1.3 shows histogram of busbar voltages in 220 kV and 400 kV network of SECI countries. It can be noticed that the voltages of all those buses are within the permitted limits in normal operating conditions. Voltages in the most of the buses are slightly above nominal values, but still within the limits. In other words, there are no voltages out of limits in the area of interest.



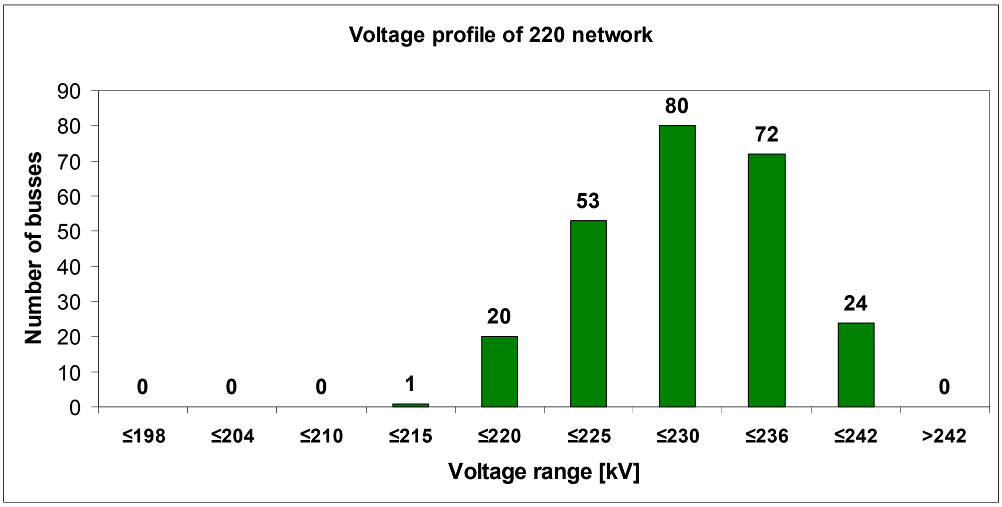


Figure 4.1.3. Voltage profile in the monitored grid in winter maximum 2015, base case topology

Results of contingency (n-1) analysis and geographical positions of 400 and 220 kV critical elements are shown in Figure 4.1.4. There are four critical lines which are overloaded. Tie-line 110 kV Trebinje (BA) – Herceg Novi (ME) is overloaded by 6 % in case of outage of tie-line 400 kV Trebinje (BA) – Podgorica (ME). This overload is well known from operational practice and it can be solved with proper dispatching actions. Tie-line 220 kV Divača (SI) – Padriciano (IT) is overloaded by 66 % in case of outage of tie-line 400 kV Divača (SI) – Redipuglia (IT). This problem is recognized even today and caused by large power flows to Italy that has to be restricted by Slovenian TSO (ELES). ELES plans to install two phase shift transformers (2x600 MVA) in the Divača SS to control power flows to Italy in the near future. This equipment could be of high importance to the power flows from SEE to Italy. There are two parallel lines 220 kV Dunamenti – Martonvasar in Hungary which are also critical. Outage of one of them causes overload of the other one by up to 1 %.

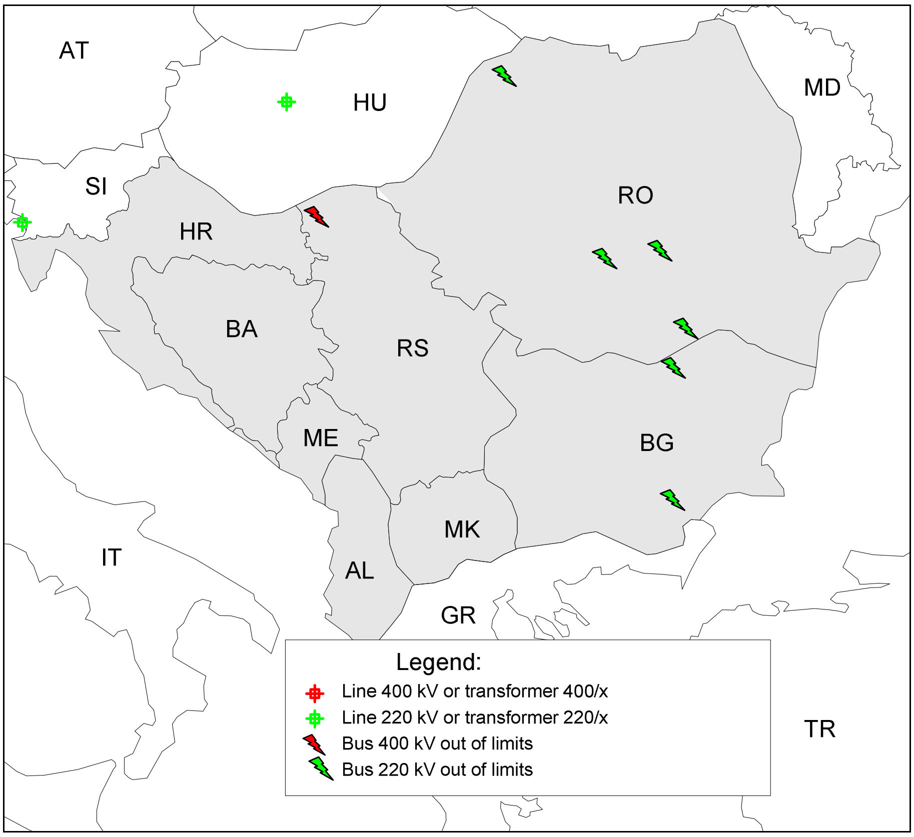


Figure 4.1.4. Geographical map with critical elements in winter maximum 2015, base case scenario

There are some buses with voltages outside of boundary limits, mostly in Greece. These voltages outside of limits can be treated as local problem, because such problems can be solved with proper dispatching actions. In addition, in some cases, such voltages out of limits are caused by outages of lines which lead to the network state with observed buses being connected to the rest of the system only through transformers to lower voltage levels.

