Appendix 13:

PSS/E ANALYSES AND RESULTS

Prepared By:
SECI Interconnection Study Task Group (ISTG)

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GENERATION INVESTMENT STUDY

Transmission network checking

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Complete GIS Report

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ABBREVIATIONS

Country codes

Country	Name	country code nodes	country code ISO
AUT	Österreich	O	AT
ALB	Shqiperia	A	AL
BUL	Bulgarija	V	BG
BiH	Bosna i Hercegovina	W	BA
SUI	Schweiz	S	CH
GER	Deutschland	D	DE
GRE	Hellas	G	GR
HUN	Magyarorszag	M	HU
CRO	Hrvatska	H	HR
ITA	Italia	I	IT
MKD	FYR Makedonija	Y	MK
ROM	Romania	R	RO
SLO	Slovenija	L	SI
TUR	Türkiye	T	TR
UKR	Ukraina	U	UA
SCG	Srbija i Crna Gora	J	CS
--	Fictitious border node	X	--

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
FACTS	Flexible AC transmission systems
GDP	Gross domestic product
MW/Mvar	Megawatt/Megavar
HV	High voltage
NTC	Net Transfer Capacity
SEE	South Eastern European Countries
SECI	**S**outh East **E**uropean **C**ooperation **I**nitiative
RTSM	Regional transmission system model
TRM	Transmission Reliability Margin
TSO	Transmission System Operator
TR	Transformer
HL	High voltage line
OHL	Overhead high voltage line
PSS/E	Power System Simulator for Engineering

Abbreviations of Electric power utilities and Transmission system operators:

EPCG	Electric power utility of Montenegro
EPS	Electric power utility of Serbia
HTSO	Hellenic transmission system operator
CENTREL	Association of transmission system operators of Czech, Hungary, Poland, and Slovakia
UCTE	Union for the Coordination of Transmission of Electricity

1 INTRODUCTION

The main objective of the Generation Investment Study is to assist the EC, IFIs and donors in identifying an 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 study would determine what the optimal timing, size and location would be of future generating capacity in the region over the next 15 years (2005 – 2020). It will also identify 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 expansion of the generation system will be optimized over a 15 year horizon (2005 – 2020) for three scenarios (isolated operation of each power system, regional operation of power systems, market conditions) using the WASP and GTMax models.

The third scenario includes power system constraints, such as the capacity of the interconnections, and other constraints such as the maximum amount of import capacity and energy each country will be willing to depend upon. For the analysis of the third scenario the study team used, in addition to the WASP model, the Generation and Transmission Maximization Model (GTMax). GTMax was used to perform modeling of the electricity grid operated under the SEE REM conditions. It took into account the transfer capabilities of the interconnection lines among the utility systems.

For more detailed view on regional transmission network operation under market conditions SECI Regional Transmission System Model in PSS/E was used. Input data concerning demand and production for several scenarios analyzed in GTMax was used in PSS/E Regional Transmission System Model (PSS/E RTSM) in order to check feasibility of such demand/production scenarios from transmission network prospective.

PSS/E RTSM was created by SECI (South East Europe Cooperative Initiative) Project Group on the Regional Transmission System Planning, sponsored by USAID. With a participation of all power system utilities in South-East Europe, the Project Group finalized PSS/E RTSM for year 2005 and 2010, suitable for load flow, short-circuit and dynamic analysis. The following countries/companies were involved in PSS/E RTSM creation: Albania – KESH; Bosnia and Herzegovina – ZEKC, EPBiH, EPRS, EPHZHB; Bulgaria – NEK; Croatia – HEP, EIHP; Macedonia – ESM; Greece – PPC/HSTO; Hungary – MVM; Romania – Transelectrica; Serbia and Montenegro – EPS, EKC, EPCG; Slovenia – ELES; Turkey – TEAS. Two models were created for each time horizon: winter maximum demand and summer minimum demand models for 2005 and 2010.

Analysis on PSS/E RTSM should provide insight to transmission network adequacy and determine what transmission reinforcements or additions priorities are eventually required to meet GTMax 2010 and 2015 generation dispatch under normal and (n-1) operating conditions.

Total of 14 GTMax scenarios were analyzed on PSS/E RTSM:

Scenario 2010 - topology 2010
- average hydrology
- dry hydrology
- wet hydrology

Scenario 2015
- average hydrology
    - topology 2010
    - topology 2015
- dry hydrology
    - topology 2010
    - topology 2015

- wet hydrology - topology 2010
- topology 2015

Scenario 2010
– average hydrology import/export – topology 2010
high load – topology 2010
Scenario 2015
– average hydrology import/export – topology 2010
– topology 2015
high load – topology 2010
– topology 2015

PSS/E RTSM was adjusted according to GTMax model concerning network topology, demand, production and exchange data. SEE Region was observed as self sufficient without any additional exchanges with UCTE.

For each GTMax scenario steady-state load flows were calculated and contingency analyses (n-1) were performed. Security criterion based on voltage profile and lines congestions (thermal loadings) were checked for each analyzed scenario. Special attention was directed on existing and planned interconnection lines between different SEE power systems (countries).

Possible network bottlenecks were identified and some solutions for transmission system relief were described. The role of new interconnection lines candidates in bottlenecks removal was evaluated.

Following chapters describe PSS/E RTSM, analyzed GTMax production, demand and exchange scenarios, results of load flow and contingency analyses. List of important regional transmission system infrastructure projects from a viewpoint of support given to analyzed GTMax dispatch scenarios is presented at the end of this report.

2. STARTING CONDITIONS

2.1. Description of PSS/E Model

For all calculations performed in this part of the study, professional software package PSS/E™ (Power System Simulator for Engineering) is used. The Power System Simulator for Engineering (PSS/E) model 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
- Equivalent Construction

Since its introduction in 1976, the PSS/E tool has become the most comprehensive, technically advanced, and widely used commercial program of its type. It is widely recognized as the most fully featured, time-tested and best performing commercial product available in the market. The program employs the latest technology and numerical algorithms to efficiently solve networks large and small.

PSS/E is comprised of the following modules:

PSS/E Power Flow: This module is basic PSS/E program module and it is powerful and easy-to-use for basic power flow network analysis (Figure 2.1.1). Besides analysis tool this module is also used for Data handling, updating, and manipulation.

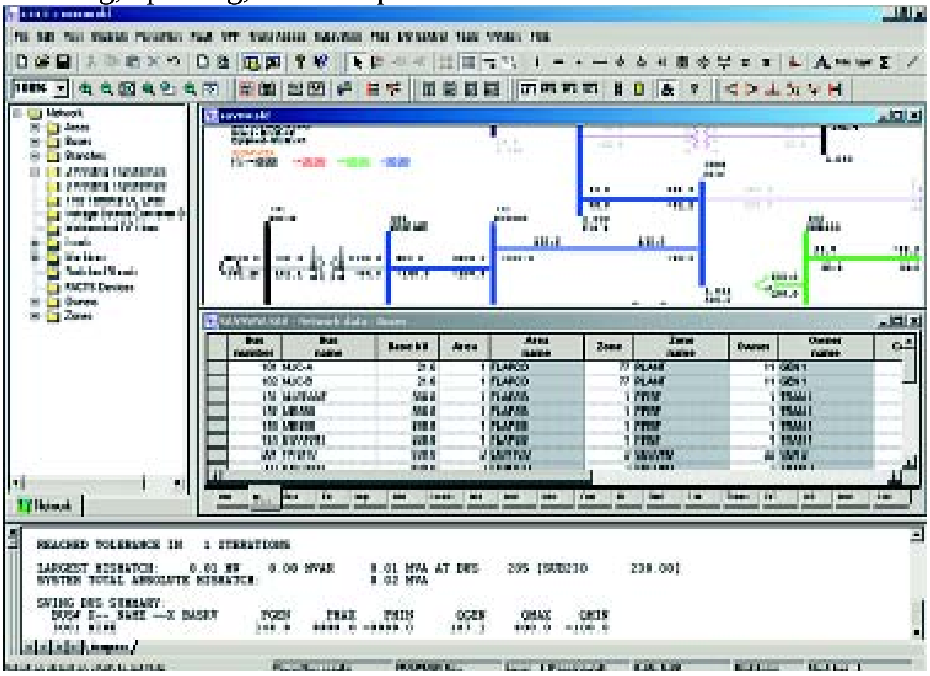


Figure 2.1.1 – PSS/E model Graphical interface

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.

Whereas the conventional load flow relies on an engineer to systematically investigate a variety of solutions before arriving at a satisfactory solution, PSS/E OPF directly changes controls to quickly determine the best solution. From virtually any reasonable starting point, you are assured that a unique and globally optimal solution will be attained; one that simultaneously satisfies system limits and minimizes costs or maximizes performance.

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 actual voltage profile from the solved power flow case.

PSS/E Dynamic Simulation: PSS/E offers users uncompromising dynamic simulation capabilities. It 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.

The organization of PSS/E is illustrated in the following figure Figure 2.1.2:

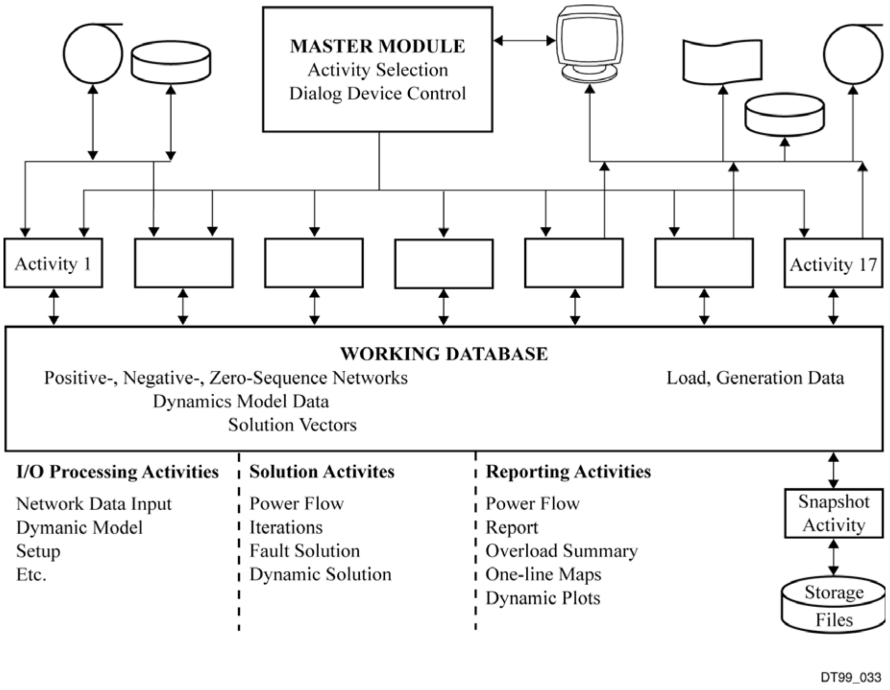


Figure 2.1.2 – Organization of PSS/E model modules

Current version of this software package and version used for calculations is version 30.2.

2.2. Prerequisites and Assumptions

For more detailed view on regional transmission network operation under market realistic conditions SECI Regional Transmission System Model (RTSM) in PSS/E is used. Figure 2.1.1 shows which countries and their transmission systems were modeled.

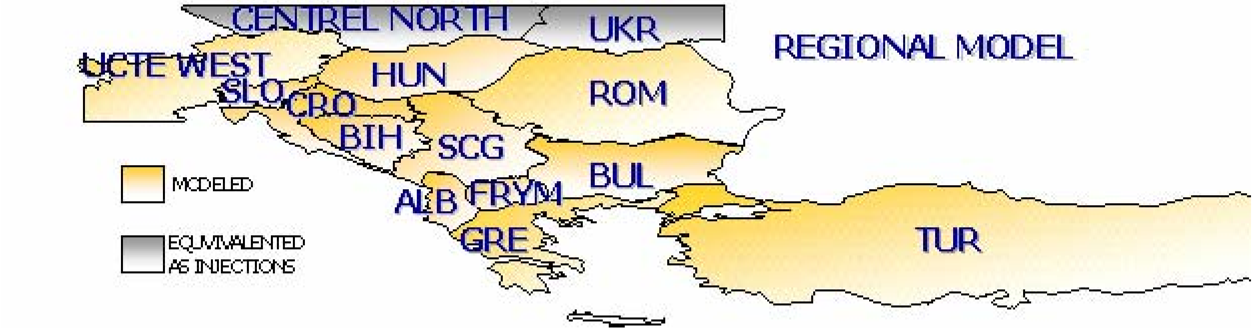


Figure 2.2.1 - SECI Regional Transmission System Model – countries modeled

High voltage transmission network of 750 kV, 400kV, 220kV, 150kV (Greece and Turkey), and 110 kV voltage levels is implemented in the model. Also, all new substations and lines that are expected to be operational till 2010 (according to the long term development plans) are modeled too. All generation units that are connected to the transmission voltage level are modeled as they are in reality (with step-up transformers). Model is designed for load-flow calculations and analysis, but with adequate data input (already developed and tested) it can be used for other type of analysis too:

- Short-circuit calculations
- Dynamics (transient stability assessment)

Figure 2.2.2 shows the main characteristics of the SECI Regional Transmission System Model. With adequate changes and appropriate data input this model is used for all calculations and analyses in this project.

AREA	ALBANIA			BULGARIA			BIH			CROATIA			HUNGARY			GREECE			FYRM			ROMANIA		
	10			20			30			40			45			50			60			70		
ELEMENT TYPE	#	W	S	#	W	S	#	W	S	#	W	S	#	W	S	#	W	S	#	W	S	#	W	S
BUSES	**97**	97	97	**635**	602	586	**236**	230	231	**247**	247	245	**47**	45	47	**993**	889	749	**117**	117	117	**1067**	1006	963
PLANTS	**14**	12	14	**112**	81	65	**38**	36	36	**59**	59	59	**8**	8	8	**100**	84	56	**22**	22	22	**132**	183	139
MACHINES	**30**	23	13	**144**	84	49	**42**	27	10	**62**	52	32	**23**	22	12	**107**	86	54	**22**	20	3	**132**	182	87
LOADS	**72**	72	72	**644**	606	590	**137**	131	131	**162**	147	147	**32**	32	33	**415**	379	267	**78**	76	73	**831**	711	679
LINES	**107**	107	107	**747**	711	709	**278**	260	261	**325**	308	308	**249**	202	202	**1051**	901	789	**145**	138	138	**1295**	1135	1135
400	**4**			**40**			**13**			**21**			**114**			**96**			**10**			**47**		
220	**21**			**56**			**39**			**28**			**135**						**3**			**114**		
150																								
110	**82**			**651**			**226**			**276**						**933**			**132**			**1134**		
66																**8**								
30																**14**								
TRANSFORMERS	**50**	44	39	**170**	129	110	**72**	66	65	**95**	93	93	**12**	12	12	**260**	236	208	**32**	32	32	**293**	203	158
STEP UP	**23**			**102**			**38**			**60**			**0**			**94**			**22**			**144**		
NETWORK	**27**			**68**			**34**			**35**			**12**			**166***			**10**			**149**		

AREA	SLOVENIA			TURKEY			SERBIA			MONTENEGRO			SCG			UKRAIN			UCTE-WEST			CENTREL			**REGIONAL**		
	75			80			90			91			90			65			55			95			**MODEL**		
ELEMENT TYPE	#	W	S	#	W	S	#	W	S	#	W	S	#	W	S	#	W	S	#	W	S	#	W	S	#	**W**	**S**
BUSES	**190**	190	190				**417**	408	368	**43**	39	35	**460**	447	403	3	3	3	**88**	88	88	2	2	2	**4182**	**3963**	**3721**
PLANTS	**57**	48	44				**69**	63	25	**11**	7	3	**80**	70	28	3	3	3	**34**	32	30	2	2	2	**661**	**640**	**506**
MACHINES	**63**	54	23				**77**	71	25	**11**	7	3	**88**	78	28	3	3	3	**34**	31	25	2	2	2	**752**	**664**	**341**
LOADS	**111**	111	111				**251**	249	240	**19**	19	19	**270**	268	259	0	0	0	**72**	72	71	0	0	0	**2824**	**2605**	**2433**
LINES	**232**	231	231	**0**			**502**	471	468	**50**	48	48	**552**	519	516	**5**	5	5	**156**	149	151	**2**	2	2	**5144**	**4668**	**4554**
400	**14**						**41**			**5**			**46**						**46**						**451**	**0**	**0**
220	**9**						**64**			**11**			**75**						**110**						**590**	**0**	**0**
150																									**0**	**0**	**0**
110	**209**						**397**			**34**			**431**												**4074**	**0**	**0**
66																									**8**	**0**	**0**
30																									**14**	**0**	**0**
TRANSFORMERS	**75**	75	75	**0**			**139**	129	92	**21**	17	13	**160**	146	105	0	0	0	**19**	19	19	0	0	0	**1238**	**1055**	**916**
STEP UP	**57**						**72**			**11**			**83**						**0**						**623**	**0**	**0**
NETWORK	**18**						**67**			**10**			**77**						**19**						**615**	**0**	**0**

#	total number of elements
W	number of elements with status in in Winter maximum model
S	number of elements with status in in Summer minimum model
*	- equivalent lines included

Figure 2.2.2 – SECI Regional Transmission System Model – model characteristics

Input data concerning demand and production for several scenarios analyzed in GTmax are used ase input data for PSS/E RTSM in order to check feasibility of such demand/production scenarios from transmission network prospective.

Electric power systems presented on Figure 2.2.3 are more detail modeled according to GTmax results.

Figure 2.2.3: Analyzed electric power systems

For the purpose of network analyses, following network models in PSS/E software tool are developed according to GTmax:

Reference cases:

Year	Hydrology	Topology
2010	average	2010
	dry	
	wet	
2015	average	2010
		2015
	dry	2010
		2015
	wet	2010
		2015

Sensitivity cases (average hydrology):

Special conditions	Year	Topology
Import/Export	2010	2010
	2015	2010
		2015
High load	2010	2010
	2015	2010
		2015

For all these models, expected topology and load distribution in corresponding system substations are modeled. In Regional Transmission Network Model for the years 2010 and 2015 the most recent information including new planed lines generator units with step-up transformers, transformers, compensators, phase shift transformers, shunts, etc are included. Generator units are connected at generator voltage level.

In the models, whole 110 kV and above network is included. Each interconnection line has assigned an X node which is placed on border of each country (not at middle of tie line). The model for year 2015 is obtained by increasing production and consumption in each electric power system according to results from GTmax calculation and respect to new planed lines and substations.
Voltage levels, with the upper and lower limits used in the study, are presented in the Table 2.2.1 These limits are used in load-flow calculations as in contingency analysis.

Table 2.2.1: 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 according to the operational and planning standards used in the monitored region, and they are 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.

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 outage cause “island” operation (in case of parallel lines and double circuit lines, outage of one line-circuit is considered);
- all transformers 400/x 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 based on 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. For these analyses is used that conductor current must not reach limits imposed by thermal limit defined for conductors material and cross-section according to standard the IEC (50) 466: 1995 – International Electro technical Vocabulary - Chapter 466: Overhead Lines. For transformers, rated installed 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 this study.

2.3. Technical Specification of New Transmission Lines Candidates and Substations

Interconnection lines between analyzed electric power systems are presented on the Figure 2.3.1 and Table 2.3.1.

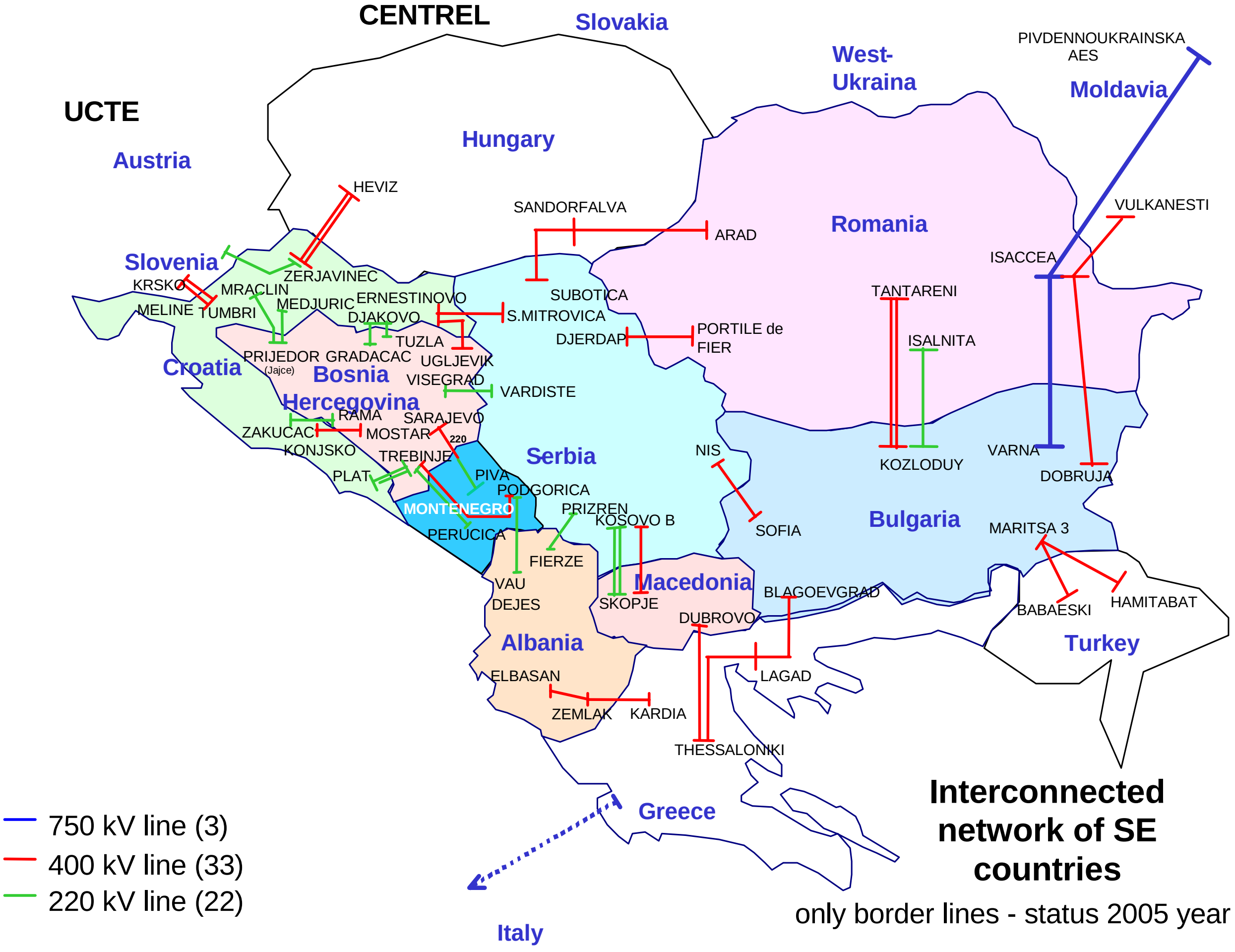


Figure 2.3.1: Interconnection lines in Southeast Europe in 2005 year

Planned interconnection lines in Southeastern Europe for years 2010 and 2015 are given in Figure 2.3.2 and Table 2.3.2 and Table 2.3.3. All of these planned interconnection lines are included in PSS/E models for target years respectively, depending of years of commissioning.

Basic technical data of new interconnection transmission lines candidates which are analyzed in 2015 year as variants only, are shown in Table 2.3.4. It should be noted that new interconnection transmission lines candidates, which are shown as doted lines, are analyzed in 2015 year as variants only.

Table 2.3.1: List of interconnection lines in Southeast Europe in 2005 year

Interconnection line	Interconnected countries	Voltage level (kV)	Conductors			Transfer Capacity (MVA)	length 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 - Lagad (Thesaloniki)	BG - GR	400	ACSR	500	2	1309	72	102	174
Dobruja - 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
Kozlodui - Tintareni (double)	BG - RO	400	ACSR	500/300	2/3	2490	14	102	116
Sofia - Nis	BG - SER	400	ACSR	500	2	1330	37	86	123
Maritsa Istok - Babeski	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 - SER	400	ACSR	490	2	1330	36	68	104
Arachtos - Galatina HVDC	GR - IT	400	HVDC			500	/	/	0
Gyor - Wien Sud (double)	HU - AT	400	ACSR	500	2	2563	59	63	122
Podgorica - Trebinje	MN - 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	RO - SER	400	ACSR	967	2	1330	1	2	3
Rosiori - Mukachevo	RO - UA	400	ACSR	450	2	1212	39	36	75
S. Mitrovica - Ernestinovo	SER - HR	400	ACSR	490	2	1330	41	52	93
Subotica - Sandorfalva	SER - HU	400	ACSR	490	2	1330	27	21	48
Maribor - Keinchtal (double)	SI - AT	400	ACSR	490	2	1330	26	37	63
Divaca - Meline	SI - HR	400	ACSR	490	2	1318	41	26	66
Krsko - Tumbri (double)	SI - HR	400	ACSR	490	2	1318	16	32	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
V.Dejes - Podgorica	AL - MN	220	ACSR	360	1	301	47	21	68
Fierze - Prizren	AL - SER	220	ACSR	360	1	301	26	45	71
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	BA - HR	220	ACSR	240	2	491	7	5	12
Trebinje - HE Dubrovnik	BA - HR	220	ACSR	240	2	491	7	5	12
Trebinje - HE Perucica	BA - MN	220	ACSR	360	1	301	20	42	63
Sarajevo20 - HE Piva**	BA - MN	220	ACSR	490	2/1	366	61	23	84
Visegrad - Pozega	BA - SER	220	ACSR	360	1	301	18	51	69
Zerjavinec - Cirkovce	HR - SI	220	ACSR	360	1	300	19	51	70
Skopje - Kosovo A	MK - SER	220	ACSR	360	1	301	18	65	82
Skopje - Kosovo A	MK - SER	220	ACSR	360	1	301	18	65	82
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	65
Divaca - Pehlin	SI - HR	220	ACSR	490	1	350	47	6	53
Divaca - Padriciano	SI - IT	220	ACSR	490	1	366	10	2	11
Mukachevo - Kisvarda	UA - HU	220	ACSR	400	1	308	54	10	64
Mukachevo - Tiszalok	UA - HU	220	ACSR	400	1	308	97	35	132

*not in model

**built as 400kV line Sarajevo20 - B.Bijela and 220kV B.Bijela - Piva, but operated as 220kV Sarajevo20 - Piva

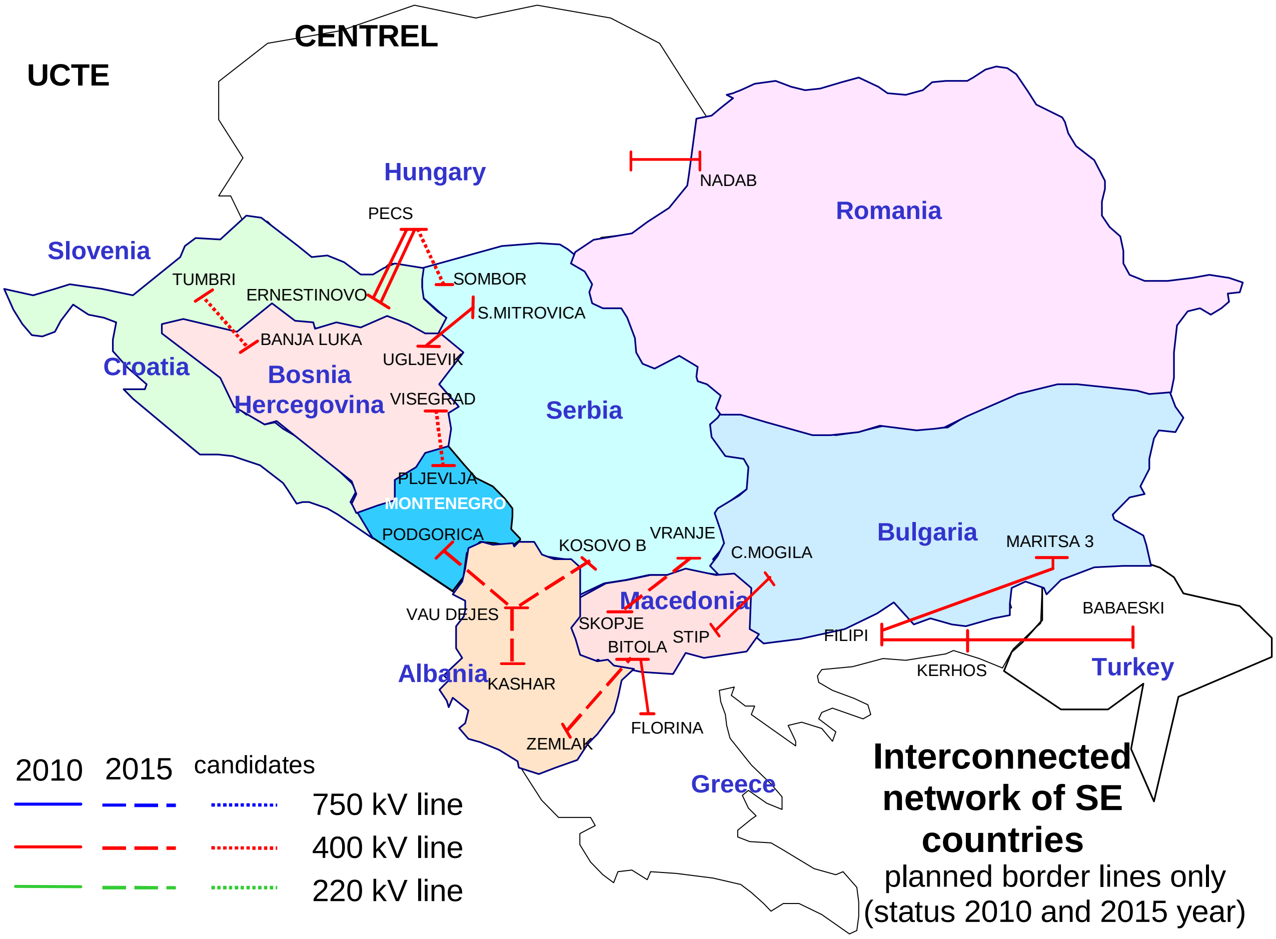


Figure 2.3.2: Planned interconnection lines in Southeast Europe in years 2010 and 2015

Table 2.3.2: List of interconnection lines in Southeast Europe, planned to come into operation in year 2010

Interconnection line	Interconnected countries	Voltage level (kV)	Conductors			Transfer Capacity (MVA)	length km		
			Type	Size (mm2)	Number per phase		I to border	border to II	total
Ugljevik - S. Mitrovica	BA - SER	400	ACSR	490	2	1330	49	29	79
Kashar - Podgorica	AL - MN	400	ACSR	490	2	1330	115	30	145
Maritsa Istok - Filipi	BG - GR	400	ACSR	400	3	1715	133	110	243
C. Mogila - Stip	BG - MK	400	ACSR	490	2	1330	80	70	150
Ernestinovo - Pecs (double)	HR - HU	400	ACSR	490/500	2	1330	44	41	85
Bekescaba - Nadab (Oradea)	HU - RO	400	ACSR	490	2	1178	31	87	118
Florina - Bitola	GR - MK	400	ACSR	490	2	1330	20	18	38
(Filipi) - Kehros - Babaeski	GR - TR	400	ACSR	400	3	1715	50	50	100

Table 2.3.3: List of interconnection lines in Southeast Europe, planned to come into operation in year 2015

Interconnection line	Interconnected countries	Voltage level (kV)	Conductors			Transfer Capacity (MVA)	length km		
			Type	Size (mm2)	Number per phase		I to border	border to II	total
Zemlak - Bitola	AL - MK	400	ACSR	490	2	1330	25	60	85
Kashar (V. Dejes) - Kosovo B	AL - SER	400	ACSR	490	2	1330	135	80	215
Skopje - Vranje - (Leskovac) - (Nis)	MK - SER	400	ACSR	490	2	1330	55	137	192

Table 2.3.4: New transmission lines candidates

Interconnection line	Interconnected countries	Voltage level (kV)	Conductors			Transfer Capacity (MVA)	length km		
			Type	Size (mm2)	Number per phase		I to border	border to II	total
Visegrad - Pljevlja	BA - MN	400	ACSR	490	2	1330	30	30	60
Tumbri - Banja Luka	HR - BA	400	ACSR	490	2	1330	50	150	200
Pecs - Sombor	HU - SER	400	ACSR	490	2	1330	20	60	80

All interconnection lines candidates that are investigated in the analyses are shown as dotted lines in Figure 2.3.2. Table 2.3.5 shows typical electrical parameters of different types of lines. These parameters are used for both the planned lines and interconnection lines candidates in the Study.

Table 2.3.5: Electrical parameters for OHL per phase and kilometer

*Type of conductor		A	-	B*	C
Positive sequence		ACSR	ACSR	CARDINAL	ACSR
		2x490 mm2	1x490 mm2	3x400 mm2	360 mm2
Series resistance	r [Ω/km per phase]	0.0294	0.058	0.0207	0.08
Series reactance	x [Ω/km per phase]	0.341	0.427	0.2824	0.436
Charging susceptance	b [μS/km per phase]	3.371	2.67	4.056	2.6
Rated current [A]		1920	960	2292	790

* In Turkey and Greece, Canadian-American standards are used

Costs of the New Interconnection Overhead Lines

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 overhead line route will involve three types of tower:

- suspension (used for straight lines),
- deviation (where the route changes direction),
- 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). In Table 2.3.6 and Table 2.3.7 average estimated prices for each new element that is expected to be in operation in 2010 and 2015 year are presented.

Total investment values for lines construction and corresponding elements till 2010 year is presented in Table 2.3.6 in EUROS. 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 following elements:

- construction of 400 kV transmission line itself
- transmission line bays (400 kV)
    - Breakers
    - Disconnectors with blades ground
    - Disconnectors without blades

- Current Measuring Transformers
- Voltage Measuring Transformers
- Lightning Arrester

These total price values of lines do not take into consideration lease of land.

Table 2.3.6: Total investment sum of interconnection lines in Southeast Europe, planned in year 2010

Interconnection line	Interconnected countries	Lines			TL Bays			Lines & Bays	Year of commisionning
		Length km	Unit price Euro/km	Total price Euro	Unit price Euro	Number of bays	Total price Euro	Total price Euro	
Ugljevik - S. Mitrovica	BA - SER	79	200,000	15,720,000	650,000	2	1,300,000	17,020,000	2005/06
Kashar (V. Dejes) - Podgorica	AL - MN	145	235,000	34,075,000	650,000	2	1,300,000	35,375,000	2006/07
Maritsa Istok - Filipi	BG - GR	243	235,000	57,105,000	650,000	2	1,300,000	58,405,000	2007/08
C. Mogila - Stip	BG - MK	150	220,000	33,000,000	650,000	2	1,300,000	34,300,000	2006/07
Ernestinovo - Pecs (double)	HR - HU	85	240,000	20,400,000	650,000	2	1,300,000	21,700,000	2007/08
Bekescaba - Nadab (Oradea)	HU - RO	118	250,000	29,500,000	650,000	2	1,300,000	30,800,000	2008
Florina - Bitola	GR - MK	38	235,000	8,930,000	650,000	2	1,300,000	10,230,000	2006/07
(Filipi) - Kehros - Babaeski	GR - TR	100	240,000	24,000,000	650,000	2	1,300,000	25,300,000	2007/08

Comments:

- Interconnection line 400 kV Ugljevik (BA) – S.Mitrovica (CS).

  This tie line should increase system stability, security and transmission capacity between west and east region and between Bosnia and Serbia and Montenegro. It is under construction (part in Bosnia is finished) and should be completed by the end of this year.

- Interconnection line 400 kV Podgorica (CS) – Kashar (V.Dejes) (AL)

  This new tie line should increase system stability, security and transmission capacity between west and east (CS–AL–GR). Feasibility Study was made two years ago. Participation for construction of this line will be proportional to the length of the line from the border (27 km in Montenegro and 115 km in Albania). It should be completed by the year 2006/7. Estimated investment cost is about 35,375 M€.

- Interconnection line 400 kV Maritsa Istok (BG) – Filipi (GR).

  Feasibility Study was made 3 two years ago. Participation for construction of this line will be proportional to the length of the line from the border (133 km in Bulgaria and 110 km in Greece). To be completed by the year 2007/8. Estimated investment cost is about 58,5 M€ and investor is unknown yet.

- Interconnection line 400 kV C. Mogila (BG) – Stip (MK)

  Feasibility Study was made 2-3 two years ago. This new tie line should increase system stability, reliability, security and transmission capacity between north and south as well as between Bulgaria and Macedonia. Participation for construction of this line will be proportional to the length of the line from the border (80 km in Bulgaria and 70 km in Greece). It should completed by the year 2006/7. Estimated investment cost is about 35 M€. Investor is unknown yet.

- Interconnection line 400 kV Ernestinovo (HR) – Pecs (HU) (double line)

  This tie line should increase system stability, security and transmission capacity between north and south regions and between Croatia and Hungary. It is included development plans of HEP (Electric Company of Croatia) and MVM (Electric Company of Hungary). It should be completed by the year 2007/8. Estimated investment cost is about 21.7 M€. Investor is unknown yet.

- Interconnection line 400 kV Bekescsaba (HU) – Nadab (Oradea) (RO)

  Construction Agreement between MVM and Transelectrica is under signing procedure. It should be completed by the year 2008.

- Interconnection line 400 kV Florina (GR) – Bitola (MK)

  Feasibility Study was made 3 two years ago. This line should increase system security and transmission capacity between north and south (MK–GR). Participation for construction of this line will be proportional to the length of the line from the border (20 km in Greece and 18 km in Macedonia). It should be completed by the year 2006/7. Estimated investment cost is about 10 M€. Investor is unknown yet.

- Interconnection line 400 kV Filipi (Kehros) (GR) – Babaeski (TR)

  Feasibility Study was made 2-3 two years ago. Participation for construction of this line will be proportional to the length of the line from the border (190 km in Greece and 70 km in Turkey). It should be completed by the year 2007/8. Estimated investment cost is about 25 M€. Investor is unknown yet.

Total investment values for lines construction and corresponding elements till 2015 is presented in Table 2.3.7 in EUROS. The investments cover total length of transmission line and construction of 400 kV bays in both substations.

Table 2.3.7: Total investment sum of interconnection lines in Southeast Europe, planned in year 2015

Interconnection line	Interconnected countries	Lines			TL Bays			Lines & Bays	Year of commissioning
		Length km	Unit price Euro/km	Total price Euro	Unit price Euro	Number of bays	Total price Euro	Total price Euro	
Zemlak - Bitola	AL - MK	85	200,000	17,000,000	650,000	2	1,300,000	18,300,000	2010/15
Kashar (V. Dejes) - Kosovo B	AL - SER	215	220,000	47,300,000	650,000	2	1,300,000	48,600,000	2010/15
Skopje - Vranje - (Leskovac) - (Nis)	MK - SER	192	240,000	46,080,000	650,000	2	1,300,000	47,380,000	2010/15

Comments:

- Interconnection line 400 kV Zemlak (AL) – Bitola (MK)

  It is included in development program of KESH-Albania. Estimated investment cost is about 18 M€. Investor is unknown yet.

- Interconnection line 400 kV Kashar (V.Dejes) – Kosovo B (CS)

  It is included in transmission development program of KEK-Kosovo. Estimated investment cost is about 48 M€. Investor is unknown yet.

- Interconnection line 400 kV Skopje (MK) – Vranje – (Leskovac – Nis) (CS)

  This tie line should increase transmission capacity, system stability and security between north and south. Feasibility Study was made one year ago. Estimated investment cost is about 21 M€ (for Skopje – Vranje) plus about 26 M€ (for Vranje – Leskovac – Nis). Donation of Greece government is expected. First phase of the project is building of the Skopje–Leskovac–Nis, and in second phase is installing of the substation Vranje on this line.

Costs of New Substations in 2010 and 2015

The purpose of the substation (or switchyard) is to transform the voltage of electricity or switch electricity circuits. Substations are usually contained within secure sites to ensure public safety. Most substations today are unmanned sites although road access is necessary for staff and for the transport of equipment, maintenance or repair. Table 2.3.8 and Table 2.3.9 present total investment costs that include costs of following elements:

- transformer unit
- transformer bays (400 kV, 220 kV, 110 kV)
    - Breakers
    - Disconnectors without blades
    - Current Measuring Transformers
    - Voltage Measuring Transformers
    - Lightning Arrester

Also these tables show investment cost for all linked lines between existed transmission lines and new substations.

Table 2.3.8: new SS which will be in operation till 2010 year

2010

Country	Position*	Name of substation	Voltage levels kV/kV	New transformers MVA	Remarks	Total cost in Euros
Albania	1	Kashar	400/220	2x400		**4,100,000**
Bulgaria	2	Sofia South	220/110	1x250	new transformer only	1,830,000
	3	Maritsa East 1	400/220	1x630	phase-shifter	3,600,000
	4	Pleven	220/110	1x200	new transformer only	1,730,000
					Total	**7,160,000**
Croatia	5	Ernestinovo	400/110	1x300	new transformer only	**2,730,000**
Macedonia	6	Stip	400/110	1x300		**3,430,000**
Romania	7	Nadab	400		no transformer	1,400,000
	8	Oradea	400/110	1x300	new transformer only	2,730,000
					Total	**4,130,000**
Serbia	9	S. Mitrovica	400/220	1x400		3,150,000
	10	Beograd 20	400/110	1x300	new transformer only	2,730,000
	11	Kolubara B	400/110	2x300		5,930,000
					Total	**11,810,000**
UNMIK	12	Pec	400/110	1x300		**4,130,000**

*position in geographical map (Figure 2.4.2)

Table 2.3.9: new SS which will be in operation till 2015 year

2015

Country	Position*	Name of substation	Voltage levels kV/kV	New transformers MVA	Remarks	Total cost in Euros
Albania	13	V. Dejes	400/200	1x400		**3,150,000**
Romania	14	Brasov	400/110	1x300	new transformer only	2,730,000
	15	Suceava	220/110	1x200	new transformer only	1,730,000
					Total	**4,460,000**
Serbia	16	Nis	400/110	1x300	new transformer only	2,730,000
	17	Vranje	400/110	1x300		4,130,000
					Total	**6,860,000**

*position in geographical map (Figure 2.4.4)

2.4. Remarks on PSS/E Transmission System Model and GTmax Model Harmonization

To investigate regional market conditions in region, GTmax software tool is used. Unlike PSS/E, with this software tool you can not analyze network conditions. Only in rough congestion analyses is possible. In order to check, whether production distribution, that is result of GTmax analyses is feasible from transmission system capabilities point of view, results from GTmax analyses has been used as input for PSS/E regional models, and then full security analysis of thus gained models has been performed.

Load-demand

GTmax load-demand level is distributed only in few GTmax network buses, unlike PSS/E model where load distribution corresponds to the real system conditions (substation by substation). Also, GTmax load-demand level includes transmission network losses, unlike PSS/E model where these losses are calculated separately. In other words, it was not possible to achieve full load-demand correspondence between GTmax and PSS/E model.

In order to achieve at least partial correspondence between GTmax load-demand and PSS/E load (on system by system level), existing load distribution in PSS/E model is scaled so level of PSS/E load increased for transmission network losses corresponds to GTmax load-demand level. Also, for some systems, production of units installed on voltage levels lower than 110 kV is included in load-demand level (load-demand is reduced for this amount). This was done system by system.

Network topology

In order for PSS/E network models to correspond to GTmax model, first step was to adjust network topology of both PSS/E and GTmax models. Topology of GTmax models for 2010 and 2015 are shown on Figure 2.4.1 and Figure 2.4.3 and corresponding real network topologies of regional network shown on Figure 2.4.2 and Figure 2.4.4.

As it can be seen, the internal system topologies are quite rough, unlike topology of system interconnections (tie lines), which are almost identical (that was one of prerequisites of GTmax model).

Transmission system model for 2015 was gained using existing model for 2010. All new interconnection lines that are predicted to be in operation in GTmax's model are also included in PSS/E model. Also, all internal network reinforcements that are in long term plans of regional TSOs are modeled too.

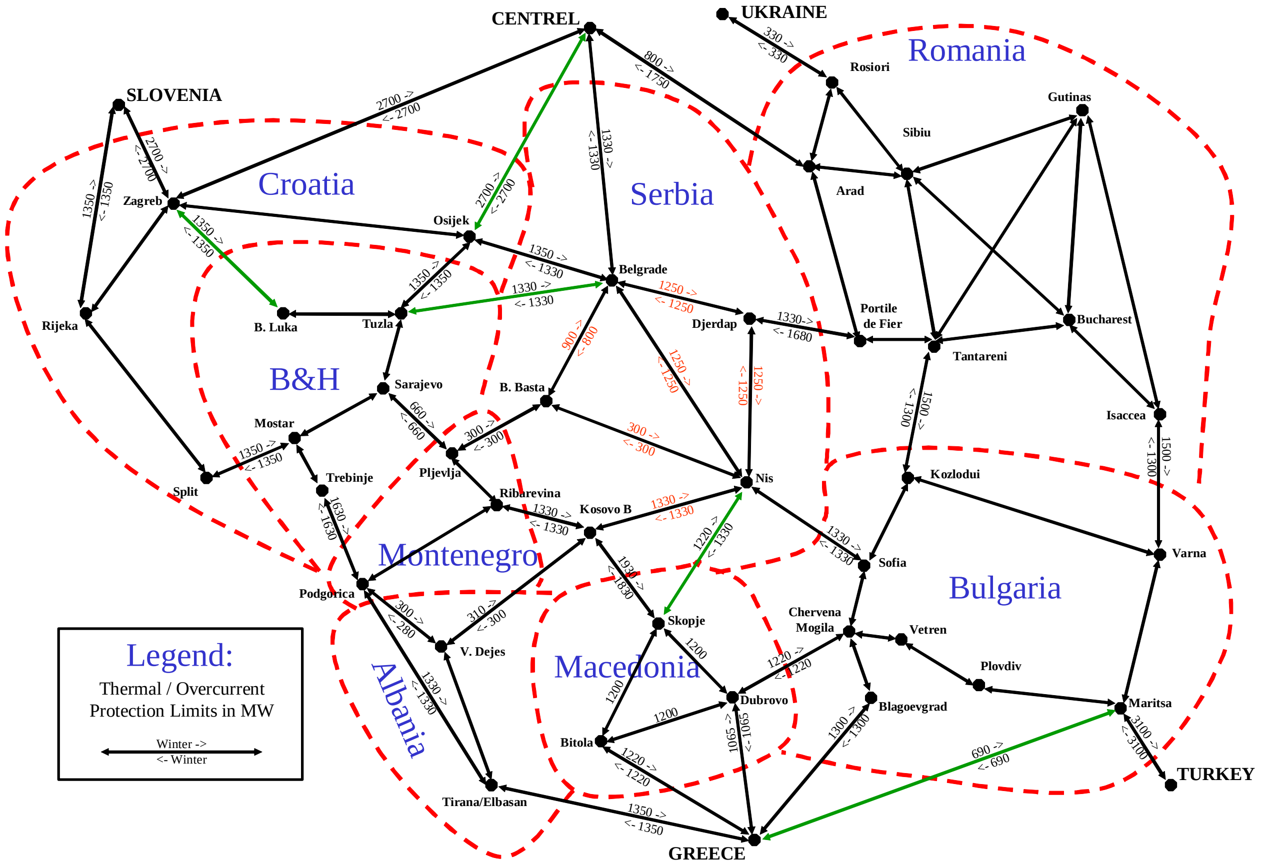


Figure 2.4.1: GTmax network topology in year 2010

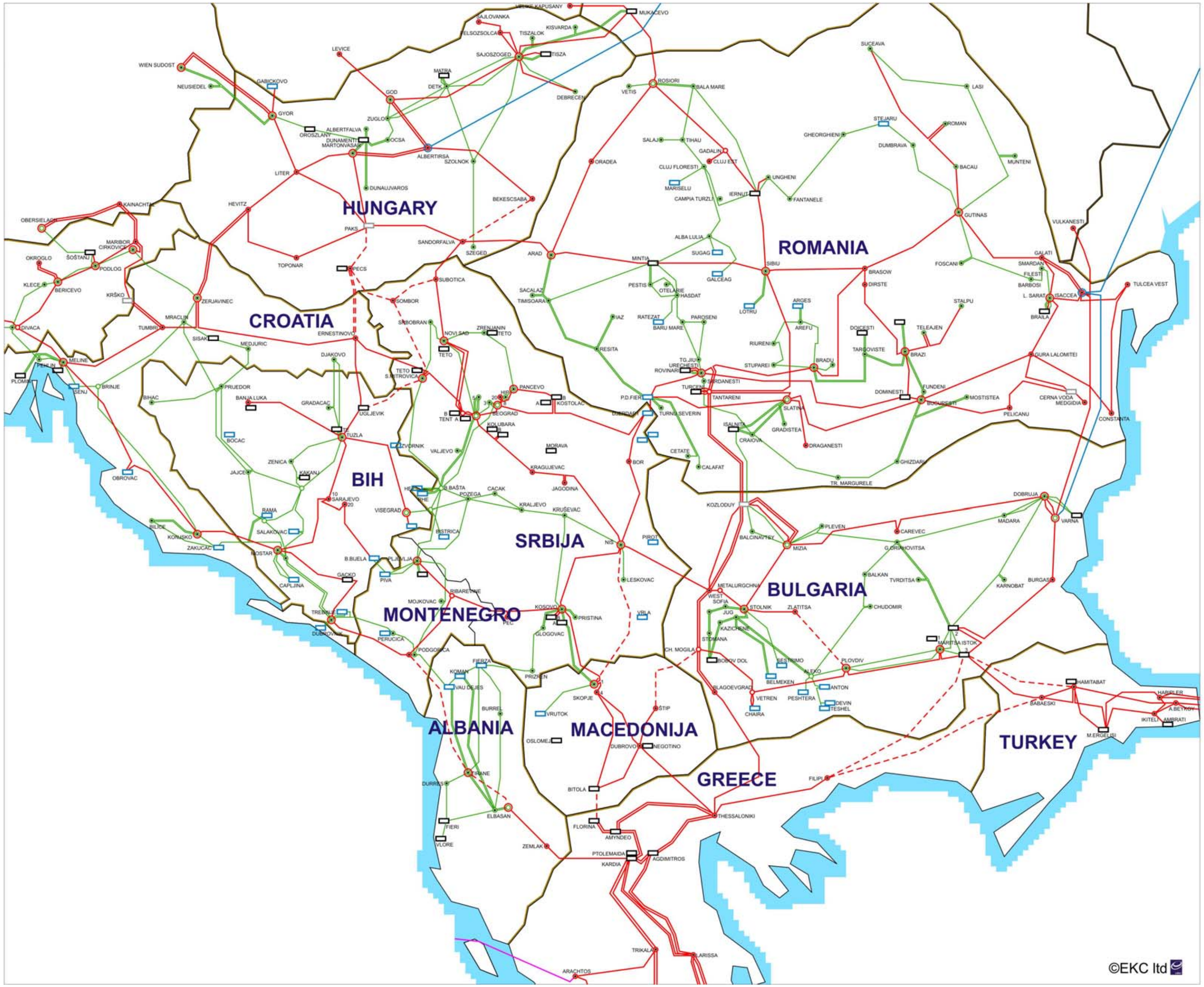


Figure 2.4.2: Real network topology in year 2010

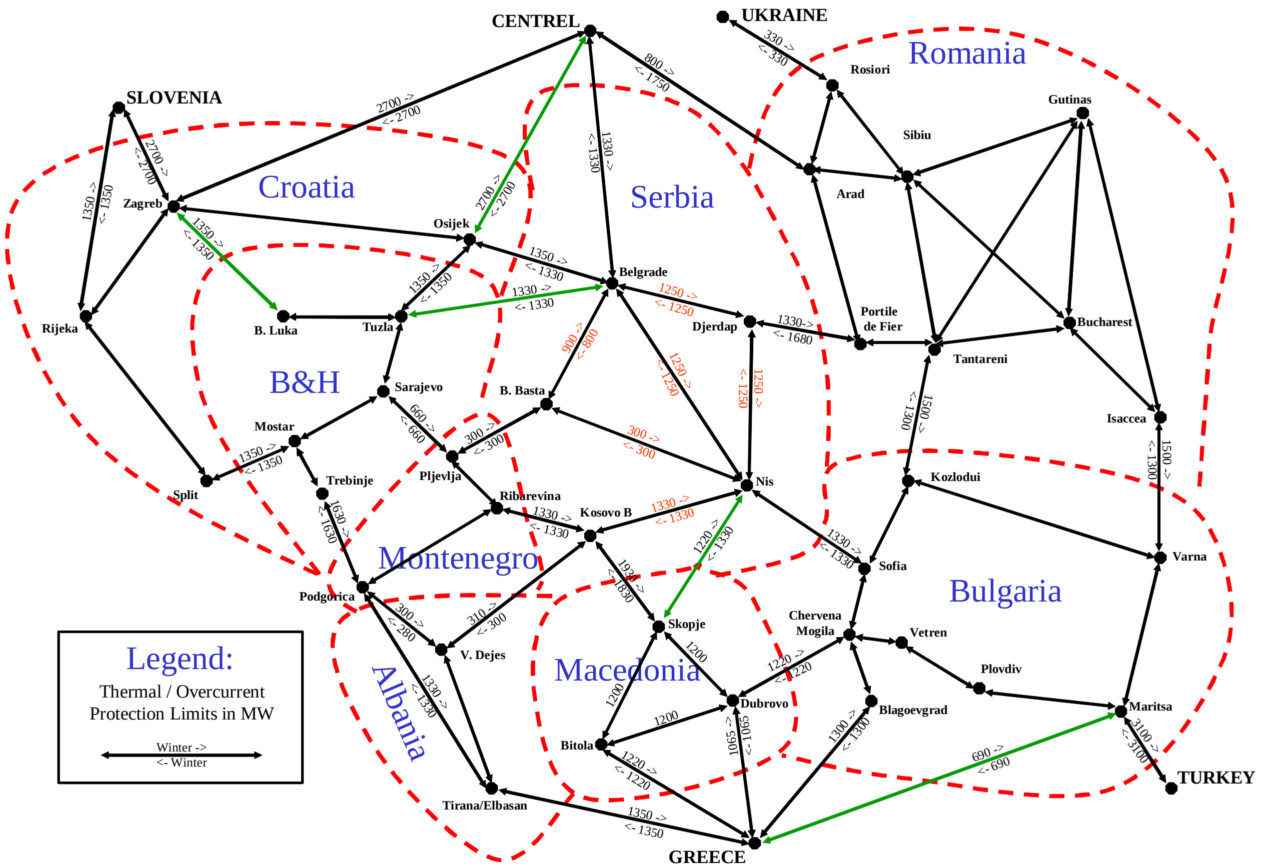


Figure 2.4.3: GTmax network topology in year 2015

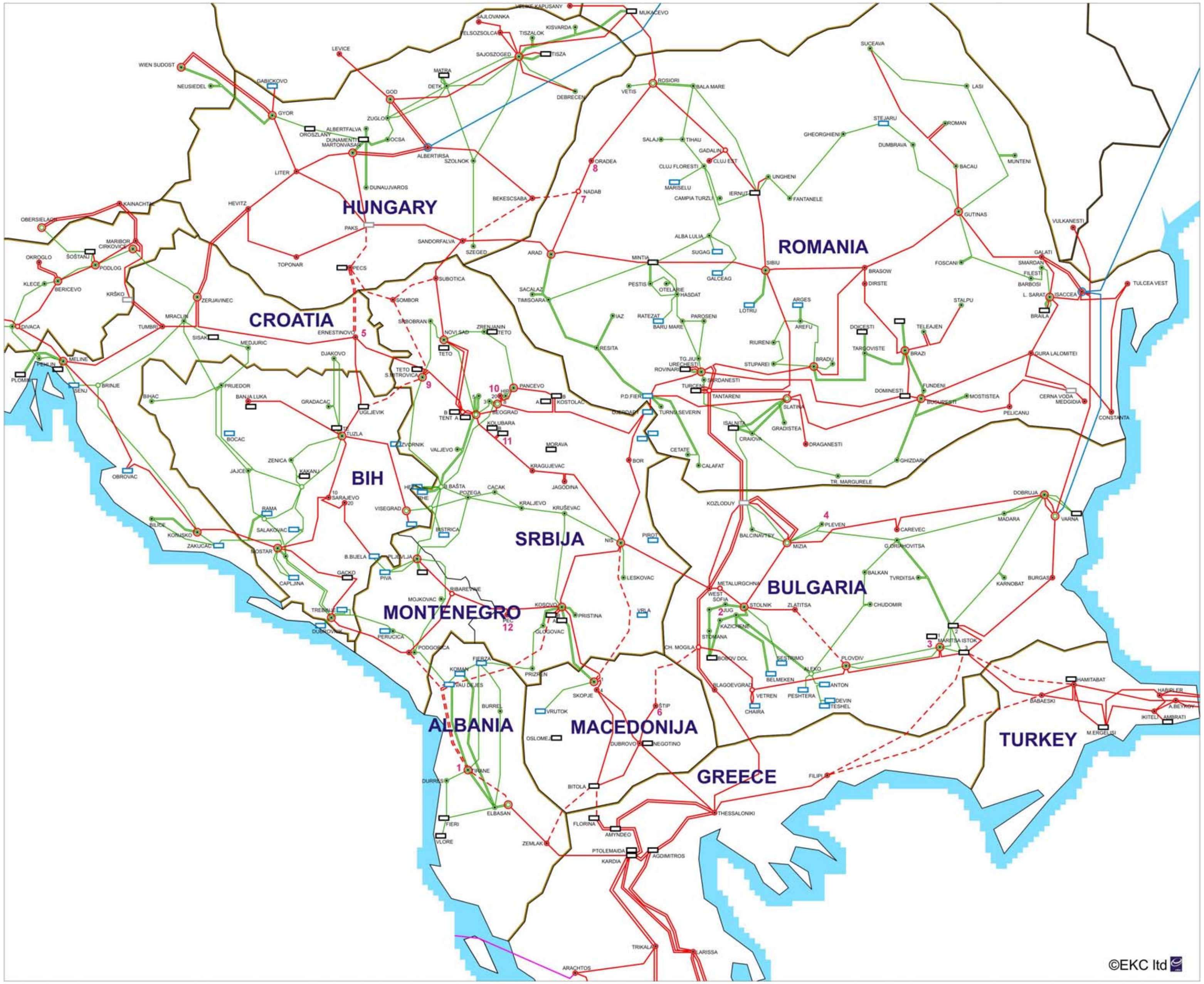


Figure 2.4.4: Real network topology in year 2015

Production distribution

In PSS/E model, all production units connected to 110 kV or higher voltage network are modeled as they are in reality, generation units plus corresponding step-up transformers. Some of the production units or plants connected to the network lower than 110 kV are modeled as negative load in corresponding buses, but most of them are included in corresponding loads in system substations. Also, in GTmax models, most of the production units are modeled as whole plants, so in order to achieve full compliance with PSS/E model, it was necessary to distribute this production on the real units themselves, as they are in PSS/E model. In following figures and tables production distribution from GTmax to PSS/E model was shown, jurisdiction by jurisdiction, but also how these units are connected to the GTmax network model, and appropriate network representation in PSS/E model.