Finally, this power system state presents base case scenarios verified by all regional TSOs as the most probable one for 2015. All other scenarios in 2015 that follow in the Study will be compared with these results. In that way it will be easy to clarify which changes and problems in the network are caused by each analyzed uncertainty.

4.2. Winter MAXIMUM 2020, base case scenario

The same principle is used for preparation of base case 2020. Table 4.2.1 shows production, demand and exchange programs and other basic information about the areas (countries) of the analyzed region. The same data for zones in Serbia are given in Table 4.2.2.

Table 4.2.1. Area totals (MW/Mvar) in area of SEE in winter maximum 2020, base case scenario

X-- AREA --X	FROM GENERATION	TO LOAD	TO BUS SHUNT	TO LINE SHUNT	FROM CHARGING	TO NET INT	LOSSES	DESIRED NET INT
10	1622.1	1723.7	0.0	0.0	0.0	-150.0	48.3	-150.0
AL	668.4	779.7	-204.7	0.0	475.2	99.8	468.8	
20	9659.9	8411.0	0.0	15.5	0.0	1000.0	233.4	1000.0
BG	3519.1	3357.9	0.0	181.2	3279.7	197.9	3061.7	
30	2949.9	2897.8	0.0	0.0	0.0	0.0	52.0	0.0
BA	1003.0	1017.2	0.0	0.0	913.7	241.7	657.9	
35	45061.4	54409.8	0.0	1.1	0.0	-9740.0	390.6	-9740.0
IT	9595.0	11942.3	0.0	147.8	12393.6	-804.6	10703.3	
40	3428.0	4359.0	0.0	0.0	0.0	-1000.0	69.0	-1000.0
HR	505.6	1075.9	0.0	0.0	1534.6	202.9	761.4	
45	6093.4	7180.0	0.1	0.0	0.0	-1200.0	113.2	-1200.0
HU	1356.1	2128.1	178.6	-29.1	2405.1	0.8	1482.8	
50	11750.1	11426.0	0.0	0.0	0.0	0.0	324.0	0.0
GR	3126.0	5724.7	203.7	9.4	6663.2	125.5	3712.1	
55	5226.8	-4356.2	0.0	4.8	0.0	9449.7	128.4	9450.0
UX	352.8	622.8	0.0	12.7	2300.4	337.5	1680.1	
60	1940.2	2001.9	0.0	0.0	0.0	-100.0	38.2	-100.0
MK	762.7	752.3	-30.9	0.0	397.7	11.4	426.4	
65	1207.6	0.0	0.0	0.0	0.0	1200.0	7.6	1200.0
UA	-165.4	0.0	0.0	0.0	652.3	365.5	121.5	
70	13261.1	12110.2	0.0	90.2	0.0	800.1	260.6	800.0
RO	3117.7	4455.6	783.3	285.8	5601.8	-27.4	3222.1	
75	3949.8	2990.0	0.0	8.9	0.0	890.0	60.9	890.0
SI	1233.4	964.6	0.0	53.8	868.3	338.5	744.8	
80	77661.6	77342.9	0.0	0.0	0.0	-800.0	1118.7	-800.0
TR	9834.4	11034.0	996.9	0.0	22660.7	-171.2	20635.5	
90	7767.9	8298.8	0.0	17.3	0.0	-749.9	201.8	-750.0
RS	2892.7	2986.6	0.0	73.4	1732.0	-666.7	2231.4	
91	864.5	938.0	0.5	2.1	0.0	-100.0	23.9	-100.0
ME	349.8	346.6	-34.6	11.4	237.2	51.5	212.0	
95	501.3	0.0	0.0	0.0	0.0	500.0	1.3	500.0
SK	-328.1	0.0	0.0	0.0	40.0	-303.0	14.8	
TOTALS	192945.3	189732.9	0.6	139.9	0.0	0.0	3071.8	0.0
	37823.0	47188.4	1892.4	746.3	62155.4	0.0	50136.6	

Table 4.2.2. Totals (MW/Mvar) of zones in Serbia in winter maximum 2020, base case scenario

X-- ZONE --X	FROM GENERATION	TO LOAD	TO BUS SHUNT	TO LINE SHUNT	FROM CHARGING	TO NET INT	LOSSES
90	7020.9	6865.0	0.0	13.5	0.0	-33.7	176.1
EMS	2509.2	2480.4	0.0	54.8	1520.3	-499.2	1993.5
901	747.0	1433.8	0.0	3.8	0.0	-716.2	25.6
UNMIK	383.5	506.2	0.0	18.6	211.7	-167.5	237.9
TOTALS	7767.9	8298.8	0.0	17.3	0.0	-749.9	201.8
	2892.7	2986.6	0.0	73.4	1732.0	-666.7	2231.4

Aggregated physical exchanges among analyzed countries are shown in the Figure 4.2.1.

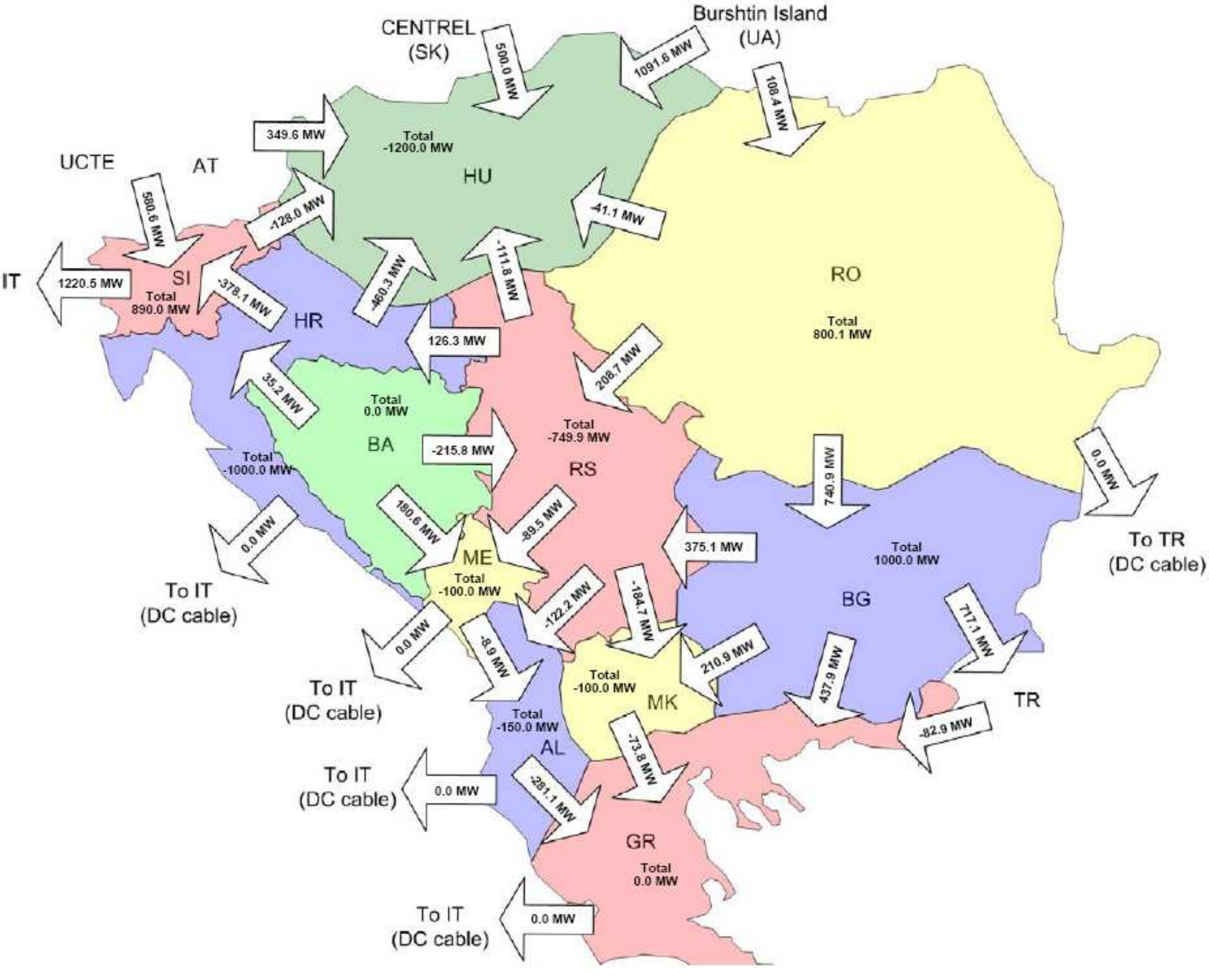


Figure 4.2.1. Aggregated border flows in area of SEE in winter maximum 2020, base case scenario

Figure 4.2.2 shows histogram of branch loadings in the transmission grids of SECI countries. All lines 220 kV, 400 kV and 750 kV in these countries are taken into consideration as well as transformers 750/400 kV and 400/220 kV. It can be noticed that all elements are loaded below 90% of their thermal limits.

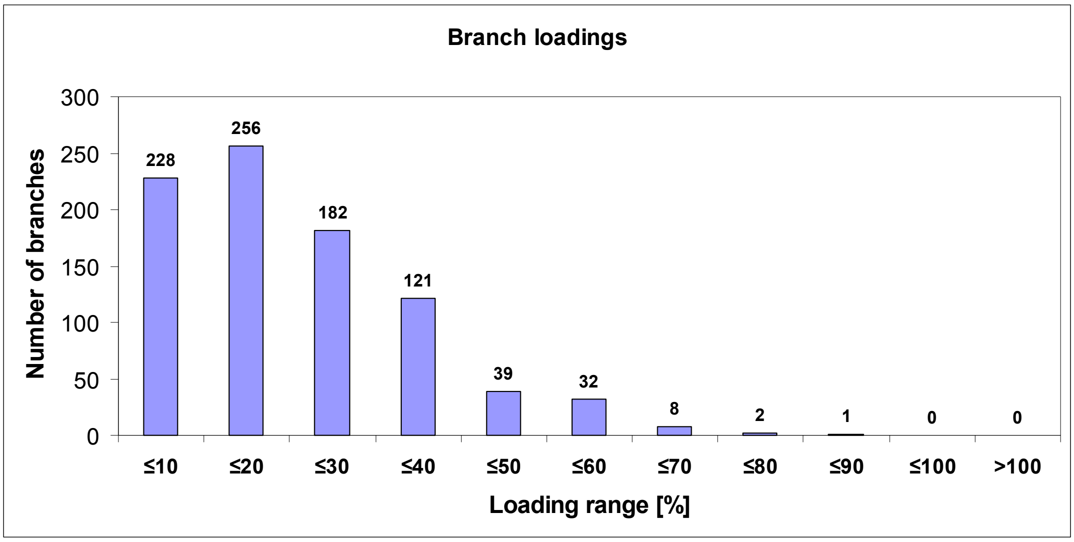
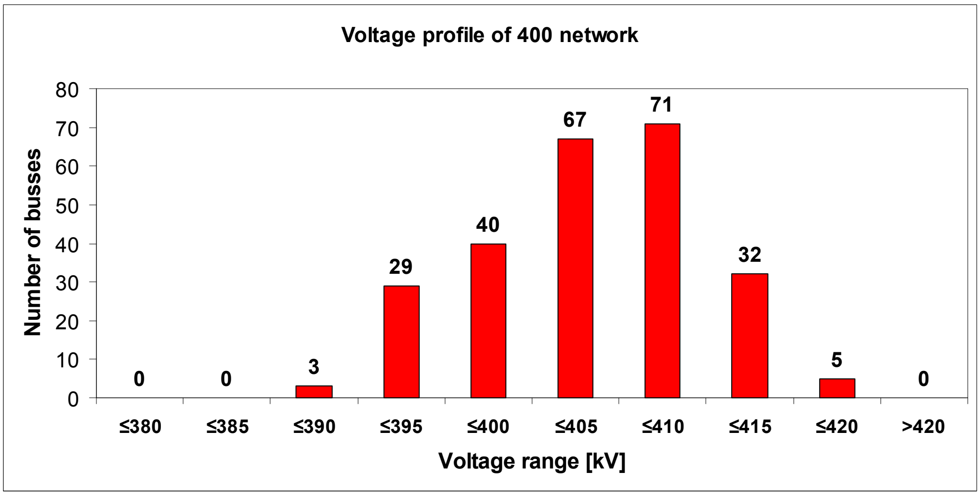


Figure 4.2.2. Histogram of branch loadings in monitored grid in winter maximum 2020, base case topology

There is only one branch which is loaded more than 80 % of its thermal limit. It is transformer 400/220 kV in Maritsa 3 in Bulgaria, loaded 82 % of its rated power. So, in the base case 2020 with all elements available there are no overloadings in the network.