Albania

GTmax	PSS/E			Remarks
Powerplant	Bus#	Bus Name	ID	
Fier 1	10021	AFIER 9 11.000	1	
Balsh	10022	AFIERV9 6.3000	4	
	10022	AFIERV9 6.3000	5	
Ulez+Shkopet	10052	AULEZ 9 6.3000	1	
	10052	AULEZ 9 6.3000	2	
	10052	AULEZ 9 6.3000	3	
	10052	AULEZ 9 6.3000	4	
	10053	ASHKP19 6.3000	1	
	10054	ASHKP29 6.3000	1	
Bistrica	10490	ABISTRIG 6.3000	G1	
	10490	ABISTRIG 6.3000	G2	
	10490	ABISTRIG 6.3000	G3	
	10490	ABISTRIG 6.3000	G4	
Fierza	10501	AFIERZ91 13.800	1	
	10502	AFIERZ92 13.800	2	
	10503	AFIERZ93 13.800	3	
	10504	AFIERZ94 13.800	4	
Komani	10511	AKOMAN91 13.800	1	
	10512	AKOMAN92 13.800	2	
	10513	AKOMAN93 13.800	3	
	10514	AKOMAN94 13.800	4	
Vau Dejes	10521	AVDEJA91 10.500	1	
	10522	AVDEJA92 10.500	2	
	10523	AVDEJA93 10.500	3	
	10524	AVDEJA94 10.500	4	
	10525	AVDEJA95 10.500	5	
Vlore	10551	ABABICG1 13.800	1	
	10552	ABABICG2 13.800	2	
	10553	ABABICG3 13.800	3	
	10554	ABABICG4 13.800	4	

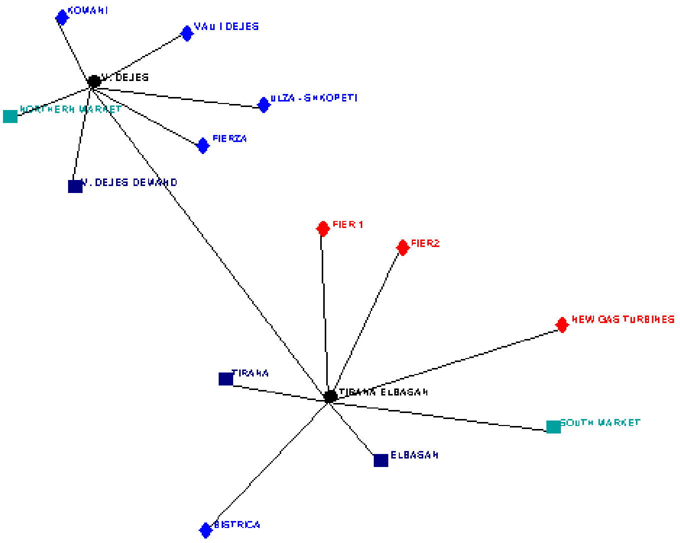


Figure 2.4.5 – GTmax model - Albania

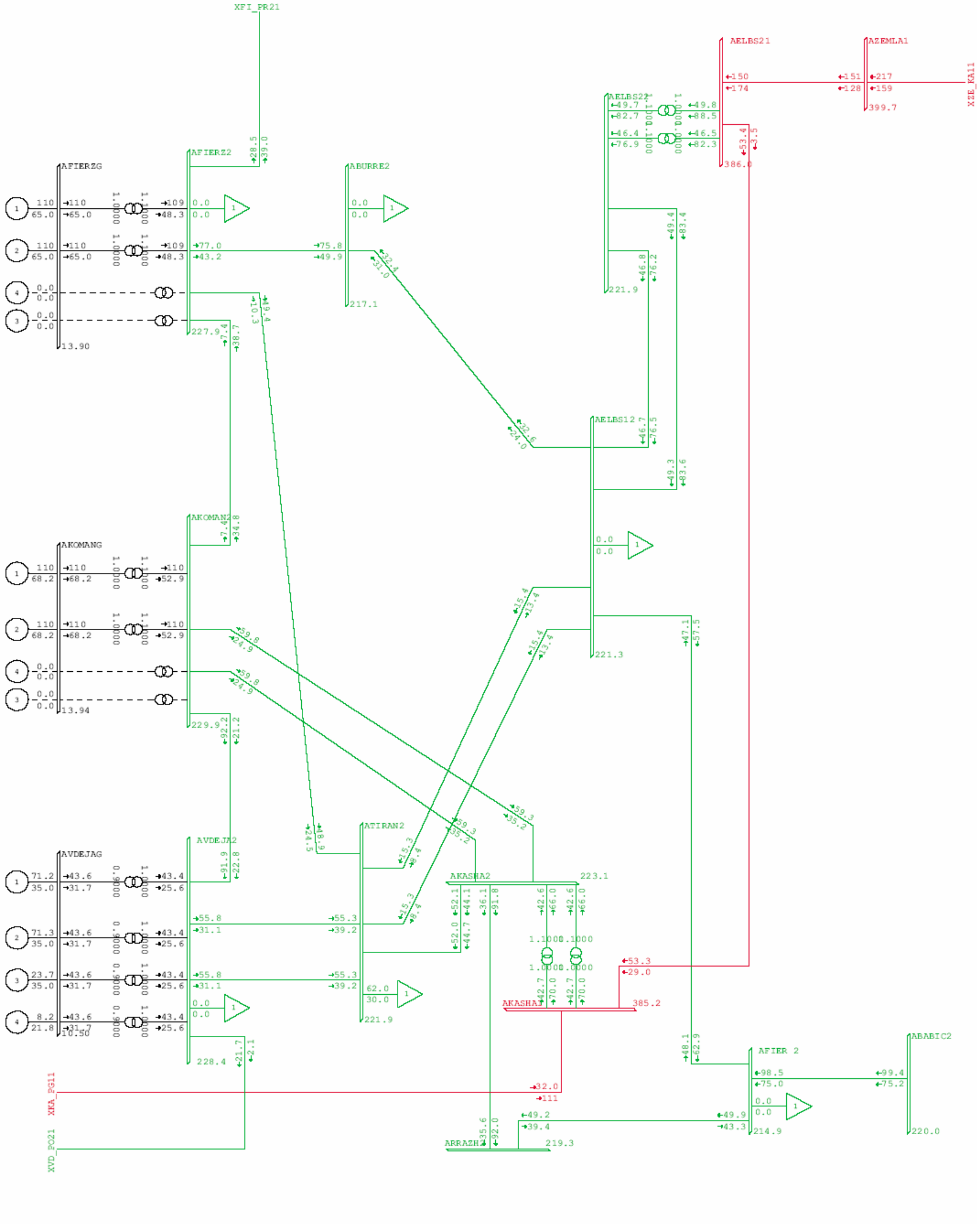


Figure 2.4.6 – PSS/E model - Albania

Bulgaria

GTmax	PSS/E			Remarks
Powerplant	Bus#	Bus Name	ID	
BELMEKEN	13200	BELM_G0 10.500	H0	
	13201	BELM_G12 10.500	H1	
	13201	BELM_G12 10.500	H2	
	13202	BELM_G34 10.500	H3	
	13202	BELM_G34 10.500	H4	
SOFIA HEAT	13206	TSF.I.G5 13.800	D5	
	13207	TSF.I.G4 6.3000	D4	
	13208	TSF.I.G3 6.3000	D3	
	13209	TSF.IG12 6.3000	D1	
	13209	TSF.IG12 6.3000	D2	
BOBOV DOL	13300	TBDOL_G1 15.750	T1	
	13301	TBDOL_G2 15.750	T2	
	13302	TBDOL_G3 15.750	T3	
SESTRIMO	13303	HSES.G1 10.500	H1	
	13304	HSES.G2 10.500	H2	
CHAIRA	13305	HCHA.G12 19.000	H1	
	13305	HCHA.G12 19.000	H2	
	13310	CHA.G34 19.000	H3	
	13310	CHA.G34 19.000	H4	
PERNIK CHP	13306	TREP.G5 10.500	D5	
	13307	TREP.G34 6.3000	D3	
	13307	TREP.G34 6.3000	D4	
MOMINA KLISURA	13308	HMKL.G1 10.500	H1	
	13309	HMKL.G2 10.500	H2	
KOZLODUY 1	13404	NKOZ_G9 24.000	N9	
KOZLODUY 2	13405	NKOZ_G10 24.000	N0	
RUSE 12	13500	TRUSEG12 6.3000	T1	
	13500	TRUSEG12 6.3000	T2	
RUSE 34	13501	TRUSEG3 13.800	T3	
	13502	TRUSEG4 13.800	T4	
RUSE 56	13503	TRUSEG5 6.3000	T5	
	13504	TRUSEG6 6.3000	T6	
SOFIA IND P	13505	TSV_G12 6.3000	I1	
	13505	TSV_G12 6.3000	I2	
VARNA THERMAL	13600	TVARN_G1 15.750	T1	
	13601	TVARN_G2 15.750	T2	
	13603	TVARN_G4 15.750	T4	
	13604	TVARN_G5 15.750	T5	
	13605	TVARN_G6 15.750	T6	
	13602	TVARN_G3 15.750	T3	
VARNA CHP	13606	TDEV.G3 10.500	I1	
	13607	TDEV_G14 6.3000	I1	
	13607	TDEV_G14 6.3000	I4	
PLOVDIV CHP	13700	TMI1_G12 6.3000	T1	
	13700	TMI1_G12 6.3000	T2	
	13701	TMI1_G3 6.3000	T3	
	13702	TMI1_G4 6.3000	T4	
MARITSA EAST 2 1	13703	TMI2_G1 18.000	T1	
	13704	TMI2_G2 18.000	T2	
	13705	TMI2_G3 18.000	T3	
	13706	TMI2_G4 18.000	T4	
MARITSA EAST 2 N	13707	TMI2_G5 15.750	T5	
	13708	TMI2_G6 15.750	T6	
	13709	TMI2_G7 15.750	T7	
	13710	TMI2_G8 15.750	T8	
MARITSA EAST 3	13711	TMI3_G1 15.750	T1	
	13712	TMI3_G2 15.750	T2	
	13713	TMI3_G3 15.750	T3	
	13714	TMI3_G4 15.750	T4	
BRIKEL	13715	TBR.G34 6.3000	I3	
	13715	TBR.G34 6.3000	I4	
	13716	TBR.G5 6.3000	I5	
	13717	TBR.G6 6.3000	I6	
PESTERA	13800	HPESHG12 10.500	H1	
	13800	HPESHG12 10.500	H2	
	13801	HPESHG34 10.500	H3	
	13801	HPESHG34 10.500	H4	
	13802	HPESH.G5 10.500	H5	
ORPHEY	13803	HANTG123 10.500	H1	
	13803	HANTG123 10.500	H2	
	13803	HANTG123 10.500	H3	

	13804	HANT.G4 10.500	H4	
BATAK	13805	HBATG123 10.500	H1	
	13805	HBATG123 10.500	H2	
	13805	HBATG123 10.500	H3	
	13806	HBAT_G4 10.500	H4	
KRICHIM	13807	HKRI.G1 10.500	H1	
	13808	HKRI.G2 10.500	H2	
DEVIN	13809	DEVIN.G1 10.500	H1	
	13810	DEVIN.G2 10.500	H2	
TESHEL	13811	HTESH.G 10.500	H1	
	13811	HTESH.G 10.500	H2	
MARITSA 3	13812	TMAR3.G3 13.800	T3	
ALEKO	13813	HALEKOG3 10.500	H3	
	13814	HALEKOG2 10.500	H2	
	13815	HALEKOG1 10.500	H1	
KARDJALY	13819	HKAR.G12 10.500	H1	
	13819	HKAR.G12 10.500	H2	
	13820	HKAR.G34 10.500	H3	
	13820	HKAR.G34 10.500	H4	
STUDEN KLADENEC	13821	HST.KG12 10.500	H1	
	13821	HST.KG12 10.500	H2	
	13822	HST.KG34 10.500	H3	
	13822	HST.KG34 10.500	H4	
IVAILOVGRAD	13823	HIW.G123 10.500	H1	
	13823	HIW.G123 10.500	H2	
	13823	HIW.G123 10.500	H3	
MARITSA EAST 1	13906	TMI1_G5 15.750	T5	
	13907	TMI1_G6 15.750	T6	
	13908	TMI1_G7 15.750	T7	
LUKOIL	-	-	-	included in total consumption
BUL SMALL HYDRO	-	-	-	included in total consumption

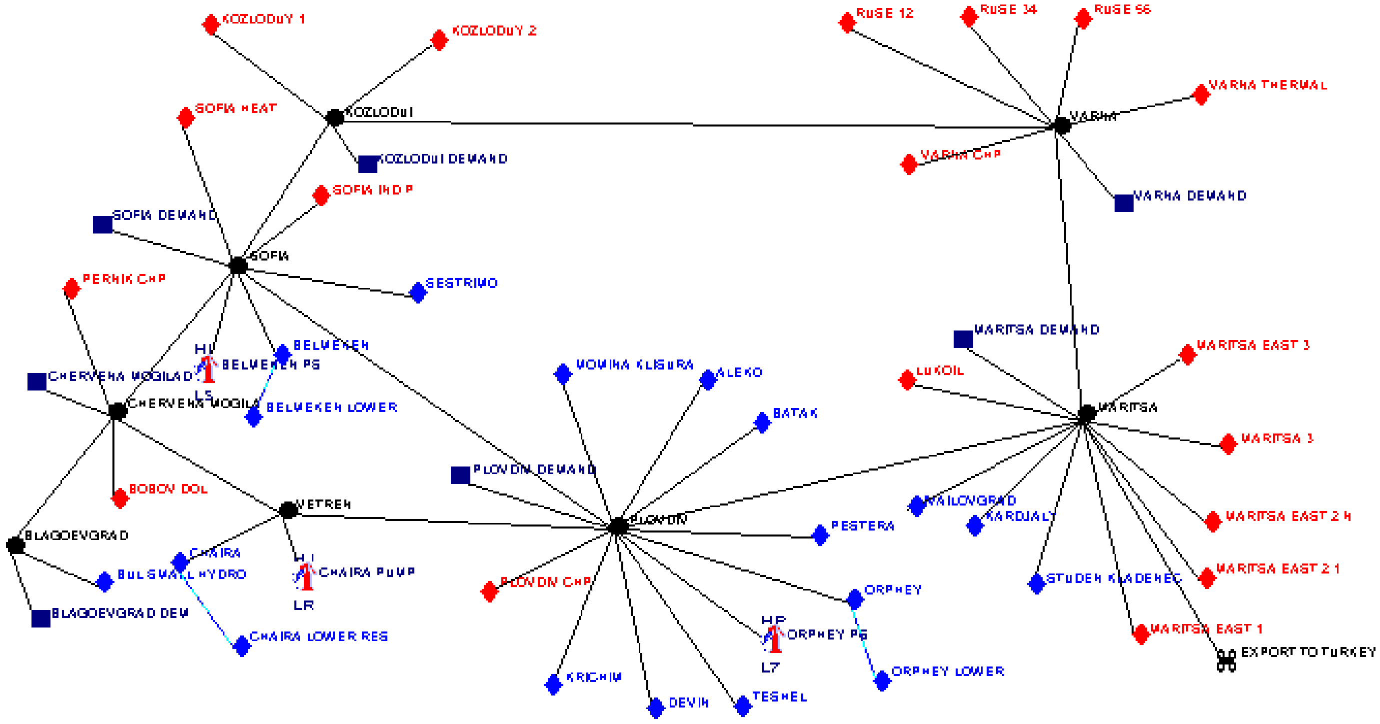


Figure 2.4.7 – GTmax model – Bulgaria

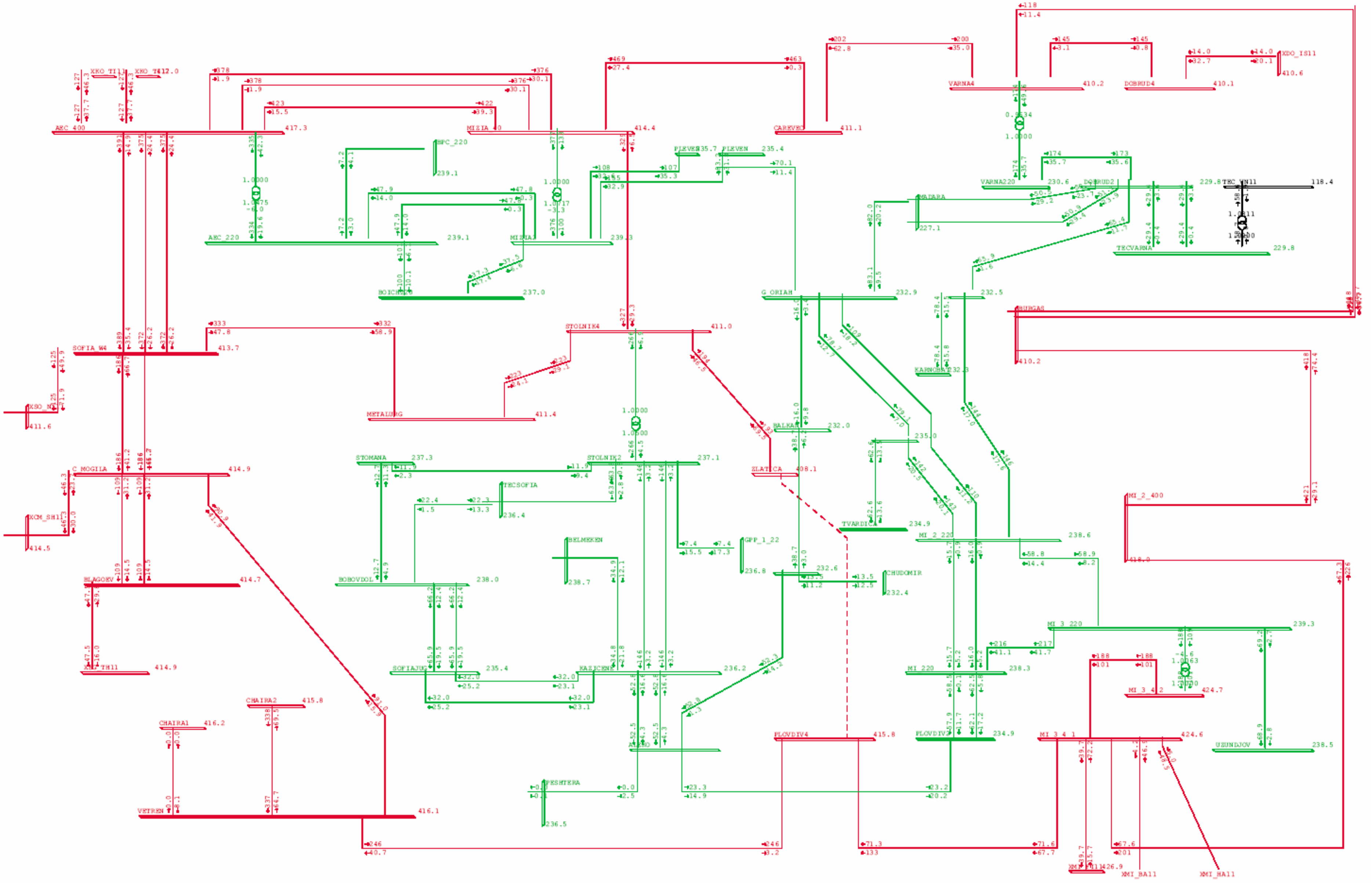


Figure 2.4.8 – PSS/E model - Bulgaria

BIH

GTmax	PSS/E			Remarks
Powerplant	Bus#	Bus Name	ID	
UGLJEVIK	14001	TE UGLJE 20.000	1	
GACKO	14002	GACKO 20.000	1	
VISEGRAD	14003	HE VISE 15.750	1	
	14003	HE VISE 15.750	2	
	14003	HE VISE 15.750	3	
TREBINJE HYDRO	14004	HE TREB 14.400	1	
	14004	HE TREB 14.400	2	
	14004	HE TREB 14.400	3	
BOCAC	14006	BOCACG1 10.500	1	
	14007	BOCACG2 10.500	2	
GRABOVICA	16001	GRAB-G1 10.500	1	
	16002	GRAB-G2 10.500	2	
SALAKOVAC	16003	SAL-G1 13.800	1	
	16004	SAL-G2 13.800	2	
	16005	SAL-G3 13.800	3	
KAKANJ 7	16006	KAK-G7 15.750	7	
TUZLA 4	16007	TUZ-G4 15.750	4	
TUZLA 5	16008	TUZ-G5 15.750	5	
TUZLA 6	16009	TUZ-G6 15.750	6	
JABLANICA	16011	JAB-G1 6.3000	1	
	16012	JAB-G2 6.3000	2	
	16013	JAB-G3 6.3000	3	
	16014	JAB-G4 6.3000	4	
	16015	JAB-G5 6.3000	5	
	16016	JAB-G6 6.3000	6	
KAKANJ 5	16025	KAK-G5 13.800	5	
KAKANJ 6	16026	KAK-G6 13.800	6	
TUZLA 3	16033	TUZ-G3 10.500	3	
RAMA	18001	RAMA G1 15.650	1	
	18002	RAMA G2 15.650	2	
MOSTAR HYDRO	18003	MOST-G1 10.500	1	
	18004	MOST-G2 10.500	2	
	18005	MOST-G3 10.500	3	
CAPLJINA	18006	CAPL-G1 15.700	1	
	18007	CAPL-G2 15.700	2	
JAJCE 1	18008	JAJ1-G1 10.500	1	
	18009	JAJ1-G2 10.500	2	
JAJCE 2	18010	JAJ2-G1 6.3000	1	
	18011	JAJ2-G2 6.3000	2	
	18012	JAJ2-G3 6.3000	3	
PEC MLINI	18015	MLINI-G1 10.500	1	
	18016	MLINI-G2 10.500	2	
DUBROVNIK G-2	-	-	-	included in Croatian production
M.BLATO	-	-	-	included in total consumption

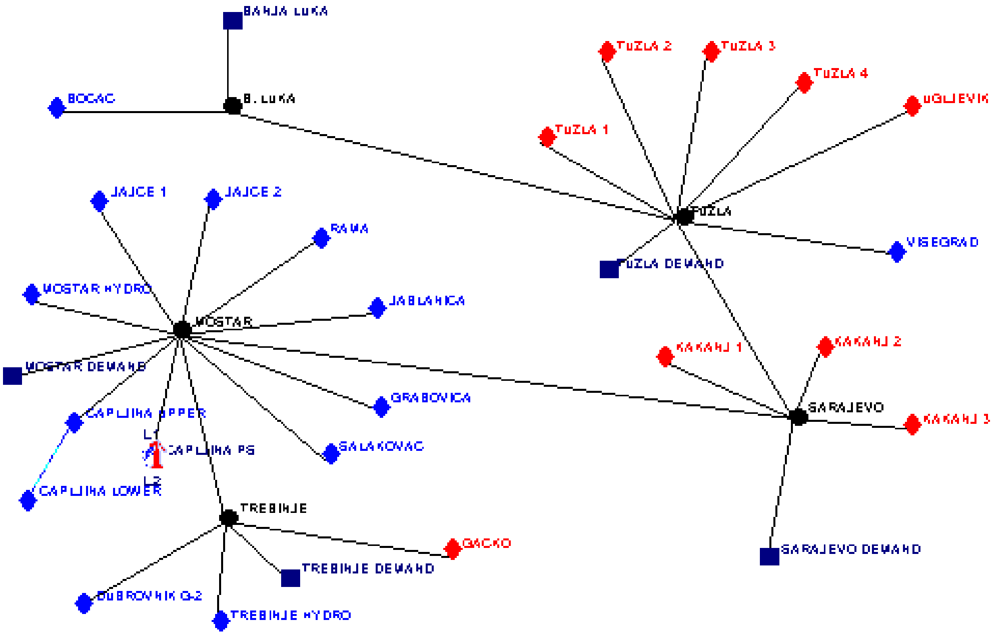


Figure 2.4.9 – GTmax model - BIH

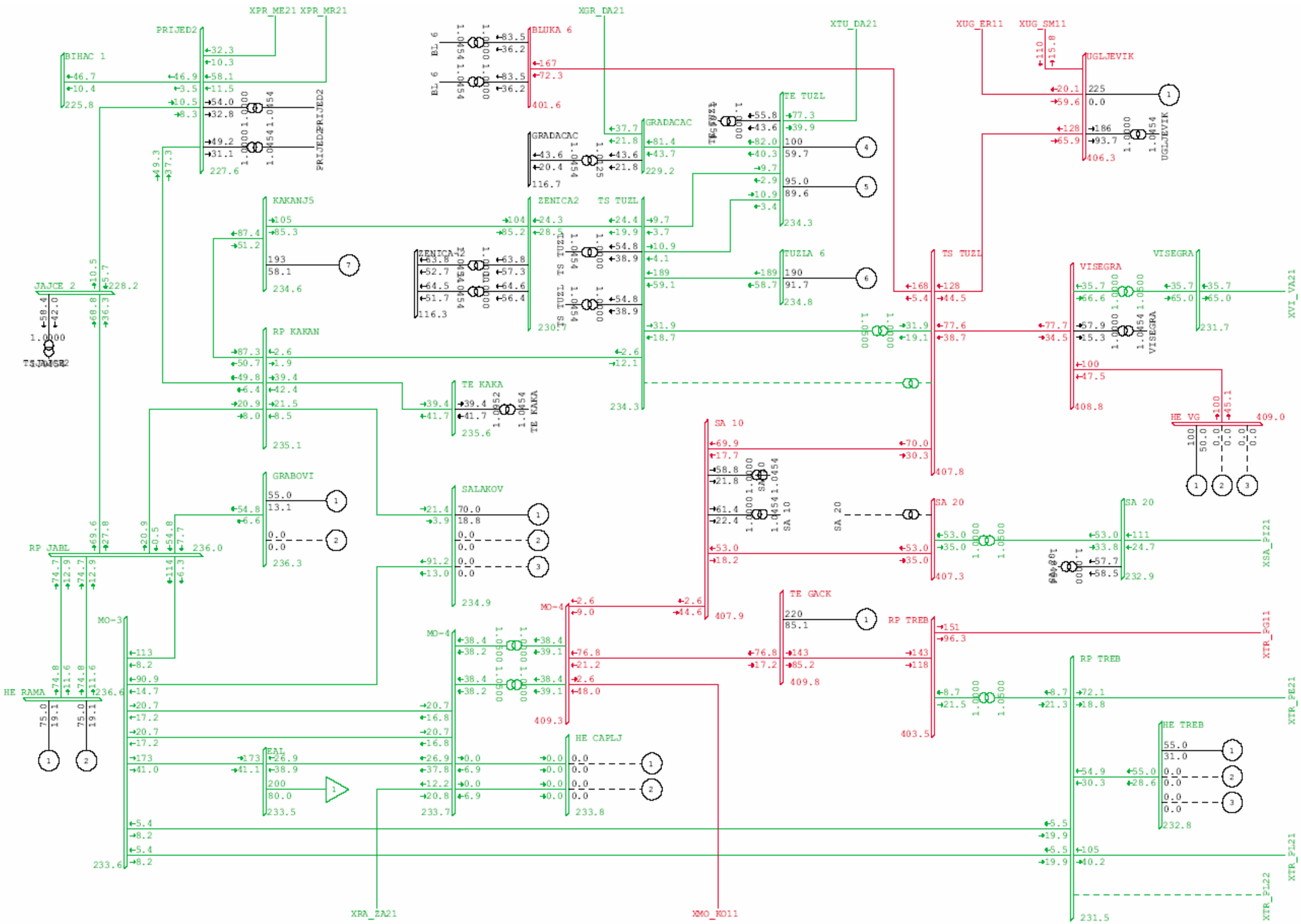


Figure 2.4.10 – PSS/E model - BIH

Croatia

GTmax	PSS/E			Remarks
Powerplant	Bus#	Bus Name	ID	
ZAGREB EL TO A	20301	EL-TOG1 10.500	1	
ZAGREB EL TO H	20302	EL-TOG2 10.500	2	
CAKOVEC	20304	HECAKOG1 6.3000	1	
	20305	HECAKOG2 6.3000	2	
DUBROVNIK G-1	20306	HEDUBRG1 6.3000	1	
DUBROVNIK G-2	20307	HEDUBRG2 6.3000	2	
GOJAK	20308	HEGOJAG1 10.500	1	
	20309	HEGOJAG2 10.500	2	
	20310	HEGOJAG3 10.500	3	
ORLOVAC	20313	HEORLOG1 10.500	1	
	20314	HEORLOG2 10.500	2	
	20315	HEORLOG3 10.000	3	
PERUCA	20316	HEPERUG1 10.500	1	
	20317	HEPERUG2 10.500	2	
RIJEKA HPP	20318	HERIJEG1 10.500	1	
	20319	HERIJEG2 10.500	2	
SENJ	20320	HESENJG1 10.500	1	
	20321	HESENJG2 10.500	2	
	20322	HESENJG3 10.500	1	
SKLOPE	20323	HESKLOG1 10.500	1	
VINODOL	20324	HEVINOG1 10.500	1	
	20325	HEVINOG2 10.500	2	
	20326	HEVINOG3 10.500	3	
ZAKUCAC	20327	HEZAKUG1 16.000	1	
	20328	HEZAKUG2 16.000	2	
	20329	HEZAKUG3 16.000	3	
	20330	HEZAKUG4 16.000	4	
JERTOVEC	20331	JERTOVG1 10.500	1	
	20332	JERTOVG2 10.500	2	
	20333	JERTOVG3 11.000	3	
	20334	JERTOVG4 11.000	4	
KRALJEVAC	20335	KRALJEVG 3.7000	1	
	20335	KRALJEVG 3.7000	2	
	20335	KRALJEVG 3.7000	3	
	20335	KRALJEVG 3.7000	4	
OSIJEK A	20336	TE-TOOG1 10.500	1	
VARAZDIN	20340	HEVARAG1 10.500	1	
	20341	HEVARAG2 10.500	2	
DUBRAVA	20342	HEDUBRG1 14.400	1	
	20343	HEDUBRG2 14.400	1	
VELEBIT	20344	RHEOBRG1 15.750	1	
	20345	RHEOBRG2 15.750	2	
PLOMIN 1	20346	TEPLOMG1 13.800	1	
PLOMIN 2	20347	TEPLOMG2 13.800	1	
RIJEKA THERMAL	20348	TERIJEG1 20.000	1	
SISAK	20350	TESISAG2 15.750	1	
ZAGREB TE TO A	20351	TE-TOG1 10.500	1	
ZAGREB ELTO K	20352	TE-TOG2 10.500	2	
	20354	TE-TOG4 10.500	4	
	20355	TE-TOG5 10.500	5	
ZAGREB TE TO C	20353	TE-TOG3 12.500	3	
DJALE	20360	HEDJALG1 10.500	1	
	20361	HEDJALG2 10.500	2	
CC 480 2	20430	KTEOSGT 15.750	1	
	20431	KTEOSST 10.500	1	
CC 480	20420	KTESISGT 15.750	1	
	20421	KTESISST 10.500	1	
GOLUBIC	-	-	-	included in total consumption
MILJACKA	-	-	-	included in total consumption
OSIJEK B	-	-	-	will not exist in 2010
OZALJ 1	-	-	-	included in total consumption
OZALJ 2	-	-	-	included in total consumption

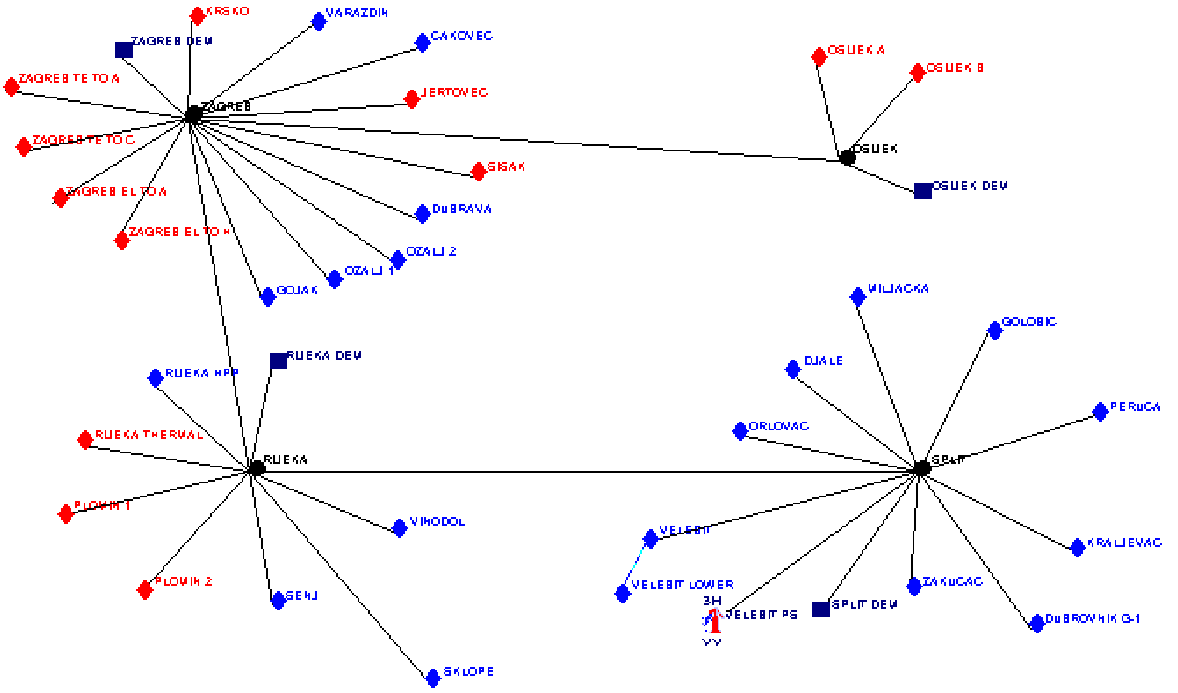


Figure 2.4.11 – GTmax model - Croatia

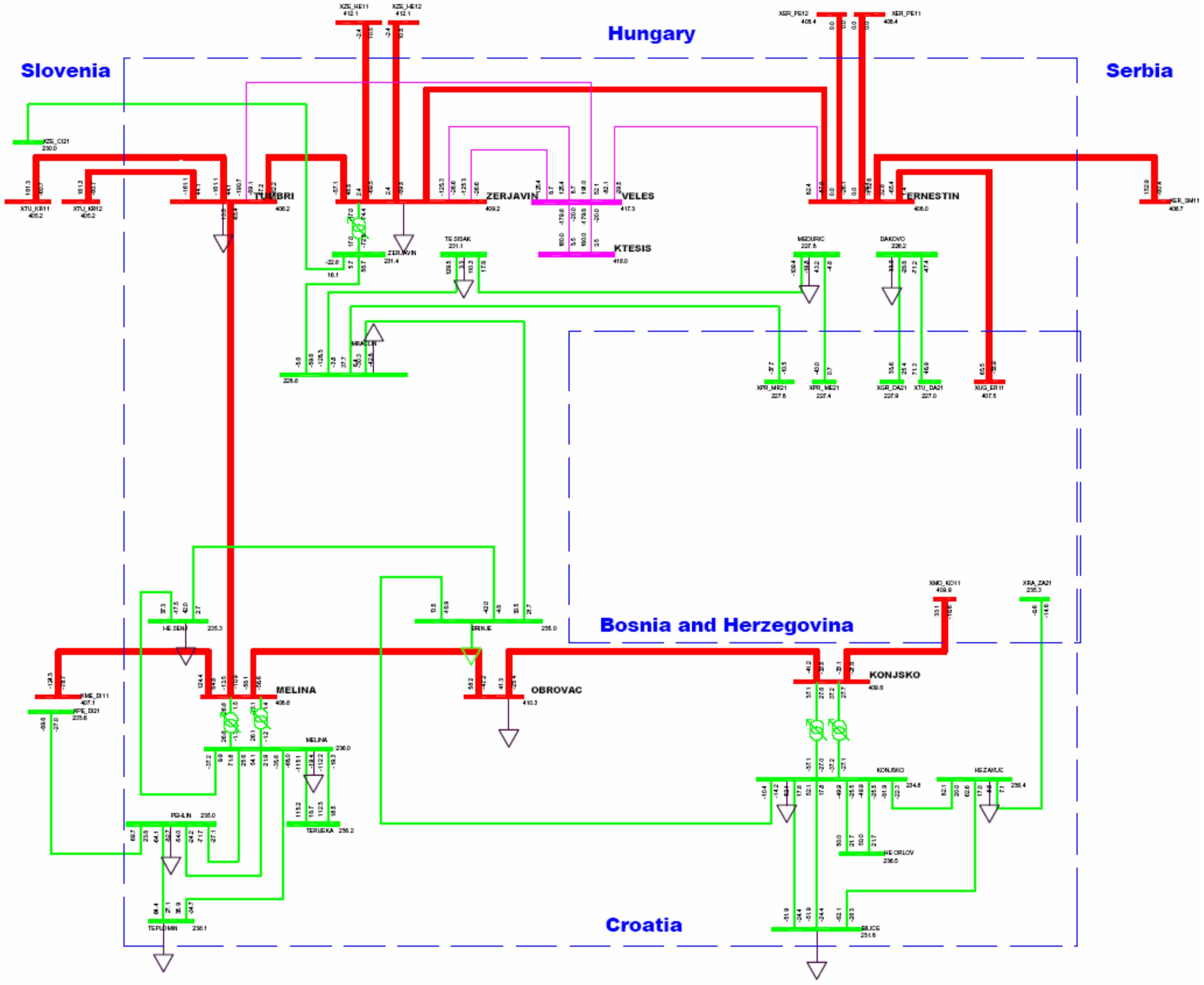


Figure 2.4.12 – PSS/E model - Croatia

Macedonia

GTmax	PSS/E			Remarks
Powerplant	Bus#	Bus Name	ID	
BITOLA 1	26301	BT 2 100 15.750	1	
BITOLA 2	26302	BT 2 400 15.750	1	
BITOLA 3	26303	BT 2 400 15.750	2	
OSLOMEJ	26311	OSLOMEJ 13.800	1	
NEGOTINO	26321	TPP NEGO 15.750	1	
VRUTOK	26331	VRUTOK 12.000	1	
	26332	VRUTOK 12.000	2	
	26333	VRUTOK 12.000	3	
	26334	VRUTOK 12.000	4	
GLOBOCICA	26341	GLOBOCIC 10.500	1	
	26342	GLOBOCIC 10.500	2	
SPILJE	26351	SPILJE 10.500	1	
	26352	SPILJE 10.500	2	
	26353	SPILJE 10.500	3	
TIKVES	26361	TIKVES 10.500	1	
	26362	TIKVES 10.500	2	
	26363	TIKVES 10.500	3	
	26364	TIKVES 10.500	4	
KOZJAK+MAT	26371	KOZJAK 10.500	1	
	26401	MATKA 2 10.500	1	
RAVEN	-	-	-	included in total consumption
VRBEN	-	-	-	included in total consumption

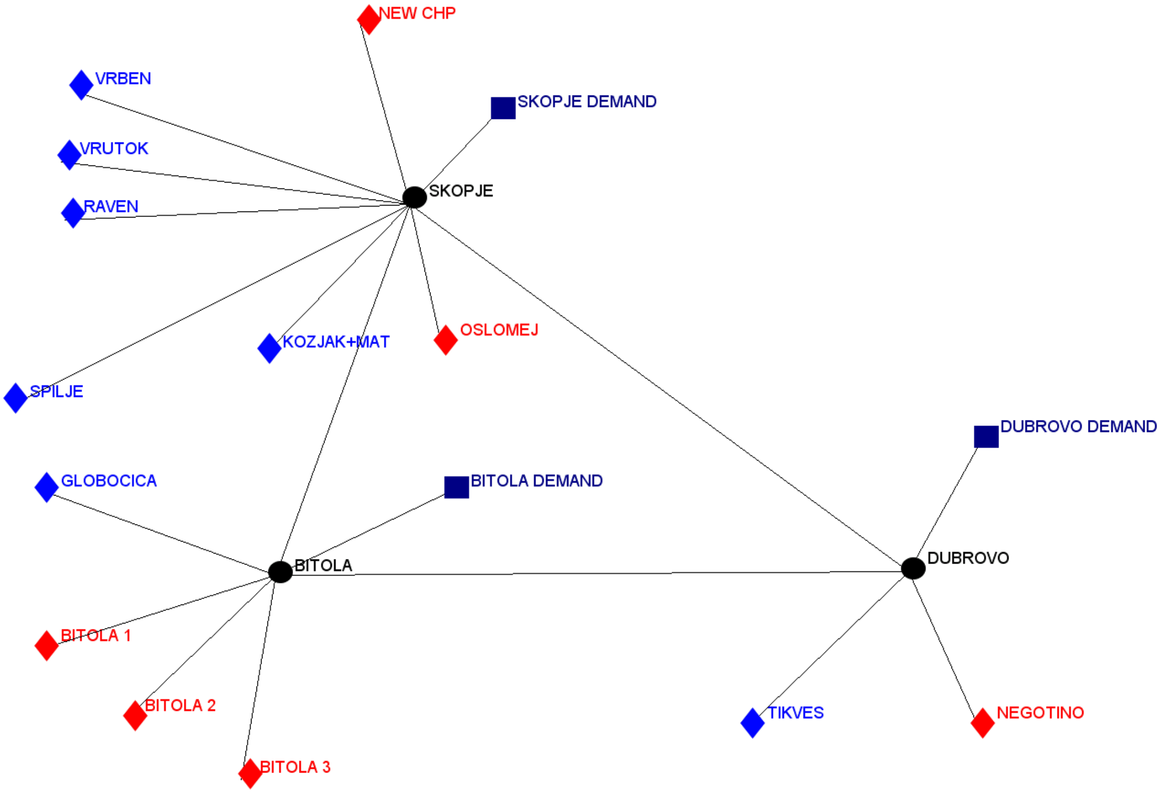


Figure 2.4.13 – GTmax model - Macedonia

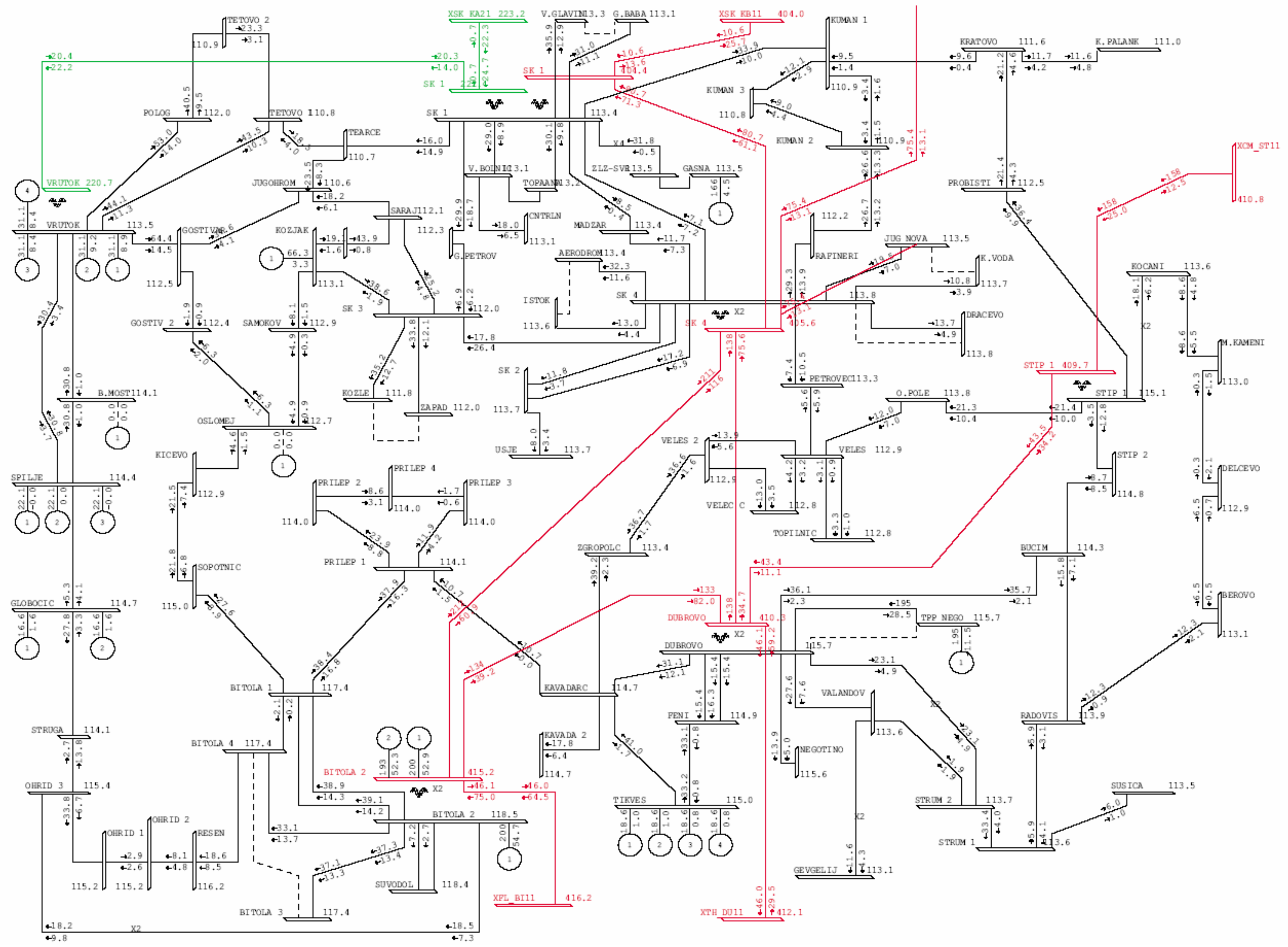


Figure 2.4.14 – PSS/E model - Macedonia

Montenegro

GTmax	PSS/E			Remarks
Powerplant	Bus#	Bus Name	ID	
PLJEVLJA THERMAL	36511	JTPLJEG1 15.750	G1	
PERUCICA	36521	JHPERUG1 10.500	G1	
	36522	JHPERUG2 10.500	G2	
	36523	JHPERUG3 10.500	G3	
	36524	JHPERUG4 10.500	G4	
	36525	JHPERUG5 10.500	G5	
	36526	JHPERUG6 10.500	G6	
	36527	JHPERUG7 10.500	G7	
SMALL HPPS	-	-	-	included in total consumption

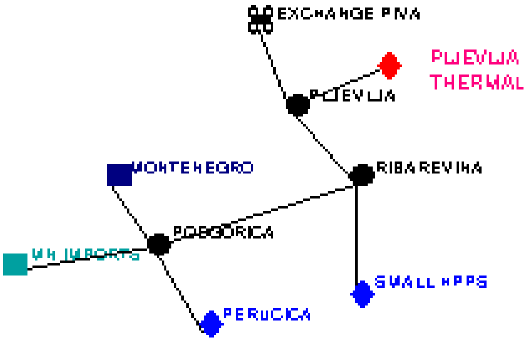


Figure 2.4.15 – GTmax model - Montenegro

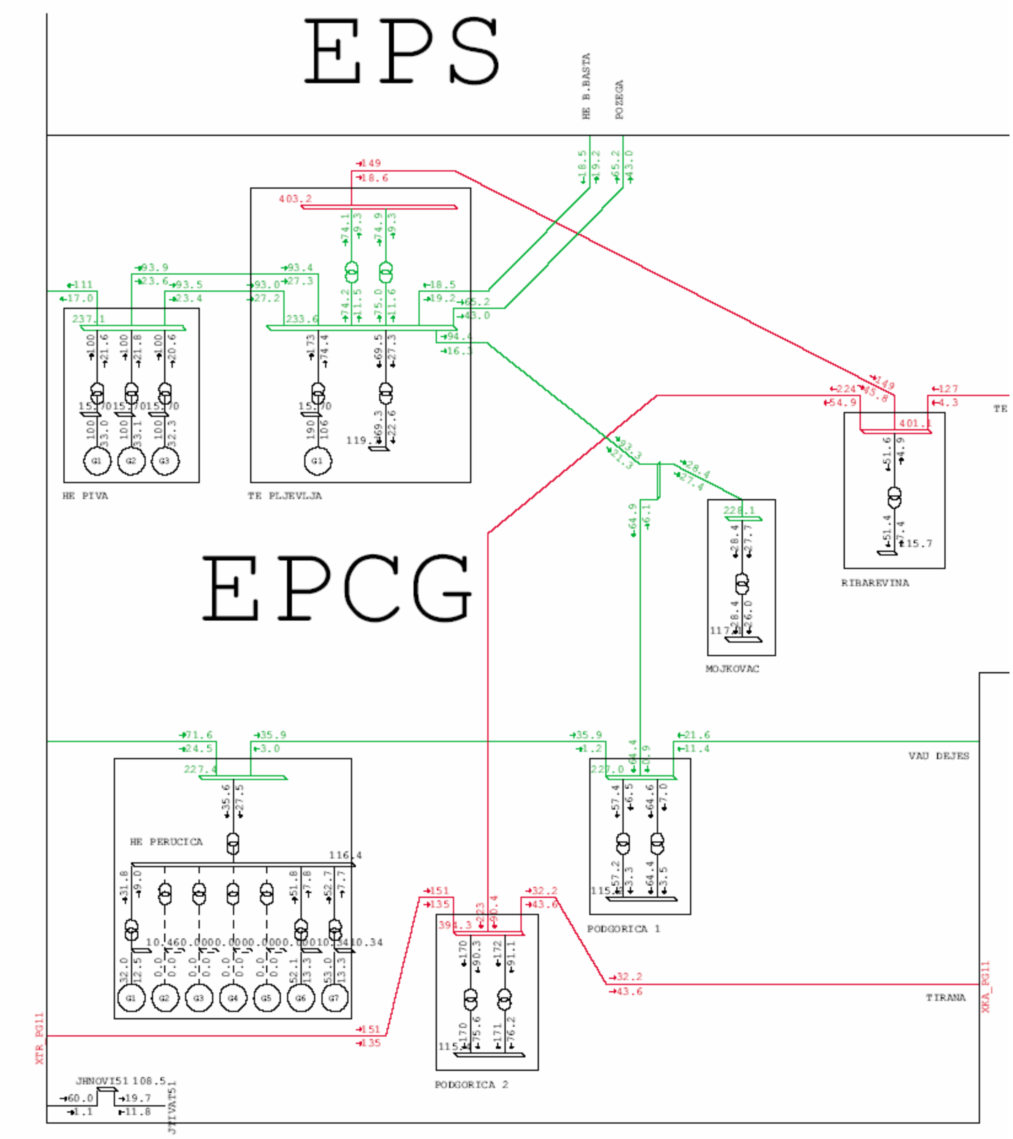


Figure 2.4.16 – PSS/E model - Montenegro

Serbia

GTmax	PSS/E			Remarks
Powerplant	Bus#	Bus Name	ID	
DJER1 AND DJER2	35001	JHDJERG1 15.750	G1	
	35001	JHDJERG1 15.750	G2	
	35003	JHDJERG3 15.750	G3	
	35003	JHDJERG3 15.750	G4	
	35005	JHDJERG5 15.750	G5	
	35005	JHDJERG5 15.750	G6	
	35171	JHDJE2G1 6.3000	G1	
	35171	JHDJE2G1 6.3000	G2	
	35173	JHDJE2G3 6.3000	G3	
	35173	JHDJE2G3 6.3000	G4	
	35175	JHDJE2G5 6.3000	G5	
	35175	JHDJE2G5 6.3000	G6	
	35177	JHDJE2G7 6.3000	G7	
	35177	JHDJE2G7 6.3000	G8	
	35179	JHDJE2G9 6.3000	G0	
	35179	JHDJE2G9 6.3000	G9	
KOSTOLAC B	35011	JTDRMNG1 22.000	G1	
	35012	JTDRMNG2 22.000	G2	
TENT A 1	35021	JTENTAG1 15.750	G1	
	35022	JTENTAG2 15.750	G2	
TENT A 2	35023	JTENTAG3 15.000	G3	
	35024	JTENTAG4 15.000	G4	
	35025	JTENTAG5 15.000	G5	
	35026	JTENTAG6 15.000	G6	
TENT B	35031	JTENTBG1 21.000	G1	
	35032	JTENTBG2 21.000	G2	
KOSOVO B THERMAL	35041	JTKOSBG1 24.000	G1	
	35042	JTKOSBG2 24.000	G2	
BAJINA BASTA	35051	JHBBASG1 15.650	G1	
	35052	JHBBASG2 15.650	G2	
	35053	JHBBASG3 15.650	G3	
	35054	JHBBASG4 15.650	G4	
BAJINA	35071	JRHBBAG1 11.000	G1	
	35072	JRHBBAG2 11.000	G2	
BISTRICA KOKIN	35081	JHBISTG1 10.500	G1	
	35082	JHBISTG2 10.500	G2	
	35111	JHKBROG1 6.3000	G1	
	35112	JHKBROG2 6.3000	G2	
KOSOVO A 3-4	35093	JTKOSAG3 15.750	G3	
	35094	JTKOSAG4 15.750	G4	
KOSOVO A5	35095	JTKOSAG5 15.750	G5	
KOSTOLAC A 1	35101	JTKSTAG1 10.500	G1	
KOSTOLAC A 2	35102	JTKSTAG2 15.750	G2	
POTPEC	35121	JHPOTPG2 8.8000	G2	
	35122	JHPOTPG3 8.8000	G3	
	35131	JHUVACG1 10.500	G1	
ZVORNIK	35141	JHZVORG1 11.000	G1	
	35142	JHZVORG2 11.000	G2	
	35143	JHZVORG3 11.000	G3	
	35144	JHZVORG4 11.000	G4	
KOLUBARA 2	35151	JTKOLUG1 10.500	G1	
	35152	JTKOLUG2 10.500	G2	
	35153	JTKOLUG3 10.500	G3	
	35154	JTKOLUG4 10.500	G4	
KOLUBARA 1	35155	JTKOLUG5 10.500	G5	
MORAVA	35161	JTMORAG1 13.500	G1	
PIROT	35181	JHPIROG1 10.500	G1	
	35182	JHPIROG2 10.500	G2	
VLASINSKE	35191	JHVRL1G1 6.3000	G1	
	35192	JHVRL1G2 6.3000	G2	
	35193	JHVRL1G3 6.3000	G3	
	35194	JHVRL1G4 6.3000	G4	
	35201	JHVRL2G1 6.3000	G1	
	35202	JHVRL2G2 6.3000	G2	
	35211	JHVRL3G1 6.3000	G1	
	35212	JHVRL3G2 6.3000	G2	
	34512	JHVRL35 110.00	2	as negative load
GAZIVODE	35221	JHGAZIG1 6.3000	G1	
	35222	JHGAZIG2 6.3000	G2	
NOVI SAD CHP	35241	JTTNSAG1 15.750	G1	
	35242	JTTNSAG2 15.750	G2	

ZRENJANIN CHP	35251	JTTZREG1 15.750	G1	
KOLUBARA B	35271	JTKOLBG1 22.000	G1	
	35272	JTKOLBG2 22.000	G2	
KOSOVO 2X450	34070	JTKOSB1 400.00	C1	
KOSOVO C 2X450	34070	JTKOSB1 400.00	C2	
PIVA	36501	JHPIVAG1 15.750	G1	
	36502	JHPIVAG2 15.750	G2	
	36503	JHPIVAG3 15.750	G3	

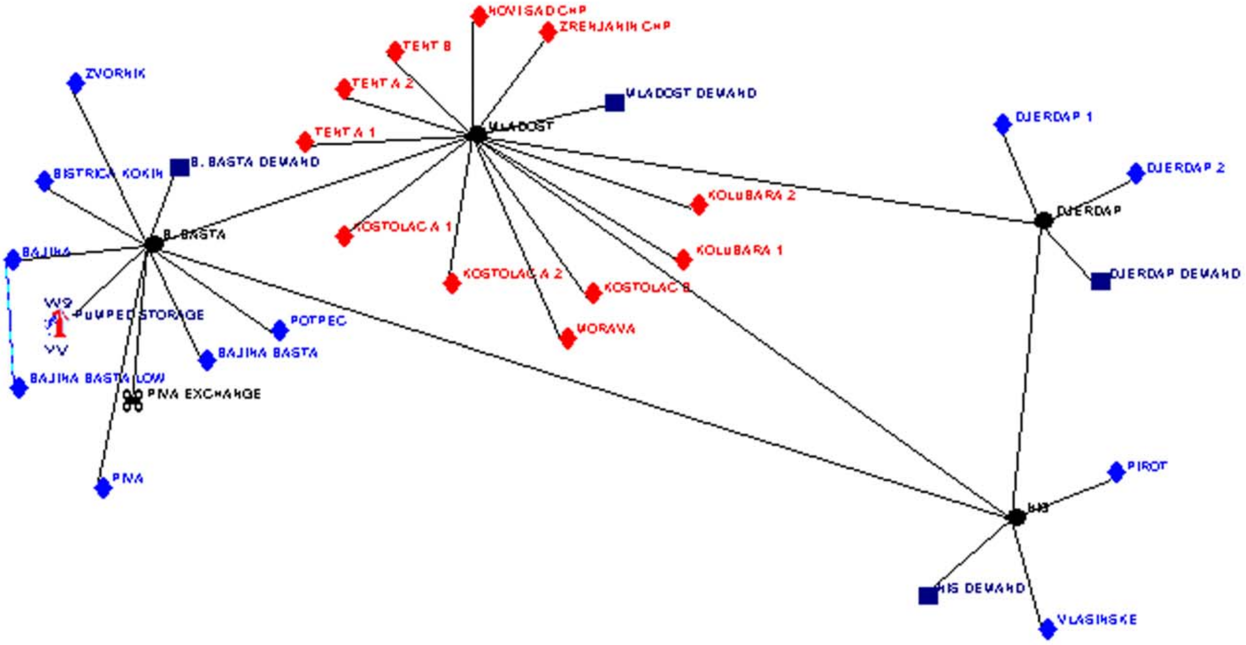


Figure 2.4.17 – GTmax model - Serbia

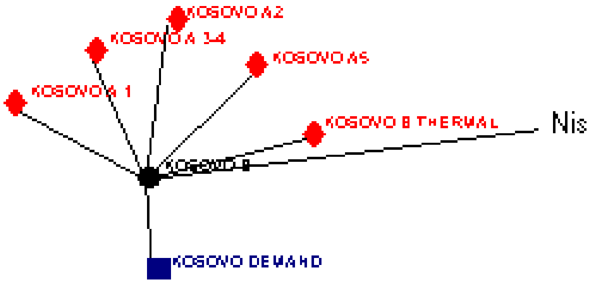


Figure 2.4.18 – GTmax model – Serbia UNMIK

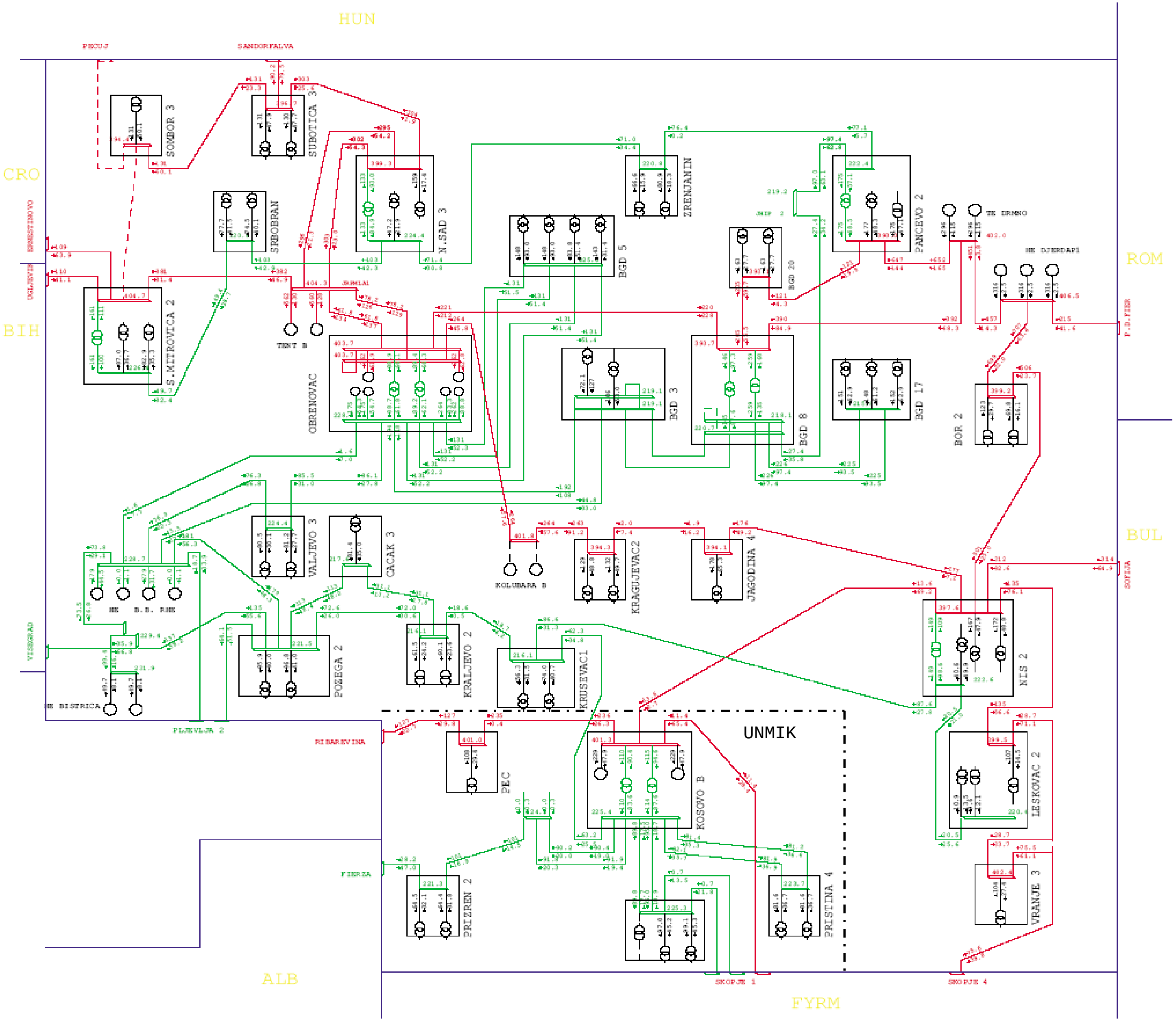


Figure 2.4.19 – PSS/E model – Serbia and UNMIK

Romania

GTmax	PSS/E			Remarks
Powerplant	Bus#	Bus Name	ID	
TURCENI 1	29110	TURCENI1 24.000	1	
	29112	TURCENI3 24.000	1	
	29113	TURCENI4 24.000	1	
TURCENI 2	29114	TURCENI5 24.000	1	
	29115	TURCENI 24.000	1	
	29116	TURCENI6 24.000	1	
	29117	TURCENI7 24.000	1	
ROVINARI	29119	ROVIN 5 24.000	1	
	29120	ROVIN 6 24.000	1	
	29121	ROVIN 3 24.000	1	
	29238	ROVIN 4 24.000	1	
	29455	ROVIN 7 24.000	1	
RIURENI	29125	AREFU 1 10.500	1	
	29126	AREFU 2 10.500	1	
	29127	AREFU 3 10.500	1	
	29128	AREFU 4 10.500	1	
BUCURESTI SUD	29136	BUC.S 5 13.800	1	
	29137	BUC.S 6 13.800	1	
	29138	BUC.S 3 10.500	1	
	29139	BUC.S 1 10.500	1	
	29317	BUC.S 2 10.500	1	
	29318	BUC.S 4 10.500	1	
GOVORA THERMAL	29140	STUPA I1 10.500	1	
	29141	STUPA I2 10.500	1	
	29142	STUPAII6 10.500	1	
	29143	STUPAII5 10.500	1	
	29144	STUPA I3 10.500	1	
	29145	STUPA I4 10.500	1	
GROZAVESTI CHP	29147	GROZAV 2 10.500	1	
	29148	GROZAV 1 10.500	1	
PROGRESU CHP	29149	PROGRS 1 10.500	1	
	29150	PROGRS4 10.500	1	
	29151	PROGRS3 10.500	1	
	29152	PROGRS 2 10.500	1	
BUCURESTI VEST	29154	BUC.V 2 13.800	1	
	29155	BUC.V 1 13.800	1	
RETEZAT	29162	RETEZAT1 15.750	1	
	29163	RETEZAT2 15.750	1	
MARISELU	29164	MARISEL1 15.750	1	
	29165	MARISEL2 15.750	1	
	29166	MARISEL3 15.750	1	
DEVA 1	29167	MINTIA 1 15.750	1	
	29168	MINTIA 2 15.750	1	
	29169	MINTIA 5 15.750	1	
GILCEAG	29170	GALCEAG1 15.750	1	
	29171	GALCEAG2 15.750	1	
SUGAG	29172	SUGAG 1 15.750	1	
	29173	SUGAG 2 15.750	1	
ORADEA	29174	ORAD I 4 10.500	1	
	29175	ORAD II1 10.500	1	
	29176	ORAD II2 10.500	1	
	29177	ORAD I 6 10.500	1	
	29178	ORAD I 5 10.500	1	
	29179	ORAD II3 10.500	1	
ARAD CHP	29181	ARAD 1 10.500	1	
RUIENI	29183	RUIENI 1 10.500	1	
	29248	RUIENI 2 10.500	1	
ISALNITA 2	29184	ISALNIT7 24.000	1	
	29185	ISALNIT8 24.000	1	
PORTILE 1	29189	P.D.F 1 15.750	1	
	29190	P.D.F 2 15.750	1	
	29191	P.D.F 3 15.750	1	
	29192	P.D.F 4 15.750	1	
	29193	P.D.F 5 15.750	1	
	29250	P.D.F.6 15.750	1	
PORTILE 2	29194	GRUIA12 6.3000	1	
	29195	GRUIA34 6.3000	1	
	29199	GRUIA56 6.3000	1	
	29196	GRUIA78 6.3000	1	
DROBETA	29197	DROBETA2 10.500	1	
	29251	DROBETA4 10.500	1	

	29252	DROBETA3 10.500	1	
	29253	DROBETA1 10.500	1	
CRAIOVA	29198	CRAI II2 15.750	1	
	29200	CRAI II1 15.750	1	
BORZESTI	29201	BORZEST7 15.750	1	
	29202	BORZEST8 15.750	1	
BORZESTI CHP	29203	BORZE I6 10.500	1	
	29205	BORZE I4 10.500	1	
	29206	BORZE I5 10.500	1	
STEJARU	29207	STEJARU5 10.500	1	
	29208	STEJARU6 10.500	1	
	29209	STEJARU 10.500	1	
SUCEAVA	29210	SUCEAVA1 10.500	1	
	29211	SUCEAVA2 10.500	1	
BACAU THERMAL	29212	BACAU 1 10.500	1	
IASI II	29214	FAI II 1 10.500	1	
	29215	FAI II 2 10.500	1	
IASI I	29216	FAI I 4 10.500	1	
	29217	FAI I 3 10.500	1	
CERNAVODA	29218	CERNAV.1 24.000	1	
BRAILA 1	29219	BRAILA 1 15.750	1	
BRAILA 2	29220	BRAILA 2 15.750	1	
	29221	BARBOSI5 10.500	1	
	29224	BARBOSI3 10.500	1	
GALATI CHP	29225	SMARDAN6 10.500	1	
	29310	SMARDAN4 10.500	1	
PALAS CHP	29226	PALAS 1 10.500	1	
	29227	PALAS 2 10.500	1	
LOTRU CIUNGET	29232	LOTRU 1 15.750	1	
	29233	LOTRU 2 15.750	1	
	29234	LOTRU 3 15.750	1	
BRASOV THERMAL	29235	BRASOV 1 10.500	1	
	29236	BRASOV 2 10.500	1	
PITESTI	29237	PITEST 4 10.500	1	
	29305	PITEST 5 10.500	1	
BRAZI CHP	29239	BRAZI 5 10.500	1	
	29267	BRAZI 7 10.500	1	
	29268	BRAZI 6 10.500	1	
	29266	BRAZI 10 10.500	1	
DEVA 2	29259	MINTIA 4 15.750	1	
	29260	MINTIA 3 15.750	1	
	29262	MINTIA 6 15.750	1	
PAROSENI	29269	PAROSEN1 10.500	1	
	29270	PAROSEN2 10.500	1	
	29271	PAROSEN3 10.500	1	
	29263	PAROS 4 18.000	1	
BRAILA 3	29299	BRAILA 3 15.750	1	
DOICESTI	29301	DOICEST8 15.750	1	
	29302	DOICEST7 15.750	1	
CERNAVODA 2	29332	CERNAV.2 24.000	1	
CERNAVODA 3	29470	CERNAV.3 24.000	1	
ARCESTI	28639	ARCESTI 110.00	1	as negative load
BABENI	28678	BABENI 110.00	1	as negative load
BACAU	28147	BACAU S 110.00	2	as negative load
BERESTI	28320	VERNEST 110.00	2	as negative load
BRADISOR	28564	BRADISO 110.00	1	as negative load
CALBUCET	-	-	-	included in total consumption
CALIMANESTI OLT	-	-	-	included in total consumption
CALIMANESTI SIRE	-	-	-	included in total consumption
CORNETU	-	-	-	included in total consumption
DAESTI	28574	DAIESTI 110.00	1	as negative load
DOICESTI	-	-	-	included in total consumption
DRAGANESTI	28752	CHE DRAG 110.00	1	as negative load
DRAGASANI	28674	CHE DRG 110.00	1	as negative load
FRUNZARU	28624	FRUNZ. 110.00	1	as negative load
GALBENI	-	-	-	included in total consumption
GUIRGIU	-	-	-	included in total consumption
GOVORA	-	-	-	included in total consumption
IONESTI	28676	IONESTI 110.00	1	as negative load
IPOTESTI	-	-	-	included in total consumption
IZBICENI	29261	IZBICEN 110.00	1	as negative load
LUDUS	-	-	-	included in total consumption
MOTRU	-	-	-	included in total consumption
MUNTENI I	28849	MUNTEAN 110.00	1	as negative load
NEHOUI	-	-	-	included in total consumption

OTHER AUTOPRODUC	-	-	-	included in total consumption
RACACIUNI	-	-	-	included in total consumption
REMETI	28850	REMETI 110.00	1	as negative load
RIMNICU VILCEA	28597	VILCEL A 110.00	2	as negative load
RUSANESTI	-	-	-	included in total consumption
SASCIORI	-	-	-	included in total consumption
SLATINA HYDRO	-	-	-	included in total consumption
STREJESTI	28645	STRAJ 110.00	1	as negative load
TARNITA	-	-	-	included in total consumption
TISMANA	-	-	-	included in total consumption
TOTAL UNDER 25	-	-	-	included in total consumption
TOTAL UNDER 25 2	-	-	-	included in total consumption
TOTAL UNDER 25 3	-	-	-	included in total consumption
TOTAL UNDER 25 4	-	-	-	included in total consumption
TOTAL UNDER 25 5	-	-	-	included in total consumption
TURNU	28844	TURNU 110.00	1	as negative load
VADURI	28102	VADURI 110.00	1	as negative load
VIDRARU	-	-	-	included in total consumption
ZAVIDENI	28675	ZAVID 110.00	1	as negative load

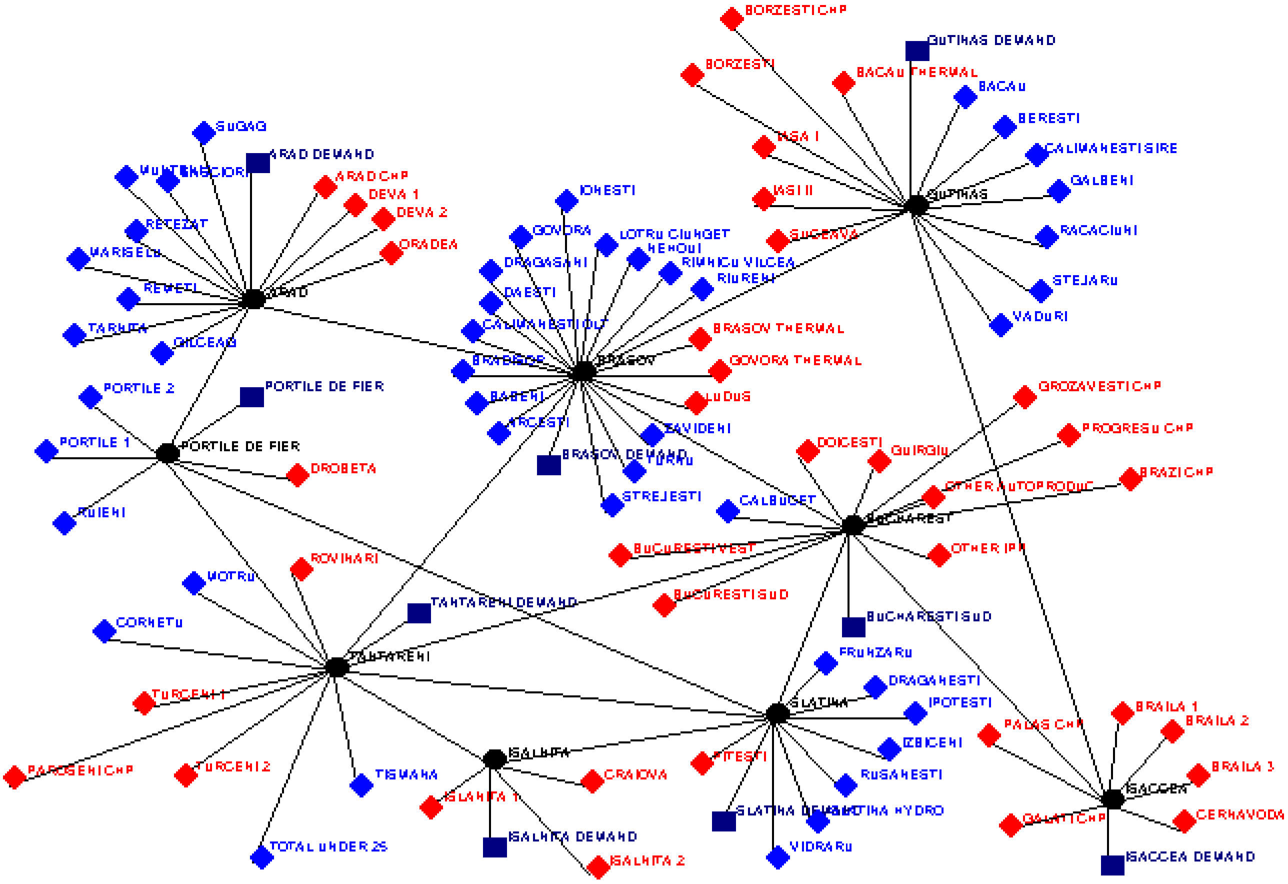


Figure 2.4.20 – GTmax model – Romania

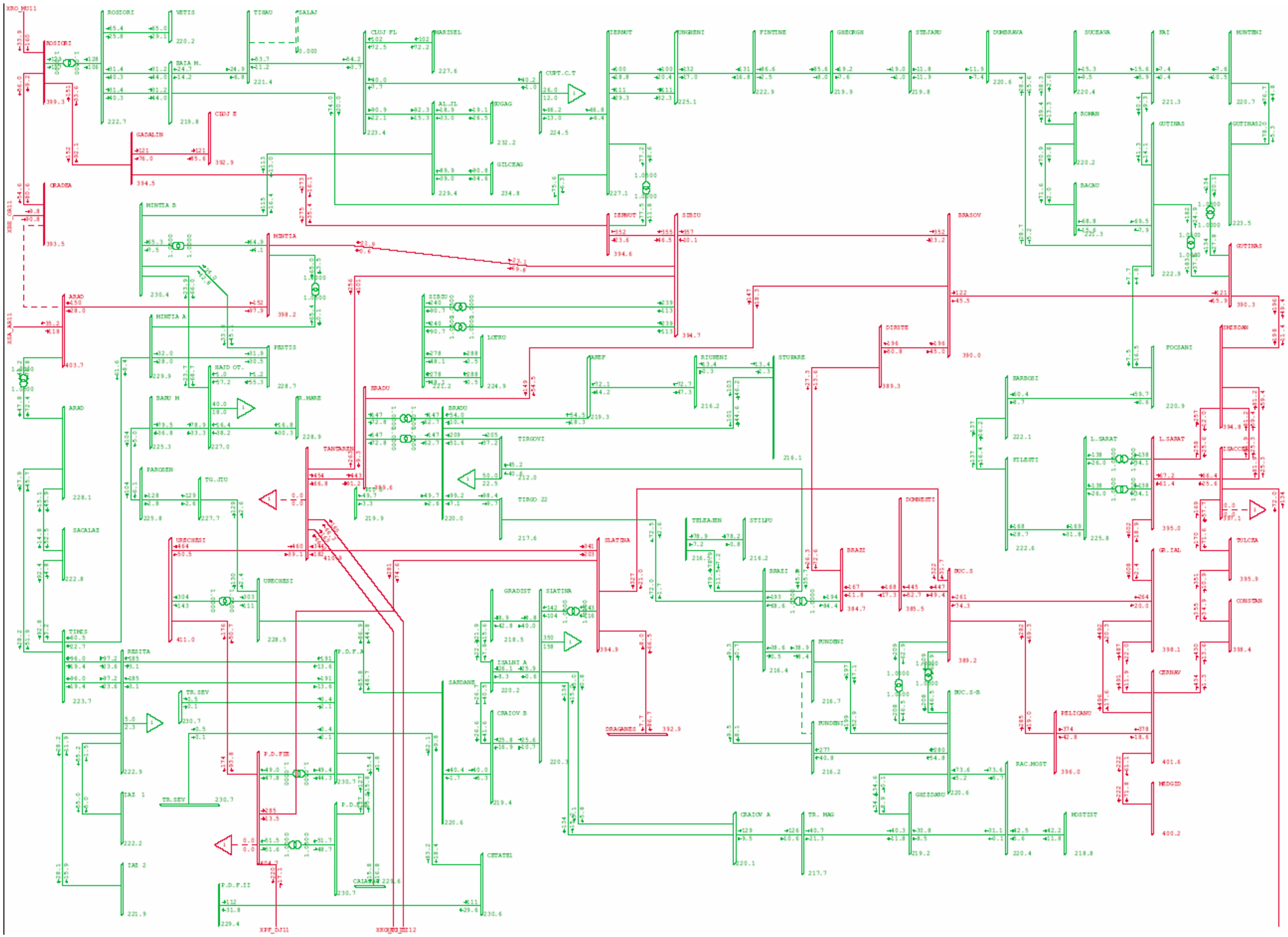


Figure 2.4.21 – PSS/E model - Romania

All these production facilities are analyzed as they will be built till 2010. Besides in sensitivity analyses for average hydrology high load scenarios in 2010 and 2015, additional production capacities are analyzed. In following tables is shown in what way these units are modeled.

BIH

GTmax	PSS/E			Remarks
Powerplant	Bus#	Bus Name	ID	
BUKBSRB	14010	HEBBG1 15.750	G1	
	14011	HEBBG2 15.750	G2	
	14012	HEBBG3 15.750	G3	
	14015	HESRBG 6.3000	G3	
	14015	HESRBG 6.3000	G2	
	14015	HESRBG 6.3000	G1	
GLAVATICEVO				included in total consumption

Bulgaria

GTmax	PSS/E			Remarks
Powerplant	Bus#	Bus Name	ID	
BELENE	12450	CAREVEC 400.00	1	

Montenegro

GTmax	PSS/E			Remarks
Powerplant	Bus#	Bus Name	ID	
KOMARNICA	36140	JNIKGR51 110.00	1	
ANDRIJEVO I ZLAT	36998	JHANDR21 220.00	1	
KOSTANICA	36999	JHKOST11 400.00	1	

Serbia (UNMIK)

GTmax	PSS/E			Remarks
Powerplant	Bus#	Bus Name	ID	
KOSOVO 3X274	34070	JTKOSB1 400.00	C1	
KOSOVO C 5X450	34070	JTKOSB1 400.00	C2	
ZHUR	36999	JPRIZ22 220.00	1	

Exchange programs-desired interchange

Because of different modeling approach of production and intersystem exchanges between GTmax and PSS/E, there are some peculiarities that need to be implemented in PSS/E model. This causes differences between exchange programs in GTmax and PSS/E. So, NPP Krsko is installed in system of Slovenia, but 50 % it is owned by Croatia. In GTmax this is modeled simply as Croatian power plant that has half power installed. But in PSS/E model, this plant is modeled as it is, in system of Slovenia, so Croatian part of energy produced is modeled as export from Slovenia to Croatia. Similar situation is with HPP Dubrovnik in Croatia, which is owned by Bosnia and Herzegovina. In case of HPP Piva, there is long term contract between Serbia and Montenegro, by which this plant operates as plant owned by Serbia in exchange for 105 MW exchange.

In order to achieve correspondence between exchange programs in GTmax and PSS/E model, following assumptions are made:

Albania: PSS/E program = GTmax program
Bulgaria: PSS/E program = GTmax program
BIH: PSS/E program = GTmax program – production (DUBROVNIK G-2)
Croatia: PSS/E program = GTmax program + production (DUBROVNIK G-2) – 50% production (KRSKO)
Macedonia: PSS/E program = GTmax program
Romania: PSS/E program = GTmax program
Serbia: PSS/E program = GTmax program (Serbia) + GTmax program (UNMIK) – production (PIVA)
Montenegro: PSS/E program = GTmax program + production (PIVA)

In sensitivity cases analyses, new generation facilities are modeled. One of them is HPP Buk Bijela and HPP Srbinje in Bosnia and Herzegovina. 1/3 of the energy produced by this plants is owned by Montenegro, so in these cases (2015 average hydrology high load scenarios) exchange program of BIH and Montenegro is calculated as:

BIH: PSS/E program = GTmax program – production (DUBROVNIK G-2)+ 1/3production(BUKBSRB)
Montenegro: PSS/E program = GTmax program + production (PIVA)-1/3production(BUKBSRB)

3 ANALYZED GENERATION, DEMAND AND EXCHANGE SCENARIOS

This chapter shortly describes analyzed generation, demand and exchange scenarios in WASP and GTMax and explains how they are modeled in PSS/E. Total number of 10 scenarios were analyzed from transmission network prospective.

WASP Scenario B results, were discussed and it was decided that WASP Scenario B “Case 1A” would be used as the Reference Case for GTmax Scenario C, and for PSS/E analyses as Reference cases. These Reference Cases include medium demand forecast, most likely fuel price forecast for all fuels and life extension and rehabilitation program as scheduled by the utilities. Within the extensive GTMax analyses in 2010 and 2015, the distribution of the new generation units to specific jurisdictions has been done. The specific (named) new generation units have defined sites and their distribution throughout the region have been done according to defined sites. Distribution of non-specific new generation units has been solved by taking into account the power balance for each jurisdiction or their specific needs. On the basis of the WASP results for the Reference Case and defined distribution of specific and non-specific new generation units, detailed GTMax simulation of the weekly operation of the regional power system have been done in average, dry and wet hydrology conditions. The generation of each power plant in peak hour of 2010 and 2015 in average, dry and wet hydrology conditions have been obtained as one of the GTMax results and have been used as input data for transmission network analyses done using PSS/E software package. Five scenarios were related to year 2010, and other five scenarios were related to year 2015.

Three scenarios for each year represent base cases and other two extra situations characterized by high demand and power imports.

3.1. Year 2010 Scenarios

Following tables 3.1.1-3.1.5 include generation and demand data dependent on analyzed hydrological situations, load level and power imports, related to year 2010. For each country one row represents GTMax data (white rows) and one row (shaded ones) equivalent data in PSS/E model according to explanations from Chapter 2. Differences in demand, hydro power plants and thermal power plants production are caused by plants connected to voltage levels below 110 kV which are not included into PSS/E model, so their overall production is included reducing demand, hydro and thermal production. This is the most obvious in Romanian power system characterized by large number of small hydro power plants connected to low voltage levels so Romanian balance in PSS/E model is quite different than on GTMax model.

Total power system balances (production minus demand) are different in GTMax and PSS/E models for Bosnia and Herzegovina (HPP Dubrovnik production is included into Croatian balance on PSS/E model), Croatia (HPP Dubrovnik is included, NPP Krsko in Slovenia is excluded from the balance), Montenegro (HPP Piva is included), and Serbia and UNMIK (HPP Piva is excluded from their balance).

WASP results for the Reference Case show that, for the period 2005-2010, the following new capacity would be added to the regional power system:

- Cernavoda nuclear unit #2
- Kolubara lignite unit #1, and
- One 500-MW Kosovo lignite plant

and these were included in the PSS/E model for 2010.

For 2010 year, additional scenarios are analyzed as Sensitivity cases. One of them is the High Load Forecast with new generation facilities implemented: HPP Zhur connected to the UNMIK node and there are also one 300 MW and one 500 MW combined cycle plant in Croatia and additional 500 MW unit connected to UNMIK node. This High Demand Forecast Case includes high demand forecast, most likely fuel price forecast for all fuels and life extension and rehabilitation program as scheduled by the utilities. On the basis of the WASP results for the High Demand Forecast Case and defined distribution of specific and non-specific new generation units, detailed GTMax simulation of the weekly operation of the regional power system have been done in average hydrology condition. The generations of each power plant in peak hour of 2010 and 2015 in average hydrology condition have been obtained as one of the GTMax results and have been used as input data for transmission network analyses done using PSS/E software package.

As second Sensitivity case, additional energy exchanges in the region are analyzed. This Import/Export Case includes medium demand forecast, most likely fuel price forecast for all fuels, life extension and rehabilitation program as scheduled by the utilities and net import of 1,500MW into the region. Following additional exchanges are simulated:

- Import 750 MW from UCTE.
- Import 500 MW from Turkey.
- Export 500 MW to Greece.
- Import 750 MW from Ukraine.

On the basis of the WASP results for the Import/Export Case and defined distribution of specific and non-specific new generation units, detailed GTMax simulation of the weekly operation of the regional power system have been done in average hydrology condition. The generations of each power plant in peak hour of 2010 and 2015 in average hydrology condition have been obtained as one of the GTMax results and have been used as input data for transmission network analyses done using PSS/E software package.

After comparison of the GTMax results for this case with the results for Base Case it can be seen that there is no new TPPs connected to UNMIK node or Mladost node in 2010 (without new TPPs on Kosovo and without Kolubara B units).

Table 3.1.1: Demand, Generation and Exchanges in SE Europe for base case - average hydrological scenario in 2010

Country	Demand (MW)	HPP Generation (MW)*	TPP and NPP Generation (MW)	Total Generation (MW)	Surplus(+)/Deficit(-)
Albania	1338	757	140	897	-441
	1338	757	140	897	-441
Bosnia and Herzegovina	2077	1591	826	2417	341
	2029	1439	826	2265	236
Bulgaria	6193	554	6426	6980	787
	6113	474	6426	6900	787
Croatia	3217	1018	749	1767	-1450
	3186	1092	411	1503	-1683
Macedonia	1229	232	730	962	-268
	1218	220	730	950	-268
Montenegro	687	228	0	228	-459
	687	540	0	540	-147
Romania	7797	2996	5730	8726	930
	7022	2256	5696	7952	930
Sebia and UNMIK	7112	2582	5090	7672	560
	7112	2270	5090	7360	248
Region Total	29649	9958	19691	29649	0
	28705	9048	19319	28367	-338**

* pumped storage HPP's included

** half of NPP Krsko (Slovenia) production (scheduled for Croatian power system)

Table 3.1.2: Demand, Generation and Exchanges in SE Europe for base case - dry hydrological scenario in 2010

Country	Demand (MW)	HPP Generation (MW)*	TPP and NPP Generation (MW)	Total Generation (MW)	Surplus(+)/Deficit(-)
Albania	1338	753	200	953	-384
	1338	753	200	953	-384
Bosnia and Herzegovina	2077	1636	1338	2974	898
	2050	1504	1338	2843	793
Bulgaria	6193	373	6426	6799	606
	6103	283	6426	6709	606
Croatia	3217	924	1632	2555	-661
	3189	1001	1294	2295	-894
Macedonia	1229	296	730	1026	-203
	1224	290	730	1020	-203
Montenegro	687	179	0	179	-508
	687	467	0	467	-220
Romania	7797	1820	5776	7596	-200
	7128	1185	5742	6927	-200
Sebia and UNMIK	7112	2476	5090	7566	454
	7112	2188	5090	7278	166
Region Total	29649	8457	21192	29649	0
	28830	7672	20820	28492	-338*

* pumped storage HPP's included

** half of NPP Krsko (Slovenia) production (scheduled for Croatian power system)

Table 3.1.3: Demand, Generation and Exchanges in SE Europe for base case - wet hydrological scenario in 2010

Country	Demand (MW)	HPP Generation (MW)*	TPP and NPP Generation (MW)	Total Generation (MW)	Surplus(+)/Deficit(-)
Albania	1338	759	140	899	-439
	1338	759	140	899	-439
Bosnia and Herzegovina	2077	1630	570	2200	124
	2019	1468	570	2038	19
Bulgaria	6193	686	6346	7032	839
	6103	596	6346	6942	839
Croatia	3217	1249	749	1998	-1219
	3187	1324	411	1735	-1452
Macedonia	1229	367	730	1097	-132
	1214	352	730	1082	-132
Montenegro	687	244	0	244	-443
	687	586	0	586	-101
Romania	7797	3744	4684	8428	632
	6706	2653	4684	7337	632
Sebia and UNMIK	7112	2662	5090	7751	639
	7112	2319	5090	7409	297
Region Total	29649	11341	18309	29649	0
	28366	10057	17971	28028	-338**

* pumped storage HPP's included

** half of NPP Krsko (Slovenia) production (scheduled for Croatian power system)

Table 3.1.4: Demand, Generation and Exchanges in SE Europe for sensitivity case – high load – average hydrological scenario in 2010

Country	Demand (MW)	HPP Generation (MW)*	TPP and NPP Generation (MW)	Total Generation (MW)	Surplus(+)/Deficit(-)
Albania	1414	790	140	930	-484
	1414	790	140	930	-484
Bosnia and Herzegovina	2114	1693	667	2360	246
	2061	1535	667	2202	141
Bulgaria	6492	518	6832	7350	858
	6425	450	6832	7282	858
Croatia	3371	1001	1507	2508	-863
	3350	1085	1169	2254	-1096
Macedonia	1262	271	730	1001	-261
	1252	261	730	991	-261
Montenegro	704	228	0	228	-476
	704	540	0	540	-163
Romania	8320	3237	5026	8263	-57
	7533	2484	4992	7476	-57
Sebia and UNMIK	7346	2774	5608	8382	1036
	7346	2462	5608	8070	724
Region Total	31022	10512	20510	31022	0
	30085	9379	20138	29747	-338**

* pumped storage HPP's included

** half of NPP Krsko (Slovenia) production (scheduled for Croatian power system)

Table 3.1.5: Demand, Generation and Exchanges in SE Europe for sensitivity case – power import – average hydrological scenario in 2010

Country	Demand (MW)	HPP Generation (MW)*	TPP and NPP Generation (MW)	Total Generation (MW)	Surplus(+)/Deficit(-)
Albania	1338	757	140	897	-440
	1338	757	140	897	-440
Bosnia and Herzegovina	2077	1734	826	2560	484
	2019	1572	826	2398	379
Bulgaria	6193	561	6346	6907	714
	6113	481	6346	6827	714
Croatia	3217	1218	749	1967	-1250
	3188	1294	411	1705	-1483
Macedonia	1229	266	730	996	-233
	1199	235	730	965	-233
Montenegro	687	228	0	228	-459
	687	540	0	540	-147
Romania	7797	2936	4756	7692	-105
	6977	2150	4722	6872	-105
Sebia and UNMIK	7112	2582	4320	6902	-210
	7112	2270	4320	6590	-522
Region Total	29649	10282	17867	28149	-1500
	28633	8788	17495	26795	-1838**

* pumped storage HPP's included

** 1500 MW of import plus half of NPP Krsko (Slovenia) production (scheduled for Croatian power system)

3.2. Year 2015 Scenarios

Following tables 3.2.1-3.2.5 include generation and demand data dependent on analyzed hydrological situations, load level and power imports, related to year 2015, using the same assumptions explained in previous subchapter.

WASP results for the Reference Case show that, for the period 2011-2015, the following new capacity would be added to the regional power system:

- Cernavoda nuclear unit #3
- Kolubara lignite unit #2
- One 300-MW and two 500-MW Kosovo lignite plants
- Two 100-MW CHP plants, and
- Two 300-MW and one 500-MW combined cycle plants

On the basis of this kind of analyses the following distribution of new non-specific generation units have been arranged:

- two 100 MW CHP units have been placed in Romania
- two 300 MW and one 500 MW combined cycle units have been placed in Croatia

all these are included in PSS/E model for 2015.

Like for 2010, and for 2015 year, additional scenarios are analyzed as Sensitivity cases. One of them is the High Load Forecast with new generation facilities implemented:

- HPP Buk Bijela with HPP Srbinje in B&H. Within the results from GTMax it can be seen that this hydro system is partially connected to Sarajevo node in B&H and partially to Montenegro node, due to the partial ownership of this hydro system.
- HPP Glavaticevo connected to Mostar node in B&H.
- HPP Dabar connected to Trebinje node in B&H.
- HPP Komarnica connected to Montenegro node.

- HPP Kostanica connected to Montenegro node.
- HPP Andrijevo and Zlatica connected to Montenegro node.
- NPP Belene nuclear plant connected to Varna node in Bulgaria,
- one 100 MW CHP unit connected to Mladost node in Serbia,
- one 500 MW combined cycle plant connected to node Zagreb in Croatia
- and additional two 300 MW and two 500 MW units connected to UNMIK node.

After comparison of the GTMax results for Export/Import Case (exchanges in/from/to SE Europe are the same as in 2010) with the results for Base Case in 2015 it can be seen that there is no Chernavoda Unit 3, no CHP unit connected to SIBIU node, no second 300 MW unit connected to Zagreb node, only one 500 MW unit connected to UNMIK node, but instead of one now there are two 300 MW units connected to UNMIK node.

As second Sensitivity case for 2015, additional energy exchanges in the region are analyzed. This was called Import/Export Case, and following additional exchanges are simulated (same as for 2010):
- Import 750 MW from UCTE.
- Import 500 MW from Turkey.
- Export 500 MW to Greece.
- Import 750 MW from Ukraine.

Table 3.2.1: Demand, Generation and Exchanges in SE Europe for base case - average hydrological scenario in 2015

Country	Demand (MW)	HPP Generation (MW)*	TPP and NPP Generation (MW)	Total Generation (MW)	Surplus(+)/Deficit(-)
Albania	1614	978	140	1118	-496
	1614	978	140	1118	-496
Bosnia and Herzegovina	2410	1648	826	2474	64
	2358	1491	826	2317	-41
Bulgaria	6688	533	6854	7387	699
	6619	465	6854	7319	699
Croatia	3752	986	1595	2581	-1171
	3721	1060	1257	2317	-1404
Macedonia	1438	379	720	1099	-340
	1427	367	720	1087	-340
Montenegro	694	230	191	421	-273
	694	542	191	733	39
Romania	9056	3424	5680	9104	48
	7973	2547	5474	8021	48
Sebia and UNMIK	7499	2584	6383	8967	1468
	7499	2272	6383	8655	1156
Region Total	33151	10762	22389	33151	0
	31906	9722	21845	31568	-338**

* pumped storage HPP’s included

** half of NPP Krsko (Slovenia) production (scheduled for Croatian power system)

Table 3.2.2: Demand, Generation and Exchanges in SE Europe for base case - dry hydrological scenario in 2015

Country	Demand (MW)	HPP Generation (MW)*	TPP and NPP Generation (MW)	Total Generation (MW)	Surplus(+)/Deficit(-)
Albania	1614	751	143	894	-720
	1614	751	143	894	-720
Bosnia and Herzegovina	2410	1656	1617	3274	864
	2382	1523	1617	3141	759
Bulgaria	6688	600	6854	7454	766
	6598	510	6854	7364	766
Croatia	3752	1177	1721	2898	-853
	3723	1253	1383	2636	-1086
Macedonia	1438	274	720	994	-444
	1429	265	720	985	-444
Montenegro	694	107	191	298	-396
	694	395	191	586	-108
Romania	9056	2033	6654	8687	-369
	8188	1371	6448	7819	-369
Sebia and UNMIK	7499	2268	6383	8651	1152
	7499	1980	6383	8363	864
Region Total	33151	8868	24283	33151	0
	32127	8049	23739	31789	-338**

* pumped storage HPP’s included

** half of NPP Krsko (Slovenia) production (scheduled for Croatian power system)

Table 3.2.3: Demand, Generation and Exchanges in SE Europe for base case - wet hydrological scenario in 2015

Country	Demand (MW)	HPP Generation (MW)*	TPP and NPP Generation (MW)	Total Generation (MW)	Surplus(+)/Deficit(-)
Albania	1614	984	140	1124	-490
	1614	984	140	1124	-490
Bosnia and Herzegovina	2410	1743	573	2316	-94
	2353	1581	573	2154	-199
Bulgaria	6688	899	6744	7643	955
	6598	809	6744	7553	955
Croatia	3752	1468	1595	3063	-688
	3721	1543	1257	2800	-921
Macedonia	1438	358	523	881	-557
	1427	347	523	870	-557
Montenegro	694	246	191	437	-257
	694	588	191	779	85
Romania	9056	3445	5488	8933	-123
	8074	2635	5316	7951	-123
Sebia and UNMIK	7499	2662	6092	8754	1255
	7499	2320	6092	8412	913
Region Total	33151	11805	21346	33151	0
	31980	10806	20836	31642	-338**

* pumped storage HPP’s included

** half of NPP Krsko (Slovenia) production (scheduled for Croatian power system)

Table 3.2.4: Demand, Generation and Exchanges in SE Europe for sensitivity case – high load – average hydrological scenario in 2015

Country	Demand (MW)	HPP Generation (MW)*	TPP and NPP Generation (MW)	Total Generation (MW)	Surplus(+)/Deficit(-)
Albania	1781	758	140	898	-883
	1781	758	140	898	-883
Bosnia and Herzegovina	2503	1989	630	2619	116
	2433	1814	630	2444	11
Bulgaria	7327	552	7674	8226	899
	7259	484	7674	8158	899
Croatia	4067	1007	1845	2852	-1215
	4040	1085	1507	2592	-1448
Macedonia	1516	179	720	899	-617
	1513	176	720	896	-617
Montenegro	736	922	191	1113	377
	736	1234	191	1425	689
Romania	10232	3584	5608	9192	-1040
	9175	2698	5436	8135	-1040
Sebia and UNMIK	8025	2472	7917	10389	2364
	8025	2160	7917	10077	2052
Region Total	36188	11463	24725	36188	0
	34962	10408	24215	34624	-338**

* pumped storage HPP's included

** half of NPP Krsko (Slovenia) production (scheduled for Croatian power system)

Table 3.2.5: Demand, Generation and Exchanges in SE Europe for sensitivity case – power import – average hydrological scenario in 2015

Country	Demand (MW)	HPP Generation (MW)*	TPP and NPP Generation (MW)	Total Generation (MW)	Surplus(+)/Deficit(-)
Albania	1614	886	140	1026	-588
	1614	886	140	1026	-588
Bosnia and Herzegovina	2410	1720	826	2546	136
	2364	1568	826	2395	31
Bulgaria	6688	840	6854	7694	1006
	6578	730	6854	7584	1006
Croatia	3752	1133	1307	2440	-1312
	3721	1207	969	2176	-1545
Macedonia	1438	379	720	1099	-340
	1417	357	720	1077	-340
Montenegro	694	230	191	421	-273
	694	542	191	733	39
Romania	9056	3030	5054	8084	-972
	8161	2256	4934	7190	-972
Sebia and UNMIK	7499	2584	5757	8341	842
	7499	2272	5757	8029	530
Region Total	33151	10802	20849	31651	-1500
	32048	9819	20391	30210	-1838**

* pumped storage HPP's included

** import of 1500 MW plus half of NPP Krsko (Slovenia) production (scheduled for Croatian power system)

4 LOAD FLOW AND CONTINGENCY ANALYSIS – REFERENCE CASES

Introduction

In this chapter load-flow and security (n-1) analysis for reference cases defined in Chapter 2 is described. The analyzed network models are:

Year	Hydrology	Topology
2010	average	2010
	dry	
	wet	
2015	average	2010
		2015
	dry	2010
		2015
	wet	2010
		2015

The load-flow analysis includes line loading and voltage profile analysis, analysis of losses and also analysis of power flows through interconnection lines.

The system reliability and adequacy is checked using “n-1” contingency criterion. List of contingencies includes:
- all interconnection lines;
- all 400 and 220 kV lines in analyzed region, except lines which outage cause “island” operation (in case of parallel and double circuit lines, outage of one line is considered);
- all transformers 400/x kV in analyzed region (in case of parallel transformers, outage of one transformer is considered).

Current thermal limits are used as rated limits of lines and transformers, as described in Chapter 2. Voltage limits are defined in Chapter 2, also.
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".

4.1 Scenario 2010 – average hydrology – 2010 topology

This part of the Study presents results of static load flow and voltage profile analyses that are conducted for complete network topology and (n-1) contingencies in the scenario which is denoted as Scenario 2010 average hydrology.

4.1.1 Line loadings

Area totals and power exchanges for the 2010-base case-average hydrology scenario are shown in Figure 4.1.1 and

Table 4.1.1. Power flows along regional interconnection lines and system balances are shown in Figure 4.1.2. Power flows along interconnection lines are also given in Table 4.1.2, while Figure 4.1.3 shows histogram of tie lines loadings.

Figure 4.1.1 - Area exchanges in analyzed electric power systems for 2010-base case-average hydrology scenario

Table 4.1.1 - Area totals in analyzed electric power systems for 2010-base case-average hydrology scenario

Country	**Generation (MW)**	**Load (MW)**	**Bus Shunt (Mvar)**	**Line Shunt (Mvar)**	**Losses (MW)**	**Net Interchange (MW)**
Albania	896.7	1287.3	0	0	50.4	-441.0
Bulgaria	6900.4	5977.3	0	14.4	121.6	787.0
Bosnia and Herzegovina	2266.1	1971.3	0	0	58.6	236.2
Croatia	1502.9	3136.7	0	0	49.0	-1682.8
Macedonia	950.3	1198.2	0	0	20.1	-268.0
Romania	7939.9	6728.3	0	80.0	201.2	930.4
Serbia and UNMIK	7355.9	6873.1	0	13.6	220.8	248.4
Montenegro	539.8	669.2	0.6	1.6	15.5	-147.0
TOTAL - SE EUROPE	*28351.9*	*27841.4*	*0.6*	*109.5*	*737.1*	*-336.7*

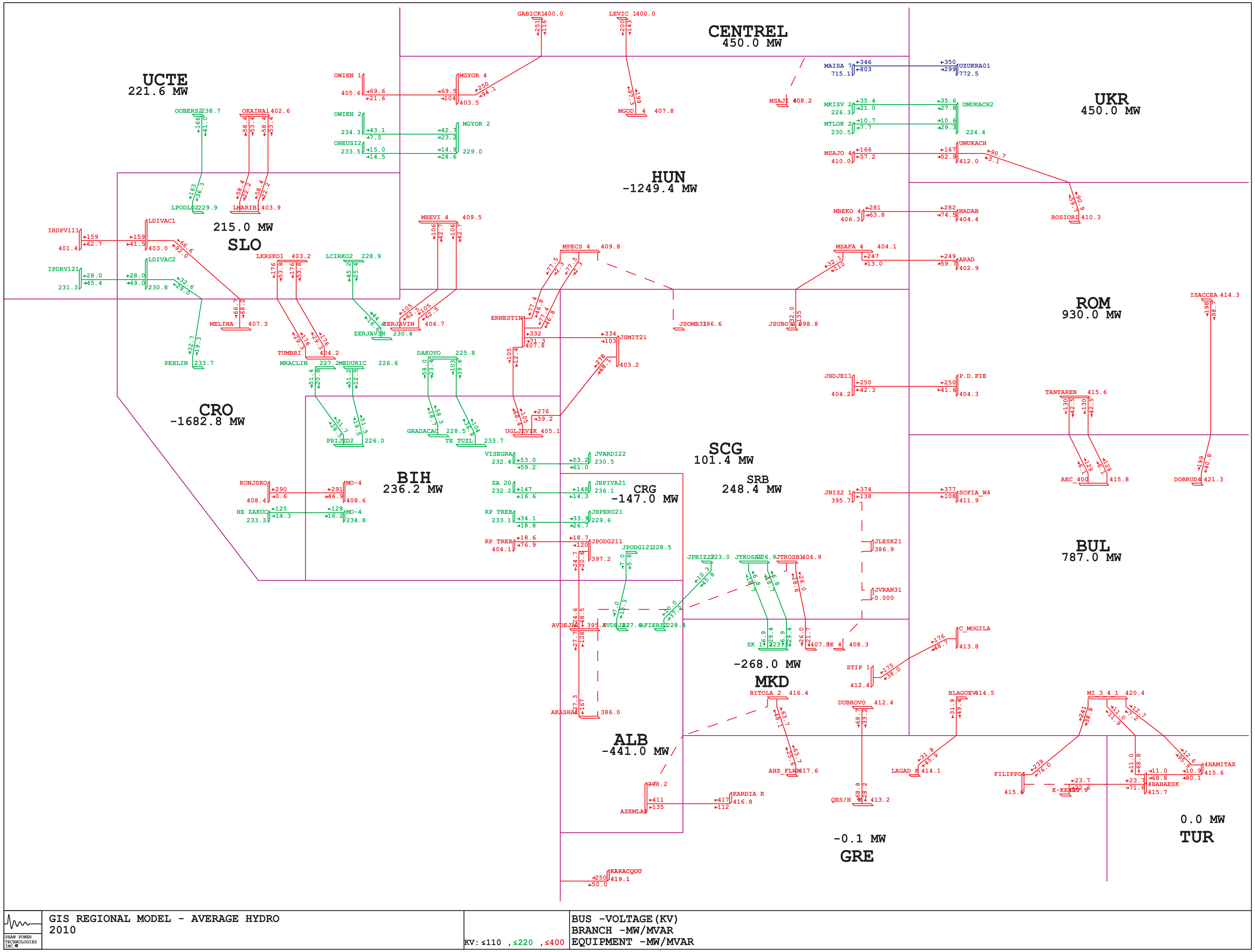


Figure 4.1.2 - Power flows along interconnection lines in the region for 2010 - base case - average hydrology scenario

Table 4.1.2 - Power flows along regional interconnection lines for 2010 - base case-average hydrology scenario

Interconnection line			**Power Flow**		**% of thermal rating**
			MW	**Mvar**	
OHL 400 kV	Zemlak (ALB)	Kardia (GRE)	-410.7	-135.0	32
OHL 220 kV	Fierze (ALB)	Prizren (SER)	-10.0	37.2	15
OHL 220 kV	V.Dejes (ALB)	Podgorica (MON)	7.0	-15.3	6
OHL 400 kV	V.Dejes (ALB)	Podgorica (MON)	-24.6	-48.5	4
OHL 400 kV	Ugljevik (B&H)	Ernestinovo (CRO)	105.4	-68.4	10
OHL 400 kV	Mostar (B&H)	Konjsko (CRO)	291.3	-46.9	22
OHL 400 kV	Ugljevik (B&H)	S. Mitrovica (SER)	-276.4	39.2	21
OHL 400 kV	Trebinje (B&H)	Podgorica (MON)	-18.6	76.9	9
OHL 220 kV	Trebinje (B&H)	Plat (CRO)	-104.8	40.0	36
OHL 220 kV	Prijedor (B&H)	Mraclin (CRO)	51.7	-28.5	18
OHL 220 kV	Prijedor (B&H)	Medjuric (CRO)	51.5	-19.5	17
OHL 220 kV	Gradacac (B&H)	Djakovo (CRO)	58.3	18.7	21
OHL 220 kV	Tuzla (B&H)	Djakovo (CRO)	103.9	36.9	36
OHL 220 kV	Mostar (B&H)	Zakucac (CRO)	127.6	-16.2	33
OHL 220 kV	Visegrad (B&H)	Vardiste (SER)	-53.0	59.2	26
OHL 220 kV	Sarajevo 20 (B&H)	Piva (MON)	-147.1	-16.6	38
OHL 220 kV	Trebinje (B&H)	Perucica (MON)	34.1	18.8	14
OHL 400 kV	Blagoevgrad (BUL)	Thessaloniki (GRE)	31.9	-49.4	8
OHL 400 kV	M.East 3 (BUL)	Filippi (GRE)	240.9	-38.9	35
OHL 400 kV	M.East 3 (BUL)	Babaeski (TUR)	11.0	-11.9	5
OHL 400 kV	M.East 3 (BUL)	Hamitabat (TUR)	12.7	-7.2	5
OHL 400 kV	C.Mogila (BUL)	Stip (MCD)	175.7	-48.7	25
OHL 400 kV	Dobrudja (BUL)	Isaccea (ROM)	199.5	-40.8	15
OHL 2x400 kV ckt.1	Kozloduy (BUL)	Tantarena (ROM)	-129.5	-6.1	10
OHL 2x400 kV ckt.2	Kozloduy (BUL)	Tantarena (ROM)	-129.5	-6.1	10
OHL 400 kV	Sofia West (BUL)	Nis (SER)	377.1	108.2	55
OHL 2x400 kV ckt.1	Zerjavinec (CRO)	Heviz (HUN)	-105.4	-62.5	9
OHL 2x400 kV ckt.2	Zerjavinec (CRO)	Heviz (HUN)	-105.4	-62.5	9
OHL 2x400 kV ckt.1	Ernestinovo (CRO)	Pecs (HUN)	-77.4	-46.8	7
OHL 2x400 kV ckt.2	Ernestinovo (CRO)	Pecs (HUN)	-77.4	-46.8	7
OHL 2x400 kV ckt.1	Tumbri (CRO)	Krsko (SLO)	-176.0	29.3	16
OHL 2x400 kV ckt.2	Tumbri (CRO)	Krsko (SLO)	-176.0	29.3	16
OHL 400 kV	Melina (CRO)	Divaca (SLO)	66.8	53.5	10
OHL 400 kV	Ernestinovo (CRO)	S.Mitrovica (SER)	-332.1	71.3	25
OHL 220 kV	Zerjavinec (CRO)	Cirkovce (SLO)	-44.9	16.6	16
OHL 220 kV	Pehlin (CRO)	Divaca (SLO)	32.7	19.3	13
OHL 400 kV	Dubrovo (MCD)	Thessaloniki (GRE)	-68.7	-33.2	6
OHL 400 kV	Bitola (MCD)	Florina (GRE)	-63.7	-48.1	6
OHL 400 kV	Skopje (MCD)	Kosovo B (UNMIK)	26.0	-21.7	3
OHL 2x220 kV ckt.1	Skopje (MCD)	Kosovo A (UNMIK)	6.9	-29.4	9
OHL 2x220 kV ckt.2	Skopje (MCD)	Kosovo A (UNMIK)	6.9	-29.4	9
OHL 400 kV	Arad (ROM)	Sandorfalva (HUN)	248.6	-59.7	21
OHL 400 kV -	Nadab (ROM)	Bekescaba (HUN)	281.9	-74.5	24
OHL 400 kV	Rosiori (ROM)	Mukacevo (UKR)	90.9	-59.7	9
OHL 400 kV	Portile De Fier (ROM)	Djerdap (SER)	249.7	41.6	19
OHL 400 kV	Subotica (SER)	Sandorfalva (HUN)	-32.0	-135.1	10
OHL 400 kV	Ribarevine (MON)	Kosovo B (UNMIK)	-296.0	-15.0	22
OHL 220 kV	Pljevlja (MON)	Bajina Basta (SER)	-46.0	10.7	17
OHL 220 kV	Pljevlja (MON)	Pozega (SER)	34.9	35.3	19

Figure 4.1.3 shows that the tie lines in the region are mostly loaded less than 25% of their thermal limits for the analyzed hydrological base case scenario in year 2010. Among total number of forty nine 400 kV and 220 kV interconnection lines in the region only seven are loaded between 25% and 50% of their thermal ratings. Only one line (OHL 400 kV Sofia – Nis between Bulgaria and Serbia) is loaded more than 50% of its thermal rating, which is set at lower value (692.8 MVA) on the Bulgarian side compared to the line rating on the Serbian side (1330.2 MVA).