Figure 4.2.3 shows histogram of voltages in 220 and 400 kV busses in grid of SECI countries. It can be noticed that voltages in all buses are within the permitted limits for normal operating conditions. Voltages in the most of the buses are slightly above nominal values, but still within limits. In other words, in the base case for 2020 there are no voltages out of limits in the area of interest.



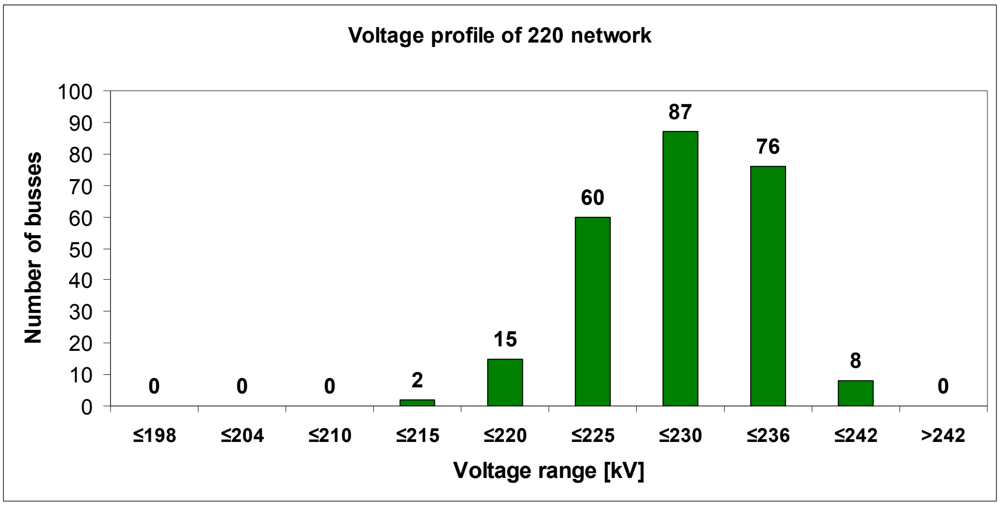


Figure 4.2.3. Voltage profile in monitored grid in winter maximum 2020, base case topology

There are eleven critical lines which are overloaded in the contingency (n-1) analysis. There are two parallel lines 220 kV in Albania, Elbasan – HPP Cekin which are critical. Outage of one of them causes overload of the other one by up to 3 %. The reason of this problem is connection of two power plants, HPP Graboves and HPP Cekin, to Elbasan through these two parallel lines. This problem should be avoided by proper engagement of these two power plants, as well as by proper realization of their connection to the transmission grid of Albania (increasing cross section of conductors). Tie-line 110 kV Trebinje (BA) – Herceg Novi (ME) is overloaded by 6 % in case of outage of tie-line 400 kV Trebinje (BA) – Podgorica (ME). This overload is well known from operational practice and it can be solved with proper dispatching actions. In the grid of Hungary there are two parallel paths Dunamenti (220 kV) – Martonvasar (220 kV) – Martonvasar (400 kV) which are critical. Outage of element in one path causes overload of elements in the other path up to 16 % in case of line overload and up to 16 % in case of transformer overload. In Romanian grid there are two parallel paths Lotru (220 kV) – Sibiu (220 kV) – Sibiu (400 kV) which are critical. Outage of element in one path causes overload of line 220 kV in the other path, up to 12 %. This problem is known from operational practice and it is solved by proper dispatching actions. In the grid of Serbia there are two parallel lines 220 kV Beograd 8 – Beograd 17 which are also critical. Outage of one of them causes overload of the other one by up to 6 %. This problem is known from operational practice and it is solved by proper dispatching actions.

There are some buses with voltages outside of boundary limits. These voltages outside of limits can be treated as local problem, because such problems can be usually solved with proper dispatching actions. In addition, in some cases, such voltages out of limits are caused by outages of lines which lead to such network state where observed buses are being connected to the rest of the system only through transformers to lower voltage levels.

Geographical positions of critical elements are shown on Figure 4.2.4.