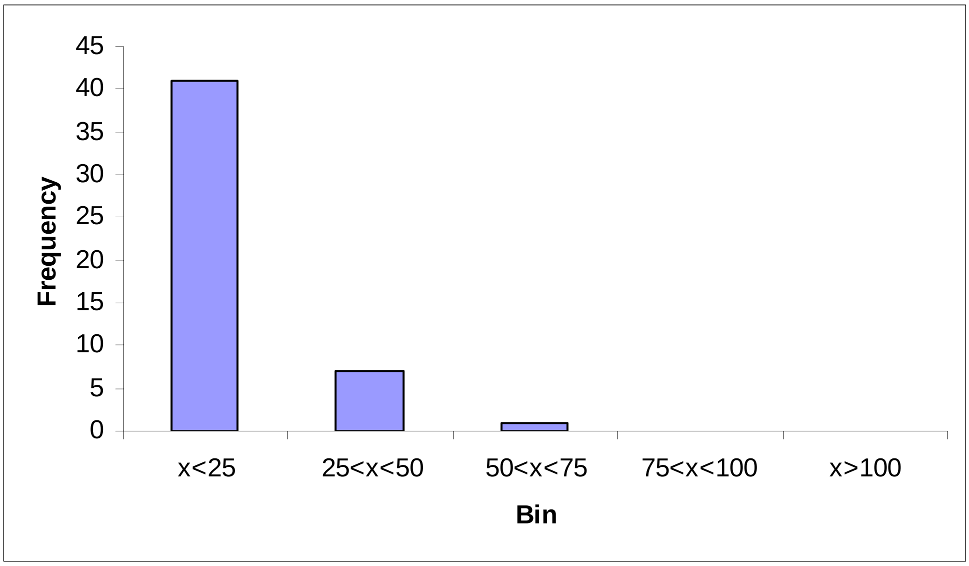


Figure 4.1.3 - Histogram of interconnection lines loadings for 2010-base case-average hydrology scenario ("Frequency" denotes number of lines and "Bin" denotes loading range in % of thermal limit)

Table 4.1.3 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 in some substations and internal 110 kV and 220 kV lines. Thus, certain internal network reinforcements are necessary to sustain given load-demand level and production pattern.

Two 220/110 kV transformers in the Fierze substation in Albania are slightly overloaded in this scenario, while the third transformer in the same substation is loaded near permitted values. It is expected that the transformers in that substation will be replaced with larger transformer units.

There are two 110 kV internal lines in Romania which are loaded over 80% of their thermal limits, but none of them is overloaded. These lines are related to the Bojuren and Domnesti nodes.

Two 220 kV lines and thirteen 110 kV lines in the Serbian power system are highly loaded when all branches are available in the analyzed scenario. Highly loaded 220 kV lines are connected to the Obrenovac substation, while 110 kV lines are located mostly in the area of Belgrade. Four 110 kV lines are overloaded, ranging between 108% $I_{thermal}$ and 118% $I_{thermal}$.

Power systems of Bulgaria, Bosnia and Herzegovina, Croatia, Macedonia and Montenegro do not have or have very few highly loaded branches in 110 kV networks.

Figure 4.1.4 shows histogram of 400 kV and 220 kV regional internal lines and 400/x kV and 220/x kV transformers loadings. 47% of observed branches are loaded below 25% of their thermal ratings, 34% are loaded between 25% and 50%, 16% are loaded between 50% and 75% and only 2% of observed branches are loaded between 75% and 100% of their thermal ratings. Two branches (transformers 220/110 kV Fierze in Albania, 102% - 106% S_n) are overloaded if all branches are in operation for the analyzed scenario.

Table 4.1.3 - Network elements loaded over 80% of thermal limits for 2010-base case-average hydrology scenario

AREA	ELEMENT	LOADING MVA	RATING MVA	PERCENT
Transformers				
ALB	TR 220/110 kV AFIER 2-AFIER 5 ckt.1	116.8	120.0	93.7
	TR 220/110 kV AFIER 2-AFIER 5 ckt.2	95.7	90.0	106.4
	TR 220/110 kV AFIER 2-AFIER 5 ckt.3	91.4	90.0	101.5
BIH	TR 400/110 kV UGLJEV 1	254.8	300	84.9
ROM	TR 400/220 kV MINTIA-MINTIA B	385.7	400.0	96.4
	TR 220/110 kV FUNDENI-FUNDE2B	173.1	200.0	86.6

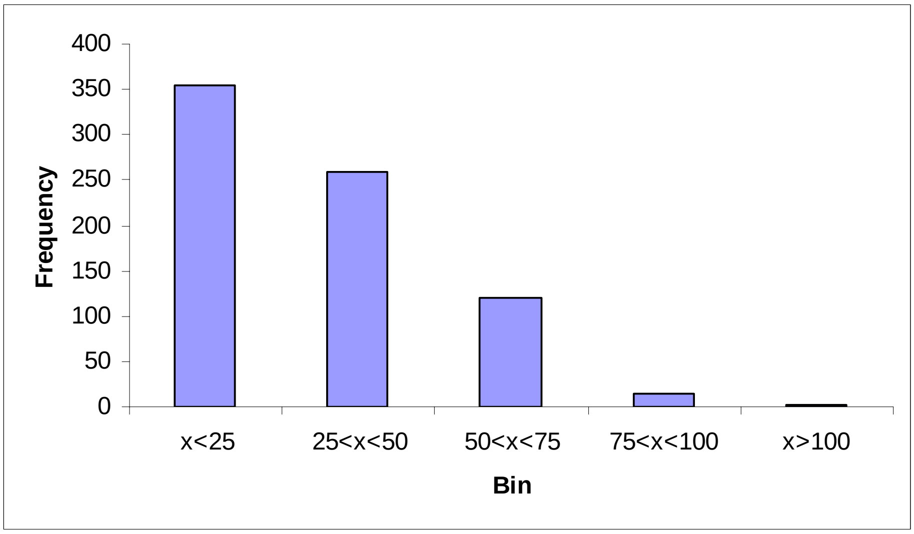


Figure 4.1.4 - Histogram of 400 kV and 220 kV regional lines loadings for 2010-base case-average hydrology scenario ("Frequency" denotes number of lines and "Bin" denotes loading range in % of thermal limit)

4.1.2 Voltage Profile in the Region

Voltage profile in the region within this scenario which is defined by given generation and demand pattern is seen as satisfactory despite several appearances of certain bus voltage deviations. The deviations are shown in Table 4.1.4, which includes only 400 kV and 220 kV network buses.

Table 4.1.4 - Bus voltage deviations for 2010-base case-average hydrology scenario, complete network

Country	**Node**	**Voltages**	
		pu	**kV**
ALBANIA	-	-	-
BOSNIA AND HERZEGOVINA	-	-	-
BULGARIA	400 kV VARNA4	1.054	421.4
	400 kV BURGAS	1.051	420.5
	400 kV MARITSA EAST2	1.055	422.1
	400 kV TECMIG5	1.051	420.5
	400 kV TECMIG7	1.051	420.5
	400 kV DOBRUD4	1.053	421.3
	400 kV MARITSA EAST 3_4_1	1.051	420.5
	400 kV TECMIG6	1.051	420.5
	220 kV SESTRIMO	1.104	242.8
	220 kV BPC_220	1.102	242.5
	220 kV MIZIA2	1.101	242.1
	220 kV AEC_220	1.103	242.6
	220 kV TECVARNA	1.104	242.9
CROATIA	-	-	-
MACEDONIA	-	-	-
MONTENEGRO	-	-	-
ROMANIA	-	-	-
SERBIA AND UNMIK	-	-	-

Bus voltage magnitudes below permitted limits are not found in the analyzed scenario. Bus voltage magnitudes that are found above permitted limits (110% $V_{nominal}$ in 110 kV and 220 kV networks and 105% $V_{nominal}$ in 400 kV network) are detected only in Bulgaria. There are eight 400 kV buses and five 220 kV buses with voltages slightly above permitted limits. Figure 4.1.5 shows histogram of voltages in monitored 400 kV and 220 kV substations.

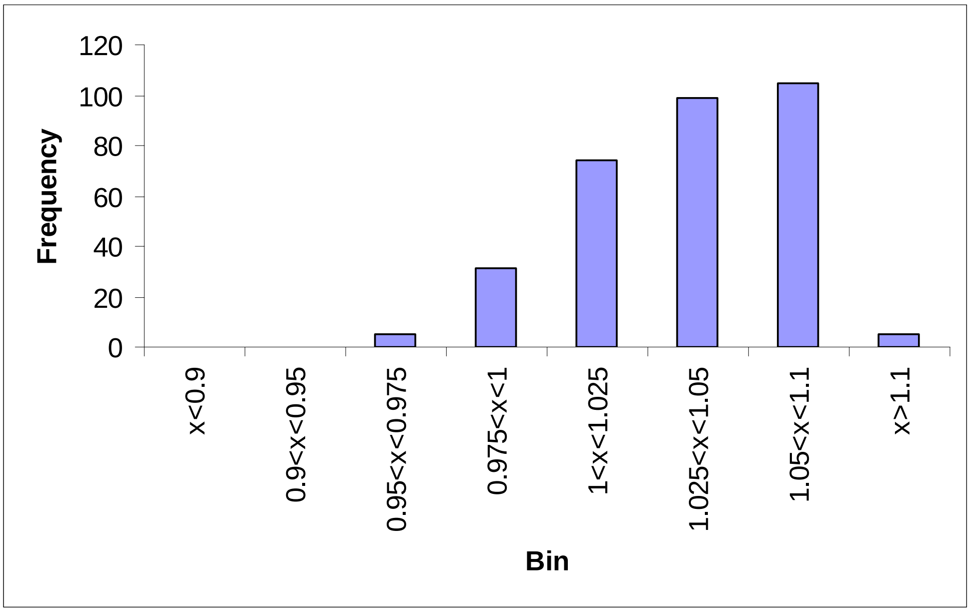


Figure 4.1.5 - Histogram of voltages in monitored substations for 2010-base case-average hydrology scenario ("Frequency" denotes number of busses and "Bin" denotes voltage range in p.u.)

It should be emphasized that these results represent only a situation when additional devices (transformer automatic tap changers, switched 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.

4.1.3 Security (n-1) analysis

Results of security (n-1) analysis for the 2010-base case-average hydrology scenario are presented in Table 4.1.5 and Table 4.1.6.

Insecure states for given generation and demand pattern are detected mostly in the power systems of Romania and Serbia, although there is one contingency in Albania which leads to insecure state.

The most critical branch in the analyzed load/generation scenario is the transformer 400/220 kV in the Mintia B substation in Romania. It is due to a high level of generation in DEVA 1 power plant (850 MW), which is connected to 220 kV busbars in that substation. Noted transformer becomes overloaded if one among eleven 400 kV and 220 kV lines or 400/220 kV transformers in the Romanian or Serbian power system goes out of operation. Secure operating conditions can be achieved if the generation level in DEVA 1 (Mintia) power plant is significantly lowered. Other way to achieve more secure operation with the same level of production in DEVA 1 power plant is to change network topology (connect generators in DEVA 1 to the second busbars or to connect two busbar systems in Mintia substation). Loss of 400/220 kV transformer in the Mintia B substation can jeopardize system security due to possible overloading of two 220 kV lines in Romania. Loss of one 400 kV line in Romania (Mintia-Arad) is critical because the 400 kV line Mintia-Sibiu can be overloaded. Single outages of 400/110 kV transformers in the stations Brasov and Dirste in Romania are also found critical, since the second transformer 400/110 kV in the Brasov substation is permanently out of operation in the model.

Loss of OHL 220 kV in the Belgrade area can cause overloading of the parallel line. Loss of one 400/110 kV transformer in the Nis substation is critical due to possible overloading of the other parallel one.

Loss of 220 kV line between the Rashbul and Tirana substations can cause overloading of 220 kV line between the Elbasan and Fier substations in Albania.

The heaviest line overloading (147% $I_{thermal}$) in the analyzed scenario is related to a 220 kV line in Romania around the Mintia substation. The heaviest transformer overloading (137% S_n) is related to the transformer 400/110 kV in the Dirste substation (Romania) when the transformer 400/110 kV in the Brasov substation is outaged (the parallel one is permanently out of operation in the model).

Figure 4.1.6 shows geographical positions of critical elements in the analyzed scenario. A green color reveals 220 kV elements (line 220 kV or transformer 220/x kV), while a red one reveals 400 kV elements (line 400 kV or transformer 400/x kV).

According to the obtained and presented results, it may be concluded that a re-dispatching of generation in the Romanian power system, especially of the DEVA 1 power plant (to decrease its generation level from the initially assumed 850 MW in this scenario), as well as certain reinforcements in the internal networks of Romania, Albania and Serbia are necessary shall this generation/load pattern be made more secure. Re-dispatching of Romanian power plants may be avoided if network topology is changed, especially in Mintia substation. None of the identified congestions is located at the border lines.

Table 4.1.5 - Lines overloadings for 2010–base case-average hydrology scenario, single outages

Outage	**Overloaded line(s)**	**Loadings**		**Country**
		MVA	**%**	
OHL 220 kV AKASHA2-ARRAZH2	OHL 220 kV AELBS12-AFIER 2	253.1	113.2	ALBANIA
OHL 400 kV MINTIA-ARAD	OHL 400 kV MINTIA-SIBIU	408.2	106.5	ROMANIA
TR 400/220 kV MINTIA B	OHL 220 kV PESTIS-MINTIA A	431.1	147.3	
TR 400/220 kV MINTIA B	OHL 220 kV PESTIS-MINTIA B	351.4	119.3	
OHL 220 kV JBGD172-JBGD8 22 ckt.1	OHL 220 kV JBGD172-JBGD8 22 ckt.2	434.8	122.2	SERBIA

Table 4.1.6 - Transformers overloadings for 2010–base case-average hydrology scenario, single outages

Outage	**Overloaded branch(es)**	**Loadings**		**Country**
		MVA	**%**	
OHL 400 kV TANTAREN-SIBIU	TR 400/220 kV MINTIA B	412.1	103.0	ROMANIA
OHL 220 kV HAJD OT-MINTIA B	TR 400/220 kV MINTIA B	404.4	101.1	
OHL 220 kV PESTIS-MINTIA A	TR 400/220 kV MINTIA B	511.2	127.8	
OHL 220 kV MINTIA A-TIMIS	TR 400/220 kV MINTIA B	412.3	103.1	
OHL 220 kV MINTIA B-AL.JL	TR 400/220 kV MINTIA B	474.8	118.7	
OHL 220 kV CLUJ FL-AL.JL	TR 400/220 kV MINTIA B	496.0	124.0	
TR 400/220 kV MINTIA A	TR 400/220 kV MINTIA B	530.8	132.7	
TR 400/220 kV MINTIA B	TR 400/220 kV MINTIA A	459.5	114.9	
TR 400/220 kV ARAD	TR 400/220 kV MINTIA B	401.2	100.3	
TR 400/220 kV BUC.S ckt.1	TR 400/220 kV BUC.S ckt.2	410.2	102.5	
400/110 kV BRASOV	400/110 kV DIRSTE	341.3	136.5	
400/110 kV DIRSTE	400/110 kV BRASOV	337.5	135.0	
400/110 kV NIS ckt.1	400/110 kV NIS ckt.2	312.3	104.1	SERBIA

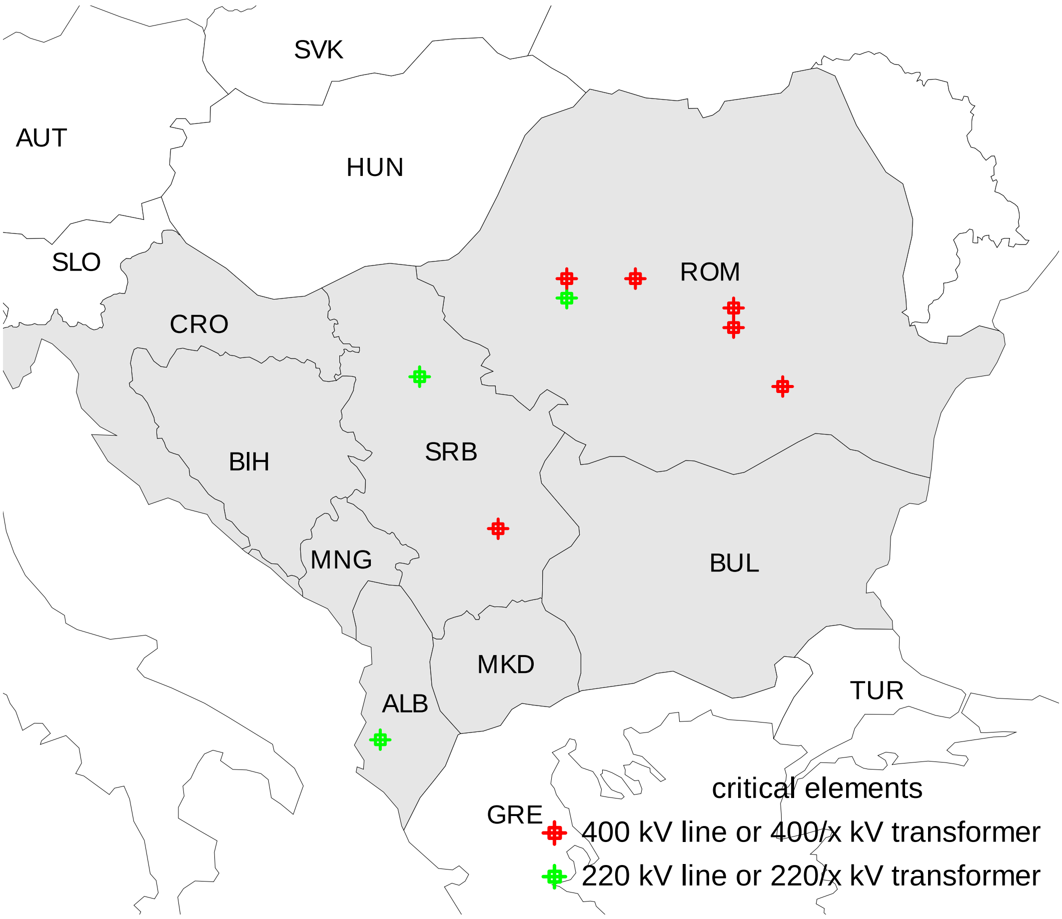


Figure 4.1.6 - Geographical positions of the critical elements for 2010-base case-average hydrology scenario

4.2 Scenario 2010 – dry hydrology

This part of the Study presents the results of static load flow and voltage profile analyses that are conducted for complete network topology and (n-1) contingencies in the scenario which is denoted as GTmax run for year 2010 - dry hydrology.

4.2.1 Lines loadings

Figure 4.2.1 shows power exchanges between areas for 2010-dry hydrology scenario. Power flows along interconnection lines in the region together with balances of the systems are shown in Figure 4.2.2. Area totals are shown in Table 4.2.1. Figure 4.2.3 shows histogram of tie lines loadings. It is concluded that most of the tie lines are loaded less than 25% of their thermal limits.

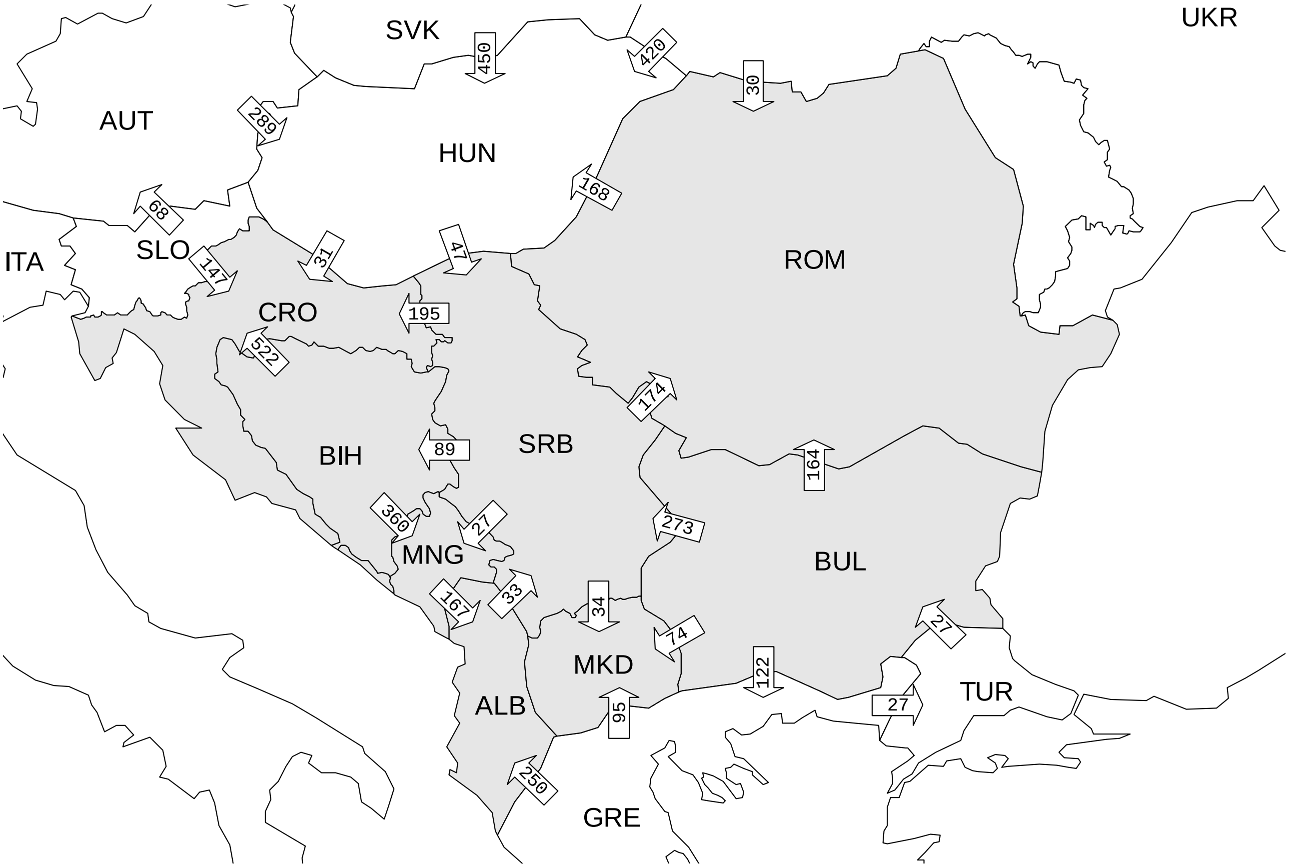


Figure 4.2.1 - Area exchanges in analyzed electric power systems for 2010-dry hydrology scenario

Table 4.2.1 - Area totals in analyzed electric power systems for 2010-dry hydrology scenario

AREA	GENERATION	LOAD	LOSSES	INTERCHANGE
ALBANIA	953.3	1290.5	46.8	-384
BULGARIA	6709.6	5970	133.6	606
BIH	2842.4	1989	60.3	793
CROATIA	2294.6	3147	41.6	-894
MACEDONIA	1021.1	1206	18.1	-203
ROMANIA	6742	6703.8	238	-199.9
SERBIA	7311.7	6944	201.6	166
MONTENEGRO	467.8	671	16.9	-220
TOTALS	28342.5	27921.3	756.9	-335.9

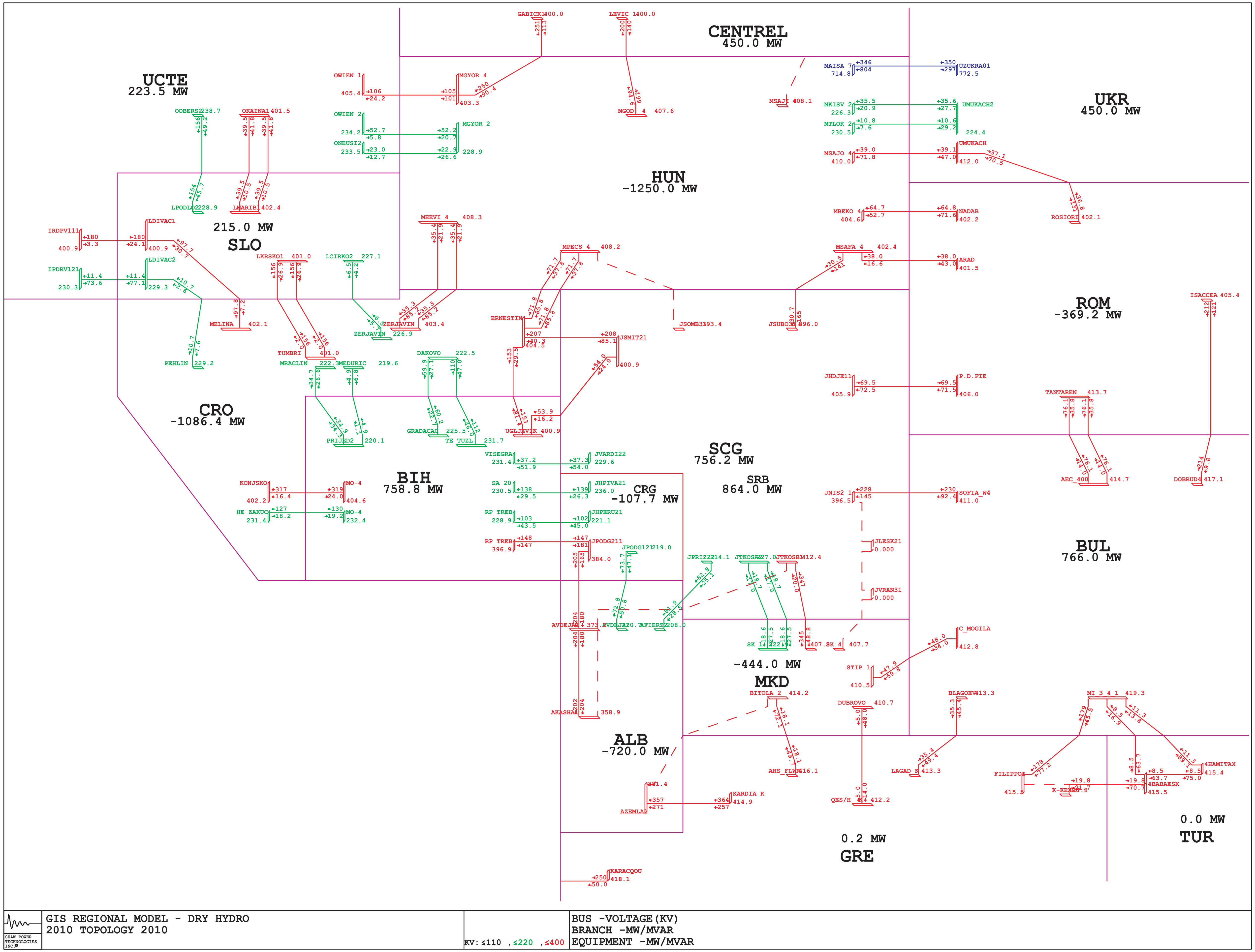


Figure 4.2.2 - Power flows along interconnection lines in the region with balances of the systems for 2015-dry hydrology scenario – 2010 topology

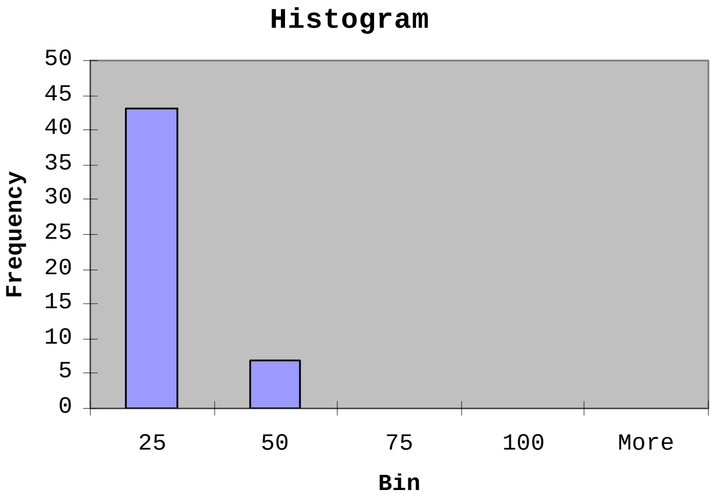


Figure 4.2.3 - Histogram of interconnection lines loadings for 2010-dry hydrology scenario ("Frequency" denotes number of lines and "Bin" denotes loading range in % of thermal limit)

Following Table 4.2.2 shows all network elements loaded over 80% of their thermal limits. As it can be seen only transformers 220/110 kV in substation Fier in Albania are highly loaded. Also, transformer 220/110 kV in substation Fundeni in Romania is loaded over 80 % of its thermal limit.
Figure 4.2.4 shows histogram of branch loadings in the system. As for the conclusion regarding thermal loadings in this scenario it can be said that almost all of the network elements are loaded less then 75% of their thermal limits, but there are some elements highly loaded. The elements loaded over 80% are transformers 220/110 kV in substation Fier and transformer 220/110 kV in substation Fundeni in Romania, so some internal network reinforcements are necessary to sustain this load-demand level and production pattern. It is expected that transformers in Fierza substation will be replaced with more powerful transformer units.

Table 4.2.2 - Network elements loaded over 80% of their thermal limits for 2010-dry hydrology scenario

BRANCH LOADINGS ABOVE 80.0 % OF RATING:

AREA	ELEMENT	LOADING MVA	RATING MVA	PERCENT
Transformers				
ALB	TR 220/110 kV AFIER 1	106.8	120	89
	TR 220/110 kV AFIER 2	87.5	90	97.2
	TR 220/110 kV AFIER 3	83.5	90	92.8
ROM	TR 220/110 kV FUNDE2 1	168.1	200	84.1

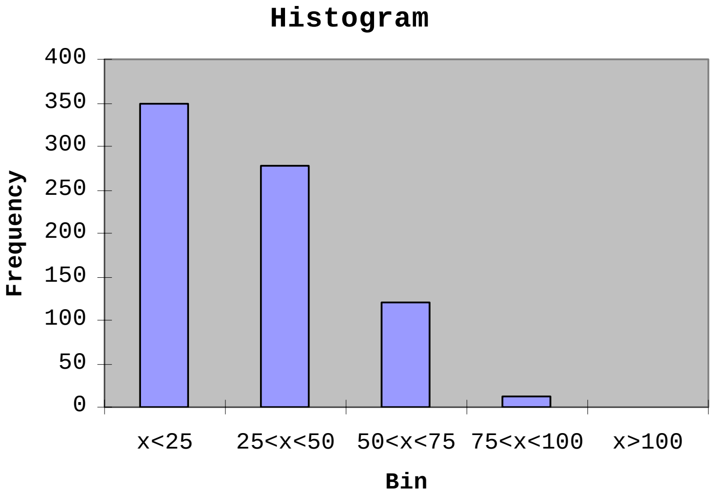


Figure 4.2.4 - Histogram of branch loadings for 2010-dry hydrology scenario ("Frequency" denotes number of branches and "Bin" denotes loading range in % of thermal limit)

4.2.2 Voltage Profile in the Region

Figure 4.2.5 shows histogram of voltages in monitored substations. Voltages in almost all monitored substations are found within permitted limits.

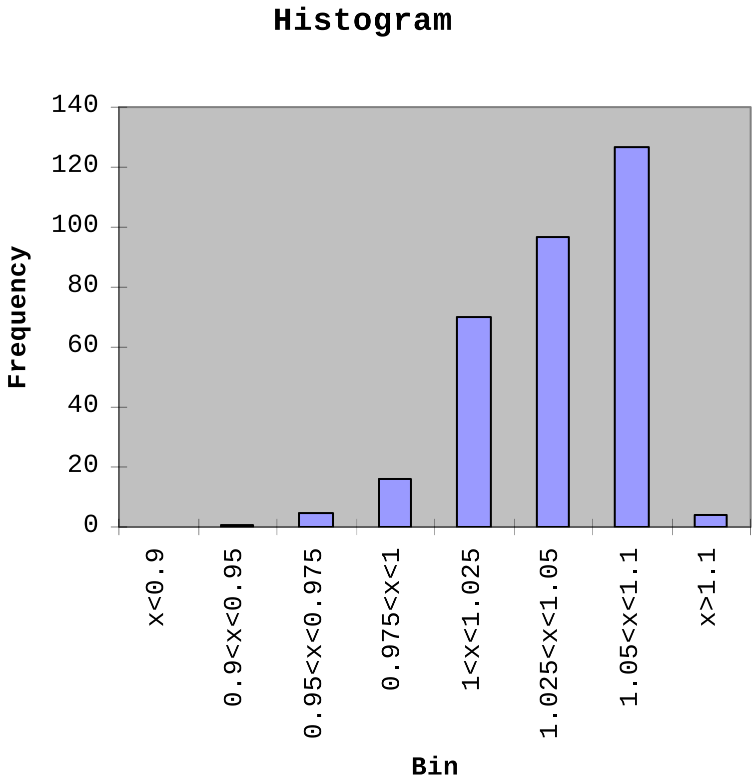


Figure 4.2.5 - Histogram of voltages in monitored substations for 2010-dry hydrology scenario ("Frequency" denotes number of busses and "Bin" denotes voltage range in p.u.)

In the rest of the monitored network the voltage profile is satisfying and that most of the substations have magnitudes in range 0.975-1.05 p.u.

4.2.3 Security (n-1) analysis

Results of security (n-1) analysis for 2010-dry hydrology scenario are presented in Table 4.2.3. Figure 4.2.6 shows the geographical position of the critical elements in monitored systems.

It can be concluded that all identified insecure states are located in internal networks that belong to monitored power systems of Romania and Serbia. In the most critical cases in Romanian system, the critical elements are transformers 400/110 kV in substations Dirste and Brasov. The most critical elements in Serbian system are lines 220 kV Beograd 8 – Beograd 17 and Obrenovac – Beograd 3.

Some of the overloadings identified can be relieved by certain dispatch actions (splitting busbars, changing lower voltage network topology in order to redistribute load-demand or change of generation units engagement), like in the case of most severe overloading in Romanian network happens on transformer 400/110 kV Dirste when transformer 400/110 kV in Brasov is outaged, but this is a consequence of the fact that second transformer unit 400/110 kV in Brasov is out of operation. Switching on of this transformer clears this critical outage. The similar situation is with outage of the 400 kV line Obrenovac-Beograd 3 in Serbia. Splitting off the 220 kV busbars in substation Beograd 3 relieves this overloading, but voltage profile in Serbian network remains critical, so additional dispatching actions are necessary too.

All in all, certain reinforcement of internal network is necessary (more about this in chapter 6) in order to make this regime more secure. None of the identified congestions is located at border lines.

Table 4.2.3 - Network overloadings for 2010-dry hydrology scenario, single outages

Area	contingency	Area	overloadings / out of limits voltages	#	limit / Unom	Flow / Voltage	rate / volt.dev.
1	2	3	4	5	6	7	8
CS	OHL 220kV JBGD172 -JBGD8 22 1	CS	HL 220kV JBGD172-JBGD8 22	2	365.8MVA	440.8MVA	123.1%
CS	OHL 400kV JBGD8 1 -JOBREN11 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	340.1MVA	115.4%
RO	TR 400/110 BRASOV 1	RO	TR 400/110kV/kV DIRSTE	1	250MVA	333.3MVA	133.3%
RO	TR 400/110 DIRSTE 1	RO	TR 400/110kV/kV BRASOV	1	250MVA	329.9MVA	132.0%
CS	TR 400/110 JNIS2 1	CS	TR 400/110kV/kV JNIS2 1	2	300MVA	338.2MVA	112.7%
RO	TR 400/220 BUC.S 1	RO	TR 400/220kV/kV BUC.S	2	400MVA	403.8MVA	101.0%
RO	TR 400/220 MINTIA 1	RO	TR 400/220kV/kV MINTIA	1	400MVA	419.5MVA	104.9%
		RO	HL 220kV PESTIS-MINTIA A	1	277.4MVA	313.9MVA	105.5%
RO	TR 400/220 MINTIA 1	RO	TR 400/220kV/kV MINTIA	1	400MVA	433MVA	108.3%

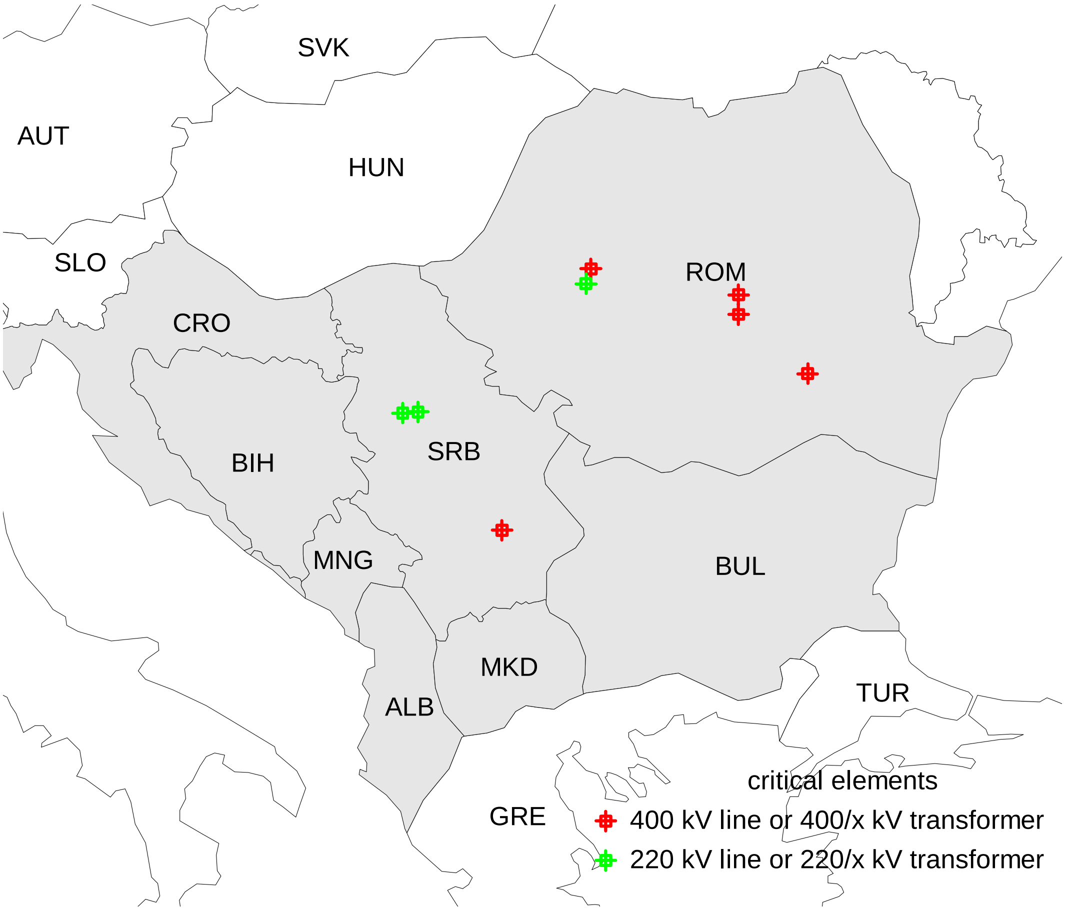


Figure 4.2.6 – Geographical position of critical elements for 2010-dry hydrology scenario

4.3 Scenario 2010 – wet hydrology

This part of the Study presents results of static load flow and voltage profile analyses that are conducted for complete network topology and (n-1) contingencies in the scenario which is denoted as Scenario 2010 – wet hydrology.

4.3.1 Line loadings

Area totals and power exchanges for the 2010-base case-wet hydrology scenario are shown in Figure 4.3.1 and Table 4.3.1. Power flows along regional interconnection lines and system balances are shown in Figure 4.3.2. Power flows along interconnection lines are also given in Table 4.3.2, while Figure 4.3.3 shows histogram of tie lines loadings.

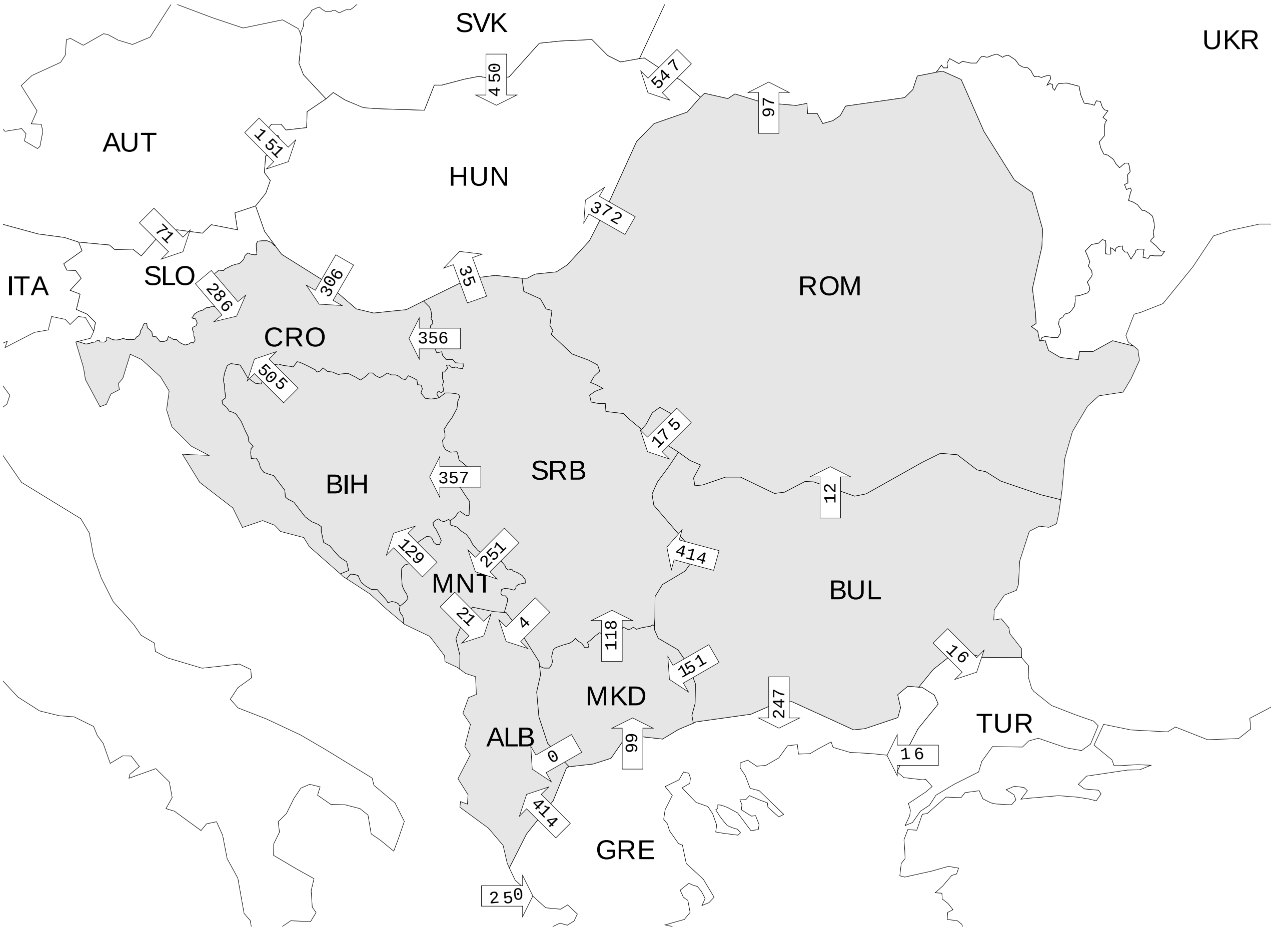


Figure 4.3.1 - Area exchanges in analyzed electric power systems for 2010-base case-wet hydrology scenario

Table 4.3.1 - Area totals in analyzed electric power systems for 2010-base case-wet hydrology scenario

Country	**Generation (MW)**	**Load (MW)**	**Bus Shunt (Mvar)**	**Line Shunt (Mvar)**	**Losses (MW)**	**Net Interchange (MW)**
Albania	898.6	1287.3	0	0	50.3	-439.0
Bulgaria	6940.4	5966.2	0	14.3	120.9	839.0
Bosnia and Herzegovina	2037.1	1961.1	0	0	57.0	19.0
Croatia	1735.4	3136.7	0	0	50.7	-1452.0
Macedonia	1081.8	1194.0	0	0	19.8	-132.0
Romania	7342.4	6423.7	0	79.9	206.6	632.2
Serbia and UNMIK	7406.2	6875.1	0	13.6	220.4	297.1
Montenegro	586.3	669.2	0.6	1.6	15.9	-101.0
TOTAL - SE EUROPE	*28028.1*	*27513.3*	*0.6*	*109.4*	*741.5*	*-336.7*

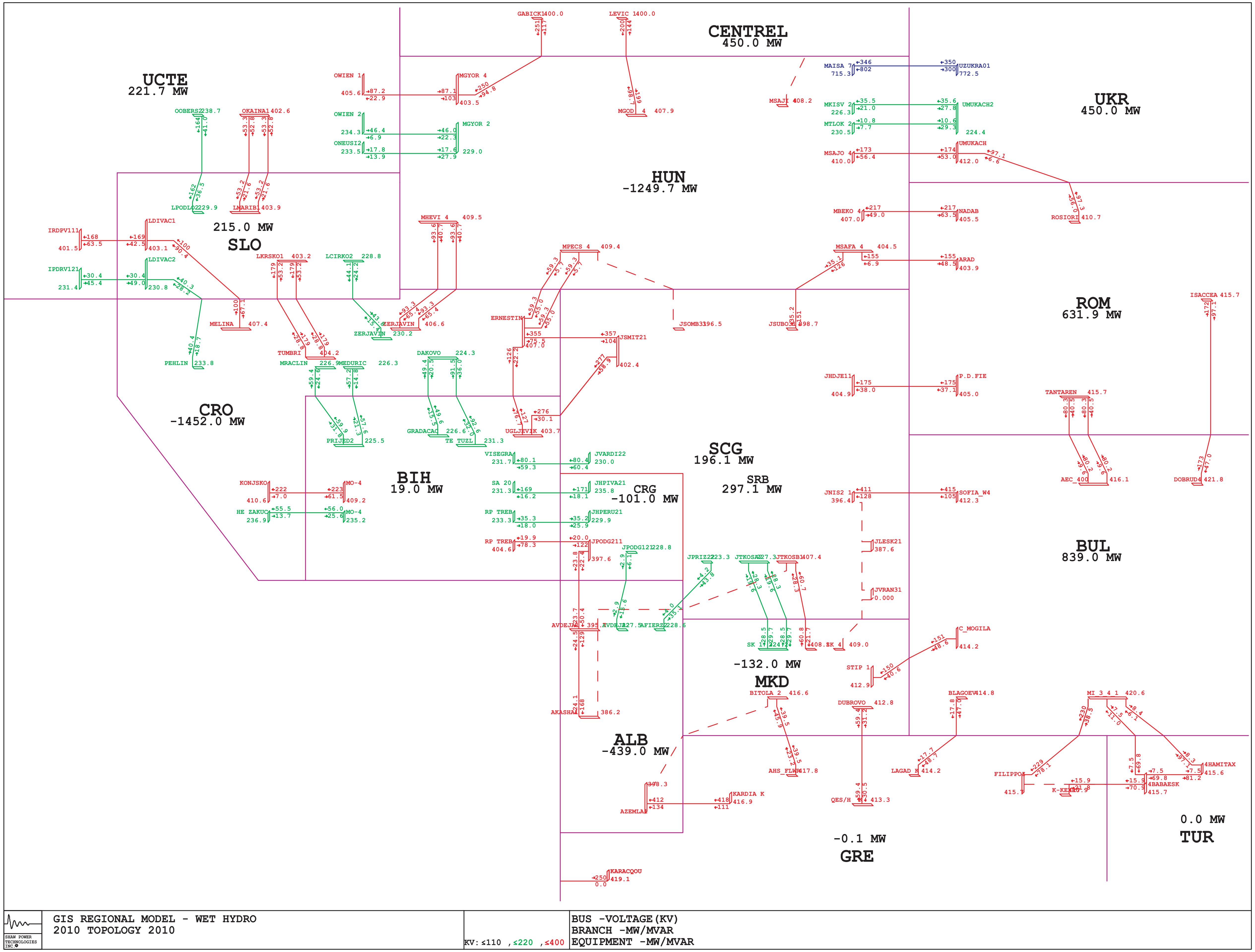


Figure 4.3.2 - Power flows along interconnection lines in the region for 2010 - base case - wet hydrology scenario

Table 4.3.2 - Power flows along regional interconnection lines for 2010 wet hydrology scenario

Interconnection line			Power Flow		% of thermal rating
			MW	Mvar	
OHL 400 kV	Zemlak (ALB)	Kardia (GRE)	-411.6	-134.3	32
OHL 220 kV	Fierze (ALB)	Prizren (SER)	-4.0	35.1	14
OHL 220 kV	V.Dejes (ALB)	Podgorica (MON)	2.9	-15.6	5
OHL 400 kV	V.Dejes (ALB)	Podgorica (MON)	-23.7	-50.4	4
OHL 400 kV	Ugljevik (B&H)	Ernestinovo (CRO)	126.8	-76.7	11
OHL 400 kV	Mostar (B&H)	Konjsko (CRO)	223.2	-61.5	17
OHL 400 kV	Ugljevik (B&H)	S. Mitrovica (SER)	-275.6	30.1	21
OHL 400 kV	Trebinje (B&H)	Podgorica (MON)	-19.9	78.3	9
OHL 220 kV	Trebinje (B&H)	Plat (CRO)	-104.8	39.9	36
OHL 220 kV	Prijedor (B&H)	Mraclin (CRO)	59.9	-31.8	21
OHL 220 kV	Prijedor (B&H)	Medjuric (CRO)	57.6	-21.3	19
OHL 220 kV	Gradacac (B&H)	Djakovo (CRO)	49.6	15.5	18
OHL 220 kV	Tuzla (B&H)	Djakovo (CRO)	92.6	32.0	32
OHL 220 kV	Mostar (B&H)	Zakucac (CRO)	56.0	-25.6	18
OHL 220 kV	Visegrad (B&H)	Vardiste (SER)	-80.1	59.3	32
OHL 220 kV	Sarajevo 20 (B&H)	Piva (MON)	-169.2	-16.2	44
OHL 220 kV	Trebinje (B&H)	Perucica (MON)	35.3	18.0	14
OHL 400 kV	Blagoevgrad (BUL)	Thessaloniki (GRE)	17.8	-47.0	7
OHL 400 kV	M.East 3 (BUL)	Filippi (GRE)	230.0	-38.5	34
OHL 400 kV	M.East 3 (BUL)	Babaeski (TUR)	7.5	-11.0	5
OHL 400 kV	M.East 3 (BUL)	Hamitabat (TUR)	8.4	-6.1	5
OHL 400 kV	C.Mogila (BUL)	Stip (MCD)	151.0	-48.6	22
OHL 400 kV	Dobrudja (BUL)	Isaccea (ROM)	172.5	-47.0	13
OHL 2x400 kV ckt.1	Kozloduy (BUL)	Tantarena (ROM)	-80.2	-9.6	6
OHL 2x400 kV ckt.2	Kozloduy (BUL)	Tantarena (ROM)	-80.2	-9.6	6
OHL 400 kV	Sofia West (BUL)	Nis (SER)	414.9	105.0	60
OHL 2x400 kV ckt.1	Zerjavinec (CRO)	Heviz (HUN)	-93.3	-65.4	9
OHL 2x400 kV ckt.2	Zerjavinec (CRO)	Heviz (HUN)	-93.3	-65.4	9
OHL 2x400 kV ckt.1	Ernestinovo (CRO)	Pecs (HUN)	-59.3	-55.0	6
OHL 2x400 kV ckt.2	Ernestinovo (CRO)	Pecs (HUN)	-59.3	-55.0	6
OHL 2x400 kV ckt.1	Tumbri (CRO)	Krsko (SLO)	-178.6	28.8	16
OHL 2x400 kV ckt.2	Tumbri (CRO)	Krsko (SLO)	-178.6	28.8	16
OHL 400 kV	Melina (CRO)	Divaca (SLO)	100.0	52.7	11
OHL 400 kV	Ernestinovo (CRO)	S.Mitrovica (SER)	-354.6	75.5	28
OHL 220 kV	Zerjavinec (CRO)	Cirkovce (SLO)	-43.8	15.4	15
OHL 220 kV	Pehlin (CRO)	Divaca (SLO)	40.4	18.7	15
OHL 400 kV	Dubrovo (MCD)	Thessaloniki (GRE)	-59.4	-31.2	6
OHL 400 kV	Bitola (MCD)	Florina (GRE)	-39.5	-45.9	4
OHL 400 kV	Skopje (MCD)	Kosovo B (UNMIK)	60.8	-21.7	5
OHL 2x220 kV ckt.1	Skopje (MCD)	Kosovo A (UNMIK)	28.5	-29.7	13
OHL 2x220 kV ckt.2	Skopje (MCD)	Kosovo A (UNMIK)	28.5	-29.7	13
OHL 400 kV	Arad (ROM)	Sandorfalva (HUN)	155.0	-48.5	28
OHL 400 kV -	Nadab (ROM)	Bekescaba (HUN)	217.3	-63.5	18
OHL 400 kV	Rosiori (ROM)	Mukacevo (UKR)	97.3	-56.0	9
OHL 400 kV	Portile De Fier (ROM)	Djerdap (SER)	174.5	37.1	13
OHL 400 kV	Subotica (SER)	Sandorfalva (HUN)	35.2	-151.3	12
OHL 400 kV	Ribarevine (MON)	Kosovo B (UNMIK)	-300.0	-16.4	22
OHL 220 kV	Pljevlja (MON)	Bajina Basta (SER)	-30.1	8.5	12
OHL 220 kV	Pljevlja (MON)	Pozega (SER)	46.0	34.5	21

Figure 4.3.3 shows that the tie lines in the region are mostly loaded less than 25% of their thermal limits for the analyzed hydrological base case scenario in year 2010. Among total number of forty nine 400 kV and 220 kV interconnection lines in the region only eight are loaded between 25% and 50% of their thermal ratings. Only one line (OHL 400 kV Sofia – Nis between Bulgaria and Serbia) is loaded more than 50% of its thermal rating, which is set at lower value (692.8 MVA) on the Bulgarian side compared to the line rating on the Serbian side (1330.2 MVA).

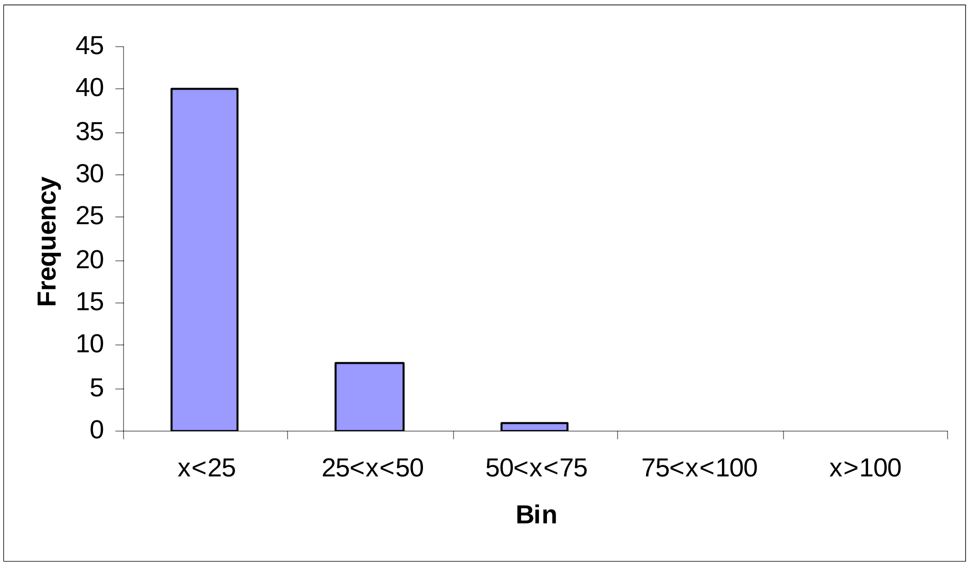


Figure 4.3.3 - Histogram of interconnection lines loadings for 2010-base case-wet hydrology scenario ("Frequency" denotes number of lines and "Bin" denotes loading range in % of thermal limit)

Table 4.3.3 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 in some substations and internal 110 kV and 220 kV lines. Thus, certain internal network reinforcements are necessary to sustain given load-demand level and production pattern.

Two 220/110 kV transformers in the Fierze substation in Albania are slightly overloaded in this scenario, while the third transformer in the same substation is loaded near permitted values.

There are three 220 kV and two 110 kV internal lines in Romania which are loaded over 80% of their thermal limits, but none of them is overloaded. These lines are related to the Lotru, Sibiu, Parosen, Bojuren and Domnesti nodes. Transformer 220/110 kV in the Fundeni substation is highly loaded in this scenario.

Two 220 kV lines and twelve 110 kV lines in the Serbian power system are highly loaded when all branches are available in the analyzed scenario. Highly loaded 220 kV lines are connected to the Obrenovac substation, while 110 kV lines are located mostly in the area of Belgrade. Four 110 kV lines are overloaded, ranging between 108% $I_{thermal}$ and 117% $I_{thermal}$.

Power systems of Bulgaria, Bosnia and Herzegovina and Croatia have several highly loaded branches in 110 kV networks. High loading of 110 kV line Komolac-Plat is caused by radial connection of one unit in the HPP Dubrovnik to the grid. High loading of 110 kV lines between the Resnik, Zitnjak and TETO substations in the Zagreb area are caused by disconnection of generating units in the TETO power plant in analyzed scenario. These combined heat and electricity generating units are normally put into the operation during winter high load period, because their main purpose is to produce heat for consumers in the Croatian capitol Zagreb.

Figure 4.3.4 shows histogram of 400 kV and 220 kV regional internal lines and 400/x kV and 220/x kV transformers loadings. 46% of observed branches are loaded below 25% of their thermal ratings, 35% are loaded between 25% and 50%, 16% are loaded between 50% and 75% and only 2% of observed branches are loaded between 75% and 100% of their thermal ratings. Two branches (transformers 220/110 kV Fierze in Albania, 101% - 106% S_n) are overloaded if all branches are in operation for the analyzed scenario.

Table 4.3.3 - Network elements loaded over 80% of thermal limits for 2010-base case-wet hydrology scenario

AREA	ELEMENT	LOADING MVA	RATING MVA	PERCENT
Lines				
ROM	OHL 220 kV LOTRU-SIBIU ckt.1	276.0	277.4	99.5
	OHL 220 kV LOTRU-SIBIU ckt.2	276.0	277.4	99.5
	OHL 220 kV TG.JIU-PAROSEN	181.6	208.1	87.3
Transformers				
ALB	TR 220/110 kV AFIER 2-AFIER 5 ckt.1	116.5	120.0	97.1
	TR 220/110 kV AFIER 2-AFIER 5 ckt.2	95.5	90.0	106.1
	TR 220/110 kV AFIER 2-AFIER 5 ckt.3	91.1	90.0	101.3
ROM	TR 220/110 kV FUNDENI-FUNDE2B	168.7	200.0	84.4

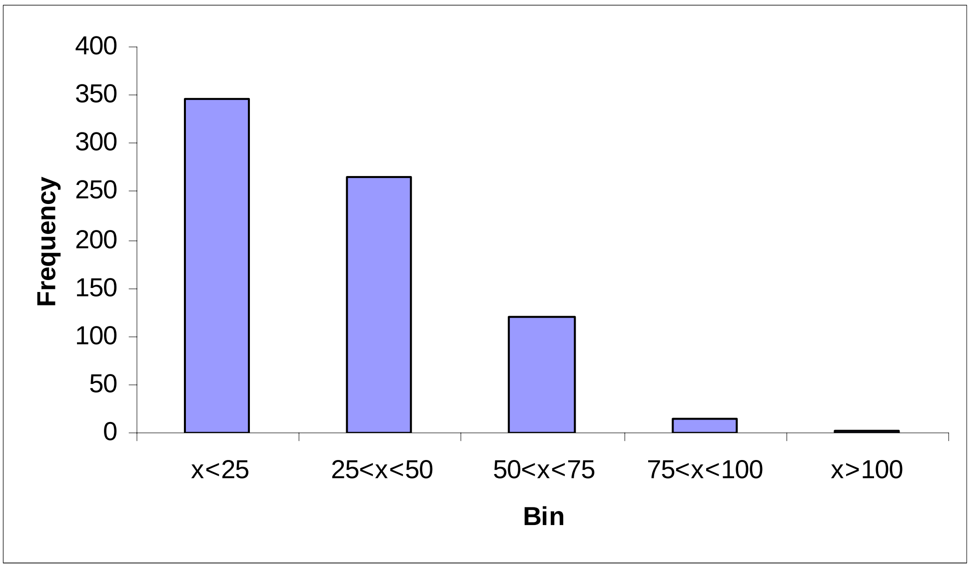


Figure 4.3.4 - Histogram of 400 kV and 220 kV regional lines loadings for 2010-base case-wet hydrology scenario ("Frequency" denotes number of lines and "Bin" denotes loading range in % of thermal limit)

4.3.2 Voltage Profile in the Region

Voltage profile in the region within this scenario which is defined by given generation and demand pattern is seen as satisfactory despite several appearances of certain bus voltage deviations which are shown in Table 4.3.4. Presented table includes only 400 kV and 220 kV network buses.

Bus voltage magnitudes below permitted limits are not found in the analyzed scenario. Bus voltage magnitudes that are found above permitted limits (110% $V_{nominal}$ in 110 kV and 220 kV networks and 105% $V_{nominal}$ in 400 kV network) are detected only in Bulgaria. There are nine 400 kV buses and four 220 kV buses with voltages slightly above permitted limits. Figure 4.2.5 shows histogram of voltages in monitored 400 kV and 220 kV substations.

Table 4.3.4 - Bus voltage deviations for 2010-base case-wet hydrology scenario, complete network

Country	**Node**	**Voltages**	
		pu	**kV**
ALBANIA	-	-	-
BOSNIA AND HERZEGOVINA	-	-	-
BULGARIA	400 kV VARNA4	1.057	421.9
	400 kV BURGAS	1.052	420.8
	400 kV MARITSA EAST2	1.056	422.2
	400 kV TECMIG5	1.052	420.6
	400 kV TECMIG7	1.051	420.6
	400 kV DOBRUD4	1.055	421.8
	400 kV MARITSA EAST 3_4_1	1.051	420.6
	400 kV MARITSA EAST	1.051	420.6
	400 kV TECMIG6	1.052	420.6
	220 kV BPC_220	1.103	242.6
	220 kV MIZIA2	1.101	242.3
	220 kV AEC_220	1.103	242.7
	220 kV TECVARNA	1.104	243.0
CROATIA	-	-	-
MACEDONIA	-	-	-
MONTENEGRO	-	-	-
ROMANIA	-	-	-
SERBIA AND UNMIK	-	-	-

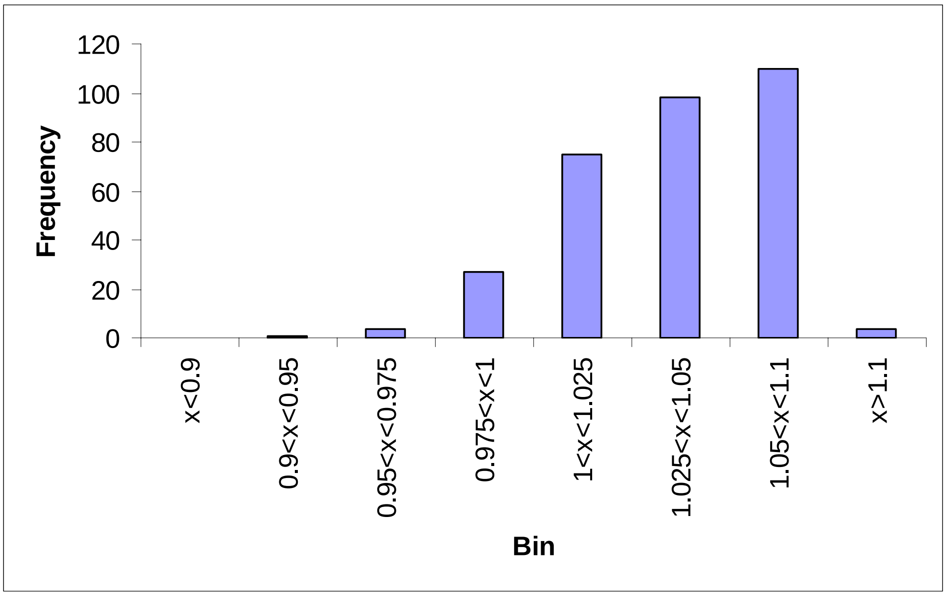


Figure 4.3.5 - Histogram of voltages in monitored substations for 2010-base case-wet hydrology scenario ("Frequency" denotes number of busses and "Bin" denotes voltage range in p.u.)

4.3.3 Security (n-1) analysis

Results of security (n-1) analysis for the 2010-base case-wet hydrology scenario are presented in Table 4.3.5 and Table 4.3.6.

Insecure states for given generation and demand pattern are detected in the power systems of Romania and Serbia, although there is one contingency in Albania which leads to insecure state.

The most critical branches in the analyzed load/generation scenario are those ones connected to the Sibiu substation 400/220 kV in Romania. Double circuit line 220 kV Lotru-Sibiu is loaded near upper limit (99% $I_{thermal}$) when all branches are available. It becomes overloaded if one circuit goes out of operation. Line 400 kV Mintia-Sibiu is overloaded when 400 kV line Sibiu-Iernut goes out of operation. Transformer 400/220 kV in Sibiu is overloaded if the parallel one is unavailable. Reasons for these overloadings are found in a rather high level of hydro generation in the LOTRU CIUNGET power station in this scenario (478 MW). More secure operation could be achieved by decreasing a generation level in this hydro power plant.

Double circuit 220 kV lines around the Resita substation (Portile de Fier-Resita and Timisoara-Resita) are overloaded if one circuit goes out of operation, due to high generation in the PORTILE 1 hydro power plant (796 MW). Secure operation could be achieved by decreasing a generation level in this power plant.

OHL 220 kV Targa Jiu-Paroseni is overloaded if one of the 400 kV lines Mintia-Sibiu, Tantareni-Sibiu in Romania or Djerdap-Kostolac B in Serbia goes out of operation. Higher engagement of the TPP Paroseni resolves these overloads.

Single outages of 400/110 kV transformers in the stations Brasov and Dirste in Romania are also recognized as critical, since the second transformer 400/110 kV in the Brasov substation is permanently out of operation in the model.

Loss of OHL 220 kV in the Belgrade area can cause overloading of the parallel line. Loss of one 400/110 kV transformer in the Nis substation is critical due to possible overloading of the other parallel one.

Loss of 220 kV line between the Rrashbul and Tirana substations can cause overloading of 220 kV line between the Elbassan and Fier substations in Albania.

The heaviest line overloading (124% $I_{thermal}$) in the analyzed scenario is related to a 400 kV line in Romania around the Sibiu substation (Mintia-Sibiu). The heaviest transformer overloading (137% S_n) is related to the transformer 400/110 kV in the Dirste substation (Romania) when the transformer 400/110 kV in the Brasov substation is outaged (the parallel one is permanently out of operation in the model).

Figure 4.3.6 shows geographical positions of critical elements in the analyzed scenario. A green color reveals 220 kV elements (line 220 kV or transformer 220/x kV), while a red one reveals 400 kV elements (line 400 kV or transformer 400/x kV).

According to the obtained and presented results, it may be concluded that a re-dispatching of generation in the Romanian power system, especially of the HPP LOTRU CIUNGET and HPP PORTILE 1 (to decrease their generation level in this scenario from the initially assumed 478 MW and 796 MW respectively) and TPP PAROSENI (to increase its generation level in this scenario from the initially assumed 120 MW), as well as certain reinforcements in the internal networks of Romania, Albania and Serbia are necessary shall this generation/load pattern be made more secure. None of the identified congestions is located at the border lines.

Table 4.3.5 - Lines overloadings for 2010–base case-wet hydrology scenario, single outages

Outage	**Overloaded line(s)**	**Loadings**		**Country**
		MVA	**%**	
OHL 220 kV AKASHA2-ARRAZH2	OHL 220 kV AELBS12-AFIER 2	251.4	111.9	ALBANIA
OHL 400 kV MINTIA-SIBIU	OHL 220 kV TG.JIU-PAROSEN	242.7	111.7	ROMANIA
OHL 400 kV TANTAREN-SIBIU	OHL 220 kV TG.JIU-PAROSEN	227.1	104.5	
OHL 400 kV SIBIU-IERNUT	OHL 400 kV MINTIA-SIBIU	477.3	124.3	
OHL 220 kV P.D.F.A-RESITA ckt.1	OHL 220 kV P.D.F.A-RESITA ckt.2	315.5	108.4	
OHL 220 kV RESITA-TIMIS ckt.1	OHL 220 kV RESITA-TIMIS ckt.2	315.9	112.8	
OHL 220 kV JBGD172-JBGD8 22 ckt.1	OHL 220 kV JBGD172-JBGD8 22 ckt.2	434.4	122.2	SERBIA

Table 4.3.6 - Transformers overloadings for 2010–base case-wet hydrology scenario, single outages

Outage	**Overloaded branch(es)**	**Loadings**		**Country**
		MVA	**%**	
TR 400/220 kV SIBIU ckt.1	TR 400/220 kV SIBIU ckt.2	527.3	131.8	ROMANIA
400/110 kV BRASOV	400/110 kV DIRSTE	332.7	133.1	
400/110 kV DIRSTE	400/110 kV BRASOV	329.7	131.9	
400/110 kV NIS ckt.1	400/110 kV NIS ckt.2	313.1	104.4	SERBIA

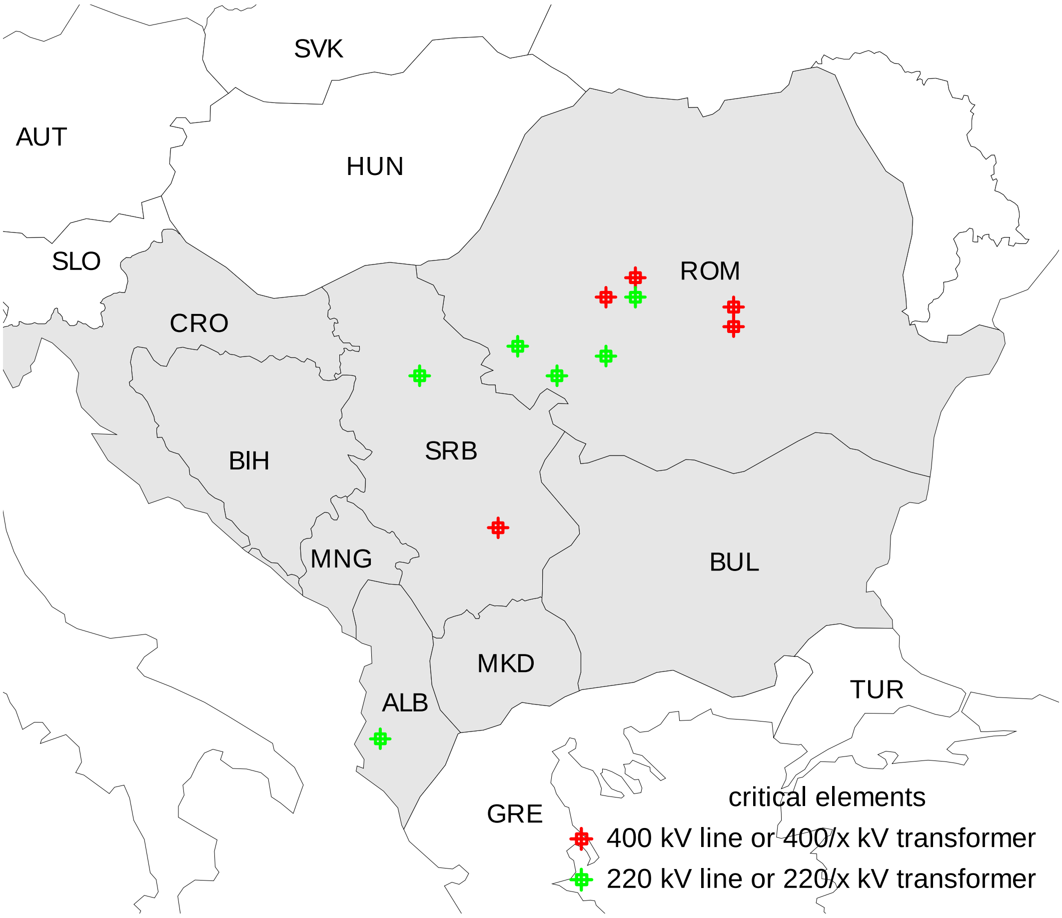


Figure 4.3.6 - Geographical positions of the critical elements for 2010-base case-wet hydrology scenario

4.4 Scenario 2015 – average hydrology – 2010 topology

This part of the Study presents results of static load flow and voltage profile analyses that are conducted for complete network topology and (n-1) contingencies in the scenario which is denoted as GTmax run for year 2015 - average hydrology and expected network topology for 2010.

4.4.1 Lines loadings

Figure 4.4.1 shows power exchanges between areas for 2015-average hydrology scenario. Power flows along interconnection lines in the region together with balances of the systems are shown in Figure 4.4.2. Area totals are shown in Table 4.4.1. Figure 4.4.3 shows histogram of tie lines loadings. It is concluded that most of the tie lines are loaded less than 25% of their thermal limits.

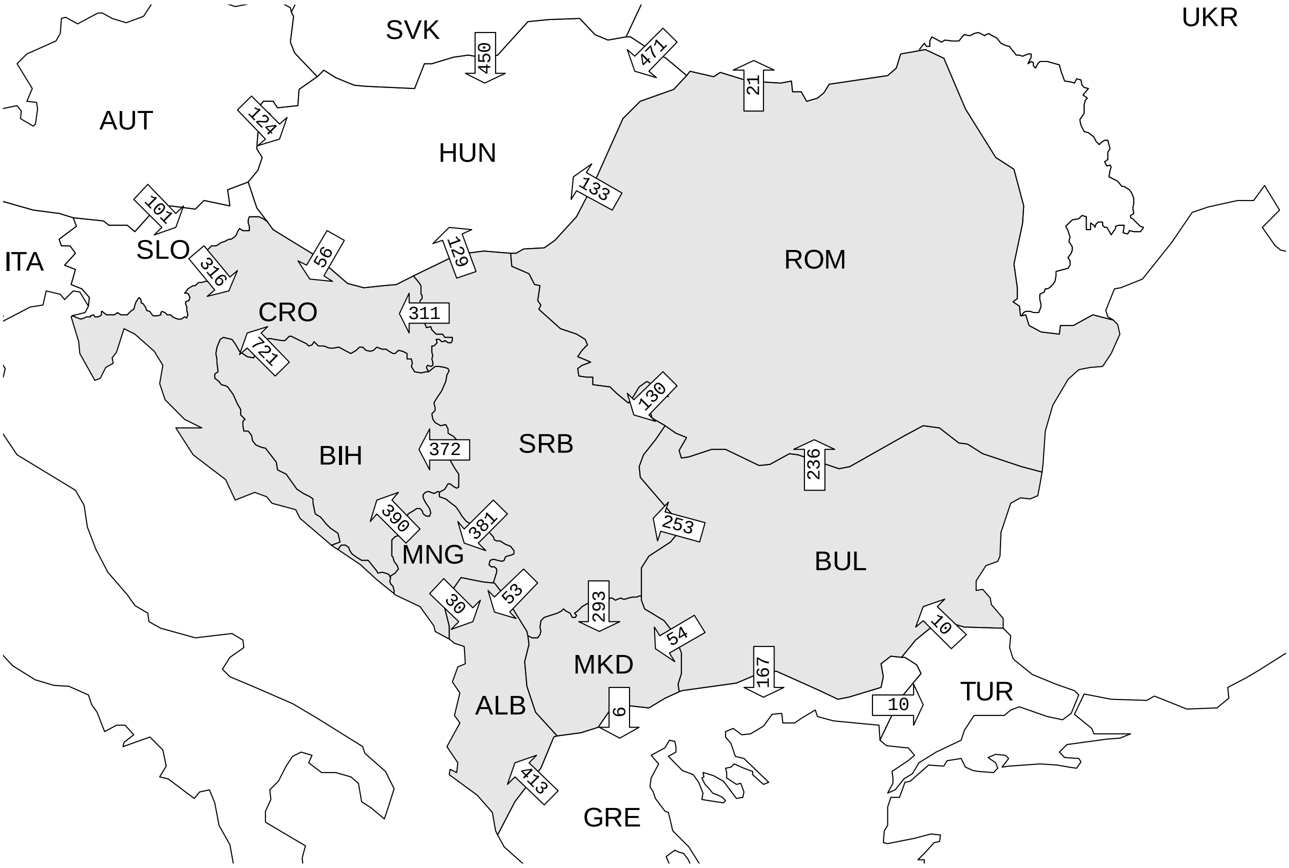


Figure 4.4.1 - Area exchanges in analyzed electric power systems for 2015-average hydrology scenario – 2010 topology

Table 4.4.1 - Area totals in analyzed electric power systems for 2015-average hydrology scenario – 2010 topology

AREA	GENERATION	LOAD	LOSSES	INTERCHANGE
ALB	1116.1	1531	81.2	-496
BUL	7332.7	6483	150.7	699
BIH	2316.6	2279	78.7	-41.1
CRO	2316.3	3657	63.4	-1404.1
MKD	1087	1407	20	-340
ROM	7712.8	7317.4	347.4	47.9
SRB	8687.6	7263	268.7	1156
CRG	735	671	25	39
TOTALS	31304.1	30608.4	1035.1	-339.3

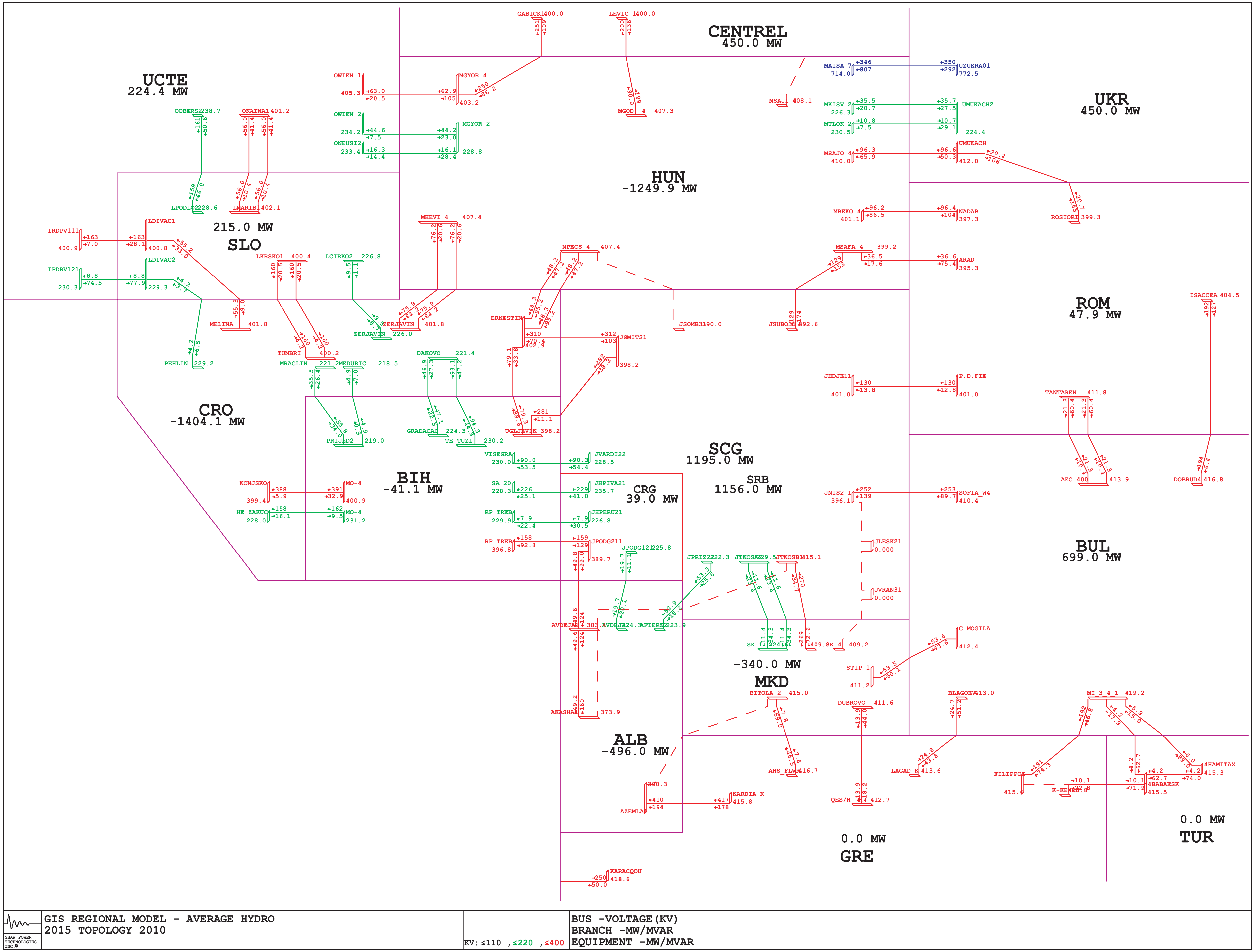


Figure 4.4.2 - Power flows along interconnection lines in the region with balances of the systems for 2015-average hydrology scenario – 2010 topology

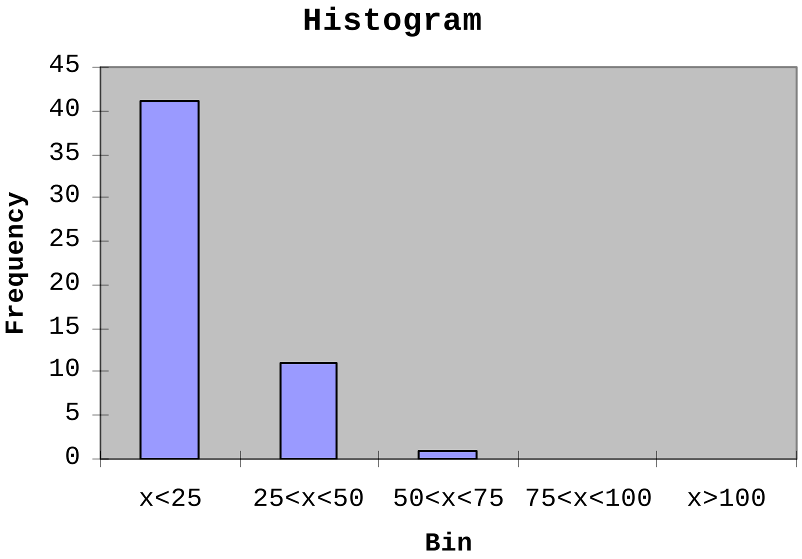


Figure 4.4.3 - Histogram of interconnection lines loadings for 2015-average hydrology scenario – 2010 topology ("Frequency" denotes number of lines and "Bin" denotes loading range in % of thermal limit)

Following Table 4.4.2 lists all network elements loaded over 80% of their thermal limits. As it can be seen some lines 220 kV voltage level in Albania, Romania and Serbia are loaded over 80%. Also, most of the elements loaded over 80% are transformers in some substations, again, in Albania, Bosnia & Herzegovina, Romania and Serbia. Figure 4.4.4 shows histogram of branch loadings in the system. As for the conclusion regarding thermal loadings in this scenario it can be said that most of the network elements are loaded between 25-75% of their thermal limits, but there are some elements highly loaded. Most of the elements loaded over 80% are transformers in some substations, so some internal network reinforcements are necessary to sustain this load-demand level and production pattern. There are some elements that are overloaded (220 kV lines Targu Jiu – Paroseni and Urechesti-Targu Jiu in Romania, and 220/110 kV transformers in Fier substation in Albania. This leads to conclusion that transmission network is not able to sustain this load-demand level and this production pattern and certain network reinforcement are necessary. It should be pointed out that higher engagement of TPP Paroseni resolves this overloads of the 220 kV lines Targu Jiu – Paroseni and Urechesti-Targu Jiu and decreases the load of the 400/220 transformer in Urechesti substation. Also, it is expected that transformers in Fier substation will be replaced with more powerful transformer units.

Table 4.4.2 - Network elements loaded over 80% of their thermal limits for 2015-average hydrology scenario – 2010 topology

BRANCH LOADINGS ABOVE 80.0 % OF RATING:

AREA	ELEMENT	LOADING MVA	RATING MVA	PERCENT
Lines				
ALB	HL 220kV AKASHA2-ARRAZH2 1	250.1	270	92.6
ROM	HL 220kV P.D.F.A-CETATE1 1	205.2	208.1	98.6
	HL 220kV P.D.F.A-RESITA 1	236.2	277.4	85.2
	HL 220kV P.D.F.A-RESITA 2	236.2	277.4	85.2
	HL 220kV P.D.F.II-CETATE1 1	267.7	277.4	96.5
	HL 220kV TG.JIU-PAROSEN 1	278.2	208.1	133.7
	HL 220kV URECHESI-TG.JIU 1	278.2	277.4	100.3
SRB	HL 220kV JBGD3 21-JOBREN2 1	261	301	86.7
Transformers				
ALB	TR 220/110 kV AELBS1 1	78	90	86.6
	TR 220/110 kV AELBS1 2	78	90	86.6
	TR 220/110 kV AELBS1 3	83.8	90	93.1
	TR 220/110 kV AFIER 1	138.2	120	115.2
	TR 220/110 kV AFIER 2	113.3	90	125.9
	TR 220/110 kV AFIER 3	108.1	90	120.2
	TR 220/110 kV AFIERZ 1	51.9	60	86.5
	TR 220/110 kV AFIERZ 2	51.9	60	86.5
	TR 220/110 kV AKASHA 1	84.1	100	84.1
	TR 220/110 kV AKASHA 2	84.1	100	84.1
BIH	TR 400/110 kV UGLJEV 1	254.8	300	84.9
ROM	TR 220/110 kV FUNDE2 1	193.3	200	96.7
	TR 220/110 kV FUNDEN 1	162.9	200	81.4
	TR 400/220 kV IERNUT 1	320.4	400	80.1
	TR 400/220 kV URECHE 1	395.4	400	98.9
SRB	TR 220/110 kV JBGD3 1	166.7	200	83.4
	TR 220/110 kV JBGD3 2	125.6	150	83.7
	TR 220/110 kV JTKOSA 2	130.7	150	87.1
	TR 220/110 kV JTKOSA 3	133	150	88.7
	TR 220/110 kV JZREN2 2	123.6	150	82.4
	TR 400/220 kV JTKOSB 2	325.8	400	81.4
	TR 400/220 kV JTKOSB 3	325.8	400	81.4

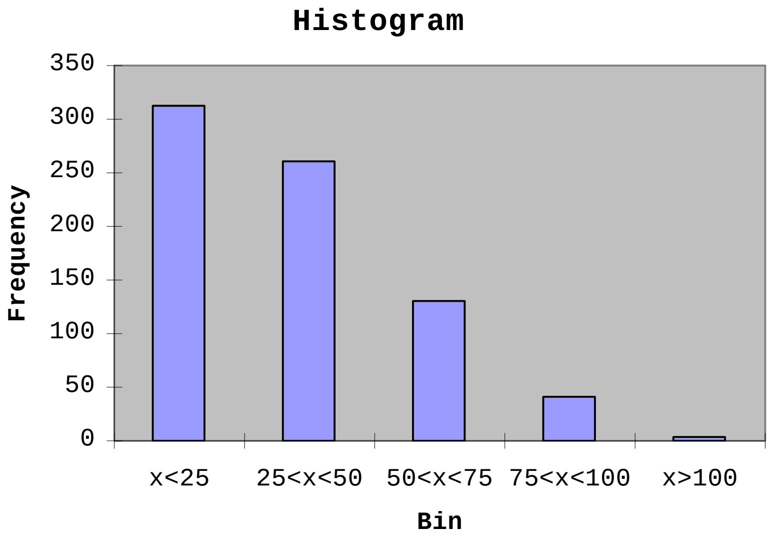


Figure 4.4.4 - Histogram of branch loadings for 2015-average hydrology scenario – 2010 network topology ("Frequency" denotes number of lines and "Bin" denotes loading range in % of thermal limit)

4.4.2 Voltage Profile in the Region

Figure 4.4.5 shows histogram of voltages in monitored substations. Voltages in almost all monitored substations are found within permitted limits. Only in substation Elbasan and Kashar, where voltages are around 373 kV, but this can be resolved with changing of the setting of the tap changing transformers in these substations.

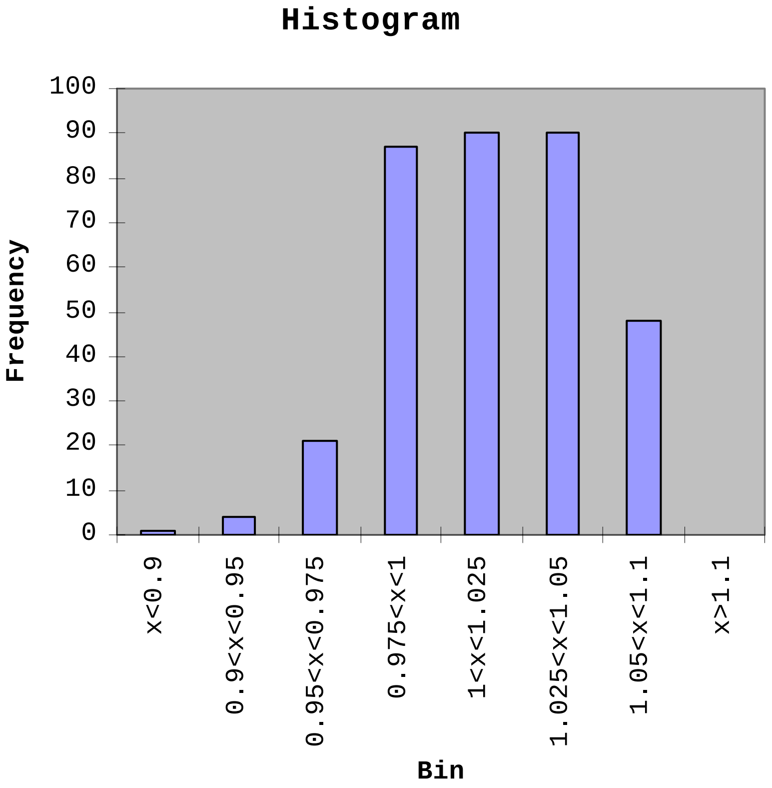


Figure 4.4.5 - Histogram of voltages in monitored substations for 2015-average hydrology scenario – 2010 network topology ("Frequency" denotes number of busses and "Bin" denotes voltage range in p.u.)

In the rest of the monitored network the voltage profile is satisfying and that most of the substations have magnitudes in range 0.975-1.05 p.u.

4.4.3 Security (n-1) analysis

Results of security (n-1) analysis for 2015-dry hydrology scenario and expected topology for 2010 are presented in Table 4.4.3. Figure 4.4.6 shows the geographical position of the critical elements in monitored systems.

It can be concluded that all identified insecure situations are located in internal networks that belong to monitored power systems of Albania, Croatia, Romania and Serbia. In most critical case in Romanian system, the critical elements are 220 kV lines Targu Jiu – Paroseni and Urechesti-Targu Jiu and 400/220 kV transformer in Urechesti substation, but these elements are overloaded by full topology too, which is the main reason why they appear as critical by most outages analyzed. As it has been stated before, this can be resolved by higher engagement of the TPP Paroseni.

Some of the overloadings identified can be relieved by changing internal network topology (splitting busbars, changing lower voltage network topology in order to redistribute load-demand or change of generation units engagement), like in the case of most severe overloading in Romanian network happens on transformer 400/110 kV Dirste when transformer 400/110 kV in Brasov is outaged, but this is a consequence of the fact that second transformer unit 400/110 kV in Brasov is out of operation. Switching on of this transformer clears this critical outage. The similar situation is with outage of the 400 kV line Obrenovac-Beograd 8 in Serbia. Splitting of the busbars in 220 kV Beograd 3 in substation relieves this overloading, but voltage profile in Serbian network remains critical, so additional dispatching actions are necessary too.

Losing the 400 kV line Kosovo B-Pec or one transformer unit in substation Kosovo B causes overloading of the transformer units in this substation. This is consequence of the low level of production in 220 kV network in Kosovo region, due to decommissioning of the generation units in TPP Kosovo A.

All in all, certain reinforcement of internal network is necessary in order to make this regime more secure (more about this in chapter 6). None of the identified congestions is located at border lines.

Table 4.4.3 - Network overloadings for 2015-average hydrology scenario, single outages – 2010 network topology

Area	contingency	Area	overloadings / out of limits voltages	#	limit / Unom	Flow / Voltage	rate / volt.dev.
1	2	3	4	5	6	7	8
	BASE CASE	RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	282.6MVA	133.7%
RO	OHL 220kV P.D.F.A -CALAFAT 1	RO	HL 220kV P.D.F.A-CETATE1	1	208.1MVA	259.4MVA	126.5%
RO	OHL 220kV P.D.F.A -RESITA 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	417.6MVA	104.4%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	299MVA	106.6%
		RO	HL 220kV P.D.F.A-RESITA	2	277.4MVA	337.8MVA	128.0%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	299MVA	142.1%
RO	OHL 220kV RESITA -TIMIS 1	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	292.7MVA	104.1%
		RO	HL 220kV RESITA-TIMIS	2	277.4MVA	348.7MVA	129.1%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	292.7MVA	138.8%
RO	OHL 220kV PESTIS -MINTIA A 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	416.1MVA	104.0%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	293.8MVA	105.4%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	287.2MVA	140.6%
RO	OHL 220kV CLUJ FL -MARISEL 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	412.9MVA	103.2%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	293.3MVA	104.7%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	293.3MVA	139.6%
RO	OHL 220kV AL.JL -GILCEAG 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	424.3MVA	106.1%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	306MVA	109.7%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	299.7MVA	146.3%
RO	OHL 400kV TANTAREN-SLATINA 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	442.8MVA	110.7%
RO	OHL 400kV TANTAREN-BRADU 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	420.4MVA	105.1%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	296.5MVA	106.2%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	296.5MVA	141.6%
RO	OHL 400kV TANTAREN-SIBIU 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	443.9MVA	111.0%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	327.5MVA	117.9%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	327.5MVA	157.2%
RO	OHL 400kV URECHESI-DOMNESTI 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	444MVA	111.0%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	299MVA	106.8%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	299MVA	142.3%
RO	OHL 400kV MINTIA -SIBIU 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	443.2MVA	110.8%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	330.1MVA	118.7%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	322.6MVA	158.2%
RO	OHL 400kV P.D.FIE -SLATINA 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	428.1MVA	107.0%
RO	OHL 400kV DOMNESTI-BRAZI 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	413.5MVA	103.4%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	295MVA	105.0%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	295MVA	140.0%
		RO	HL 220kV BUC.S-B-FUNDENI	1	320MVA	331.2MVA	102.7%
RO	OHL 400kV SUCEAVA -GADALIN 1	RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	282MVA	136.7%
RO	OHL 400kV SMIRDAN -GUTINAS 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	413.5MVA	103.4%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	298.1MVA	106.7%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	298.1MVA	142.2%
RO	OHL 400kV GADALIN -ROSIORI 1	RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	280.1MVA	135.6%
CS	OHL 220kV JBGD172 -JBGD8 22 1	CS	HL 220kV JBGD172-JBGD8 22	2	365.8MVA	462.8MVA	133.3%
CS	OHL 400kV JBGD8 1 -JOBREN11 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	429.3MVA	155.8%
CS	OHL 400kV JHDJE11 -JTDRMN1 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	436.7MVA	109.2%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	316.6MVA	113.9%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	316.6MVA	151.8%
		CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	319.6MVA	109.6%
CS	OHL 400kV JNSAD31 -JSUBO31 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	422.5MVA	105.6%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	303.6MVA	108.6%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	303.6MVA	144.7%
CS	OHL 400kV JTKOSB1 -JPEC 1 A	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	294.1MVA	104.9%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	294.1MVA	139.8%
		CS	TR 400/220kV/kV JTKOSB1	1	400MVA	419.7MVA	104.9%
		CS	TR 400/220kV/kV JTKOSB1	2	400MVA	438.6MVA	109.6%
		CS	TR 400/220kV/kV JTKOSB1	3	400MVA	438.6MVA	109.6%
RO	TR 400/110 BRASOV 1	RO	TR 400/110kV/kV DIRSTE	1	250MVA	385.8MVA	154.3%
RO	TR 400/110 CLUJ E 1	RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	282.5MVA	137.1%
RO	TR 400/110 DIRSTE 1	RO	TR 400/110kV/kV BRASOV	1	250MVA	380MVA	152.0%
CS	TR 400/110 JNIS2 1	CS	TR 400/110kV/kV JNIS2 1	2	300MVA	332.5MVA	110.8%
RO	TR 400/220 BUC.S 1	RO	TR 400/220kV/kV BUC.S	2	400MVA	483MVA	120.8%
RO	TR 400/220 IERNUT 1	RO	HL 400kV GADALIN-CLUJ E	1	238.3MVA	238.1MVA	102.9%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	282.5MVA	137.4%
		RO	HL 220kV STEJARU-GHEORGH	1	208.1MVA	211.8MVA	121.7%
CS	TR 400/220 JTKOSB 1	CS	TR 400/220kV/kV JTKOSB1	2	400MVA	457.2MVA	114.3%
		CS	TR 400/220kV/kV JTKOSB1	3	400MVA	457.2MVA	114.3%
RO	TR 400/220 SLATINA 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	424.9MVA	106.2%

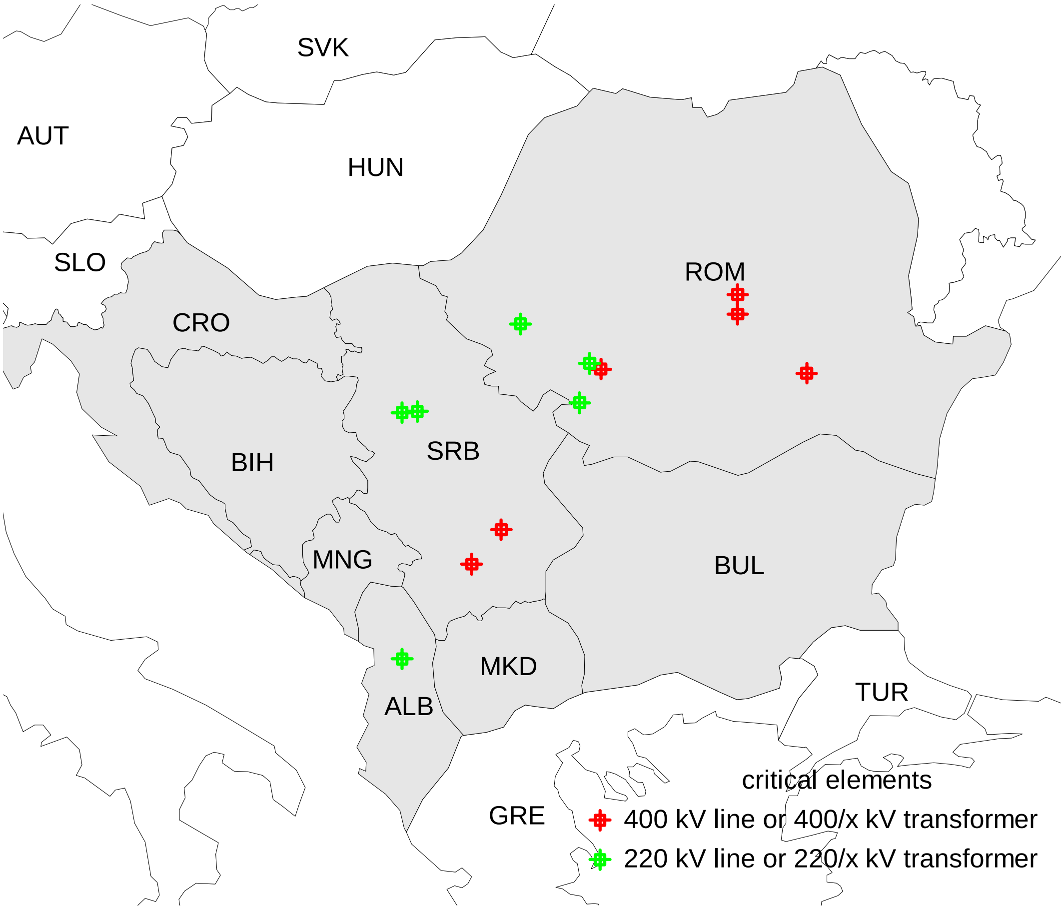


Figure 4.4.6 – Geographical position of critical elements for 2015-average hydrology scenario

4.5 Scenario 2015 – average hydrology – topology 2015

This part of the Study presents results of static load flow and voltage profile analyses that are conducted for complete network topology and (n-1) contingencies in the scenario which is denoted as GTmax run for year 2015 - average hydrology and expected network topology for 2015.

4.5.1 Lines loadings

Figure 4.5.1 shows power exchanges between areas for 2015-average hydrology scenario. Power flows along interconnection lines in the region together with balances of the systems are shown in Figure 4.5.2. Area totals are shown in Table 4.5.1. Figure 4.5.3 shows histogram of tie lines loadings. It is concluded that most of the tie lines are loaded less than 25% of their thermal limits.

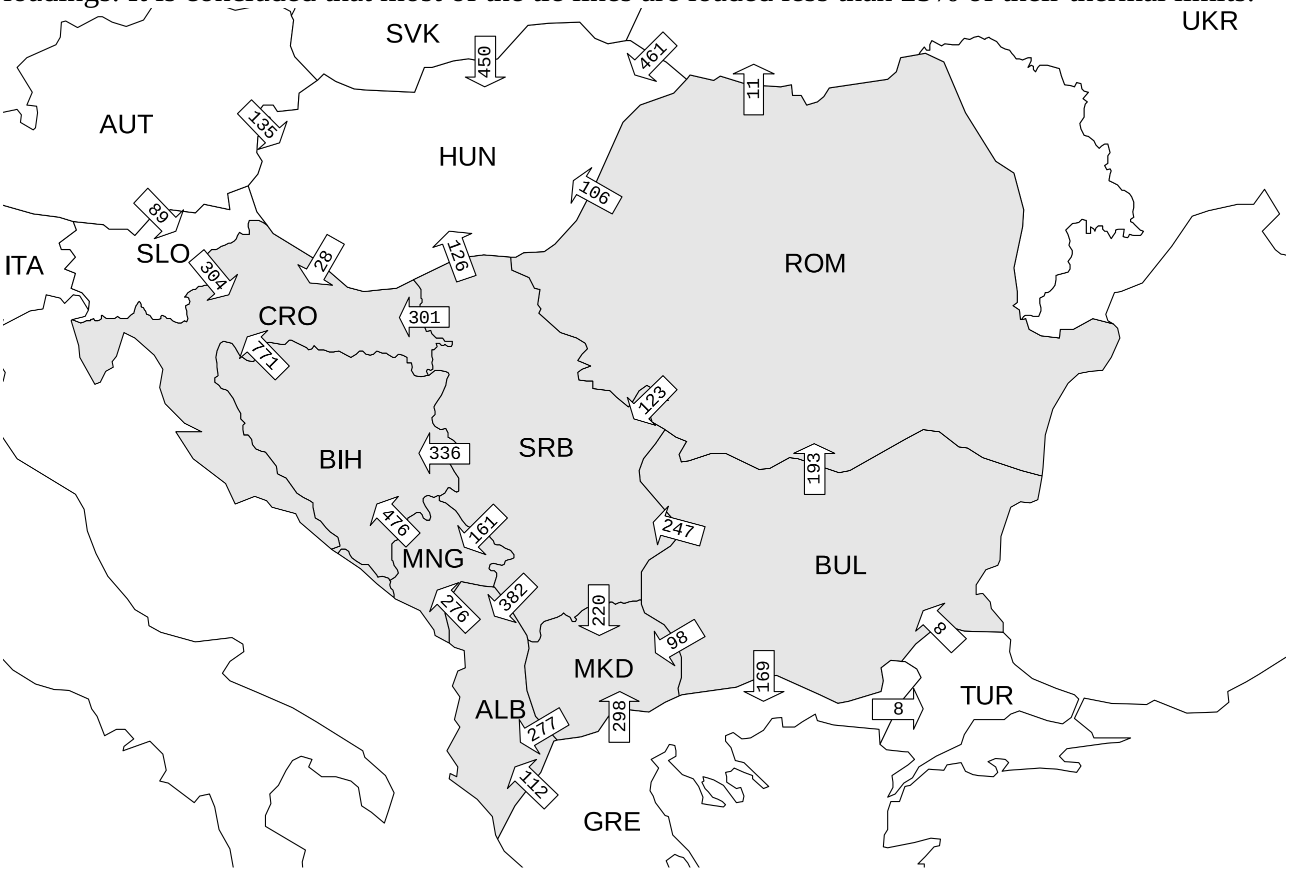


Figure 4.5.1 - Area exchanges in analyzed electric power systems for 2015-average hydrology scenario

Table 4.5.1 - Area totals in analyzed electric power systems for 2015-average hydrology scenario

AREA	GENERATION	LOAD	LOSSES	INTERCHANGE
ALB	1118.1	1541	73.1	-496
BUL	7332.9	6483	150.9	699
BIH	2317.2	2279	79.2	-41
CRO	2317	3657	64	-1404
MKD	1088.4	1407	21.4	-340
ROM	7708.6	7317.4	343.1	48.1
SRB	8689.4	7279	254.4	1156
CRG	735.2	676	20.3	39
TOTALS	31306.8	30639.4	1006.4	-338.9

As it can be seen, new elements that are expected to be build till 2015 cause totally different distribution of power flows in the southern part of the region (Albania, FYR of Macedonia, Serbia, and Montenegro).

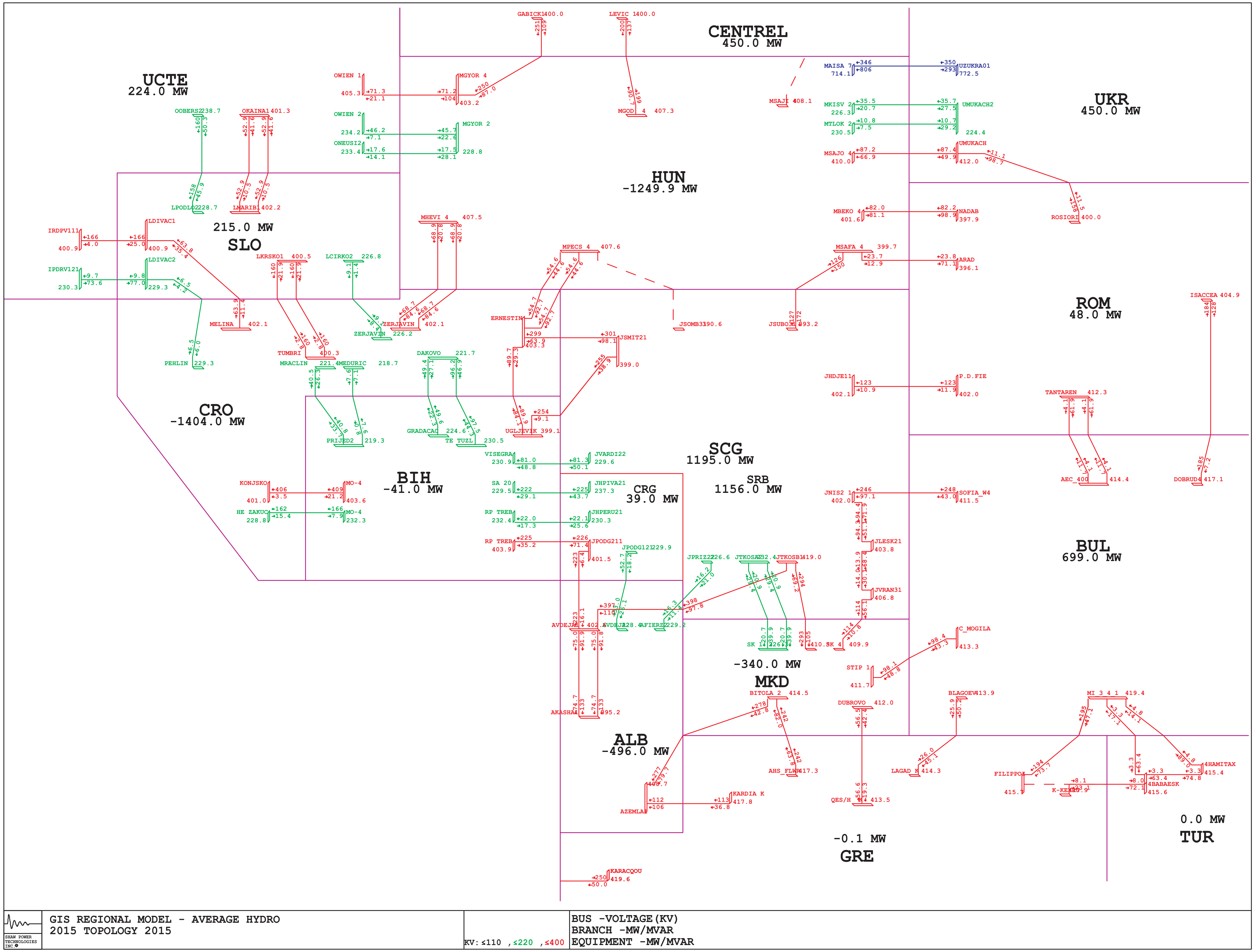


Figure 4.5.2 - Power flows along interconnection lines in the region with balances of the systems for 2015-average hydrology scenario

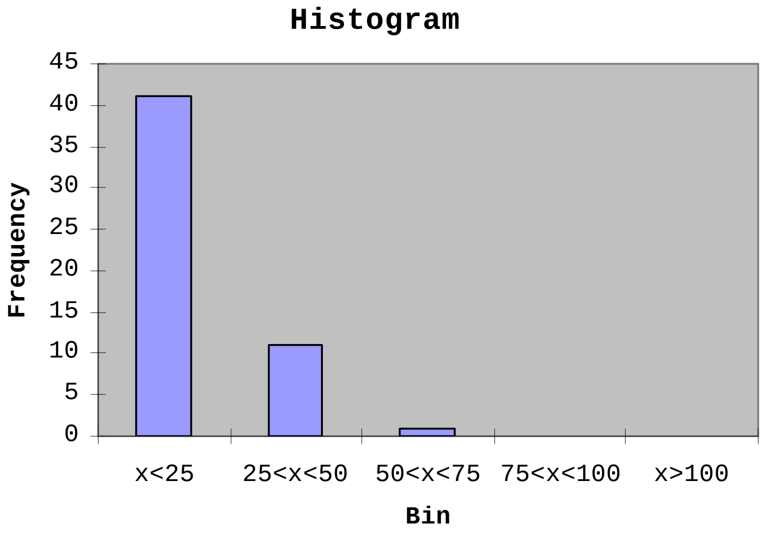


Figure 4.5.3 - Histogram of interconnection lines loadings for 2015-average hydrology scenario ("Frequency" denotes number of lines and "Bin" denotes loading range in % of thermal limit)

Following PSS/E output (Table 4.5.2) lists all network elements loaded over 80% of their thermal limits. Figure 4.5.4 shows histogram of branch loadings in the system.