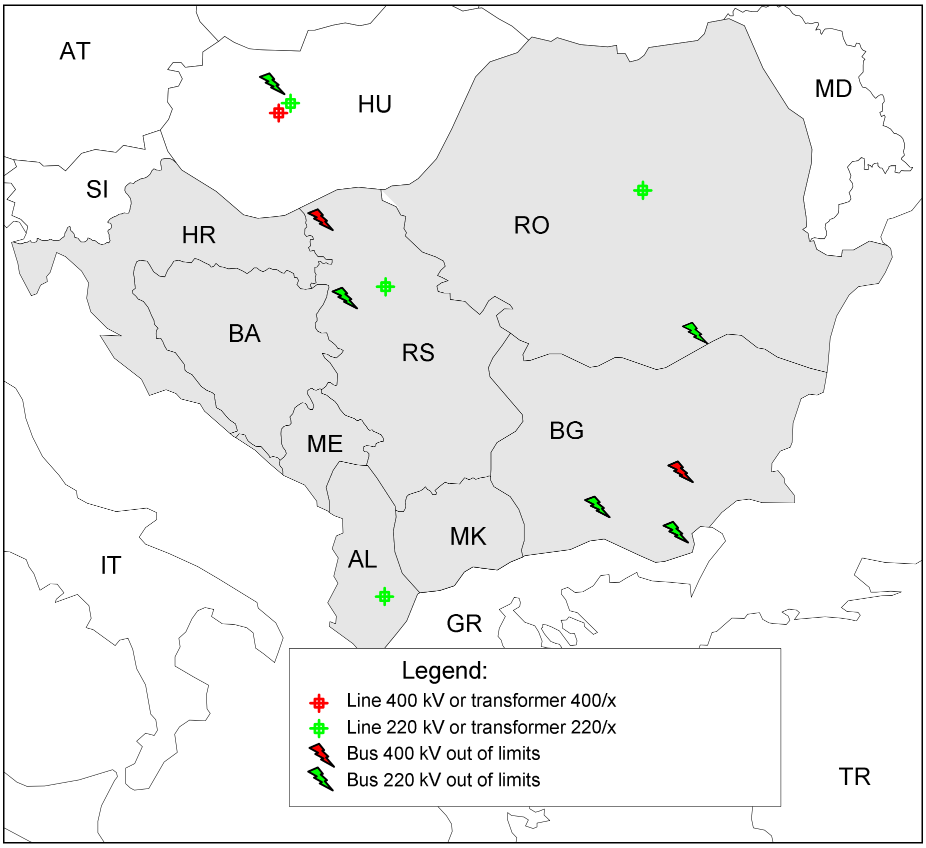


Figure 4.2.4. Geographical map with critical elements in winter maximum 2020, base case scenario

In this way main characteristic of the base case scenarios for 2015 and 2020 are described. In the following chapters the results of 73 different scenarios are given, while more detailed results are prepared in Appendix II.

5. IMPACT OF DIFFERENT UNCERTAINTIES ON PLANNED TRANSMISSION INVESTMENTS

This chapter gives summary of impacts of analyzed different uncertainties on transmission network in SECI region. Because of different base case exchange scenarios in 2015 and 2020, tables with summary of the impacts are given separately for 2015 and 2020. Structures of the tables are the same. Also, all critical elements, regardless of analyzed target year are defined in each of the tables, which make tables easier for comparison.

Depending on estimation of which scenario is more realistic, further analyses of detected bottlenecks elimination should be performed.

5.1. Impact on Different Uncertainties in Year 2015

Geographical map with elements in winter maximum 2015 found critical in any analyzed scenario is given on the Figure 5.1.1. There are seven 400 kV lines/transformers and eleven 220 kV lines that are found critical in different development scenarios in the region in 2015.

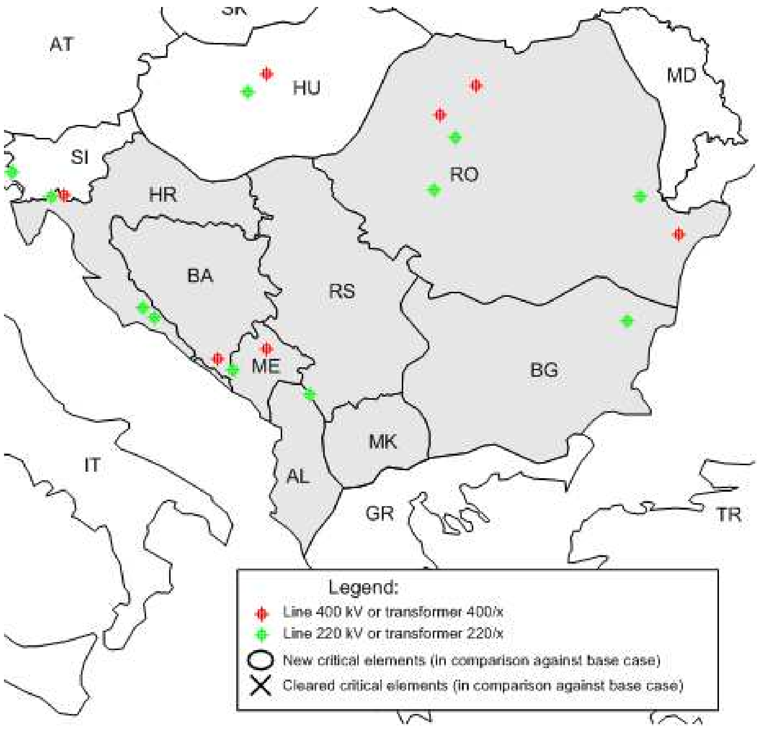


Figure 5.1.1. Geographical map with critical elements in winter maximum 2015 in all analyzed scenarios

Summary of the critical elements in all analyzed scenarios in target year 2015 (for easer comparison given together with element critical in 2020) is given in Table 5.1.1. From the table it can be seen in which scenarios given branches appear as critical.

Internal line 220 kV Dunamenti – Martonvasar in Hungary and tie-line between Slovenia and Italy 220 kV Divača (SI) – Padriciano (IT) appear to be critical elements in the base case scenario. Accordingly, these two lines appear as critical in almost all of the analyzed scenarios.

Most of the critical elements appear as critical in only one analyzed regime, while only three elements appear as critical in more then one uncertainty scenario.

Tie-line 220 kV Pehlin (HR) – Divača (SI) between Croatia and Slovenia appears as critical in 4 different uncertainties (TPP Kosovo C, NPP Krško 2, WPP and uncertainty in balance of Turkey). This tie-line appears as critical as a consequence of transit of significant amount of power between east and west, through transmission network of Croatia. In the case of significant power exchange (through southern transmission path of Croatia) reinforcements on border between Croatia and Slovenia should be considered.

Transformer 400/220 kV in Trebinje (BiH) appears as critical in case of 2 different uncertainties (connection to Italian market by HVDC Albania – Italy and Montenegro – Italy). This is consequence of transit of power exported from BiH to Italy, via transmission network of Montenegro. In case when such significant power exchange (from southern part of BiH to Montenegro) became realistic, reinforcements in area of SS Trebinje should be considered.