Table 4.5.2 - Network elements loaded over 80% of their thermal limits for 2015-average hydrology scenario

BRANCH LOADINGS ABOVE 80.0 % OF RATING:

AREA	ELEMENT	LOADING MVA	RATING MVA	PERCENT
Lines				
ALB	HL 220kV AKASHA2-ARRAZH2 1	237.7	270	88
ROM	HL 220kV P.D.F.A-CETATE1 1	205	208.1	98.5
	HL 220kV P.D.F.A-RESITA 1	232.2	277.4	83.7
	HL 220kV P.D.F.A-RESITA 2	232.2	277.4	83.7
	HL 220kV P.D.F.II-CETATE1 1	267.5	277.4	96.4
	HL 220kV TG.JIU-PAROSEN 1	272.6	208.1	131
	HL 220kV URECHESI-TG.JIU 1	272.6	277.4	98.3
SRB	HL 220kV JBGD3 21-JOBREN2 1	261.8	301	87
Transformers				
ALB	TR 220/110 kV AELBS1 1	74.3	90	82.5
	TR 220/110 kV AELBS1 2	74.3	90	82.5
	TR 220/110 kV AELBS1 3	79.8	90	88.7
	TR 220/110 kV AFIER 1	134.9	120	112.5
	TR 220/110 kV AFIER 2	110.6	90	122.9
	TR 220/110 kV AFIER 3	105.6	90	117.3
	TR 220/110 kV AFIERZ 1	50.3	60	83.8
	TR 220/110 kV AFIERZ 2	50.3	60	83.8
	TR 220/110 kV AKASHA 1	82.1	100	82.1
	TR 220/110 kV AKASHA 2	82.1	100	82.1
ROM	TR 220/110 kV FUNDE2 1	193	200	96.5
	TR 220/110 kV FUNDEN 1	162.6	200	81.3
	TR 400/220 kV URECHE 1	390.9	400	97.7
SRB	TR 220/110 kV JBGD3 1	166.6	200	83.3
	TR 220/110 kV JBGD3 2	125.8	150	83.9
	TR 220/110 kV JZREN2 2	123.5	150	82.3
BIH	TR 400/110 kV UGLJEV 1	252.5	300	84.2

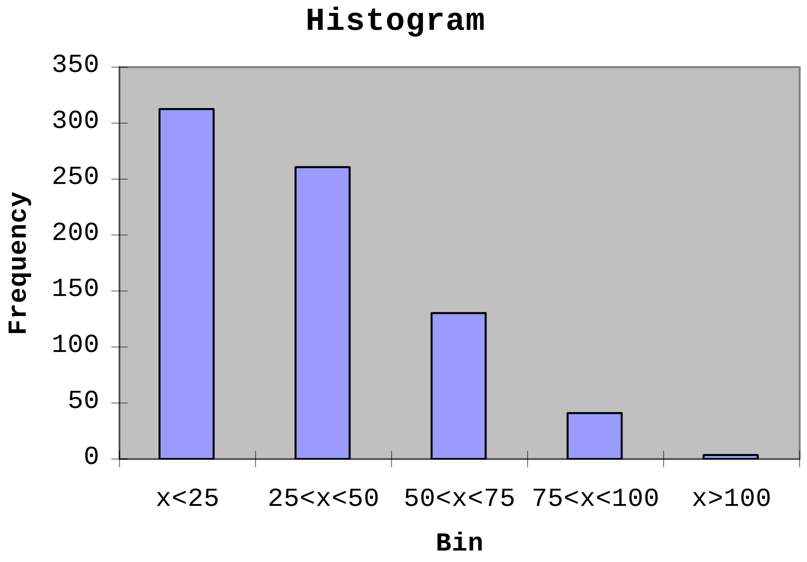


Figure 4.5.4 - Histogram of branch loadings for 2015-average hydrology scenario ("Frequency" denotes number of lines and "Bin" denotes loading range in % of thermal limit)

As it can be seen from these outputs, most of the network elements are loaded between 25-75% of their thermal limits and most of the elements loaded over 80% are transformers in some substations, so some internal network reinforcements are necessary to sustain this load-demand level and production pattern. Also, planned network reinforcements compared to network topology 2010, reduce load of some elements in southern part of Serbia.

4.5.2 Voltage Profile in the Region

Figure 4.5.5 shows histogram of voltages in monitored substations. Voltages in all monitored substations are found within permitted limits. It is concluded that voltage profile is satisfying and that most of the substations have magnitudes in range 1-1.05 p.u.

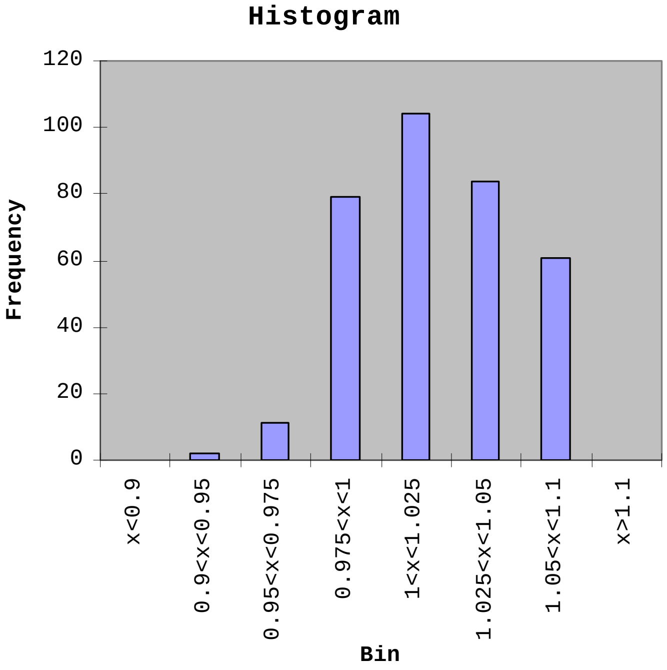


Figure 4.5.5 - Histogram of voltages in monitored substations for 2015-average hydrology scenario ("Frequency" denotes number of busses and "Bin" denotes voltage range in p.u.)

4.5.3 Security (n-1) analysis

Results of security (n-1) analysis for 2015-average hydrology scenario are presented in Table 4.5.3 and Figure 4.5.6.

Like for expected topology 2010 (previous chapter), it can be concluded that all identified insecure situations are located in internal networks that belong to monitored power systems of Albania, Croatia, Romania and Serbia. Also, the planned network reinforcements till 2015 resolve some of the noticed critical contingencies, especially in southern part of Serbia. The rest of the conclusions are the same as for the analyzed topology 2010, and that is that certain level of network reinforcement is necessary to make this regime more secure.

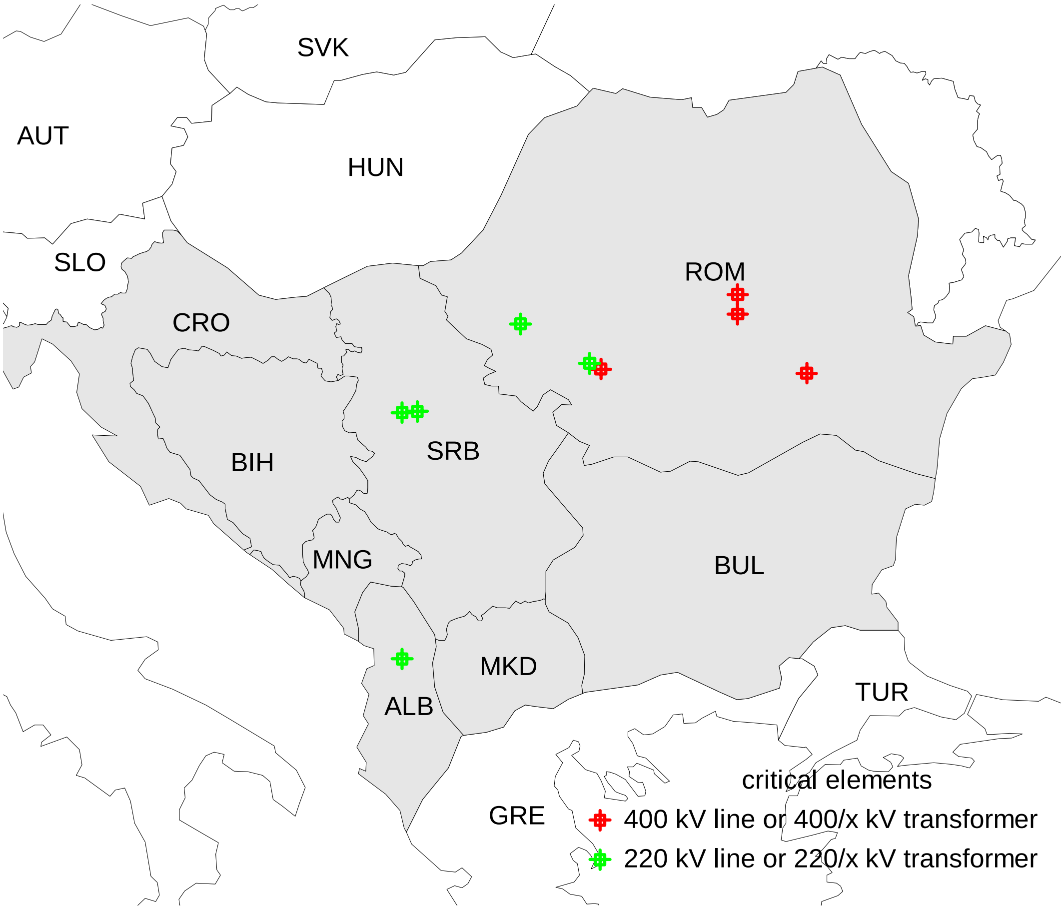


Figure 4.5.6 – Geographical position of critical elements for 2015-average hydrology scenario

Table 4.5.3 - Network overloadings for 2015-average hydrology scenario, single outages

Area	contingency	Area	overloadings / out of limits voltages	#	limit / Unom	Flow / Voltage	rate / volt.dev.
1	2	3	4	5	6	7	8
	BASE CASE	RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	277.6MVA	131.0%
AL	OHL 220kV AELBS12 -AFIER 2 1	AL	HL 220kV AKASHA2-ARRAZH2	1	270MVA	364.3MVA	142.6%
BA	OHL 400kV VISEGRA -HE VG 1	BA	HL 220kV RP KAKAN-KAKANJ5	1	316MVA	338.8MVA	103.8%
RO	OHL 220kV P.D.F.A -CALAFAT 1	RO	HL 220kV P.D.F.A-CETATE1	1	208.1MVA	259.1MVA	125.9%
RO	OHL 220kV P.D.F.A -RESITA 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	413.4MVA	103.3%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	293.7MVA	104.4%
		RO	HL 220kV P.D.F.A-RESITA	2	277.4MVA	333.5MVA	125.7%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	293.7MVA	139.2%
RO	OHL 220kV RESITA -TIMIS 1	RO	HL 220kV RESITA-TIMIS	2	277.4MVA	343.7MVA	126.7%
RO	OHL 220kV CRAIOV B-ISALNI A 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	412.5MVA	103.1%
RO	OHL 220kV PESTIS -MINTIA A 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	412.7MVA	103.2%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	289.3MVA	103.5%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	283MVA	138.1%
RO	OHL 220kV CLUJ FL -AL.JL 1	RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	264.9MVA	124.7%
RO	OHL 220kV AL.JL -GILCEAG 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	420.3MVA	105.1%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	301MVA	107.6%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	294.9MVA	143.5%
RO	OHL 400kV TANTAREN-SLATINA 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	437.9MVA	109.5%
RO	OHL 400kV TANTAREN-BRADU 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	416.1MVA	104.0%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	291.3MVA	104.0%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	291.3MVA	138.6%
RO	OHL 400kV TANTAREN-SIBIU 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	438.7MVA	109.7%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	321.3MVA	115.3%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	321.3MVA	153.7%
RO	OHL 400kV URECHESI-DOMNESTI 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	439.9MVA	110.0%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	294MVA	104.7%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	294MVA	139.5%
RO	OHL 400kV MINTIA -SIBIU 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	437.6MVA	109.4%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	323.1MVA	115.8%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	316MVA	154.4%
RO	OHL 400kV P.D.FIE -SLATINA 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	424.6MVA	106.2%
RO	OHL 400kV SUCEAVA -GADALIN 1	RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	276.9MVA	133.8%
RO	OHL 400kV SMIRDAN -GUTINAS 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	409.4MVA	102.4%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	292.8MVA	104.5%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	292.8MVA	139.3%
RO	OHL 400kV SIBIU -IERNUT 1	RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	277.6MVA	134.5%
RO	OHL 400kV GADALIN -CLUJ E 1	RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	277.8MVA	134.5%
CS	OHL 220kV JBGD172 -JBGD8 22 1	CS	HL 220kV JBGD172-JBGD8 22	2	365.8MVA	463.6MVA	133.1%
CS	OHL 400kV JBGD8 1 -JOBREN11 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	432.1MVA	156.1%
CS	OHL 400kV JBOR 21 -JHDJE11 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	414.3MVA	103.6%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	291.3MVA	103.8%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	291.3MVA	138.4%
CS	OHL 400kV JHDJE11 -JTDRMN1 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	430.1MVA	107.5%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	309.2MVA	110.8%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	309.2MVA	147.7%
		CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	319.4MVA	109.2%
CS	OHL 400kV JNSAD31 -JSUBO31 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	418.4MVA	104.6%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	298.5MVA	106.4%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	298.5MVA	141.9%
RO	TR 400/110 BRASOV 1	RO	TR 400/110kV/kV DIRSTE	1	250MVA	385.1MVA	154.1%
RO	TR 400/110 CLUJ E 1	RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	277.8MVA	134.4%
RO	TR 400/110 DIRSTE 1	RO	TR 400/110kV/kV BRASOV	1	250MVA	379.5MVA	151.8%
RO	TR 400/220 BUC.S 1	RO	TR 400/220kV/kV BUC.S	2	400MVA	482.6MVA	120.6%
RO	TR 400/220 IERNUT 1	RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	277.8MVA	134.6%
		RO	HL 220kV STEJARU-GHEORGH	1	208.1MVA	210.4MVA	120.3%
CS	TR 400/220 JBGD8 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	314.5MVA	108.5%
		CS	HL 220kV JBGD3 22-JBGD8 22	2	365.8MVA	372MVA	107.5%
RO	TR 400/220 SLATINA 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	421MVA	105.2%

4.5.4 Summary of Impacts - 2015 topology versus 2010 topology

Compared to the expected topology 2010, analyzed in previous chapter, it can be seen that the network losses are smaller as a consequence of building of new elements for 2015 network topology, especially in the cases of Albania, Serbia and Montenegro. Overall reduction of loses is around 30 MW.

Also, planned network reinforcements compared to network topology 2010, reduce load of some elements in southern part of Serbia.

Compared to the 2010 topology, voltage profile is somewhat better, especially in southern and central part of Serbia, as well as in Albania.

Realization of the planed investments till 2015 has impact on secure operation of the network. Some of the insecure states identified with 2010 topology are relieved and do not exist with expected 2015 network topology. Also, level of overloadings due to outages is decreased.

All in all overall network performance is better, especially in the region where new planed investments are to be realized (Albania, southern Serbia and Montenegro).

4.6 Scenario 2015 – dry hydrology – 2010 topology

This part of the Study presents the results of static load flow and voltage profile analyses that are conducted for complete network topology and (n-1) contingencies in the scenario which is denoted as GTmax run for year 2015 - dry hydrology and expected network topology for 2010.

4.6.1 Lines loadings

Figure 4.6.1 shows power exchanges between areas for 2015-dry hydrology scenario. Power flows along interconnection lines in the region together with balances of the systems are shown in Figure 4.6.2. Area totals are shown in Table 4.6.1. Figure 4.6.3 shows histogram of tie lines loadings. It is concluded that most of the tie lines are loaded less than 25% of their thermal limits.

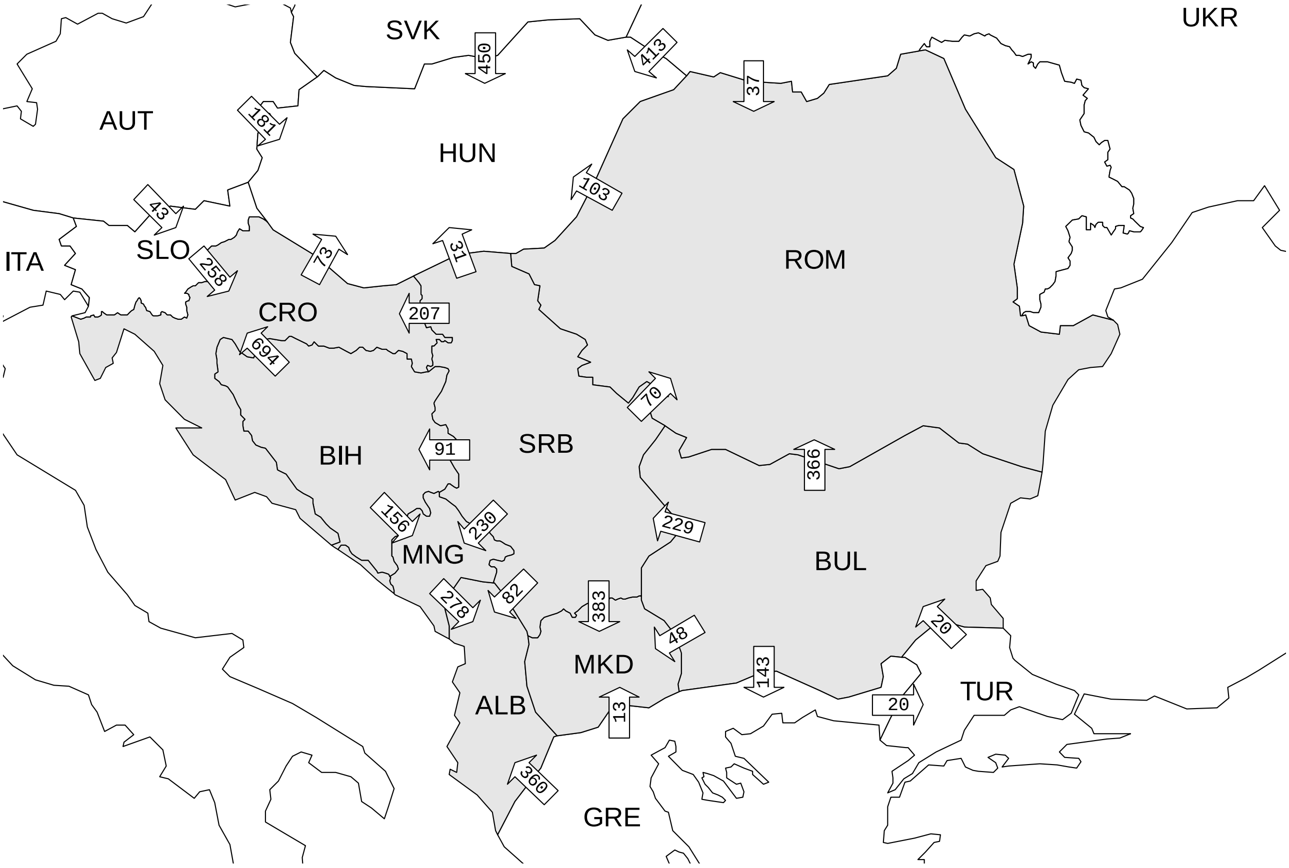


Figure 4.6.1 - Area exchanges in analyzed electric power systems for 2015-dry hydrology scenario – topology 2010

Table 4.6.1 - Area totals in analyzed electric power systems for 2015-dry hydrology scenario – topology 2010

AREA	GENERATION	LOAD	LOSSES	INTERCHANGE
ALBANIA	894.7	1521.9	92.7	-720
BULGARIA	7363.9	6450	147.9	766
BIH	3140.9	2304	78.2	758.8
CROATIA	2636.7	3665	58.2	-1086.4
MACEDONIA	985.1	1410	19.1	-444
ROMANIA	7724.6	7798.4	295.5	-369.2
SERBIA	8397.9	7296	237.9	864
MONTENEGRO	586.3	672	22.1	-107.7
TOTALS	31730.1	31117.3	951.6	-338.5

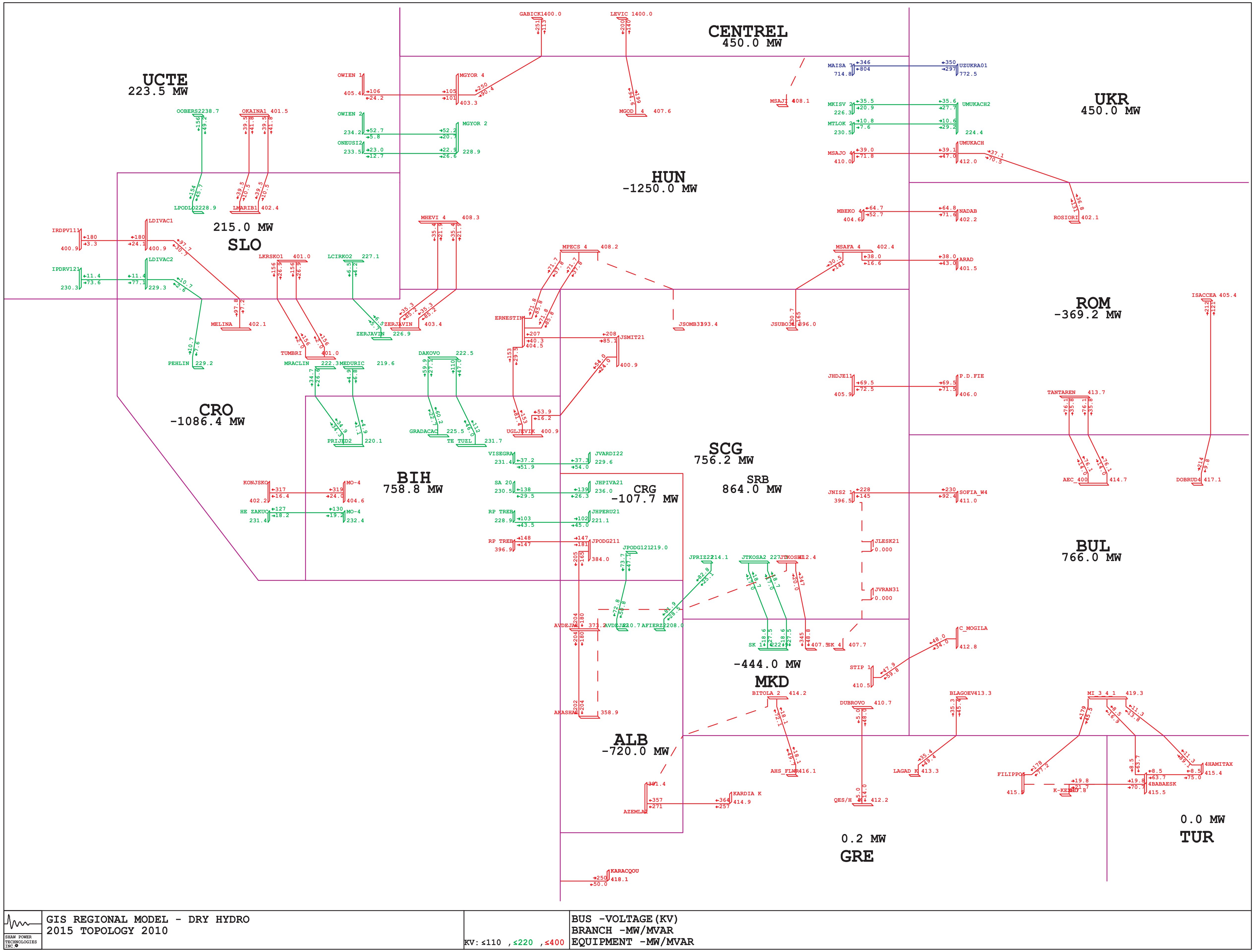


Figure 4.6.2 - Power flows along interconnection lines in the region with balances of the systems for 2015-dry hydrology scenario – 2010 topology

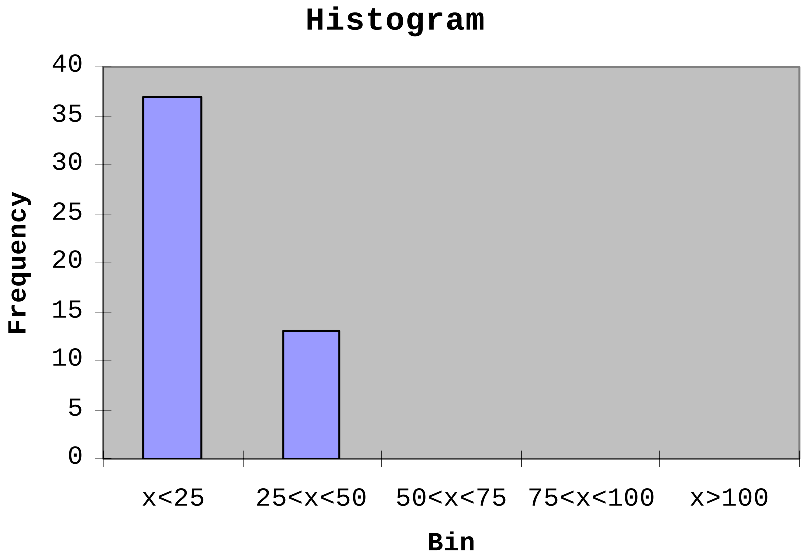


Figure 4.6.3 - Histogram of interconnection lines loadings for 2015-dry hydrology scenario – topology 2010 ("Frequency" denotes number of lines and "Bin" denotes loading range in % of thermal limit)

Following Table 4.6.2 lists all network elements loaded over 80% of their thermal limits. As it can be seen some lines 220 kV voltage level in Albania, Romania and Serbia are loaded over 80%. Also, the most of the elements loaded over 80% are transformers in some substations, again, in Albania, Bosnia & Herzegovina, Romania and Serbia. Figure 4.6.4 shows histogram of branch loadings in the system.

As for the conclusion regarding thermal loadings in this scenario it can be said that the most of the network elements are loaded less then 75% of their thermal limits, but there are some elements highly loaded. Most of the elements loaded over 80% are transformers in some substations, so some internal network reinforcements are necessary to sustain this load-demand level and production pattern. There are some elements that are overloaded (220 kV line Kashar – Rashbul and transformers 220/110 kV in substation Fierza and one transformer 220/110 kV in substation Elbasan 1in Albania). This leads to conclusion that transmission network is not able to sustain this load-demand level and this production pattern needs reinforcement as necessary. It should be pointed out that it is expected that transformers in substation Fierza will be replaced with more powerful transformer units.

Table 4.6.2 - Network elements loaded over 80% of their thermal limits for 2015-dry hydrology scenario – 2010 topology

BRANCH LOADINGS ABOVE 80.0 % OF RATING:

AREA	ELEMENT	LOADING MVA	RATING MVA	PERCENT
Lines				
ALB	HL 220kV AKASHA2-ARRAZH2 1	275.3	270	102
ROM	HL 220kV BUC.S-B-FUNDENI 1	261.2	320	81.6
SRB	HL 220kV JBGD3 21-JOBREN2 1	293.6	301	97.5
Transformers				
ALB	TR 220/110 kV AELBS1 1	84.7	90	94.1
	TR 220/110 kV AELBS1 2	84.7	90	94.1
	TR 220/110 kV AELBS1 3	91	90	101.1
	TR 220/110 kV AFIER 1	146.8	120	122.3
	TR 220/110 kV AFIER 2	120.3	90	133.7
	TR 220/110 kV AFIER 3	114.8	90	127.6
	TR 220/110 kV AFIERZ 1	59	60	98.3
	TR 220/110 kV AFIERZ 2	59	60	98.3
	TR 220/110 kV AKASHA 1	90.8	100	90.8
	TR 220/110 kV AKASHA 2	90.8	100	90.8
	TR 220/110 kV ARRAZH 1	84.7	100	84.7
	TR 220/110 kV ARRAZH 2	84.7	100	84.7
	TR 220/110 kV ATIRAN 3	98.2	120	81.9
BIH	TR 400/110 kV UGLJEV 1	242.4	300	80.8
ROM	TR 220/110 kV FUNDE2 1	199.9	200	99.9
	TR 220/110 kV FUNDEN 1	168.5	200	84.2
	TR 400/220 kV IERNUT 1	325.2	400	81.3
SRB	TR 220/110 kV JBGD3 1	171.1	200	85.6
	TR 220/110 kV JBGD3 2	129.8	150	86.5
	TR 220/110 kV JPRIS4 1	121.6	150	81.1
	TR 220/110 kV JPRIS4 2	121.6	150	81.1
	TR 220/110 kV JTKOSA 2	133.3	150	88.9
	TR 220/110 kV JTKOSA 3	135.7	150	90.5
	TR 400/220 kV JTKOSB 1	323.1	400	80.8
	TR 400/220 kV JTKOSB 2	337.6	400	84.4
	TR 400/220 kV JTKOSB 3	337.6	400	84.4

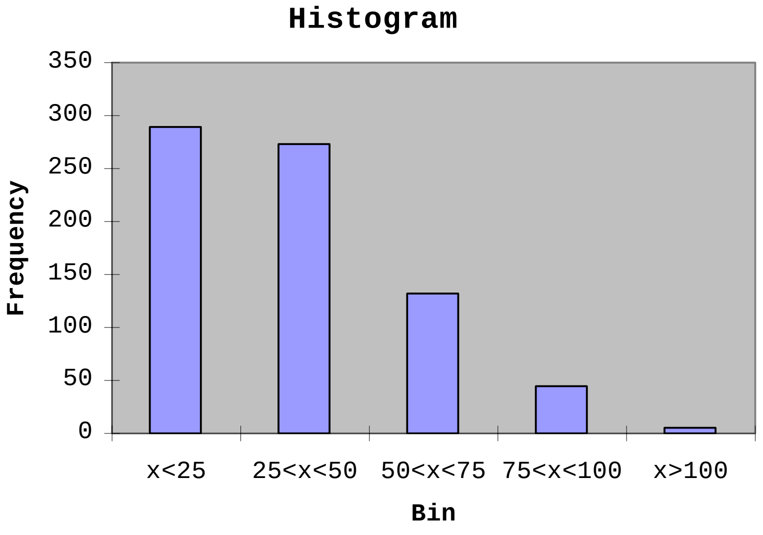


Figure 4.6.4 - Histogram of branch loadings for 2015-dry hydrology scenario – 2010 network topology ("Frequency" denotes number of lines and "Bin" denotes loading range in % of thermal limit)

4.6.2 Voltage Profile in the Region

Figure 4.6.5 shows histogram of voltages in monitored substations. Voltages in almost all monitored substations are found within permitted limits. Only in substations Elbasan and Kashar voltages are below limits (around 359 kV), but this can be resolved with changing of the setting of the tap changing transformers in these substations. Also, as a consequence of high imports, voltages in network of Albania are very near low limits.

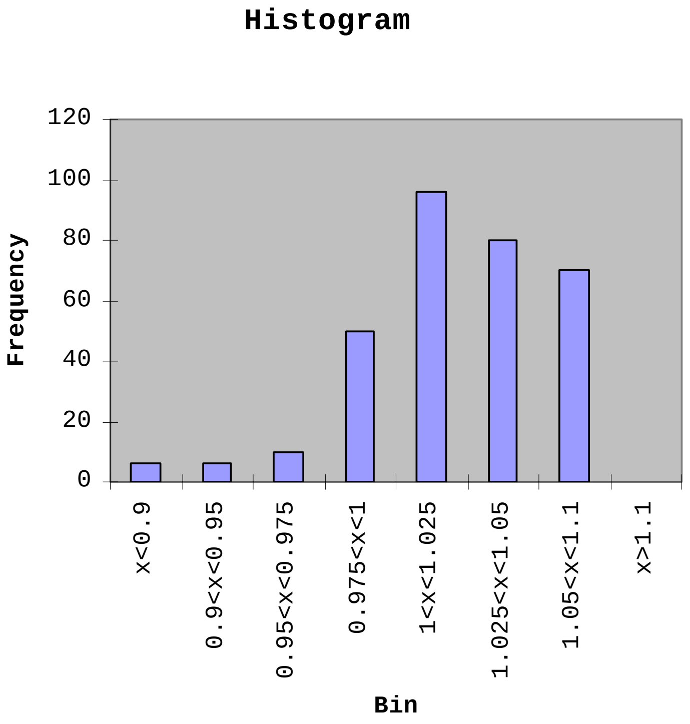


Figure 4.6.5 - Histogram of voltages in monitored substations for 2015-dry hydrology scenario – 2010 network topology ("Frequency" denotes number of busses and "Bin" denotes voltage range in p.u.)

In the rest of the monitored network the voltage profile is satisfying and that most of the substations have magnitudes in range 0.975-1.05 p.u.

4.6.3 Security (n-1) analysis

Results of security (n-1) analysis for 2015-dry hydrology scenario and expected topology for 2010 are presented in Table 4.6.3. Figure 4.6.6 shows the geographical position of the critical elements in monitored systems.

It can be concluded that all identified insecure situations are located in internal networks that belong to monitored power systems of Albania, Romania and Serbia. The most critical element in Albanian system is 220 kV line Elbasan-Fierza. In most critical case in Romanian system, the critical elements are transformers 400/110 kV in substations Dirste and Brasov. The most critical element in Serbian system are line 220 kV Obrenovac – Beograd 3.

Some of the overloadings identified can be relieved by dispatch actions (splitting busbars, changing lower voltage network topology in order to redistribute load-demand or change of generation units engagement), like in the case of most severe overloading in Romanian network happens on transformer 400/110 kV Dirste when transformer 400/110 kV in Brasov is outaged, but this is a consequence of the fact that second transformer unit 400/110 kV in Brasov is out of operation. Switching on of this transformer clears this critical outage. The similar situation is in case of outage of the 400 kV line Obrenovac – Beograd 8 in Serbia. Splitting off the 220 kV busbars in substation Beograd 3 relieves this overloading, but voltage profile in Serbian network remains critical, so additional dispatching actions are necessary too.

All in all, certain reinforcement of internal network is necessary in order to make this regime more secure. None of the identified congestions is located at border lines.

Table 4.6.3 - Network overloadings for 2015-dry hydrology scenario, single outages – 2010 network topology

Area	contingency	Area	overloadings / out of limits voltages	#	limit / Unom	Flow / Voltage	rate / volt.dev.
1	2	3	4	5	6	7	8
	BASE CASE	AL	HL 220kV AKASHA2-ARRAZH2	1	270MVA	242.3MVA	102.0%
AL	OHL 220kV AFIERZ2 -ABURRE2 1	AL	HL 220kV AKASHA2-ARRAZH2	1	270MVA	261.1MVA	126.2%
AL	OHL 220kV ATIRAN2 -AKASHA2 1	AL	HL 220kV AKASHA2-ARRAZH2	1	270MVA	254.3MVA	106.6%
AL	OHL 220kV AELBS12 -AFIER 2 1	AL	HL 220kV AKASHA2-ARRAZH2	1	270MVA	361.1MVA	180.3%
AL	OHL 220kV AFIER 2 -ARRAZH2 1	AL	HL 220kV AELBS12-AFIER 2	1	270MVA	194.4MVA	104.8%
RO	OHL 220kV FUNDENI -BUC.S-B 1	RO	HL 220kV BUC.S-B-FUNDENI	1	320MVA	342.8MVA	106.8%
CS	OHL 220kV JBBAST2 -JBGD3 21 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	327.8MVA	111.5%
CS	OHL 220kV JBGD172 -JBGD8 22 1	CS	HL 220kV JBGD172-JBGD8 22	2	365.8MVA	466.5MVA	133.2%
CS	OHL 220kV JBGD3 22-JBGD8 21 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	312.8MVA	106.4%
CS	OHL 220kV JGLOGO2 -JPRIZ22 1	AL	HL 220kV AKASHA2-ARRAZH2	1	270MVA	231.3MVA	128.2%
CS	OHL 220kV JHIP 2 -JPANC22 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	304.5MVA	103.4%
CS	OHL 220kV JNSAD32 -JOBREN2 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	311.5MVA	105.2%
CS	OHL 220kV JNSAD32 -JZREN22 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	312.6MVA	106.1%
CS	OHL 220kV JOBREN2 -JSABA32 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	314.3MVA	106.6%
CS	OHL 400kV JBGD8 1 -JOBREN11 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	511.9MVA	184.1%
		CS	HL 220kV JBGD3 22-JBGD8 22	2	365.8MVA	354.7MVA	106.4%
CS	OHL 400kV JBGD8 1 -JBGD201 A	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	306.4MVA	103.9%
CS	OHL 400kV JHDJE11 -JTDRMN1 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	324.4MVA	110.4%
CS	OHL 400kV JKRAG21 -JTKOLB1 A	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	306.5MVA	103.9%
CS	OHL 400kV JPANC21 -JTDRMN1 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	314.9MVA	107.7%
CS	OHL 400kV JTKOSB1 -JPEC 1 A	CS	TR 400/220kV/kV JTKOSB1	1	400MVA	413.9MVA	103.5%
		CS	TR 400/220kV/kV JTKOSB1	2	400MVA	432.5MVA	108.1%
		CS	TR 400/220kV/kV JTKOSB1	3	400MVA	432.5MVA	108.1%
RO	TR 400/110 BRASOV 1	RO	TR 400/110kV/kV DIRSTE	1	250MVA	401MVA	160.4%
RO	TR 400/110 DIRSTE 1	RO	TR 400/110kV/kV BRASOV	1	250MVA	394.4MVA	157.7%
CS	TR 400/110 JNIS2 1	CS	TR 400/110kV/kV JNIS2 1	2	300MVA	363.8MVA	121.3%
AL	TR 400/220 AELBS2 1	AL	TR 400/220kV/kV AELBS22	2	300MVA	307.5MVA	102.5%
		AL	HL 220kV AKASHA2-ARRAZH2	1	270MVA	259.2MVA	132.1%
RO	TR 400/220 BRAZI 1	RO	HL 220kV BUC.S-B-FUNDENI	1	320MVA	346.4MVA	109.9%
RO	TR 400/220 BUC.S 1	RO	TR 400/220kV/kV BUC.S	2	400MVA	506.1MVA	126.5%
RO	TR 400/220 IERNUT 1	RO	HL 220kV STEJARU-GHEORGH	1	208.1MVA	191.8MVA	108.6%
CS	TR 400/220 JBGD8 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	342.9MVA	117.8%
		CS	HL 220kV JBGD3 22-JBGD8 22	2	365.8MVA	385.9MVA	110.9%
CS	TR 400/220 JBGD8 2	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	320.8MVA	109.4%
CS	TR 400/220 JNIS2 1	CS	TR 400/110kV/kV JNIS2 1	1	300MVA	303.3MVA	101.1%
CS	TR 400/220 JPANC2 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	300.3MVA	101.8%
CS	TR 400/220 JTKOSB 1	CS	TR 400/220kV/kV JTKOSB1	2	400MVA	471.5MVA	117.9%
		CS	TR 400/220kV/kV JTKOSB1	3	400MVA	471.5MVA	117.9%
RO	TR 400/220 MINTIA 1	RO	HL 220kV PESTIS-MINTIA A	1	277.4MVA	324.3MVA	111.1%
RO	TR 400/220 ROSIORI 1	RO	TR 400/220kV/kV IERNUT	1	400MVA	425.1MVA	106.3%

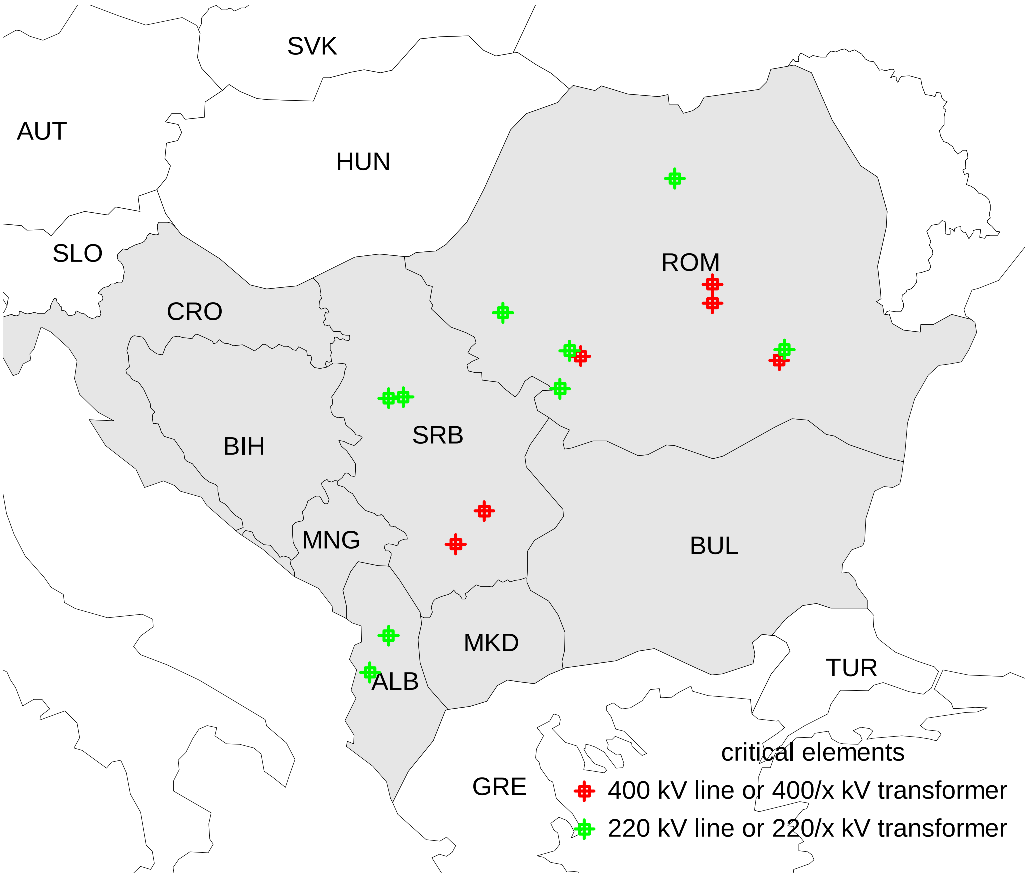


Figure 4.6.6 – Geographical position of critical elements for 2015-dry hydrology scenario – topology 2010

4.7 Scenario 2015 – dry hydrology – topology 2015

This part of the Study presents the results of static load flow and voltage profile analyses that are conducted for complete network topology and (n-1) contingencies in the scenario which is denoted as GTmax run for year 2015 - dry hydrology and expected network topology for 2015.

4.7.1 Lines loadings

Figure 4.7.1 shows power exchanges between areas for 2015-dry hydrology scenario. Power flows along interconnection lines in the region together with balances of the systems are shown in Figure 4.7.2. Area totals are shown in Table 4.7.1. Figure 4.7.3 shows histogram of tie lines loadings. It is concluded that most of the tie lines are loaded less than 25% of their thermal limits.

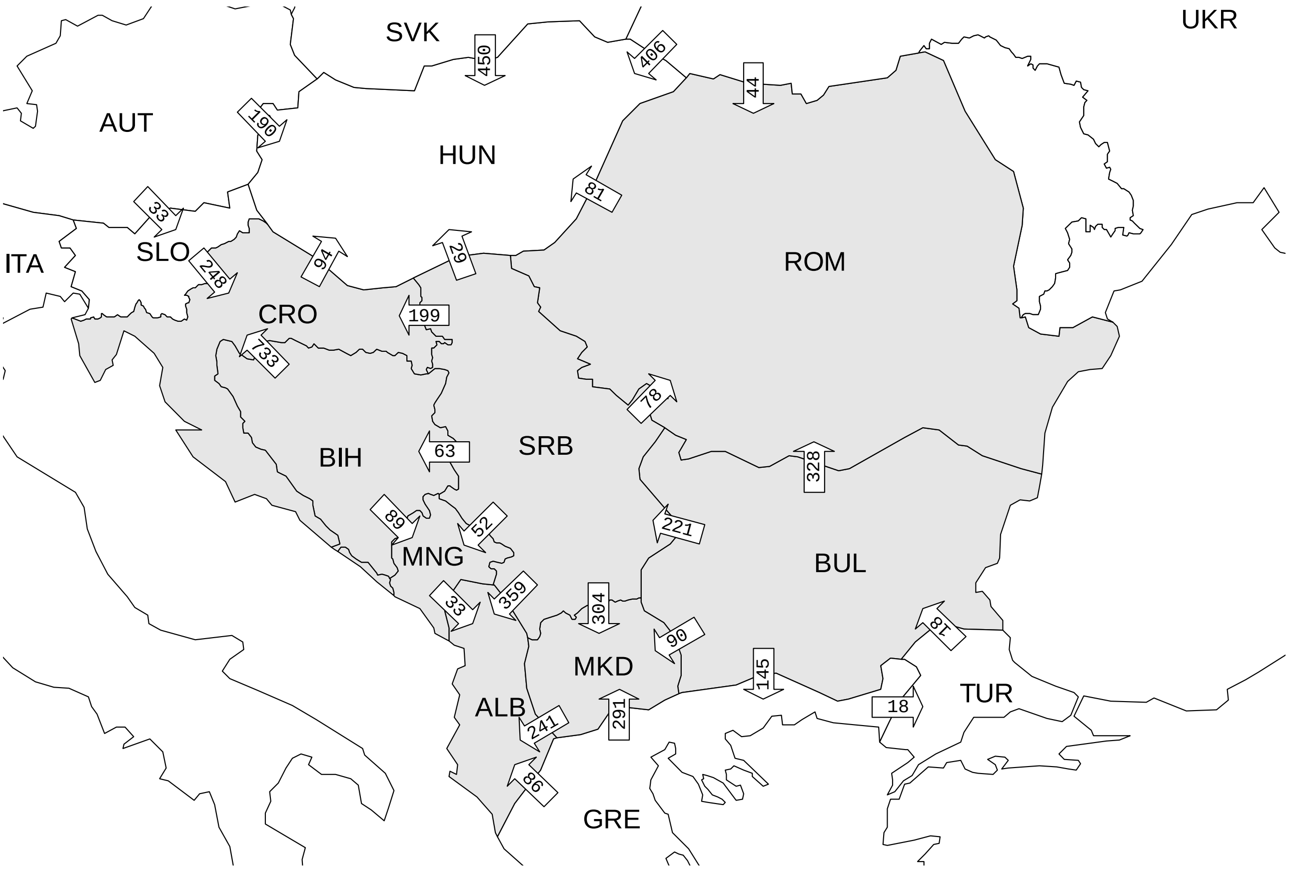


Figure 4.7.1 - Area exchanges in analyzed electric power systems for 2015-dry hydrology scenario

As it can be seen, new elements that are expected to be build till 2015 cause totally different distribution of power flows in the southern part of the region (Albania, FYR of Macedonia, Serbia and Montenegro).

Compared to the expected topology 2010, analyzed in previous chapter, it can be seen that the network losses are decreased as a consequence of building of new elements for 2015 network topology, especially in the cases of Albania, Serbia and Montenegro. Overall reduction of loses is around 40 MW.

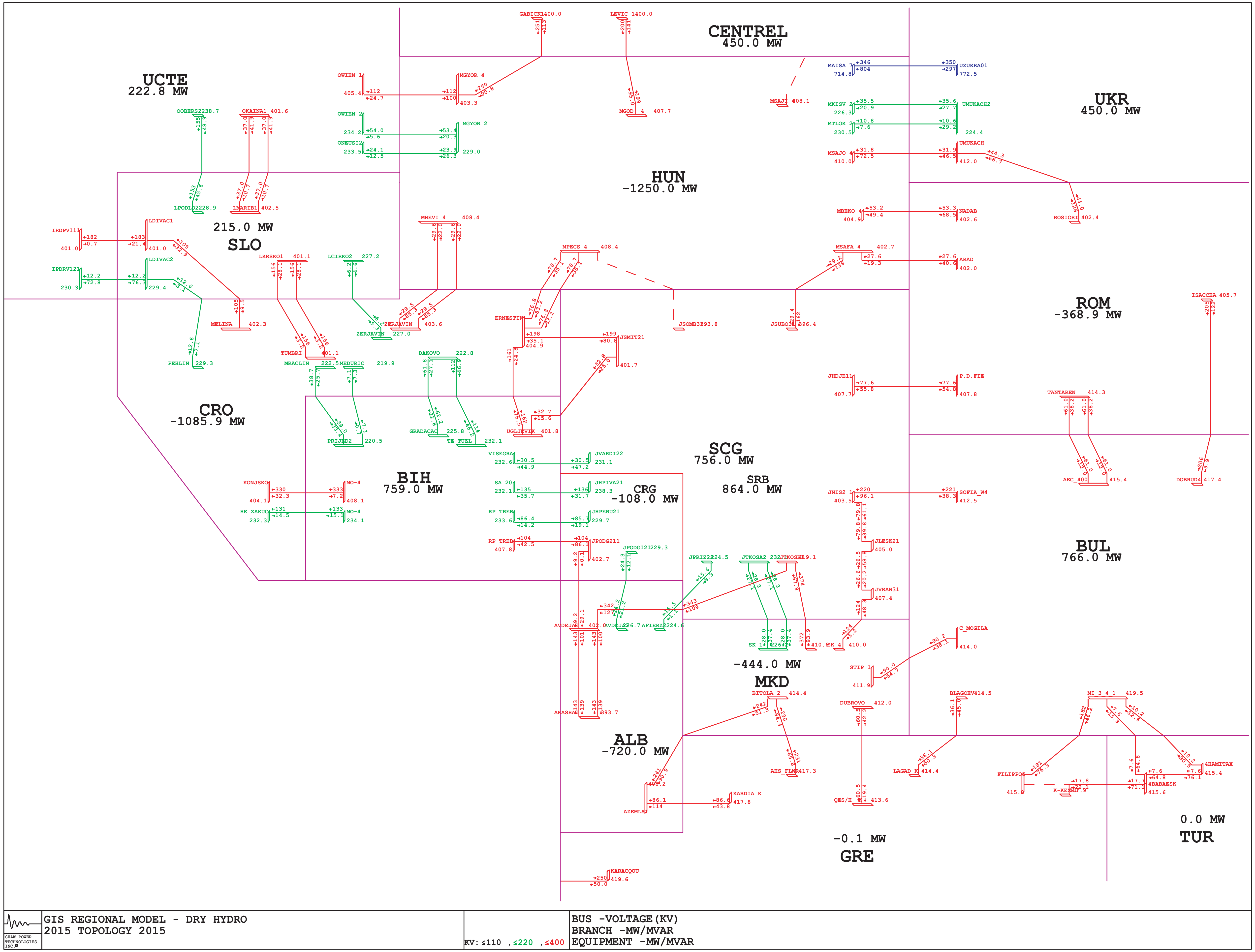


Figure 4.7.2 - Power flows along interconnection lines in the region with balances of the systems for 2015-dry hydrology scenario

Table 4.7.1 - Area totals in analyzed electric power systems for 2015-dry hydrology scenario

AREA	GENERATION	LOAD	LOSSES	INTERCHANGE
ALBANIA	893.6	1542	71.6	-720
BULGARIA	7363.9	6450	147.8	766
BIH	3141.2	2305	77.1	759
CROATIA	2637.7	3665	58.7	-1085.9
MACEDONIA	985.2	1409	20.2	-444
ROMANIA	7722.9	7798.4	293.5	-368.9
SERBIA	8396.3	7308	224.3	864
MONTENEGRO	586.3	678	16.4	-108
TOTALS	31727.1	31155.4	909.6	-337.8

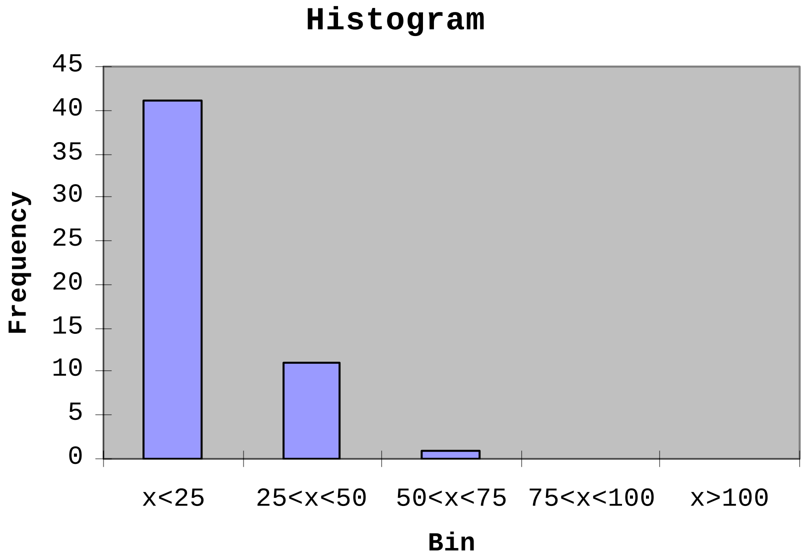


Figure 4.7.3 - Histogram of interconnection lines loadings for 2015-dry hydrology scenario ("Frequency" denotes number of lines and "Bin" denotes loading range in % of thermal limit)

Following Table 4.7.2 lists all network elements loaded over 80% of their thermal limits. Figure 4.7.4 shows histogram of branch loadings in the system.

Table 4.7.2 - Network elements loaded over 80% of their thermal limits for 2015-dry hydrology scenario

BRANCH LOADINGS ABOVE 80.0 % OF RATING:

AREA	ELEMENT	LOADING MVA	RATING MVA	PERCENT
	Lines			
ALB	HL 220kV AKASHA2-ARRAZH2 1	242.7	270	89.9
ROM	HL 220kV BUC.S-B-FUNDENI 1	260.6	320	81.4
SRB	HL 220kV JBGD3 21-JOBREN2 1	294.6	301	97.9
	Transformers			
ALB	TR 220/110 kV AELBS1 1	75.4	90	83.8
	TR 220/110 kV AELBS1 2	75.4	90	83.8
	TR 220/110 kV AELBS1 3	81	90	90
	TR 220/110 kV AFIER 1	136.9	120	114.1
	TR 220/110 kV AFIER 2	112.2	90	124.7
	TR 220/110 kV AFIER 3	107.1	90	119
	TR 220/110 kV AFIERZ 1	52.1	60	86.9
	TR 220/110 kV AFIERZ 2	52.1	60	86.9
	TR 220/110 kV AKASHA 1	83.5	100	83.5
	TR 220/110 kV AKASHA 2	83.5	100	83.5
BIH	TR 400/110 kV UGLJEV 1	240.7	300	80.2
ROM	TR 220/110 kV FUNDE2 1	199.6	200	99.8
	TR 220/110 kV FUNDEN 1	168.2	200	84.1
	TR 400/220 kV IERNUT 1	324.2	400	81.1
SRB	TR 220/110 kV JBGD3 1	170.9	200	85.5
	TR 220/110 kV JBGD3 2	130	150	86.6

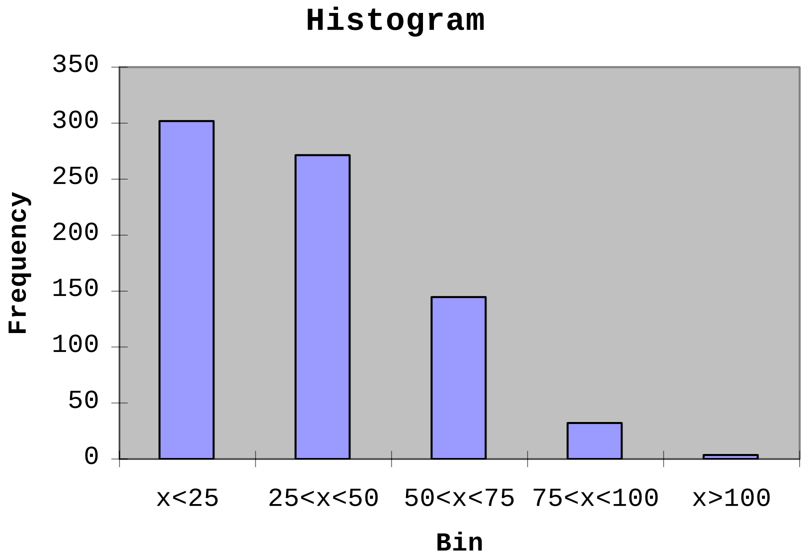


Figure 4.7.4 - Histogram of branch loadings for 2015-dry hydrology scenario ("Frequency" denotes number of lines and "Bin" denotes loading range in % of thermal limit)

As it can be seen from these outputs, most of the network elements are loaded less then 75% of their thermal limits and most of the elements loaded over 80% are transformers in some substations, so some internal network reinforcements are necessary to sustain this load-demand level and production pattern. There are some elements that are overloaded (transformers 220/110 kV in substation Fierza in Albania). This leads to conclusion that transmission network is not able to sustain this load-demand level and this production pattern needs reinforcement as necessary. It should be pointed out that it is expected that transformers in substation Fierza will be replaced with more powerful transformer units. Also, planned network reinforcements compared to network topology 2010, reduce loading of some elements in southern part of Serbia.

4.7.2 Voltage Profile in the Region

Figure 4.7.5 shows histogram of voltages in monitored substations. Voltages in all monitored substations are found within permitted limits. It is concluded that voltage profile is satisfying and that most of the substations have magnitudes in range 1-1.05 p.u. Compared to the 2010 topology, voltage profile is somewhat better, especially in southern and central part of Serbia, as well as in Albania.

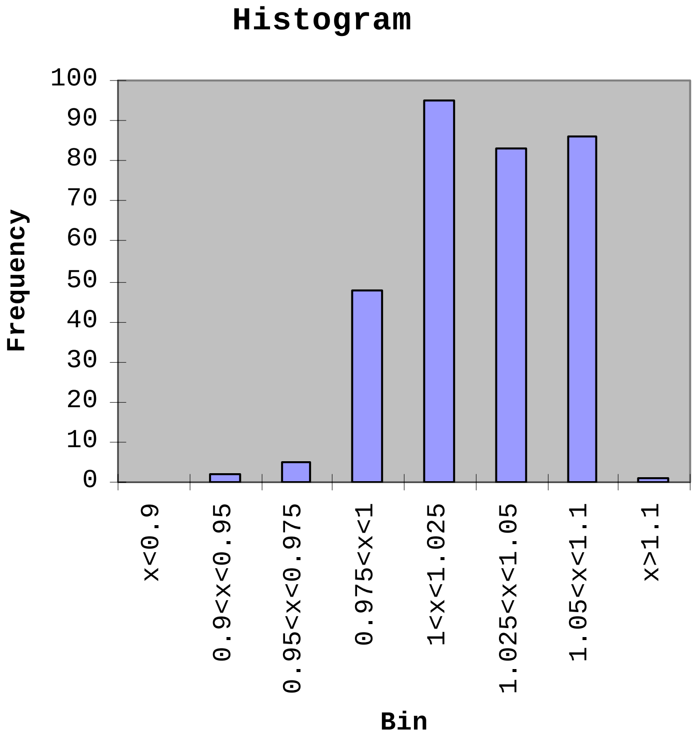


Figure 4.7.5 - Histogram of voltages in monitored substations for 2015-dry hydrology scenario ("Frequency" denotes number of busses and "Bin" denotes voltage range in p.u.)

4.7.3 Security (n-1) analysis

Results of security (n-1) analysis for 2015-dry hydrology scenario are presented in Table 4.7.3. Figure 4.7.6 shows the geographical position of the critical elements in monitored systems.

Like for expected topology 2010 (previous chapter), it can be concluded that all identified insecure situations are located in internal networks that belong to monitored power systems of Albania, Romania and Serbia. Also, the planned network reinforcements till 2015 resolve some of the noticed critical contingencies, especially in southern part of Serbia. The rest of the conclusions are the same as in case of the analyzed topology 2010, and that is that certain level of network reinforcement is necessary to make this regime more secure.

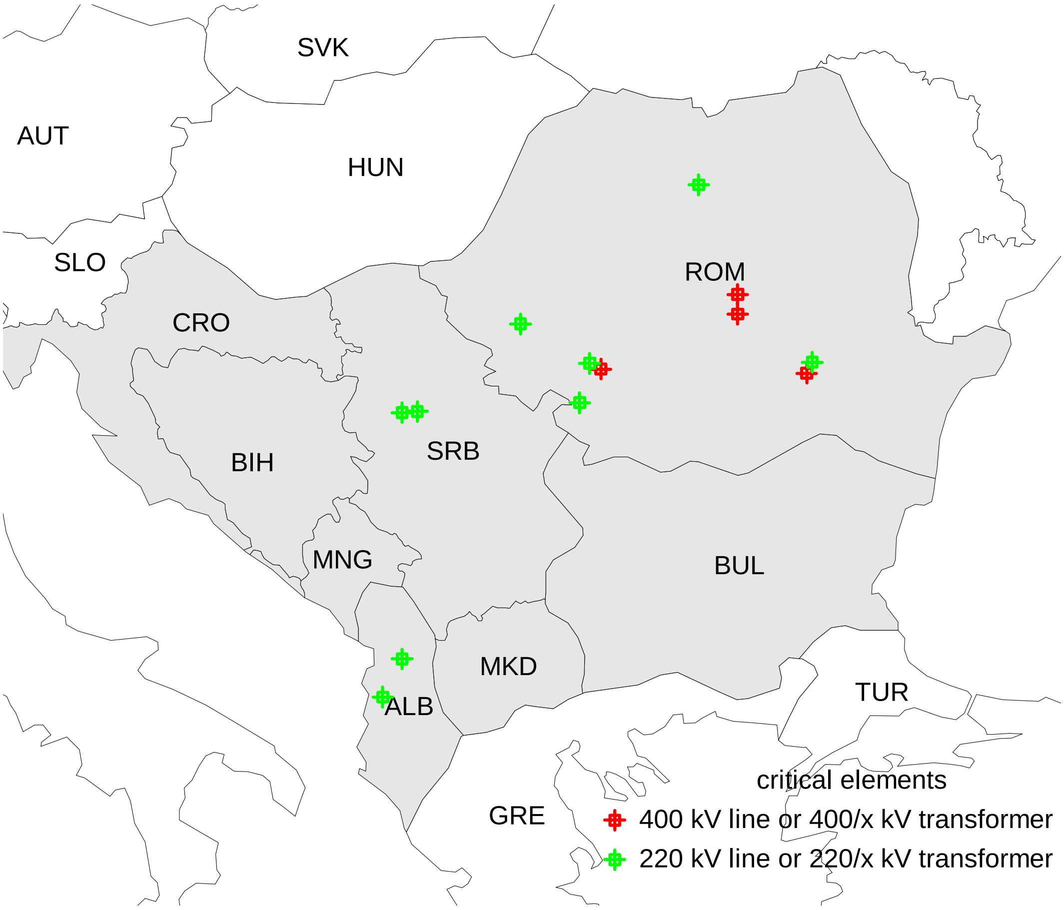


Figure 4.7.6 – Geographical position of critical elements for 2015-dry hydrology scenario

Table 4.7.3 - Network overloadings for 2015-dry hydrology scenario, single outages

Area	contingency	Area	overloadings / out of limits voltages	#	limit / Unom	Flow / Voltage	rate / volt.dev.
1	2	3	4	5	6	7	8
AL	OHL 220kV AELBS12 -AFIER 2 1	AL	HL 220kV AKASHA2-ARRAZH2	1	270MVA	376.7MVA	151.9%
RO	OHL 220kV FUNDENI -BUC.S-B 1	RO	HL 220kV BUC.S-B-FUNDENI	1	320MVA	342.5MVA	106.6%
RO	OHL 220kV STEJARU -GHEORGH 1	RO	TR 400/220kV/kV IERNUT	1	400MVA	406.2MVA	101.5%
RO	OHL 400kV DOMNESTI-BRAZI 1	RO	HL 220kV BUC.S-B-FUNDENI	1	320MVA	330.3MVA	102.0%
CS	OHL 220kV JBBAST2 -JBGD3 21 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	331MVA	112.3%
CS	OHL 220kV JBGD172 -JBGD8 22 1	CS	HL 220kV JBGD172-JBGD8 22	2	365.8MVA	467.1MVA	133.0%
CS	OHL 220kV JBGD3 22-JBGD8 21 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	314MVA	106.6%
CS	OHL 220kV JHIP 2 -JPANC22 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	305.8MVA	103.6%
CS	OHL 220kV JNSAD32 -JOBREN2 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	313.5MVA	105.6%
CS	OHL 220kV JNSAD32 -JZREN22 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	314.5MVA	106.5%
CS	OHL 220kV JOBREN2 -JVALJ32 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	301.6MVA	101.5%
CS	OHL 400kV JBGD8 1 -JOBREN11 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	514.9MVA	184.3%
		CS	HL 220kV JBGD3 22-JBGD8 22	2	365.8MVA	359.3MVA	107.2%
CS	OHL 400kV JBGD8 1 -JBGD201 A	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	308.3MVA	104.2%
CS	OHL 400kV JHDJE11 -JTDRMN1 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	324.2MVA	110.1%
CS	OHL 400kV JKRAG21 -JTKOLB1 A	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	307.8MVA	104.0%
CS	OHL 400kV JPANC21 -JTDRMN1 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	316MVA	107.8%
AL	TR 400/110 AZEMLA 1	AL	HL 220kV AKASHA2-ARRAZH2	1	270MVA	263.6MVA	108.6%
RO	TR 400/110 BRASOV 1	RO	TR 400/110kV/kV DIRSTE	1	250MVA	401.1MVA	160.4%
RO	TR 400/110 DIRSTE 1	RO	TR 400/110kV/kV BRASOV	1	250MVA	394.7MVA	157.9%
RO	TR 400/220 BRAZI 1	RO	HL 220kV BUC.S-B-FUNDENI	1	320MVA	346.3MVA	109.8%
RO	TR 400/220 BUC.S 1	RO	TR 400/220kV/kV BUC.S	2	400MVA	506MVA	126.5%
RO	TR 400/220 IERNUT 1	RO	HL 220kV STEJARU-GHEORGH	1	208.1MVA	190.9MVA	107.9%
CS	TR 400/220 JBGD8 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	344.1MVA	117.9%
		CS	HL 220kV JBGD3 22-JBGD8 22	2	365.8MVA	388.2MVA	111.3%
CS	TR 400/220 JBGD8 2	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	322MVA	109.5%
CS	TR 400/220 JPANC2 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	301.9MVA	102.0%
RO	TR 400/220 MINTIA 1	RO	HL 220kV PESTIS-MINTIA A	1	277.4MVA	325.2MVA	111.3%
RO	TR 400/220 ROSIORI 1	RO	TR 400/220kV/kV IERNUT	1	400MVA	425.1MVA	106.3%

4.7.4 Summary of Impacts - 2015 topology versus 2010 topology

Compared to the expected topology 2010, analyzed in previous chapter, it can be seen that the network losses are reduced as a consequence of building of new elements for 2015 network topology, especially in the cases of Albania, Serbia and Montenegro. Overall reduction of losses is around 40 MW.

Also, planned network reinforcements compared to network topology 2010, reduce load of some elements in southern part of Serbia.

Compared to the 2010 topology, voltage profile is somewhat better, especially in southern and central part of Serbia, as well as in Albania.

Realization of the planed investments till 2015 has impact on secure operation of the network. Some of the insecure states identified with 2010 topology are relieved and do not exist with expected 2015 network topology. Also, levels of overloadings due to outages are decreased.

All in all overall network performance is better, especially in the region where new planed investments are to be realized (Albania, southern Serbia and Montenegro).

4.8 Scenario 2015 – wet hydrology – 2010 topology

This part of the Study presents results of static load flow and voltage profile analyses that are conducted for complete network topology and (n-1) contingencies in the scenario which is denoted as Scenario 2015 wet hydrology and expected network topology for 2010.

4.8.1 Line loadings

Area totals and power exchanges for the 2015-base case-wet hydrology-topology 2010 scenario are shown in Figure 4.8.1 and Table 4.8.1. Power flows along regional interconnection lines and system balances are shown in Figure 4.8.2. Power flows along interconnection lines are also given in Table 4.8.2, while Figure 4.8.3 shows histogram of tie lines loadings.

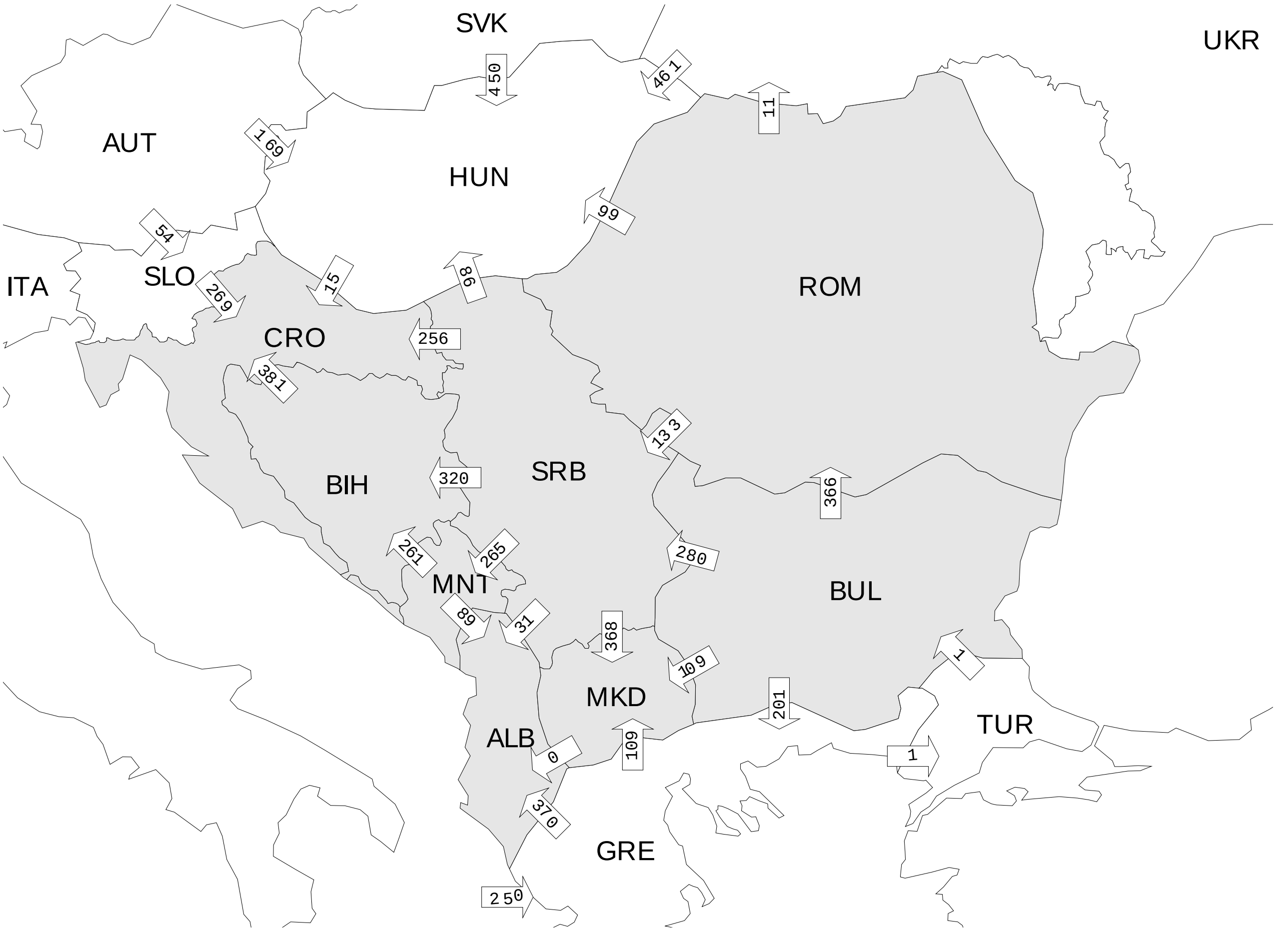


Figure 4.8.1 - Area exchanges in analyzed electric power systems for 2015-base case-wet hydrology-2010 topology scenario

Table 4.8.1 - Area totals in analyzed electric power systems for 2015-base case-wet hydrology-topology 2010 scenario

Country	**Generation (MW)**	**Load (MW)**	**Bus Shunt (Mvar)**	**Line Shunt (Mvar)**	**Losses (MW)**	**Net Interchange (MW)**
Albania	1124.5	1528.9	0	0	85.8	-490.1
Bulgaria	7553.2	6446.1	0	14.7	137.4	955.0
Bosnia and Herzegovina	2154.2	2278.6	0	0	74.8	-199.3
Croatia	2799.9	3660.4	0	0	60.9	-921.3
Macedonia	869.5	1407.6	0	0	18.9	-557.0
Romania	7953.9	7704.0	0	74.3	298.9	-123.3
Serbia and UNMIK	8413.1	7209.2	0	12.7	278.4	912.7
Montenegro	778.7	669.8	0.5	1.7	21.6	85.0
TOTAL - SE EUROPE	*31646.9*	*30904.6*	*0.5*	*103.4*	*976.6*	*-338.3*

Figure 4.8.3 shows that the tie lines in the region are mostly loaded less than 25% of their thermal limits for the analyzed hydrological base case scenario in year 2015, examined on network topology in 2010. Among total number of forty nine 400 kV and 220 kV interconnection lines in the region only eight are loaded between 25% and 50% of their thermal ratings. Only one line (OHL 400 kV Sarajevo 20 – Piva between Bosnia and Herzegovina and Montenegro) is loaded more than 50% of its thermal rating.

Table 4.8.3 lists all network elements, observing only lines 400 kV and 220 kV and transformers 400/x kV and 220/x kV, that are loaded over 80% of their thermal limits. Most of the elements loaded over 80% are transformers in some substations and internal 110 kV and 220 kV lines. Thus, certain internal network reinforcements are necessary to sustain given load-demand level and generation pattern.

All three 220/110 kV transformers in the Fierze substation in Albania are overloaded in this scenario. There are eight 220/110 kV transformers in Albania which are highly loaded. Line 220 kV from Tirana to Rashbull is loaded near its limit. There are fourteen 110 kV lines in Albania loaded over 80% of their thermal rating and five of them are overloaded (the largest overloading is noticed for the 110 kV line Fierze-F.arrez).

Power systems of Bulgaria and Bosnia and Herzegovina have several highly loaded branches in the 110 kV networks. Highly loaded high voltage branches are 220 kV line M.East-St.Zagora in Bulgaria and transformer 400/110 kV in TPP Ugljevik in Bosnia and Herzegovina. Line 110 kV Orasje-Zupanja between Croatia and Bosnia and Herzegovina is overloaded too (135 % $I_{thermal}$).

There are ten 220 kV and four 110 kV internal lines in Romania which are loaded over 80% of their thermal limits, whereas four of them are overloaded. These lines are related to the Lotru, Sibiu, Tg.Jiu and Parosen nodes. Transformer 400/220 kV in the Urechesti substation is slightly overloaded in this scenario.

Three 220 kV lines and nineteen 110 kV lines in the Serbian power system are highly loaded or overloaded when all branches are available in the analyzed scenario. Highly loaded 220 kV lines are connected to the Obrenovac substation, while 110 kV lines are located mostly in the areas of Belgrade, Bor, Kragujevac, Sombor and Novi Sad. One 220 kV line and nine 110 kV lines are overloaded, ranging between 104% $I_{thermal}$ and 129% $I_{thermal}$.

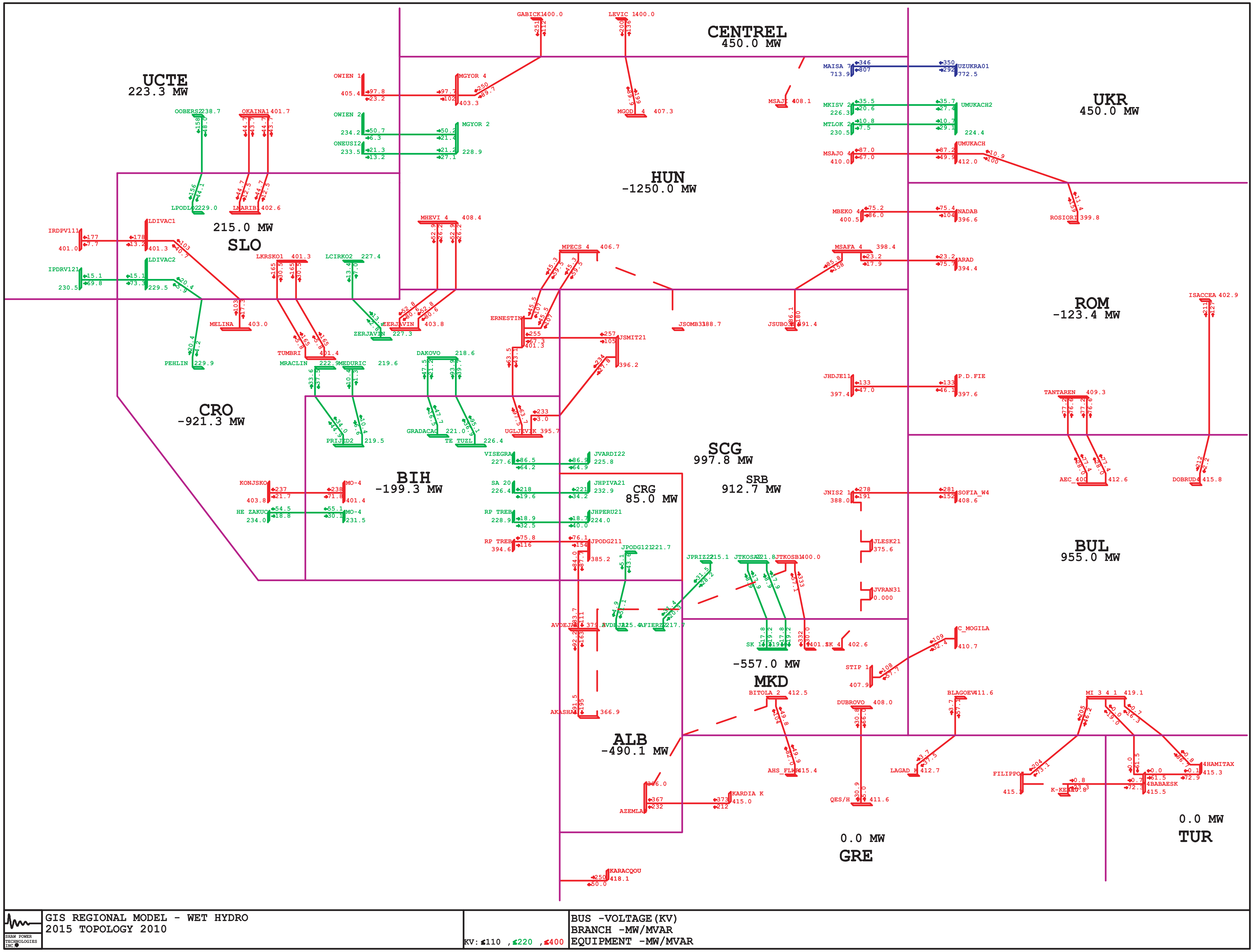


Figure 4.8.2 - Power flows along interconnection lines in the region for 2015 - base case - wet hydrology scenario – topology 2010

Table 4.8.2 - Power flows along regional interconnection lines for 2015 - base case-wet hydrology scenario-topology 2010

Interconnection line			**Power Flow**		**% of thermal rating**
			MW	**Mvar**	
OHL 400 kV	Zemlak (ALB)	Kardia (GRE)	-367.1	-231.6	33
OHL 220 kV	Fierze (ALB)	Prizren (SER)	-31.4	20.3	14
OHL 220 kV	V.Dejes (ALB)	Podgorica (MON)	-4.9	-51.1	19
OHL 400 kV	V.Dejes (ALB)	Podgorica (MON)	-83.7	-111.5	11
OHL 400 kV	Ugljevik (B&H)	Ernestinovo (CRO)	63.7	-97.5	9
OHL 400 kV	Mostar (B&H)	Konjsko (CRO)	237.9	-71.8	19
OHL 400 kV	Ugljevik (B&H)	S. Mitrovica (SER)	-232.7	-3.0	18
OHL 400 kV	Trebinje (B&H)	Podgorica (MON)	-75.8	115.9	13
OHL 220 kV	Trebinje (B&H)	Plat (CRO)	-104.8	40.5	37
OHL 220 kV	Prijedor (B&H)	Mraclin (CRO)	34.0	-44.9	18
OHL 220 kV	Prijedor (B&H)	Medjuric (CRO)	10.4	-6.6	4
OHL 220 kV	Gradacac (B&H)	Djakovo (CRO)	47.7	16.5	18
OHL 220 kV	Tuzla (B&H)	Djakovo (CRO)	95.1	36.9	35
OHL 220 kV	Mostar (B&H)	Zakucac (CRO)	55.1	-30.1	18
OHL 220 kV	Visegrad (B&H)	Vardiste (SER)	-86.5	64.2	35
OHL 220 kV	Sarajevo 20 (B&H)	Piva (MON)	-217.9	-19.6	58
OHL 220 kV	Trebinje (B&H)	Perucica (MON)	18.9	32.5	14
OHL 400 kV	Blagoevgrad (BUL)	Thessaloniki (GRE)	-3.7	-57.1	8
OHL 400 kV	M.East 3 (BUL)	Filippi (GRE)	205.4	-46.2	30
OHL 400 kV	M.East 3 (BUL)	Babaeski (TUR)	0.0	-19.0	5
OHL 400 kV	M.East 3 (BUL)	Hamitabat (TUR)	-0.7	-16.3	5
OHL 400 kV	C.Mogila (BUL)	Stip (MCD)	108.7	-32.4	16
OHL 400 kV	Dobrudja (BUL)	Isaccea (ROM)	212.0	-2.2	15
OHL 2x400 kV ckt.1	Kozloduy (BUL)	Tantarena (ROM)	77.4	28.0	8
OHL 2x400 kV ckt.2	Kozloduy (BUL)	Tantarena (ROM)	77.4	28.0	8
OHL 400 kV	Sofia West (BUL)	Nis (SER)	280.6	151.6	45
OHL 2x400 kV ckt.1	Zerjavinec (CRO)	Heviz (HUN)	-52.8	-80.6	7
OHL 2x400 kV ckt.2	Zerjavinec (CRO)	Heviz (HUN)	-52.8	-80.6	7
OHL 2x400 kV ckt.1	Ernestinovo (CRO)	Pecs (HUN)	45.5	-106.9	9
OHL 2x400 kV ckt.2	Ernestinovo (CRO)	Pecs (HUN)	45.5	-106.9	9
OHL 2x400 kV ckt.1	Tumbri (CRO)	Krsko (SLO)	-165.2	5.8	14
OHL 2x400 kV ckt.2	Tumbri (CRO)	Krsko (SLO)	-165.2	5.8	14
OHL 400 kV	Melina (CRO)	Divaca (SLO)	103.3	3.0	10
OHL 400 kV	Ernestinovo (CRO)	S.Mitrovica (SER)	-255.3	67.3	21
OHL 220 kV	Zerjavinec (CRO)	Cirkovce (SLO)	-13.4	-2.8	5
OHL 220 kV	Pehlin (CRO)	Divaca (SLO)	20.4	-4.2	6
OHL 400 kV	Dubrovo (MCD)	Thessaloniki (GRE)	-30.8	-66.0	5
OHL 400 kV	Bitola (MCD)	Florina (GRE)	-49.8	-103.8	8
OHL 400 kV	Skopje (MCD)	Kosovo B (UNMIK)	-331.6	30.0	25
OHL 2x220 kV ckt.1	Skopje (MCD)	Kosovo A (UNMIK)	-17.8	-19.2	8
OHL 2x220 kV ckt.2	Skopje (MCD)	Kosovo A (UNMIK)	-17.8	-19.2	8
OHL 400 kV	Arad (ROM)	Sandorfalva (HUN)	23.2	-75.7	7
OHL 400 kV -	Nadab (ROM)	Bekescaba (HUN)	75.4	-103.7	11
OHL 400 kV	Rosiori (ROM)	Mukacevo (UKR)	11.4	-159.3	14
OHL 400 kV	Portile De Fier (ROM)	Djerdap (SER)	133.0	46.1	11
OHL 400 kV	Subotica (SER)	Sandorfalva (HUN)	86.1	-180.5	16
OHL 400 kV	Ribarevine (MON)	Kosovo B (UNMIK)	-452.0	4.3	35
OHL 220 kV	Pljevlja (MON)	Bajina Basta (SER)	40.2	5.4	14
OHL 220 kV	Pljevlja (MON)	Pozega (SER)	105.0	42.5	38

Figure 4.8.4 shows histogram of 400 kV and 220 kV regional internal lines and 400/x kV and 220/x kV transformers loadings. 37% of observed branches are loaded below 25% of their thermal ratings, 36% are loaded between 25% and 50%, 19% are loaded between 50% and 75%, 7% of observed branches are loaded between 75% and 100% of their thermal ratings and 1% of them are overloaded (ten branches in total) if all branches are in operation for the analyzed scenario.

Table 4.8.3 - Network elements loaded over 80% of thermal limits for 2015-base case-wet hydrology-2010 topology scenario (branches 400 kV and 220 kV)

AREA	ELEMENT	LOADING MVA	RATING MVA	PERCENT
Lines				
ALB	OHL 220 kV AKASHA2-ARRAZH2	259.3	270.0	96.0
BUL	OHL 220 kV MI_2_220-ST ZAGORA	191.0	228.6	83.5
ROM	OHL 220 kV MINTIA-SIBIU	324.2	381.1	85.1
	OHL 220 kV P.D.F.II-CETATE1	269.0	277.4	97.0
	OHL 220 kV LOTRU-SIBIU ckt.1	303.6	277.4	109.4
	OHL 220 kV LOTRU-SIBIU ckt.2	303.6	277.4	109.4
	OHL 220 kV URECHESI-TG.JIU	280.4	277.4	101.1
	OHL 220 kV P.D.F.A-CETATE1	206.0	208.1	99.0
	OHL 220 kV P.D.F.A-RESITA ckt.1	239.1	277.4	86.2
	OHL 220 kV P.D.F.A-RESITA ckt.2	239.1	277.4	86.2
	OHL 220 kV TG.JIU-PAROSEN	280.4	208.1	134.7
	OHL 220 kV BUC.S-B-FUNDENI	285.4	320.0	89.2
SRB	OHL 220 kV JBGD3 21-JOBREN2	313.3	301.0	104.1
Transformers				
ALB	TR 220/110 kV AFIERZ2-AFIERZ5 ckt.1	54.6	60.0	91.1
	TR 220/110 kV AFIERZ2-AFIERZ5 ckt.2	54.6	60.0	91.1
	TR 220/110 kV AELBS12-AELBS15 ckt.1	81.4	90.0	90.5
	TR 220/110 kV AELBS12-AELBS15 ckt.2	81.4	90.0	90.5
	TR 220/110 kV AELBS12-AELBS15 ckt.3	87.5	90.0	97.2
	TR 220/110 kV AKASHA2-AKASH25 ckt.1	87.2	100.0	87.2
	TR 220/110 kV ARRAZH2-ARRAZB5 ckt.1	80.3	100.0	80.3
	TR 220/110 kV ARRAZH2-ARRAZB5 ckt.1	80.3	100.0	80.3
	TR 220/110 kV AFIER 2-AFIER 5 ckt.1	141.1	120.0	117.5
	TR 220/110 kV AFIER 2-AFIER 5 ckt.2	115.6	90.0	128.5
	TR 220/110 kV AFIER 2-AFIER 5 ckt.3	110.4	90.0	122.6
B&H	TR 400/110 kV UGLJEVIK	270.0	300.0	90.0
ROM	TR 400/220 kV URECHESI	414.4	400.0	103.6
	TR 400/220 kV BUC.S-BUC.S-B ckt.2	340.0	400.0	85.0
	TR 400/220 kV BUC.S-BUC.S-B ckt.3	340.0	400.0	85.0
	TR 220/110 kV FUNDENI	175.9	200.0	88.0
	TR 220/110 kV FUNDENI-FUNDE2B	208.6	200.0	104.3
SRB	TR 400/220 kV JBGD8-JBGD8 22	338.0	400.0	84.5
	TR 400/220 kV JTKOSB1-JTKOSB2 ckt.1	324.6	400.0	81.1
	TR 400/220 kV JTKOSB1-JTKOSB2 ckt.2	324.6	400.0	81.1
	TR 400/110 kV JJAGO41-JJAGO45	247.4	300.0	82.5
	TR 220/110 kV JBGD3 21-JBGD 351	197.2	200.0	98.6
	TR 220/110 kV JBGD3 22-JBGD 352	134.5	150.0	89.7
	TR 220/110 kV JTKOSA2-JTKOSA5 ckt.2	131.9	150.0	87.9
	TR 220/110 kV JTKOSA2-JTKOSA5 ckt.3	134.2	150.0	89.5
	TR 220/110 kV JZREN22-JZREN25	121.9	150.0	81.3

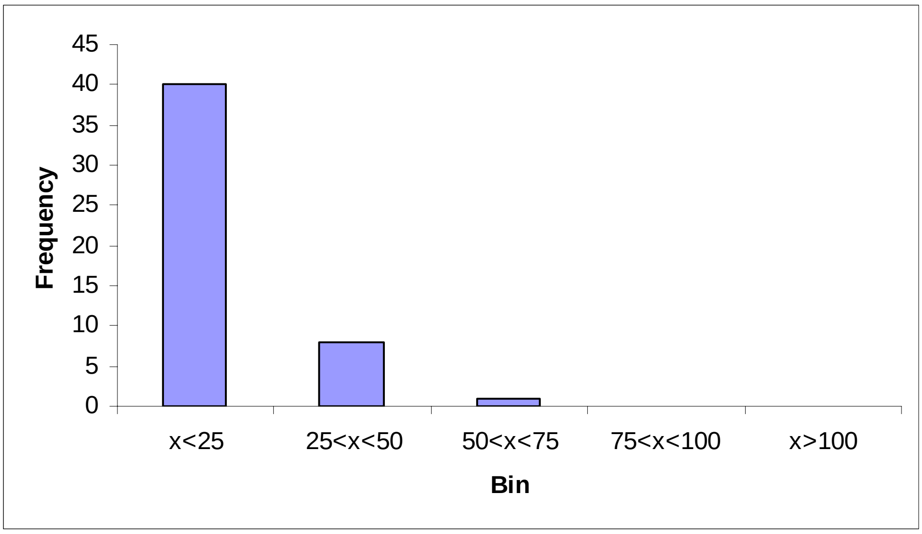


Figure 4.8.3 - Histogram of interconnection lines loadings for 2015-base case-wet hydrology-2010 topology scenario ("Frequency" denotes number of lines and "Bin" denotes loading range in % of thermal limit)

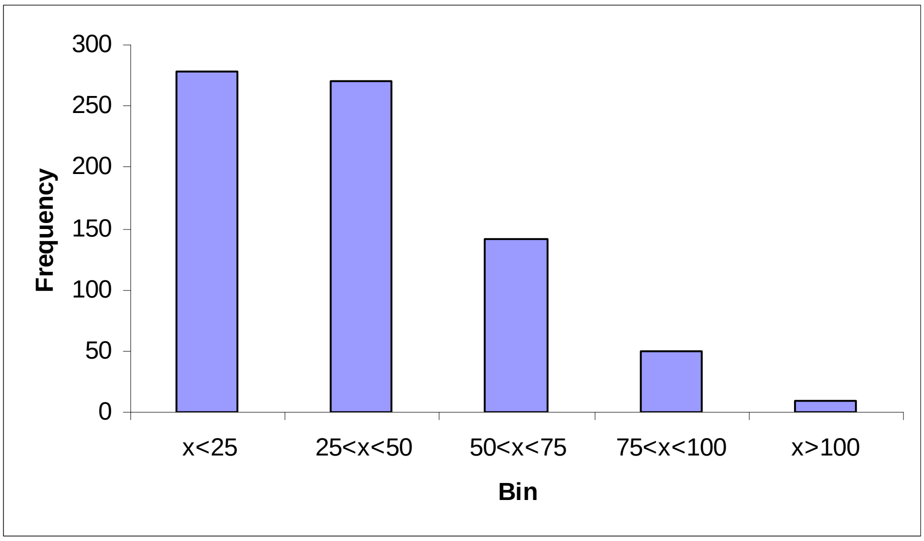


Figure 4.8.4 - Histogram of 400 kV and 220 kV regional lines loadings for 2015-base case-wet hydrology-2010 topology scenario ("Frequency" denotes number of lines and "Bin" denotes loading range in % of thermal limit)

4.8.2 Voltage Profile in the Region

Voltage profile in the region within this scenario which is defined by given generation and demand pattern is seen as satisfactory despite several appearances of certain bus voltage deviations. The deviations are shown in Table 4.8.4, which includes only 400 kV and 220 kV network buses.

Bus voltage magnitudes which are found below permitted limits (90% $V_{nominal}$ in 220 kV network and 95% $V_{nominal}$ in 400 kV network) are detected in Albania (three 400 kV and two 220 kV nodes) and Serbia (three 400 kV nodes). Bus voltage magnitudes that are found above permitted limits (110% $V_{nominal}$ in 110 kV and 220 kV networks and 105% $V_{nominal}$ in 400 kV network) are detected only in Bulgaria in one node. Figure 4.8.5 shows histogram of bus voltage magnitudes in monitored 400 kV and 220 kV substations.

Table 4.8.4 - Bus voltage deviations for 2015-base case-wet hydrology-2010 topology scenario, complete network

Country	**Node**	**Voltages**	
		pu	**kV**
ALBANIA	400 kV AELBS21	0.917	366.7
	400 kV AVDEJA1	0.948	379.3
	400 kV AKASHA1	0.917	366.9
	220 kV AFIER 2	0.856	188.3
	220 kV ABABIC2	0.868	191.0
BOSNIA AND HERZEGOVINA	-	-	-
BULGARIA	400 kV MARITSA EAST2	1.051	420.3
CROATIA	-	-	-
MACEDONIA	-	-	-
MONTENEGRO	-	-	-
ROMANIA	-	-	-
SERBIA AND UNMIK	400 kV JBGD201	0.947	378.9
	400 kV JPANC21	0.944	377.5
	400 kV JLESK21	0.939	375.6

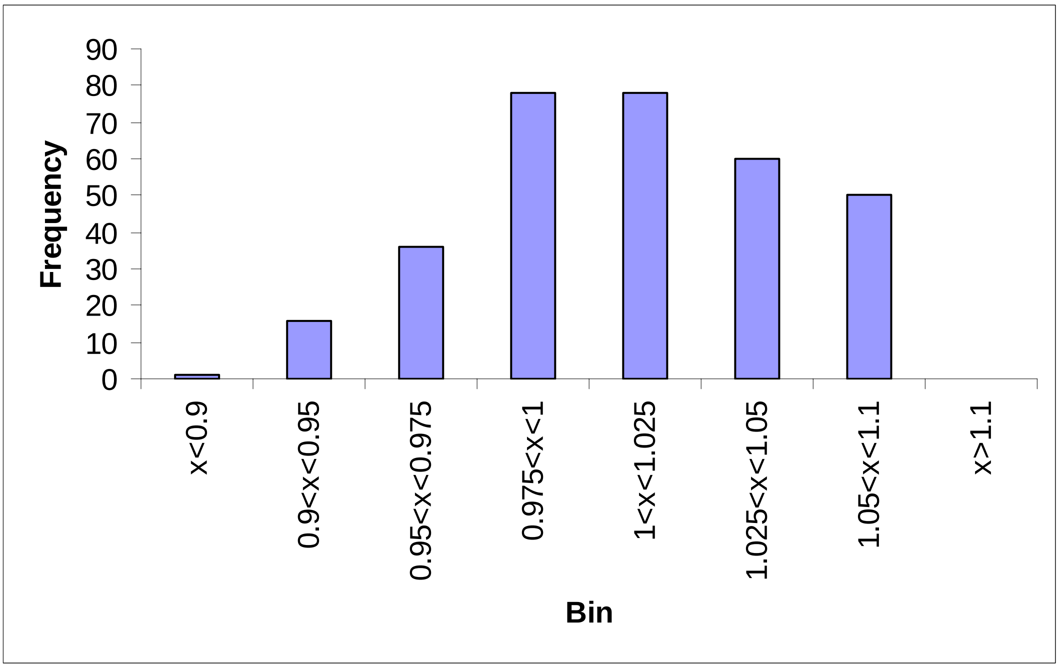


Figure 4.8.5 - Histogram of voltages in monitored substations for 2015-base case-wet hydrology-2010 topology scenario ("Frequency" denotes number of busses and "Bin" denotes voltage range in p.u.)

It should be emphasized that these results represent only a situation when additional devices (transformer automatic tap changers, switched 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.

4.8.3 Security (n-1) analysis

Results of security (n-1) analysis for the 2015-base case-wet hydrology-2010 topology scenario are presented in Table 4.8.5 and Table 4.8.6. Critical contingencies which are included there are related only to the branches which are not overloaded in the base case when all branches are available.

Insecure states for given generation and demand pattern are detected in the power systems of Romania, Serbia, Albania, although there is one contingency in Bulgaria which leads to insecure state.

The most often overloaded lines in the Romanian power system are 400 kV OHL Mintia-Sibiu, 220 kV OHL Bucuresti Sud-Fundeni and lines 220 kV connected to the Portile de Fier substation. These lines are overloaded in several contingency cases. Lines 220 kV Lotru-Sibiu, Urechesti-Targa Jiu, Paroseni-Targa Jiu and transformer in 400/220 kV substation Urechesti are already overloaded in the base case when all branches are available. Possible actions to reduce the loading of the critical branches look for a re-dispatching of the generators in Romania within this scenario, especially the HPP LOTRU CIUNGET (dispatched at 510 MW in the base case), HPP PORTILE 1 (921 MW), TPP ROVINARI (540 MW) and TPP PAROSENI.

Line 400 kV Mintia-Sibiu has rating of 381 MVA on the model which seems as too low value, so contingencies in which this line is overloaded are not included in the contingency tables. It is overloaded if one among following lines goes out of operation: 400 kV Sibiu-Iernut (loading of Mitia-Sibiu line is 142.3 % $I_{thermal}$), 400 kV Iernut-Gadalin (107.7 % $I_{thermal}$), 400 kV Rosiori-Gadalin (100.3 % $I_{thermal}$), 220 kV Urechesi-Tg.Jiu (117.7 % $I_{thermal}$), 220 kV Tg.Jiu-Parosen (117.6 % $I_{thermal}$) and 220 kV Baru M-Hajd Ot (100.0 % $I_{thermal}$).

Line 220 kV Buc.S-B-Fundeni is the double circuit line but one circuit is permanently out of operation on the model which is the reason why this line is included in the contingency tables.

Installed capacity in the substations 400/220 Bucuresti Sud, Brasov, Dirste, Sibiu and Brazi in Romania are too low to support this generation/demand scenario.

Critical lines in the Serbian power system for this scenario are detected mostly in 220 kV network of the Beograd area. Installed transformer capacities are inadequate in the Kragujevac, Nis, Kosovo B and Pancevo substations.

Single outages of 400/110 kV transformers in the stations Brasov and Dirste in Romania are also found critical, since the second transformer 400/110 kV in the Brasov substation is permanently out of operation in the model.

The heaviest line overloading (197% $I_{thermal}$) in the analyzed scenario is related to 220 kV line in Serbia (Beograd 3-Obrenovac) when the line 400 kV Beograd 1-Obrenovac goes out of operation. The heaviest transformer overloading (168% S_n) is related to the transformer 400/110 kV in the Dirste substation (Romania) when the transformer 400/110 kV in the Brasov substation is outaged (the parallel one is permanently out of operation in the model).

Figure 4.8.6 shows geographical positions of the critical elements in the analyzed scenario. A green color reveals 220 kV elements (line 220 kV or transformer 220/x kV), while a red one reveals 400 kV elements (line 400 kV or transformer 400/x kV).

According to the obtained and presented results, it may be concluded that the network topology as predicted to exist in 2010 is not suitable for the analyzed generation pattern. Larger investments in the internal networks, especially in the power systems of Romania, Serbia and Albania, will be necessary in order to support such generation pattern.

Table 4.8.5 - Lines overloadings for 2015–base case-wet hydrology-2010 topology scenario, single outages

Outage	**Overloaded line(s)**	**Loadings**		**Country**
		MVA	**%**	
Base case	TR 400/220 kV URECHESI	418.5	104.6	ROMANIA
	OHL 220 kV LOTRU-SIBIU ckts. 1 & 2	311.4	109.4	
	OHL 220 kV URECHESI-TG.JIU	282.1	101.1	
	OHL 220 kV TG.JIU-PAROSEN	282.1	134.7	
	OHL 220 kV JBGD3 21-JOBREN2	299.7	104.1	SERBIA
OHL 220 kV AFIERZ2-ABURRE2	OHL 220 kV AKASHA2-ARRAZH2	256.7	112.9	ALBANIA
TR 400/220 kV AELBS21-AELBS22	OHL 220 kV AKASHA2-ARRAZH2	253.7	109.1	
OHL 400 kV RP TREB-JPODG221	OHL 220 kV AKASHA2-ARRAZH2	242.9	105.4	B&H/MONT /ALB
OHL 220 kV G_ORIAH-MI_2_220	OHL 220 kV MI_2_220_ST.ZAGORA	255.4	105.1	BULGARIA
OHL 400 kV TANTAREN-BRADU	OHL 220 kV BUC.S-B-FUNDENI	329.5	108.3	ROMANIA
OHL 400 kV DOMNESTI-BUC.S	OHL 220 kV BUC.S-B-FUNDENI	321.8	102.7	
OHL 400 kV DOMNESTI-BRAZI	OHL 220 kV BUC.S-B-FUNDENI	355.5	114.6	
OHL 220 kV P.D.F.A-CALAFAT	OHL 220 kV P.D.F.A-CETATE1	259.9	128.7	
OHL 220 kV P.D.F.A-RESITA ckt.1	OHL 220 kV P.D.F.A-RESITA ckt.2	338.8	129.6	
OHL 220 kV RESITA-TIMIS ckt.1	OHL 220 kV RESITA-TIMIS ckt.2	342.8	128.2	
OHL 220 kV FUNDENI- BUC.S-B	OHL 220 kV BUC.S-B-FUNDENI	368.3	118.1	
TR 400/220 kV BRAZI	OHL 220 kV BUC.S-B-FUNDENI	369.7	122.0	
OHL 400 kV JHDJE11-JTDRMN1	OHL 220 kV P.D.F.A-RESITA ckt.1&2	266.6	102.0	SER/ROM
OHL 400 kV JTKOSB1-JPEC 1	OHL 220 kV AKASHA2-ARRAZH2	243.2	107.0	SER/ALB
OHL 220 kV JBGD172-JBGD8 22 ckt.1	OHL 220 kV JBGD172-JBGD8 22 ckt.2	475.9	140.2	SERBIA
TR 400/220 kV JBGD8	OHL 220 kV JBGD3 22-JBGD8 22	364.7	108.4	

Table 4.8.6 - Transformers overloadings for 2015–base case-wet hydrology-2010 topology scenario, single outages

Outage	**Overloaded branch(es)**	**Loadings**		**Country**
		MVA	**%**	
TR 400/220 kV BUC.S-BUC.S-B ckt.1	TR 400/220 kV BUC.S-BUC.S-B ckt.2	536.5	134.1	ROMANIA
400/110 kV BRASOV	TR 400/110 kV DIRSTE	420.0	168.0	
400/110 kV DIRSTE	TR 400/110 kV BRASOV	410.8	164.3	
TR 400/220 kV SIBIU ckt.1	TR 400/220 kV SIBIU ckt.2	573.0	143.3	
TR 400/220 kV BRAZI	TR 400/220 kV BUC.S ckt.1	413.3	103.3	
	TR 400/220 kV BUC.S ckt.2	413.3	103.3	
TR 400/110 kV JKRAG ckt.1	TR 400/110 kV JKRAG ckt.2	316.5	105.5	SERBIA
TR 400/110 kV NIS ckt.1	TR 400/110 kV NIS ckt.2	340.4	113.5	
OHL 220 kV JBGD3 22-JBGD8 22	TR 400/220 kV JBGD8 1-JBGD8 22	412.1	103.0	
TR 400/110 kV JPANC ckt.1	TR 400/110 kV JPANC ckt.2	334.0	111.3	
TR 400/110 kV JTKOSB ckt.1	TR 400/110 kV JTKOSB ckt.2	439.3	109.8	

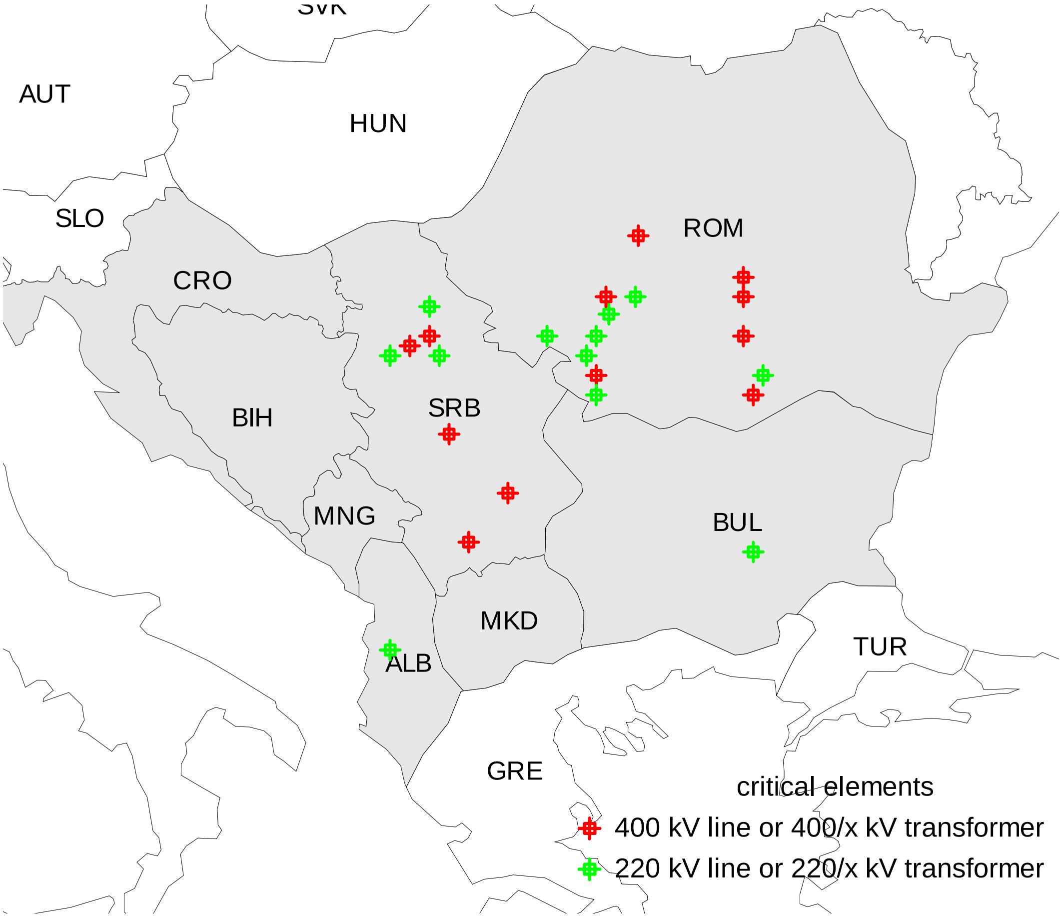


Figure 4.8.6 - Geographical positions of the critical elements for 2015-base case-wet hydrology-topology 2010 scenario

4.9 Scenario 2015 – wet hydrology – topology 2015

This part of the Study presents results of static load flow and voltage profile analyses that are conducted for complete network topology and (n-1) contingencies in the scenario which is denoted as Scenario 2015 wet hydrology and expected network topology for 2015.

4.9.1 Line loadings

Area totals and power exchanges for the 2015-base case-wet hydrology-topology 2015 scenario are shown in Figure 4.9.1 and Table 4.9.1. Power flows along regional interconnection lines and system balances are shown in Figure 4.9.2. Power flows along interconnection lines are also given in Table 4.9.2, while Figure 4.9.3 shows histogram of tie lines loadings.

Figure 4.9.1 - Area exchanges in analyzed electric power systems for 2015-base case-wet hydrology-2015 topology scenario

Table 4.9.1 - Area totals in analyzed electric power systems for 2015-base case-wet hydrology-topology 2015 scenario

Country	**Generation (MW)**	**Load (MW)**	**Bus Shunt (Mvar)**	**Line Shunt (Mvar)**	**Losses (MW)**	**Net Interchange (MW)**
Albania	1111.0	1528.9	0	0	72.1	-490.0
Bulgaria	7553.3	6446.1	0	14.7	137.5	955.0
Bosnia and Herzegovina	2155.1	2278.6	0	0	75.6	-199.0
Croatia	2800.9	3660.4	0	0	61.6	-921.1
Macedonia	870.8	1407.6	0	0	20.2	-557.0
Romania	7950.3	7704.0	0	74.5	294.8	-123.0
Serbia and UNMIK	8398.5	7209.2	0	13.2	263.2	913.0
Montenegro	774.1	669.8	0.5	1.8	16.9	85.0
TOTAL - SE EUROPE	*31613.9*	*30904.6*	*0.5*	*104.2*	*941.8*	*-337.2*

New elements that are expected to be built till 2015 cause significantly different distribution of power flows in the southern part of the region (Albania, FYR of Macedonia, Serbia, Montenegro).

Compared to the expected topology 2010, analyzed in the previous chapter, it can be seen that the network losses are smaller as a consequence of building the new elements in the 2015 network topology, especially in the cases of Albania, Serbia and Montenegro. Overall reduction of losses is about 35 MW.

Figure 4.9.3 shows that the tie lines in the region are mostly loaded less than 25% of their thermal limits for the analyzed hydrological base case scenario in year 2015, examined on the planned network topology for that year. Among total number of fifty two 400 kV and 220 kV interconnection lines in the region only eight are loaded between 25% and 50% of their thermal ratings. Only one line (OHL 400 kV Sarajevo 20 – Piva between Bosnia and Herzegovina and Montenegro) is loaded more than 50% of its thermal rating.

Table 4.9.4 lists all network elements, observing only lines 400 kV and 220 kV and transformers 400/x kV and 220/x kV, that are loaded over 80% of their thermal limits. Most of the elements loaded over 80% are transformers in some substations and internal 110 kV and 220 kV lines. Thus, certain internal network reinforcements are necessary to sustain given load-demand level and generation pattern.

Being compared to the same generation pattern, but with the 2010 network topology, the loading relief of some branches and transformers in the southern Serbia and Albania may be noticed.

Figure 4.9.4 shows histogram of 400 kV and 220 kV regional internal lines and 400/x kV and 220/x kV transformers loadings. 38% of observed branches are loaded below 25% of their thermal ratings, 36% are loaded between 25% and 50%, 20% are loaded between 50% and 75%, 5% of observed branches are loaded between 75% and 100% of their thermal ratings and 1% of them are overloaded (nine branches in total) if all branches are in operation for the analyzed scenario.

Being compared to the same generation pattern on the 2010 network topology, it is noticed that there are no significant changes in the total number of branches and the ranges of internal lines loading. Only one internal branch is loaded below permitted limit in the case of building new interconnection lines as predicted to exist in 2015.