The third element which appears as critical in more then one uncertainty is the line 220 kV Lotru – Sibiu in Romania. This line appears as critical in 3 different uncertainties (connection to Italian market by HVDC Albania – Italy and Croatia – Italy and uncertainty in balance of Romania). The problem with overload of this line is known from operational practice and it is solved by proper dispatching actions, so it can be treated as local problem.

In addition, from the summary table it can be seen that commissioning of HVDC cable from Montenegro to Italy, for 1000 MW of export to Italy, causes overloads in the area of Trebinje, in BiH, (transformer 400/220 kV in Trebinje and tie-line 220 kV Trebinje (BA) – Perucica (ME)) as well as in the area of Pljevlja, in Montenegro (transformer 400/220 kV in Pljevlja). This is result of transit of significant power (1000 MW) through transmission grid of Montenegro.

Substation Trebinje is electrically close to the candidate substation Tivat, which is planned as connection spot for HVDC cable on Montenegrian side, so area of Trebinje appears as critical in case of export of power to Italy through the cable, regardless of position of generation source for this export.

On the other hand, transformer 400/220 kV in Pljevlja appears as critical in case of export of power to Italy through the cable, when generation source is on the west. In such case, significant amount of the power flows through western part of Serbia (which consists of 220 kV network) to Pljevlja.

Also, it can be seen that commissioning of HVDC cable from Croatia to Italy, for 1000 MW of export to Italy, causes overloads in area of Konjsko, in Croatia (220 kV path Imotski – Zakučac – Konjsko). Substation Konjsko is connection spot of HVDC cable on the Croatian side. This 220 kV path, which is critical, connects Konjsko to the east and in all analyzed regimes the most significant power which feeds the cable flows from southern area of BiH to Croatia, through 400 and 220 kV tie-lines.

For all three possible HVDC solutions between SEE and Italian market (Albanian, Montenegrin and Croatian) a loss of the HVDC cable could cause serious overloadings on the Croatian – Slovenian and Slovenian – Italian borders. So, additional network reinforcements are of utmost importance together with any option of HVDC link construction.

In the case of commissioning HVDC cable between Romania and Turkey, with usage of this cable for exchange of 1000 MW in both directions, it can be seen that three critical elements appear in transmission network of Romania. Since substation Constanta is connection spot of the cable on Romanian side, line 400 kV Constanta – Cerna Voda appears as critical in case of export power from Turkey to CENTREL. Transformer 400/220 kV in Rosiori and line 220 kV Ungheni – Iernut are overloaded in case of power export from Ukraine to Turkey. The reason for these overloads is in the fact that these branches are on the transmission path (connection between Romania and Ukraine in realized through substation Rosiori and line Ungheni – Iernut is on transmission path from northwest Romania to east Romania).

In the case of large wind penetration in the area of SECI countries, there are critical elements in Bulgaria (220 kV line Dobrudzha – Madara), in Romania (220 kV line Forcani Vest – Barbosi) and between Croatia and Slovenia (tie-line 400 kV Melina (HR) – Divača (SI)).

Tie-line 220 kV between Albania and Serbia, Fierza (AL) – Prizren (RS), appears as critical in case when power system of Albania exports 500 MW. The reason for this is loop-flow, where power generated on north side of Albania flows through path north Albania – Serbia – Macedonia – Greece – south Albania.

Table 5.1.1. Summary on impacts of Different Uncertainties in Year 2015

Critical element	**Base case**	Power plants construction uncertainties				Connection to Italian/Turkish market uncertainties				Power balance uncertainties for the territories										
		TPP Kosovo	NPP Krsko 2	HPP Kozjak	WPP	AL - IT	ME - IT	HR - IT	RO - TR	AL	BG	BA	HR	MK	ME	RO	RS	SI	TR	UNMIK
Line 220 kV Dunamenti - Martonvasar (HU)	**X**		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Tie-line 220 kV Divaca (SI) - Padriciano (IT)	**X**	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Tie-line 220 kV Pehlin (HR) - Divaca (SI)		X	X		X														X	
Transformer 400/220 kV in Trebinje (BA)						X	X													
Transformer 400/220 kV in Pljevlja (ME)							X													
Tie-line 220 kV Trebinje (BA) - Perucica (ME)							X													
Line 220 kV Zakucac - Konjsko (HR)								X												
Line 220 kV Zakucac - Imotski (HR)								X												
Tie-line 220 kV Fierza (AL) - Prizren (RS)										X										
Transformer 400/220 kV in Sibiu (RO)																X				
Line 220 kV Lotru - Sibiu (RO)						X		X								X				
Line 220 kV Beograd 8 - Beograd 17 (RS)																				
Transformer 400/220 in Maritsa East																				
Line 400 kV Sajoszoged - Detk (HU)									X											
Tie-line 400 kV Melina (HR) - Divaca (SI)					X															
Line 220 kV Dobrudzha - Madara (BG)					X															
Line 220 kV Focsani Vest - Barbosi (RO)					X															
Transformer 400/220 in Rosiori (RO)									X											
Line 220 kV Ungheni - Iernut (RO)									X											
Line 400 kV Constanza - Cernavoda (RO)									X											
Line 400 kV Tantareni - Turceni (RO)																				
Line 220 kV Orlovac - Konjsko (HR)																				
Line 220 kV Elbasan - Cekin (AL)																				

5.2. Impact on Different Uncertainties in Year 2020

Geographical map with elements in winter maximum 2020 found critical in any analyzed scenario is given on the Figure 5.2.1. There are four 400 kV lines/transformers and six 220 kV lines that are found critical in different development scenarios in the region in 2020.

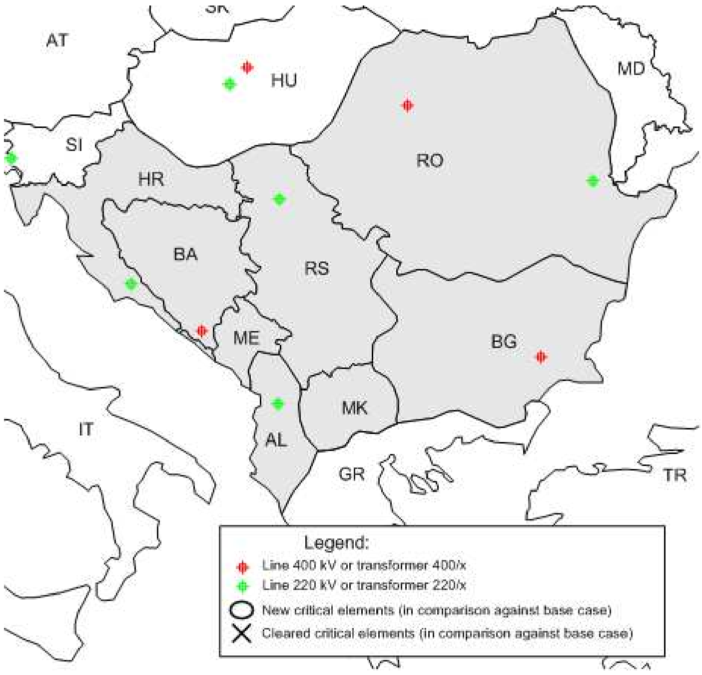


Figure 5.2.1. Geographical map with critical elements in winter maximum 2015 in all analyzed scenarios

Summary of the critical elements in all analyzed scenarios in target year 2020 is given in Table 5.2.1. From the table it can be seen in which scenarios given branches appear as critical.

Analogue to the 2015 base case, internal line 220 kV Dunamenti – Martonvasar in Hungary appears as critical elements in the 2020 base case scenario. Because of that this line appears as critical in almost all of the analyzed scenarios, but, as stated before, these lines are not considered as the part of SECI region. Namely, Hungarian network model comprises of some equivalents, without 120 kV network elements given in details as the rest of SEE network. Accordingly, all problems notified in Hungarian network should be double-checked later on.

Also, lines 220 kV Lotru – Sibiu in Romania, Beograd 8 – Beograd 17 in Serbia and Elbasan – Cekin in Albania appear to be critical elements in the base case scenario. Because of that these lines appear as critical in almost all of the analyzed scenarios. It should be noted that problems with overloads of lines Lotru – Sibiu and Beograd 8 – Beograd 17 are known from operational practice and can be resolved by proper dispatching actions and should be treated as local problems. The problem with Elbasan – Cekin (ALB) line overload is described in the base case 2020 scenario description (subchapter 4.2).

Table 5.2.1 shows that most of the critical elements appear as critical only in one analyzed regime and only two elements appear as critical in more then one uncertainty. Besides the lines mentioned as the problem in the base case, there are two branches critical in more then one different uncertainty: OHL 220 kV Divača (SI) – Padriciano (IT) and OHL 220 kV Sajoszoged – Detk (HU).

In addition, from the summary table it can be seen that commissioning of HVDC cable from Montenegro to Italy, for 1000 MW of export to Italy, causes overloads in the area of Trebinje, in BiH, (transformer 400/220 kV in Trebinje). This is result of transit of significant power (1000 MW) through transmission grid of Montenegro. Substation Trebinje is first neighbor to substation Tivat, which is connection spot for HVDC cable on Montenegrian side, so area of Trebinje appears as critical in case of export of power to Italy through the cable, regardless of position of generation source for this export.

The same conclusion concerning possible overloadings on the Croatian – Slovenian and Slovenian – Italian borders following the HVDC link outage given for 2015 study cases is valid for 2020 timeframe, too.

In case of large wind penetration, in area of SECI countries, there is one critical element in Romania (400 kV line Tantareni – Turceni).

Transformer 400/220 kV in Maritsa, in Bulgaria, is critical element in case of export of significant power from Turkey to west, because the most significant part of power exported from Turkey flows through substation Maritsa.

OHL 220 kV Orlovac – Konjsko (HR) noted as critical in large WPP integration scenario should be treated and reinforced within the WPP grid connection process, and not treated as the classic contingency problem of the regional importance.

Table 5.2.1. Summary on impacts of Different Uncertainties in Year 2020

Critical element	Base case	Power plants construction uncertainties				Connection to Italian/Turkish market uncertainties				Power balance uncertainties for the territories										
		TPP Kosovo	NPP Krsko 2	HPP Kozjak	WPP	AL - IT	ME - IT	HR - IT	RO - TR	AL	BG	BA	HR	MK	ME	RO	RS	SI	TR	UNMIK
Line 220 kV Dunamenti - Martonvasar (HU)	**X**		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Tie-line 220 kV Divaca (SI) - Padriciano (IT)		X	X			X														X
Tie-line 220 kV Pehlin (HR) - Divaca (SI)																				
Transformer 400/220 kV in Trebinje (BA)							X													
Transformer 400/220 kV in Pljevlja (ME)																				
Tie-line 220 kV Trebinje (BA) - Perucica (ME)																				
Line 220 kV Zakucac - Konjsko (HR)																				
Line 220 kV Zakucac - Imotski (HR)																				
Tie-line 220 kV Fierza (AL) - Prizren (RS)																				
Transformer 400/220 kV in Sibiu (RO)																				
Line 220 kV Lotru - Sibiu (RO)	**X**	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Line 220 kV Beograd 8 - Beograd 17 (RS)	**X**	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Transformer 400/220 in Maritsa East																			X	
Line 400 kV Sajoszoged - Detk (HU)									X									X		
Tie-line 400 kV Melina (HR) - Divaca (SI)																				
Line 220 kV Dobrudzha - Madara (BG)																				
Line 220 kV Focsani Vest - Barbosi (RO)																				
Transformer 400/220 in Rosiori (RO)																				
Line 220 kV Ungheni - Iernut (RO)																				
Line 400 kV Constanza - Cernavoda (RO)																				
Line 400 kV Tantareni - Turceni (RO)					X															
Line 220 kV Orlovac - Konjsko (HR)					X															
Line 220 kV Elbasan - Cekin (AL)	**X**	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

6. CONCLUSION

This Study is a part of continuing efforts of SECI Regional Transmission Planning Working Group on the harmonized transmission system planning in South East Europe. After working group establishment in 2001 detailed regional power system models for 2005, 2010, 2015 and 2020 were developed and harmonized in details, while at the same time several study activities have been undertaken.

The first study within this group was untitled "*Regional Electricity Interconnection Study*" [7] from 2002 and it was dealing with regional power system modelling and common transmission system development. The most important regional generation study was finished and issued in 2004 [1]. It was untitled "*Regional Balkans Infrastructure Study (REBIS) – Electricity and Generation Investment Study (GIS)*". 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). Within this study transmission system analyses were done by EIHP and EKC under SECI umbrella. Due to a number of significant changes that emerged since 2004, concerning primarily the growth of gas price and the decrease of imported coal price, the updating of original GIS was required. Consequently, in 2007 the study untitled „*Evaluation of Investments in Transmission Network to Sustain Generation and Market Development in SEE*" [4] was launched and issued by the same aforementioned group of authors in order to revise and identify an indicative priority list of 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 updated GIS study horizon. Finally, in 2007 the study untitled "*Transmission Network Investment Criteria*" [3] was also issued by EIHP and EKC under the same background of the SECI Transmission System Planning Group. Its aim was to establish transmission system planning criteria and methodology for regional transmission project prioritization.

The Study given in this document is continuation of all aforementioned activities. Namely, during all those studies transmission planners were faced to different uncertainties, even before introduction of market conditions in power system. Introduction of market environment makes transmission planning more difficult. Locations and capacities of new power plants, their biding behaviour, existence of the present ones in the future, consumer's reaction on instantaneous electricity price (price elasticity), electricity and power trading, hydrological conditions, branches and generators availability, regulatory aspects etc., are hard to be predicted even for the purpose of short-term planning. Network development based on deterministic power flow analyses of several possible system conditions will not give the clear picture of future transmission system operating conditions and transmission system investments will not be satisfactory evaluated, especially concerning a risk that is caused due to some uncertainties.

Besides Executive Summary presented in this document this Study consists of three parts: study body text, Appendix I and Appendix II. Due to large number of scenarios that have been analyzed here (73 scenarios), study body text comprises of more than 200 pages, with additional several hunderds of pages of detailed reports given in Appendices. Appendix I gives detailed TSO answers on the Questionnaire on the planning uncertainties that were used for determination of analyzed scenarios, while on the Appendix II detailed calculation results are presented.

This Study resulted with a large set of 73 scenario reports describing power exchanges, element loadings, security assessments, voltage profiles and network losses. Along with the detailed impact of every single scenario on the regional transmission system, in Chapter 5 of this Executive Summary the list of the most critical elements in the region is given. According to the summary of all analyzed uncertainty impacts the most critical elements in the region can be detected as follows:

- Tie-line 220 kV between Slovenia and Italy, Divača – Padriciano, appears as critical in the case of export of significant amount of power from east of the region to Italy, without commissioning of any Adriatic HVDC submarine cable.
- Transmission network in the area of Trebinje, in BiH (especially transformer 400/220 kV in Trebinje) appears as critical in the case of usage of HVDC cable Montenegro – Italy for exporting power to Italy, regardless of geographical position of generation source of the exported power. In addition, this transformer can appear as critical in case of export of power from BiH to south-east area of the region.
- Transmission network 220 kV in the area of Konjsko (220 kV path Konjsko – Zakučac – Imotski), in Croatia, appears as critical in case of usage of HVDC cable Croatia – Italy for exporting power to Italy.
- Transformer 400/220 kV in Maritsa, in Bulgaria, appears as critical in case of export of significant amount of power from Turkey to west of the region.
- Tie-line 220 kV between Croatia and Slovenia, Pehlin – Divača, appears as critical element in case of exchange of significant power between south-east part of the region and Italy (or Slovenia).
- In the case of HVDC cable Romania – Turkey, critical elements appear only in network of Romania, in area of connection spot of the HVDC (400 kV line Constanta – Cernavoda), in area of connection between Romania and Ukraine (transformer 400/220 kV in Rosiori) and 220 kV path which connects northwest Romania and east Romania (line 220 kV Unghenni – Iernut).

Special importance should be given to the possible network bottlenecks in the case of commissioning of HVDC submarine cable to Italy. For all three possible HVDC solutions between SEE and Italian market (Albanian, Montenegrin and Croatian) HVDC cable outage could cause serious overloadings on the Croatian – Slovenian and Slovenian – Italian borders, so additional network reinforcements are of utmost importance together with any option of HVDC link construction. It is estimated that other detected critical elements are mainly of local importance or that the problem can be released by local dispatching actions.

Finally, knowing that all inputs, questionnaire details, analyzed scenarios and detailed models were defined and harmonized by the responsible TSOs, this Study can be taken as one of the most detailed studies on transmission system development in South East Europe and good basis for prioritization of future regional transmission infrastructure investments.

Future activities should be focused on the detailed techno-economic analyses in order to eliminate detected regional bottlenecks. Also, additional detailed analyses of possible interchanges between SEE region and neighbouring regions/markets (Italy, Turkey, Central and Western Europe, UPS/IPS) should be further steps in evaluation of transmission infrastructure to sustain expected market development.

7. REFERENCES

[1] Regional Balkans Infrastructure Study (REBIS) – Electricity and Generation Investment Study (GIS); the World Bank, 2004

[2] Evaluation of investments in transmission network to sustain generation and market development in SEE; EIHP, EKC, 2007

[3] Transmission Network Investment Criteria; EIHP, EKC, 2007

[4] Memorandum of Understanding on the Regional Electricity Market in South East Europe and its Integration into the European Union Internal Electricity Market ("The Athens Memorandum – 2002"), 25 November 2002

[5] Memorandum of Understanding on the Regional Energy Market in South East Europe and its Integration into the European Community Internal Energy Market – The Athens Memorandum – 2003, 8 December 2003

[6] Treaty Establishing the Energy Community, 2005

[7] Regional Electricity Interconnection Study; EIHP, EKC, 2002