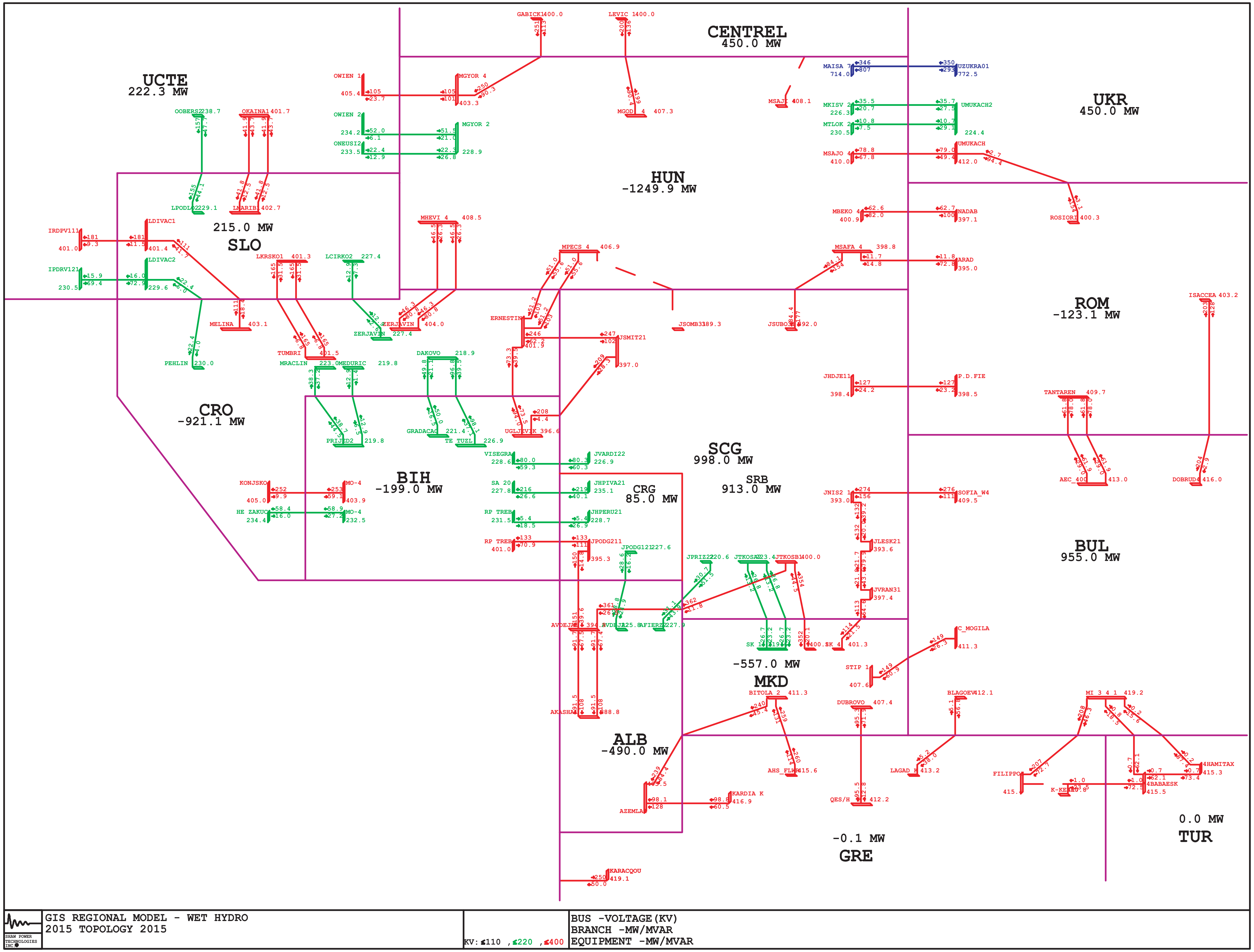


Figure 4.9.2 - Power flows along interconnection lines in the region for 2015 - base case - wet hydrology scenario – topology 2015

Table 4.9.2 - Power flows along regional interconnection lines for 2015 - base case-wet hydrology scenario-topology 2015

Interconnection line			**Power Flow**		**% of thermal rating**
			MW	**Mvar**	
OHL 400 kV	Zemlak (ALB)	Kardia (GRE)	-98.1	-128.3	12
OHL 220 kV	Fierze (ALB)	Prizren (SER)	31.1	43.9	20
OHL 220 kV	V.Dejes (ALB)	Podgorica (MON)	28.8	-24.9	13
OHL 400 kV	V.Dejes (ALB)	Podgorica (MON)	150.5	-39.6	12
OHL 400 kV	Ugljevik (B&H)	Ernestinovo (CRO)	73.5	-94.0	9
OHL 400 kV	Mostar (B&H)	Konjsko (CRO)	253.5	-59.1	19
OHL 400 kV	Ugljevik (B&H)	S. Mitrovica (SER)	-208.1	-4.4	16
OHL 400 kV	Trebinje (B&H)	Podgorica (MON)	-133.1	70.9	13
OHL 220 kV	Trebinje (B&H)	Plat (CRO)	-104.8	40.2	36
OHL 220 kV	Prijedor (B&H)	Mraclin (CRO)	38.7	-44.5	19
OHL 220 kV	Prijedor (B&H)	Medjuric (CRO)	12.9	-6.5	5
OHL 220 kV	Gradacac (B&H)	Djakovo (CRO)	50.0	16.5	18
OHL 220 kV	Tuzla (B&H)	Djakovo (CRO)	98.1	37.1	35
OHL 220 kV	Mostar (B&H)	Zakucac (CRO)	58.9	-27.2	19
OHL 220 kV	Visegrad (B&H)	Vardiste (SER)	-80.0	59.3	32
OHL 220 kV	Sarajevo 20 (B&H)	Piva (MON)	-215.8	-26.6	57
OHL 220 kV	Trebinje (B&H)	Perucica (MON)	5.4	18.5	9
OHL 400 kV	Blagoevgrad (BUL)	Thessaloniki (GRE)	-5.1	-56.8	8
OHL 400 kV	M.East 3 (BUL)	Filippi (GRE)	208.0	-46.3	30
OHL 400 kV	M.East 3 (BUL)	Babaeski (TUR)	1.0	-18.5	5
OHL 400 kV	M.East 3 (BUL)	Hamitabat (TUR)	0.0	-15.6	5
OHL 400 kV	C.Mogila (BUL)	Stip (MCD)	149.4	-26.3	21
OHL 400 kV	Dobrudja (BUL)	Isaccea (ROM)	204.0	-2.9	15
OHL 2x400 kV ckt.1	Kozloduy (BUL)	Tantarena (ROM)	61.9	29.0	7
OHL 2x400 kV ckt.2	Kozloduy (BUL)	Tantarena (ROM)	61.9	29.0	7
OHL 400 kV	Sofia West (BUL)	Nis (SER)	276.1	111.2	42
OHL 2x400 kV ckt.1	Zerjavinec (CRO)	Heviz (HUN)	-46.3	-80.8	7
OHL 2x400 kV ckt.2	Zerjavinec (CRO)	Heviz (HUN)	-46.3	-80.8	7
OHL 2x400 kV ckt.1	Ernestinovo (CRO)	Pecs (HUN)	51.2	-103.2	9
OHL 2x400 kV ckt.2	Ernestinovo (CRO)	Pecs (HUN)	51.2	-103.2	9
OHL 2x400 kV ckt.1	Tumbri (CRO)	Krsko (SLO)	-165.2	6.8	14
OHL 2x400 kV ckt.2	Tumbri (CRO)	Krsko (SLO)	-165.2	6.8	14
OHL 400 kV	Melina (CRO)	Divaca (SLO)	111.0	4.3	10
OHL 400 kV	Ernestinovo (CRO)	S.Mitrovica (SER)	-245.7	62.2	20
OHL 220 kV	Zerjavinec (CRO)	Cirkovce (SLO)	-12.9	-2.6	4
OHL 220 kV	Pehlin (CRO)	Divaca (SLO)	22.4	-4.0	7
OHL 400 kV	Dubrovo (MCD)	Thessaloniki (GRE)	-95.3	-71.9	8
OHL 400 kV	Bitola (MCD)	Florina (GRE)	-259.0	-130.7	24
OHL 400 kV	Skopje (MCD)	Kosovo B (UNMIK)	-351.8	20.1	27
OHL 2x220 kV ckt.1	Skopje (MCD)	Kosovo A (UNMIK)	-26.7	-23.2	11
OHL 2x220 kV ckt.2	Skopje (MCD)	Kosovo A (UNMIK)	-26.7	-23.2	11
OHL 400 kV	Arad (ROM)	Sandorfalva (HUN)	11.8	-72.8	6
OHL 400 kV -	Nadab (ROM)	Bekescaba (HUN)	62.7	-100.0	10
OHL 400 kV	Rosiori (ROM)	Mukacevo (UKR)	3.1	-154.0	13
OHL 400 kV	Portile De Fier (ROM)	Djerdap (SER)	126.8	23.2	10
OHL 400 kV	Subotica (SER)	Sandorfalva (HUN)	84.4	-176.8	16
OHL 400 kV	Ribarevine (MON)	Kosovo B (UNMIK)	-281.4	26.7	22
OHL 220 kV	Pljevlja (MON)	Bajina Basta (SER)	49.2	11.1	17
OHL 220 kV	Pljevlja (MON)	Pozega (SER)	113.7	45.4	38
OHL 400 kV*	Skopje 4 (MCD)	Vranje (SER)	113.6	21.5	10
OHL 400 kV*	Zemlak (ALB)	Bitola (MCD)	239.8	45.4	19
OHL 400 kV*	V.Dejes (ALB)	Kosovo B (UNMIK)	-360.9	-26.5	27

* new lines planned till 2015

Table 4.9.3 - Network elements loaded over 80% of thermal limits for 2015-base case-wet hydrology-2015 topology scenario (branches 400 kV and 220 kV)

AREA	ELEMENT	LOADING MVA	RATING MVA	PERCENT
Lines				
ALB	OHL 220 kV AKASHA2-ARRAZH2	237.0	270.0	87.8
BUL	OHL 220 kV MI_2_220-ST ZAGORA	190.4	228.6	83.3
ROM	OHL 220 kV MINTIA-SIBIU	313.4	381.1	82.2
	OHL 220 kV P.D.F.II-CETATE1	268.4	277.4	96.8
	OHL 220 kV LOTRU-SIBIU ckt.1	303.4	277.4	109.4
	OHL 220 kV LOTRU-SIBIU ckt.2	303.4	277.4	109.4
	OHL 220 kV URECHESI-TG.JIU	275.4	277.4	99.3
	OHL 220 kV P.D.F.A-CETATE1	205.6	208.1	98.8
	OHL 220 kV P.D.F.A-RESITA ckt.1	235.6	277.4	84.9
	OHL 220 kV P.D.F.A-RESITA ckt.2	235.6	277.4	84.9
	OHL 220 kV TG.JIU-PAROSEN	275.4	208.1	132.3
	OHL 220 kV BUC.S-B-FUNDENI	284.6	320.0	88.9
SRB	OHL 220 kV JBGD3 21-JOBREN2	312.6	301.0	103.8
Transformers				
ALB	TR 220/110 kV AFIERZ2-AFIERZ5 ckt.1	50.2	60.0	83.7
	TR 220/110 kV AFIERZ2-AFIERZ5 ckt.2	50.2	60.0	83.7
	TR 220/110 kV AELBS12-AELBS15 ckt.1	74.8	90.0	83.2
	TR 220/110 kV AELBS12-AELBS15 ckt.2	74.8	90.0	83.2
	TR 220/110 kV AELBS12-AELBS15 ckt.3	80.4	90.0	89.3
	TR 220/110 kV AKASHA2-AKASH25 ckt.1	82.3	100.0	82.3
	TR 220/110 kV AKASHA2-AKASH25 ckt.2	82.3	100.0	82.3
	TR 220/110 kV AFIER 2-AFIER 5 ckt.1	134.5	120.0	112.1
	TR 220/110 kV AFIER 2-AFIER 5 ckt.2	110.3	90.0	122.5
	TR 220/110 kV AFIER 2-AFIER 5 ckt.3	105.2	90.0	116.9
B&H	TR 400/110 kV UGLJEVIK	267.6	300.0	89.2
ROM	TR 400/220 kV URECHESI	410.3	400.0	102.6
	TR 400/220 kV BUC.S-BUC.S-B ckt.1	339.3	400.0	84.8
	TR 400/220 kV BUC.S-BUC.S-B ckt.2	339.3	400.0	84.8
	TR 220/110 kV FUNDENI	175.7	200.0	87.8
	TR 220/110 kV FUNDENI-FUNDE2B	208.3	200.0	104.1
SRB	TR 400/220 kV JBGD8-JBGD8 22	334.9	400.0	83.7
	TR 220/110 kV JBGD3 21-JBGD 351	196.6	200.0	98.3
	TR 220/110 kV JBGD3 22-JBGD 352	134.4	150.0	89.6
	TR 220/110 kV JZREN22-JZREN25	121.5	150.0	81.0

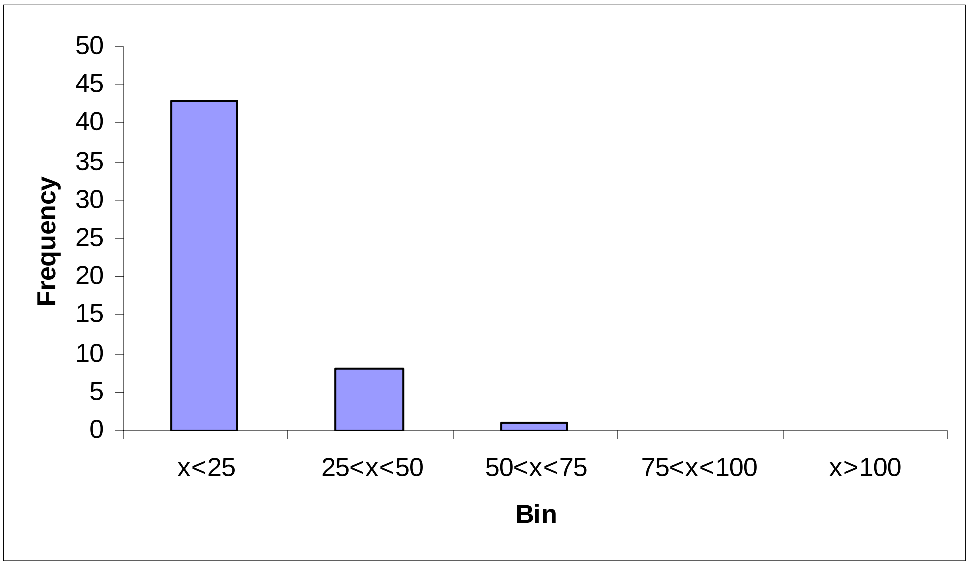


Figure 4.9.3 - Histogram of interconnection lines loadings for 2015-base case-wet hydrology-2015 topology scenario ("Frequency" denotes number of lines and "Bin" denotes loading range in % of thermal limit)

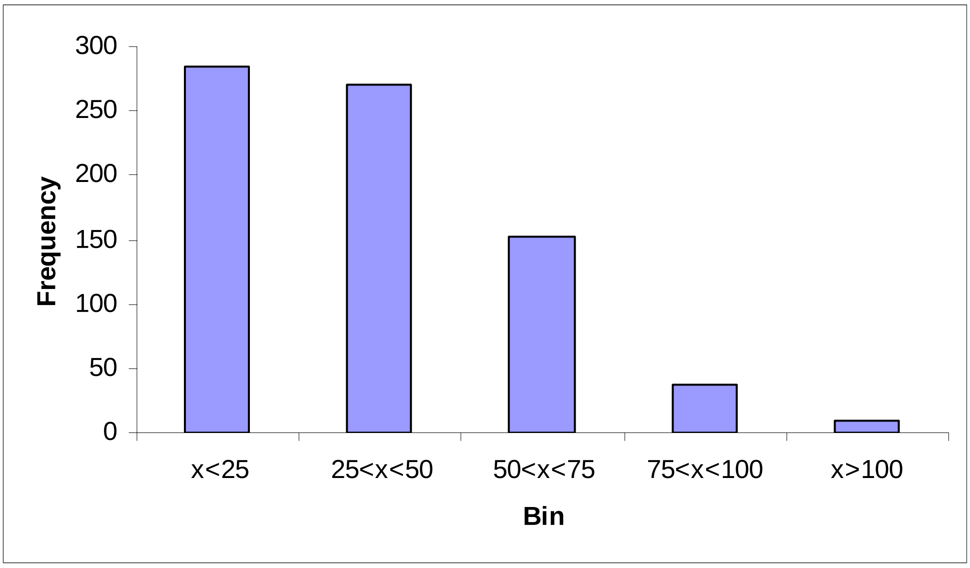


Figure 4.9.4 - Histogram of 400 kV and 220 kV regional lines loadings for 2015-base case-wet hydrology-2015 topology scenario ("Frequency" denotes number of lines and "Bin" denotes loading range in % of thermal limit)

4.9.2 Voltage Profile in the Region

Voltage profile in the region within this scenario which is defined by given generation and demand pattern is seen as satisfactory despite several appearances of certain bus voltage deviations. The deviations are shown in Figure 4.9.5, which includes only 400 kV and 220 kV network buses.

Table 4.9.4 - Bus voltage deviations for 2015-base case-wet hydrology-2015 topology scenario, complete network

Country	**Node**	**Voltages**	
		pu	**kV**
ALBANIA	-	-	-
BOSNIA AND HERZEGOVINA	-	-	-
BULGARIA	400 kV MARITSA EAST2	1.051	420.4
CROATIA	-	-	-
MACEDONIA	-	-	-
MONTENEGRO	-	-	-
ROMANIA	-	-	-
SERBIA AND UNMIK	400 kV JPANC21	0.947	378.8

Bus voltage magnitudes which are found below permitted limits (90% $V_{nominal}$ in 220 kV network and 95% $V_{nominal}$ in 400 kV network) are detected only in Serbia (one 400 kV node). Bus voltage magnitudes that are found above permitted limits (110% $V_{nominal}$ in 110 kV and 220 kV networks and 105% $V_{nominal}$ in 400 kV network) are detected only in Bulgaria in one node. Figure 4.3.11 shows a histogram of voltages in monitored 400 kV and 220 kV substations.

Being compared to the same generation pattern on the 2010 network topology, it is noticed that there are significant voltage profile improvements, especially in the power systems of Albania and Serbia.

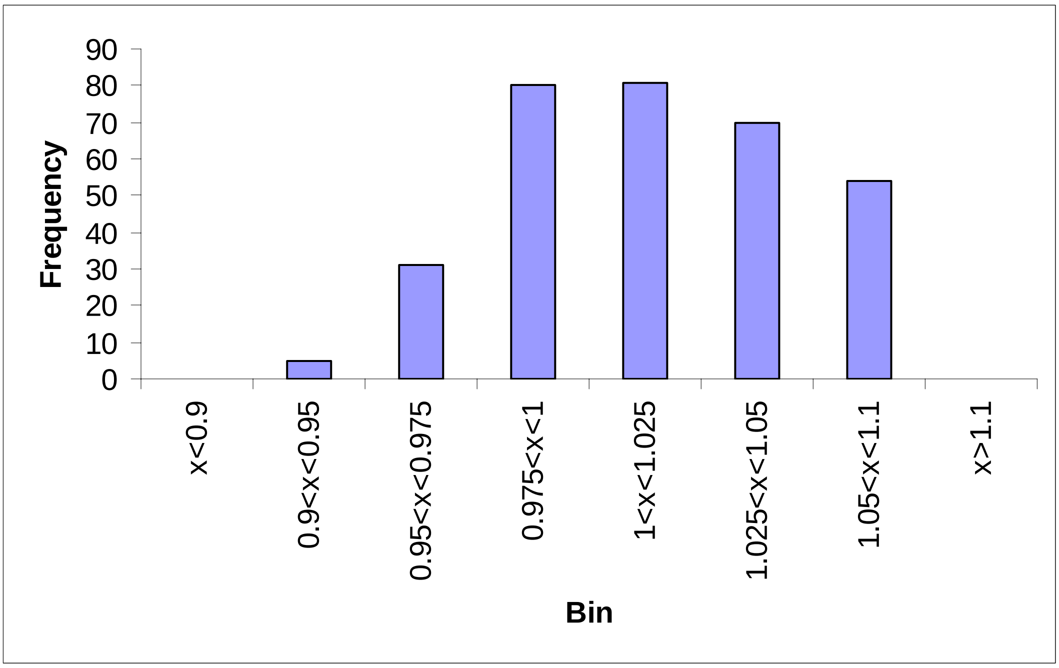


Figure 4.9.5 - Histogram of voltages in monitored substations for 2015-base case-wet hydrology-2015 topology scenario ("Frequency" denotes number of busses and "Bin" denotes voltage range in p.u.)

4.9.3 Security (n-1) analysis

Results of security (n-1) analysis for the 2015-base case-wet hydrology-2015 topology scenario are presented in Table 4.9.5 and Table 4.9.6. Critical contingencies which are included there are related only to the branches which are not overloaded in the base case when all branches are available.

Insecure states for given generation and demand pattern are detected in the power systems of Romania, Serbia, Albania, although there is one contingency in Bulgaria and Bosnia and Herzegovina each which leads to insecure state.

Being compared to the same generation and demand scenario on the 2010 network topology, it is concluded that there are several new contingency cases in the power system of Albania and one new contingency case in the power systems of Romania and Bosnia and Herzegovina (marked with red color in Table 4.9.5 and Table 4.9.6). At the same time, several contingency cases do not appear any more (marked in blue color in Table 4.9.5 and Table 4.9.6). These contingency cases are related to the power systems of Albania, Serbia and Romania, although it is noticed that the influence of the new investments is less significant in the power system of Romania than it is in Albania and southern Serbia.

There are no contingency cases in the 2015 network topology which are related to the interconnection lines. The same conclusion is valid for the 2010 network topology and analyzed generation/demand scenario.

Figure 4.9.6 shows geographical positions of the critical elements in the analyzed scenario. A green color reveals 220 kV elements (line 220 kV or transformer 220/x kV), while a red one reveals 400 kV elements (line 400 kV or transformer 400/x kV).

According to the obtained and presented results, it may be concluded that the network topology as predicted to exist in 2015 is not suitable for the analyzed generation pattern. Larger investments in the internal networks, especially in power systems of Romania, Serbia and Albania, are necessary shall such generation pattern be supported.

Table 4.9.5 - Lines overloadings for 2015–base case-wet hydrology-2015 topology scenario, single outages

Outage	**Overloaded line(s)**	**Loadings**		**Country**
		MVA	**%**	
Base case	TR 400/220 kV URECHESI	414.9	103.7	ROMANIA
	OHL 220 kV LOTRU-SIBIU ckt. 1 & 2	311.3	109.4	
	OHL 220 kV URECHESI-TG.JIU			
	OHL 220 kV TG.JIU-PAROSEN	277.5	132.3	
	OHL 220 kV JBGD3 21-JOBREN2	299.9	103.8	SERBIA
OHL 400 kV AELBS21-AZEMLA1	OHL 220 kV AKASHA2-ARRAZH2	242.5	100.5	ALBANIA
OHL 220 kV AELBS12-AFIER 2	OHL 220 kV AKASHA2-ARRAZH2	359.7	143.7	
TR 400/110 kV AZEMLA1-AZEMLK5	OHL 220 kV AKASHA2-ARRAZH2	254.1	102.6	
OHL 220 kV AFIERZ2-ABURRE2	OHL 220 kV AKASHA2-ARRAZH2			
TR 400/220 kV AELBS21-AELBS22	OHL 220 kV AKASHA2-ARRAZH2			
OHL 400 kV RP TREB-JPODG221	OHL 220 kV AKASHA2-ARRAZH2			B&H/MONT/ALB
OHL 220 kV G_ORIAH-MI_2_220	OHL 220 kV MI_2_220_ST.ZAGORA	254.6	104.7	BULGARIA
OHL 400 kV TANTAREN-BRADU	OHL 220 kV BUC.S-B-FUNDENI	328.6	107.7	ROMANIA
OHL 400 kV DOMNESTI-BUC.S	OHL 220 kV BUC.S-B-FUNDENI	321.0	102.3	
OHL 400 kV DOMNESTI-BRAZI	OHL 220 kV BUC.S-B-FUNDENI	354.5	114.1	
OHL 220 kV P.D.F.A-CALAFAT	OHL 220 kV P.D.F.A-CETATE1	259.6	128.2	
OHL 220 kV P.D.F.A-RESITA ckt.1	OHL 220 kV P.D.F.A-RESITA ckt.2	335.1	127.6	
OHL 220 kV RESITA-TIMIS ckt.1	OHL 220 kV RESITA-TIMIS ckt.2	338.3	126.1	
OHL 220 kV FUNDENI- BUC.S-B	OHL 220 kV BUC.S-B-FUNDENI	367.8	117.8	
TR 400/220 kV BRAZI	OHL 220 kV BUC.S-B-FUNDENI	369.5	121.8	
OHL 400 kV JHDJE11-JTDRMN1	OHL 220 kV P.D.F.A-RESITA ckt.1&2			SER/ROM
OHL 400 kV JTKOSB1-JPEC 1	OHL 220 kV AKASHA2-ARRAZH2			SER/ALB
OHL 220 kV JBGD172-JBGD8 22 ckt.1	OHL 220 kV JBGD172-JBGD8 22 ckt.2	475.6	139.6	SERBIA
TR 400/220 kV JBGD8	OHL 220 kV JBGD3 22-JBGD8 22	366.1	108.4	

Table 4.9.6 - Transformers overloadings for 2015–base case-wet hydrology-2015 topology scenario, single outages

Outage	**Overloaded branch(es)**	**Loadings**		**Country**
		MVA	**%**	
OHL 400 kV BLUKA 6-TS TUZL	TR 400/110 kV UGLJEVIK	311.0	103.7	B&H
OHL 220 kV BUC.S-B-FUNDENI	TR 400/220 kV BRAZI	414.2	103.6	ROMANIA
TR 400/220 kV BUC.S-BUC.S-B ckt.1	TR 400/220 kV BUC.S-BUC.S-B ckt.2	535.9	134.0	
TR 400/110 kV BRASOV	TR 400/110 kV DIRSTE	419.2	167.7	
TR 400/110 kV DIRSTE	TR 400/110 kV BRASOV	410.2	164.1	
TR 400/220 kV SIBIU ckt.1	TR 400/220 kV SIBIU ckt.2	571.7	142.9	
TR 400/220 kV BRAZI	TR 400/220 kV BUC.S ckt.1	413.1	103.3	
	TR 400/220 kV BUC.S ckt.2	413.1	103.3	
TR 400/110 kV JKRAG ckt.1	TR 400/110 kV JKRAG ckt.2	314.4	104.8	SERBIA
TR 400/110 kV NIS ckt.1	TR 400/110 kV NIS ckt.2			
OHL 220 kV JBGD3 22-JBGD8 22	TR 400/220 kV JBGD8 1-JBGD8 22	411.2	102.8	
TR 400/110 kV JPANC ckt.1	TR 400/110 kV JPANC ckt.2	332.5	110.8	
TR 400/110 kV JTKOSB ckt.1	TR 400/110 kV JTKOSB ckt.2			

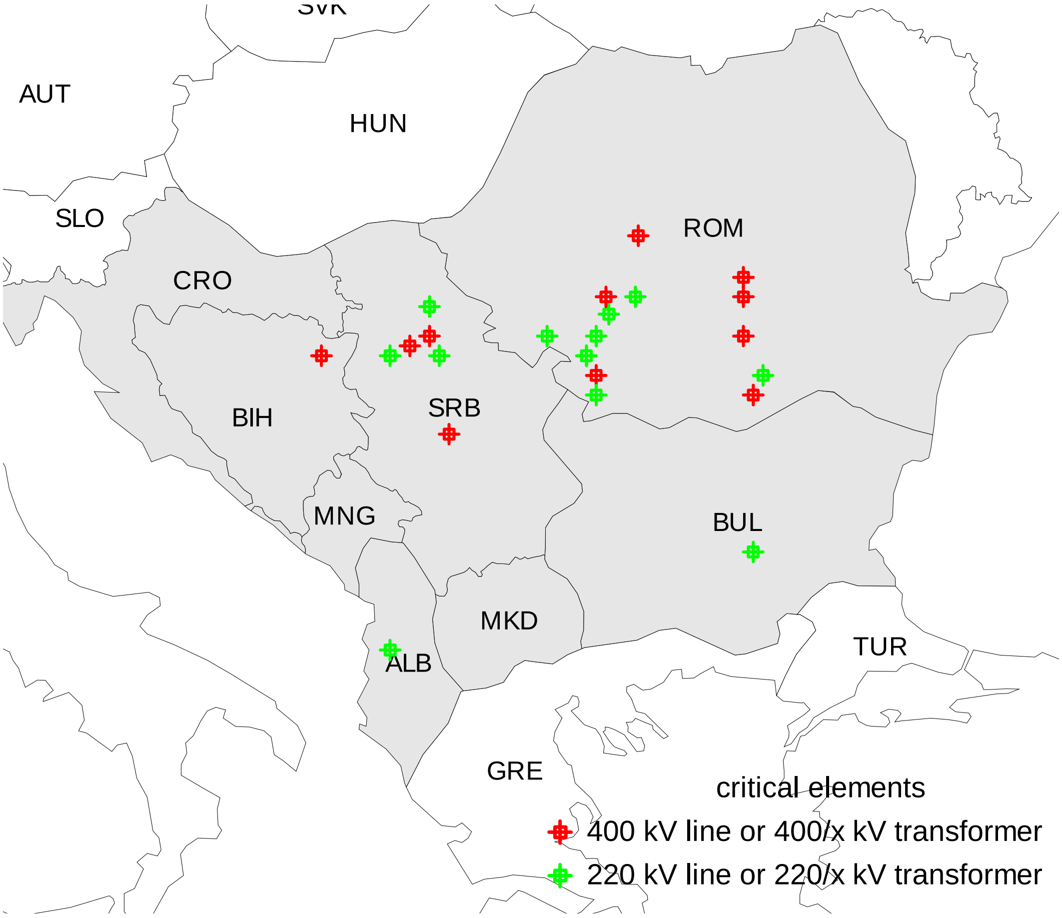


Figure 4.9.6 - Geographical positions of the critical elements for 2015-base case-wet hydrology-topology 2015 scenario

4.9.4 Summary of Impacts - 2015 topology versus 2010 topology

Compared to the expected topology 2010, analyzed in previous chapter, it can be seen that the network losses are smaller as a consequence of building the new elements for 2015 network topology, especially in the cases of Albania, Serbia and Montenegro. Overall reduction of losses is around 35 MW.

Comparing to the same generation pattern on the 2010 network topology, it is noticed that there are no significant changes in the total number of branches and the ranges of internal lines loading.

Being compared to the same generation pattern on the 2010 network topology, it is noticed that there are significant voltage profile improvements, especially in the power systems of Albania and Serbia.

Being compared to the same generation and demand scenario on the 2010 network topology, it is concluded that there are several new contingency cases in the power system of Albania and one new contingency case in the power systems of Romania and Bosnia and Herzegovina. At the same time, several contingency cases do not appear any more. These contingency cases are related to the power systems of Albania, Serbia and Romania, although it is noticed that the influence of the new investments is less significant in the power system of Romania than it is in Albania and southern Serbia.

Planned new investments in 2015 make overall network performance better, especially in the region where new planed investments are to be realized (Albania, southern Serbia and Montenegro), but do not solve all contingences which are happening for analyzed generation and demand scenario. Further internal network reinforcements, especially in the power systems of Romania, Albania and Serbia, will be necessary in order to allow such generation dispatch with significant level of network operation security.

5 LOAD FLOW AND CONTINGENCY ANALYSIS – SENSITIVITY CASES

Introduction

In this chapter load-flow and security (n-1) analysis for sensitivity cases defined in Chapter 2 is described. The analyzed network models are:

Special conditions	Year	Topology
Import/Export	2010	2010
	2015	2010
		2015
High load	2010	2010
	2015	2010
		2015

The load-flow analysis includes line loading and voltage profile analysis, analysis of losses and also analysis of power flows through interconnection lines.

The system reliability and adequacy is checked using “n-1” contingency criterion. List of contingencies includes:

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

Current thermal limits are used as rated limits of lines and transformers, as described in Chapter 2. Voltage limits are defined in Chapter 2, also.
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".

5.1 Scenario 2010 – average hydrology – import/export - 2010 topology

This part of the Study presents results of static load flow and voltage profile analyses that are conducted for complete network topology and (n-1) contingencies in the scenario which is denoted as Scenario 2010 – sensitivity case – average hydrology – import 1500 MW.

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

- Import 750 MW from UCTE
- Import 500 MW from Turkey
- Export 500 MW to Greece
- Import 750 MW from Ukraine

5.1.1 Line loadings

Area totals and power exchanges for the 2010-sensitivity case-average hydrology-import 1500 MW scenario are shown in Figure 5.1.1 and Table 5.1.1. Power flows along regional interconnection lines and system balances are shown in Figure 5.1.2. Power flows along interconnection lines are also given in Table 5.1.2, while Figure 5.1.3 shows histogram of tie lines loadings.

Figure 5.1.1 - Area exchanges in analyzed electric power systems for 2010-sensitivity case-average hydrology-import 1500 MW scenario

Table 5.1.1 - Area totals in analyzed electric power systems for 2010-sensitivity case-average hydrology-import 1500 MW scenario

Country	**Generation (MW)**	**Load (MW)**	**Bus Shunt (Mvar)**	**Line Shunt (Mvar)**	**Losses (MW)**	**Net Interchange (MW)**
Albania	898.2	1288.5	0	0	49.7	-440.0
Bulgaria	6827.0	5967.5	0	14.2	131.2	714.0
Bosnia and Herzegovina	2398.3	1965.0	0	0	54.3	379.0
Croatia	1705.2	3143.3	0	0	44.9	-1483.0
Macedonia	965.5	1178.3	0	0	20.1	-233.0
Romania	6877.4	6733.1	0	80.0	169.1	-104.8
Serbia and UNMIK	6591.7	6901.7	0	13.4	198.6	-521.9
Montenegro	542.1	670.2	0.5	1.5	16.9	-147.0
TOTAL - SE EUROPE	*26805.4*	*27847.6*	*0.5*	*109.1*	*684.8*	*-1836.7*

By comparing the average hydrology situation in 2010 and balanced SE Europe power system to the average hydrology situation and 1500 MW of power import, significant increase of power flows is noticed along Slovenian-Croatian, Ukrainian-Romanian and Bosnian-Montenegrin interfaces. However, interconnection lines are not jeopardised since they are loaded far below their thermal ratings. Power flows through Bosnian-Croatian, Serbian-Bosnian, Serbian-Croatian, Serbian-Montenegrin and Grecian-Albanian interfaces are decreased at the same time.

Power losses, compared to the situation of balanced SE Europe power system, are increased in the power systems of Bulgaria (7.9 %) and Montenegro (9 %). In other power systems these losses are decreased, with the most significant drop in Romania (-16 %) and Serbia and UNMIK (-10.1 %). Regional power losses are decreased (-7.1 %) when the situation includes additional power import.

Figure 5.1.3 shows that the tie lines in the region are mostly loaded less than 25% of their thermal limits for the analyzed import/export scenario in year 2010. Among total number of forty nine 400 kV and 220 kV interconnection lines in the region only seven are loaded between 25% and 50% of their thermal ratings. Only one line (OHL 400 kV Sofia – Nis between Bulgaria and Serbia) is loaded more than 50% of its thermal rating, which is set at lower value (692.8 MVA) on the Bulgarian side compared to the line rating on the Serbian side (1330.2 MVA).

Table 5.1.3 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 in some substations and internal 110 kV and 220 kV lines. Thus, certain internal network reinforcements are necessary to sustain given load-demand level and generation pattern including import of 1500 MW from analyzed directions.

Figure 5.1.4 shows histogram of 400 kV and 220 kV regional internal lines and 400/x kV and 220/x kV transformers loadings. Some 46% of observed branches are loaded below 25% of their thermal ratings, 36% are loaded between 25% and 50%, 16% are loaded between 50% and 75% and only 1% of observed branches are loaded between 75% and 100% of their thermal ratings. Two branches (transformers 220/110 kV Fierze in Albania, 102% - 106% S_n) are overloaded when all branches are in operation for the analyzed scenario.

By comparing the average hydrology situation in 2010 and balanced SE Europe power system to the average hydrology situation and 1500 MW of power import it is noticed that power system of Bosnia and Herzegovina is slightly relieved, while some highly loaded branches appear in the power system of Bulgaria. Distribution of internal branches loading stays almost the same.

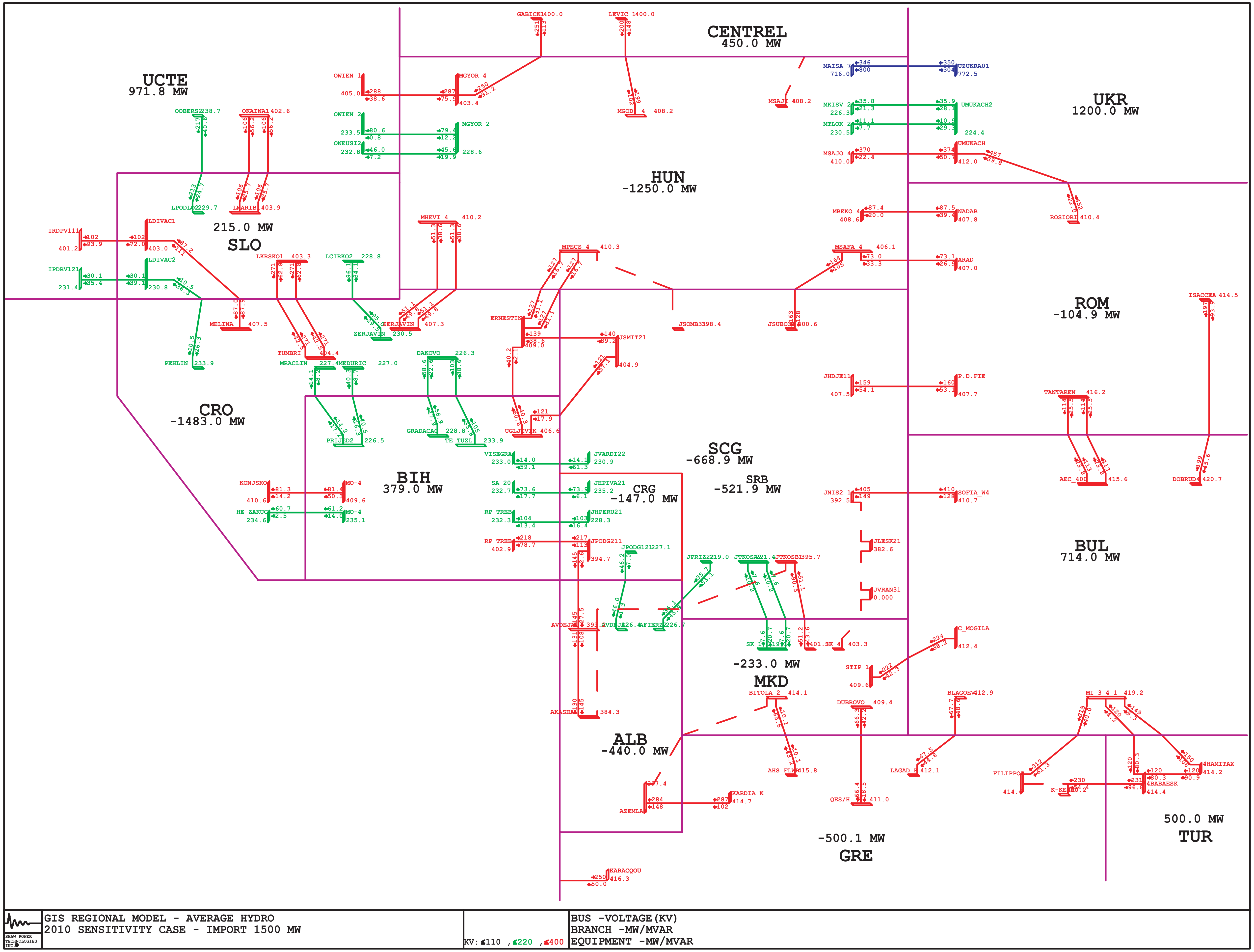


Figure 5.1.2 - Power flows along interconnection lines in the region for 2010-sensitivity case-average hydrology-import 1500 MW scenario

Table 5.1.2 - Power flows along regional interconnection lines for 2010-sensitivity case-average hydrology-import 1500 MW scenario

Interconnection line			**Power Flow**		**% of thermal rating**
			MW	**Mvar**	
OHL 400 kV	Zemlak (ALB)	Kardia (GRE)	-283.7	-148.0	24
OHL 220 kV	Fierze (ALB)	Prizren (SER)	36.1	45.9	21
OHL 220 kV	V.Dejes (ALB)	Podgorica (MON)	-46.0	-1.3	16
OHL 400 kV	V.Dejes (ALB)	Podgorica (MON)	-144.6	-27.5	11
OHL 400 kV	Ugljevik (B&H)	Ernestinovo (CRO)	40.3	-60.6	6
OHL 400 kV	Mostar (B&H)	Konjsko (CRO)	81.4	-50.3	7
OHL 400 kV	Ugljevik (B&H)	S. Mitrovica (SER)	-120.9	17.9	10
OHL 400 kV	Trebinje (B&H)	Podgorica (MON)	218.2	78.7	19
OHL 220 kV	Trebinje (B&H)	Plat (CRO)	-104.8	40.1	36
OHL 220 kV	Prijedor (B&H)	Mraclin (CRO)	38397	-17.2	7
OHL 220 kV	Prijedor (B&H)	Medjuric (CRO)	40.5	-16.3	13
OHL 220 kV	Gradacac (B&H)	Djakovo (CRO)	58.9	17.9	21
OHL 220 kV	Tuzla (B&H)	Djakovo (CRO)	104.6	35.8	36
OHL 220 kV	Mostar (B&H)	Zakucac (CRO)	61.2	-14.0	19
OHL 220 kV	Visegrad (B&H)	Vardiste (SER)	-14.0	59.1	20
OHL 220 kV	Sarajevo 20 (B&H)	Piva (MON)	-73.6	-17.7	19
OHL 220 kV	Trebinje (B&H)	Perucica (MON)	103.7	13.4	33
OHL 400 kV	Blagoevgrad (BUL)	Thessaloniki (GRE)	67.7	-48.6	12
OHL 400 kV	M.East 3 (BUL)	Filippi (GRE)	314.9	-40.0	44
OHL 400 kV	M.East 3 (BUL)	Babaeski (TUR)	-119.9	4.2	11
OHL 400 kV	M.East 3 (BUL)	Hamitabat (TUR)	-149.5	9.3	10
OHL 400 kV	C.Mogila (BUL)	Stip (MCD)	223.5	-38.2	32
OHL 400 kV	Dobrudja (BUL)	Isaccea (ROM)	198.6	-45.6	15
OHL 2x400 kV ckt.1	Kozloduy (BUL)	Tantarena (ROM)	-113.5	-23.8	9
OHL 2x400 kV ckt.2	Kozloduy (BUL)	Tantarena (ROM)	-113.5	-23.8	9
OHL 400 kV	Sofia West (BUL)	Nis (SER)	409.7	128.1	60
OHL 2x400 kV ckt.1	Zerjavinec (CRO)	Heviz (HUN)	-51.1	-69.8	6
OHL 2x400 kV ckt.2	Zerjavinec (CRO)	Heviz (HUN)	-51.1	-69.8	6
OHL 2x400 kV ckt.1	Ernestinovo (CRO)	Pecs (HUN)	-126.8	-31.1	10
OHL 2x400 kV ckt.2	Ernestinovo (CRO)	Pecs (HUN)	-126.8	-31.1	10
OHL 2x400 kV ckt.1	Tumbri (CRO)	Krsko (SLO)	-270.6	42.5	24
OHL 2x400 kV ckt.2	Tumbri (CRO)	Krsko (SLO)	-270.6	42.5	24
OHL 400 kV	Melina (CRO)	Divaca (SLO)	-87.0	73.5	12
OHL 400 kV	Ernestinovo (CRO)	S.Mitrovica (SER)	-139.2	38.6	12
OHL 220 kV	Zerjavinec (CRO)	Cirkovce (SLO)	-95.0	29.5	32
OHL 220 kV	Pehlin (CRO)	Divaca (SLO)	-10.5	26.3	11
OHL 400 kV	Dubrovo (MCD)	Thessaloniki (GRE)	-66.3	-42.2	6
OHL 400 kV	Bitola (MCD)	Florina (GRE)	-10.1	-65.6	5
OHL 400 kV	Skopje (MCD)	Kosovo B (UNMIK)	51.2	43.6	8
OHL 2x220 kV ckt.1	Skopje (MCD)	Kosovo A (UNMIK)	7.6	-20.7	7
OHL 2x220 kV ckt.2	Skopje (MCD)	Kosovo A (UNMIK)	7.6	-20.7	7
OHL 400 kV	Arad (ROM)	Sandorfalva (HUN)	73.1	-26.9	14
OHL 400 kV -	Nadab (ROM)	Bekescaba (HUN)	87.5	-39.4	8
OHL 400 kV	Rosiori (ROM)	Mukacevo (UKR)	-452.1	22.0	38
OHL 400 kV	Portile De Fier (ROM)	Djerdap (SER)	159.5	53.1	12
OHL 400 kV	Subotica (SER)	Sandorfalva (HUN)	-163.4	-127.7	17
OHL 400 kV	Ribarevine (MON)	Kosovo B (UNMIK)	-38.0	12.2	5
OHL 220 kV	Pljevlja (MON)	Bajina Basta (SER)	-73.1	5.8	24
OHL 220 kV	Pljevlja (MON)	Pozega (SER)	30.9	31.4	17

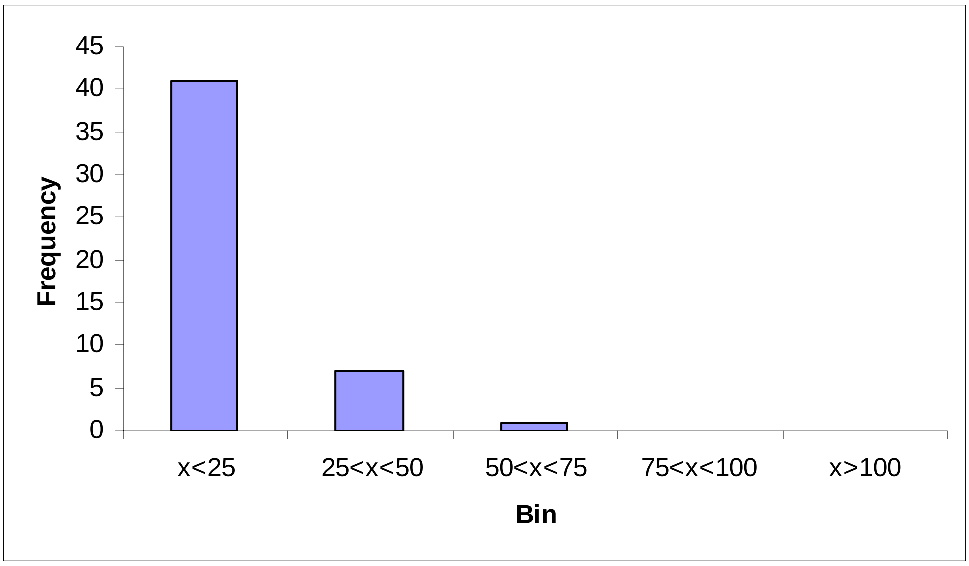


Figure 5.1.3 - Histogram of interconnection lines loadings for 2010-sensitivity case-average hydrology-import 1500 MW scenario ("Frequency" denotes number of lines and "Bin" denotes loading range in % of thermal limit)

Table 5.1.3 - Network elements loaded over 80% of thermal limits for 2010-sensitivity case-average hydrology-import 1500 MW scenario

AREA	ELEMENT	LOADING MVA	RATING MVA	PERCENT
Lines				
ALB	OHL 110 kV AFIERZ5-AFARRZ5	61.7	68.0	90.7
BUL	OHL 220 kV M.EAST-ST.ZAGORA	188.8	228.6	82.6
Transformers				
ALB	TR 220/110 kV AFIER 2-AFIER 5 ckt.1	117.1	120.0	97.6
	TR 220/110 kV AFIER 2-AFIER 5 ckt.2	96.0	90.0	106.6
	TR 220/110 kV AFIER 2-AFIER 5 ckt.3	91.6	90.0	101.8
ROM	TR 220/110 kV FUNDENI-FUNDE2B	173.9	200.0	86.9

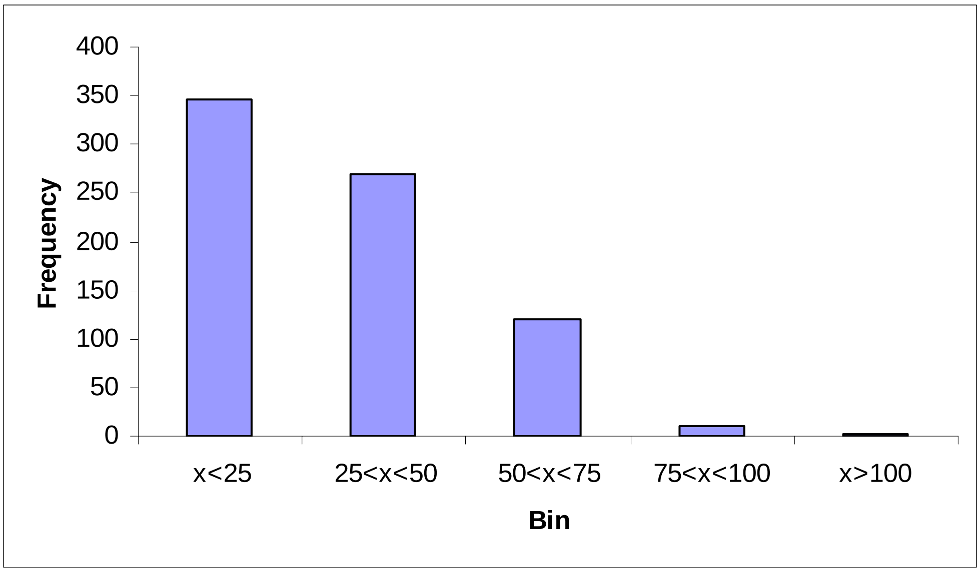


Figure 5.1.4 - Histogram of 400 kV and 220 kV regional lines loadings for 2010-sensitivity case-average hydrology-import 1500 MW scenario ("Frequency" denotes number of lines and "Bin" denotes loading range in % of thermal limit)

5.1.2 Voltage Profile in the Region

Voltage profile in the region within this scenario which is defined by given generation pattern and power import is seen as satisfactory despite several appearances of certain bus voltage deviations. The deviations are shown in Table 5.1.4, which includes only 400 kV and 220 kV network buses.

Table 5.1.4 - Bus voltage deviations for 2010-sensitivity case-average hydrology-import 1500 MW scenario, complete network

Country	**Node**	**Voltages**	
		pu	**kV**
ALBANIA	-	-	-
BOSNIA AND HERZEGOVINA	-	-	-
BULGARIA	400 kV VARNA4	1.052	420.8
	400 kV MARITSA EAST2	1.053	421.0
	400 kV DOBRUD4	1.052	420.7
	220 kV SESTRIMO	1.104	242.8
	220 kV BPC_220	1.101	242.2
	220 kV AEC_220	1.102	242.4
	220 kV TECVARNA	1.103	242.7
CROATIA	-	-	-
MACEDONIA	-	-	-
MONTENEGRO	-	-	-
ROMANIA	-	-	-
SERBIA AND UNMIK	-	-	-

Bus voltage magnitudes which are found below permitted limits (90% $V_{nominal}$ in 220 kV network and 95% $V_{nominal}$ in 400 kV network) are not detected in the analyzed scenario. Bus voltage magnitudes that are found above permitted limits (110% $V_{nominal}$ in 110 kV and 220 kV networks and 105% $V_{nominal}$ in 400 kV network) are detected only in Bulgaria, where tree 400 kV buses and four 220 kV buses have the magnitudes slightly above permitted limits. Figure 5.1.5 shows histogram of voltages in monitored 400 kV and 220 kV substations.

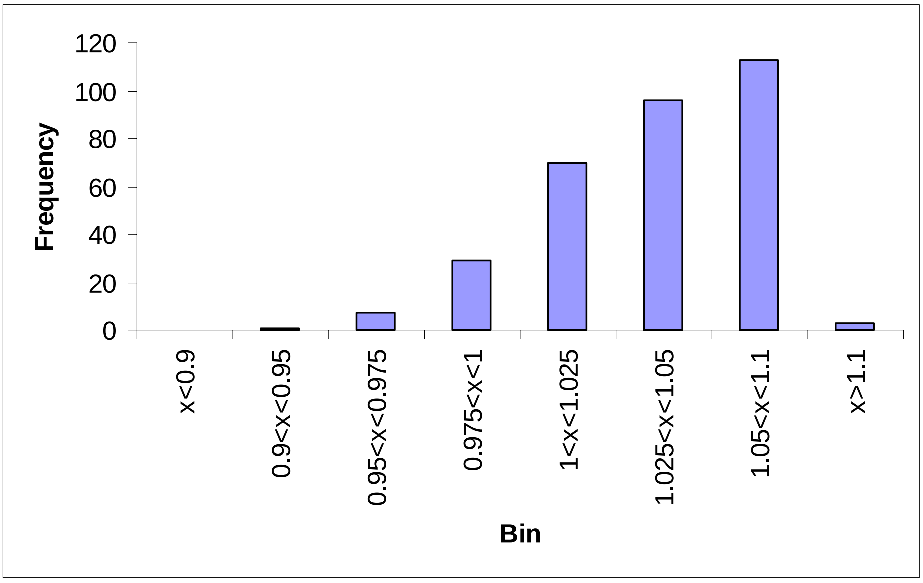


Figure 5.1.5 - Histogram of voltages in monitored substations for 2010-sensitivity case-average hydrology-import 1500 MW scenario ("Frequency" denotes number of busses and "Bin" denotes voltage range in p.u.)

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.

5.1.3 Security (n-1) analysis

Results of security (n-1) analysis for the 2010-sensitivity case-average hydrology-import 1500 MW scenario are presented in Tables 5.1.5 - 5.1.6.

Insecure system situations for given generation pattern and power import are detected in the power systems of Albania, Bulgaria, Romania and Serbia.

Loss of 220 kV line between the Rrashbul and Tirana substations can cause overloading of 220 kV line between the Elbassan and Fier substations in Albania. The opposite case is also found critical.

Loss of 400 kV line in Bulgaria, M.East 2-Bourgas can cause overloading of 400 kV line Plovdiv-M. East 3. Loss of 220 kV line M. East 2-G.Oryahovitsa can cause overloading of 220 kV line M. East 2-St. Zagora.

Single outages of 400/110 kV transformers in the stations Brasov and Dirste in Romania are also found critical, since in the model the second transformer 400/110 kV in the Brasov substation is permanently switched out of operation.

Loss of OHL 220 kV in the Belgrade area can cause overloading of the parallel line. Loss of 220 kV line between pumped storage power plant Bajina Basta and SS Pozega is also found critical. Loss of one 400/110 kV transformer in the Nis substation is critical due to possible overloading of the other parallel one but this problem could be solved by dispatcher intervention.

Figure 5.1.6 shows geographical positions of critical elements in the analyzed scenario. A green colour reveals 220 kV elements (line 220 kV or transformer 220/x kV), while a red one reveals 400 kV elements (line 400 kV or transformer 400/x kV).

According to the obtained and presented results, it may be concluded that certain reinforcements in the internal networks of Romania, Bulgaria, Albania and Serbia are necessary shall this generation pattern and 1500 MW of power import be made more secure. None of the identified congestions is located at the border lines.

By comparing the average hydrology situation in 2010 and balanced SE Europe power system to the average hydrology situation and 1500 MW of power import, it may be noticed that some critical contingencies in the Romanian power system disappear, especially those connected with Mintia substation, while some new contingencies appear in the power system of Bulgaria (lines around Maritsa East substation). This is due to different dispatching conditions of DEVA 1 power plant in Romania (disconnected in import/export scenario, dispatched with 850 MW in the base case) and power import through Turkish-Bulgarian interface that goes through Maritsa East 3 substation.

Table 5.1.5 - Lines overloadings for 2010-sensitivity case-average hydrology-import 1500 MW scenario, single outages

Outage	**Overloaded line(s)**	**Loadings**		**Country**
		MVA	**%**	
OHL 220 kV AKASHA2-ARRAZH2	OHL 220 kV AELBS12-AFIER 2	254.8	116.3	ALBANIA
OHL 220 kV AELBS12-AFIER 2	OHL 220 kV AKASHA2-ARRAZH2	263.3	100.6	
OHL 400 kV BURGAS-MI_2_400	OHL 400 kV PLOVDIV4-MI_400	762.3	107.4	BULGARIA
OHL 220 kV G_ORIAH-MI_2_220	OHL 220 kV MI_2_220-ST.ZAGORA	255.0	104.2	
OHL 220 kV JBGD172-JBGD8 22 ckt.1	OHL 220 kV JBGD172-JBGD8 22 ckt.2	438.3	122.9	SERBIA
OHL 220 kV JBBAST2-JPOZEG2	OHL 220 kV JPOZEG2-JVARDI22	294.0	100.0	

Table 5.1.6 - Transformers overloadings for 2010-sensitivity case-average hydrology-import 1500 MW scenario, single outages

Outage	**Overloaded branch(es)**	**Loadings**		**Country**
		MVA	**%**	
TR 400/220 kV BUC.S ckt.1	TR 400/220 kV BUC.S ckt.2	407.4	101.9	ROMANIA
400/110 kV BRASOV	400/110 kV DIRSTE	343.9	137.5	
400/110 kV DIRSTE	400/110 kV BRASOV	340.6	136.2	
400/110 kV NIS ckt.1	400/110 kV NIS ckt.2	304.8	101.6	SERBIA

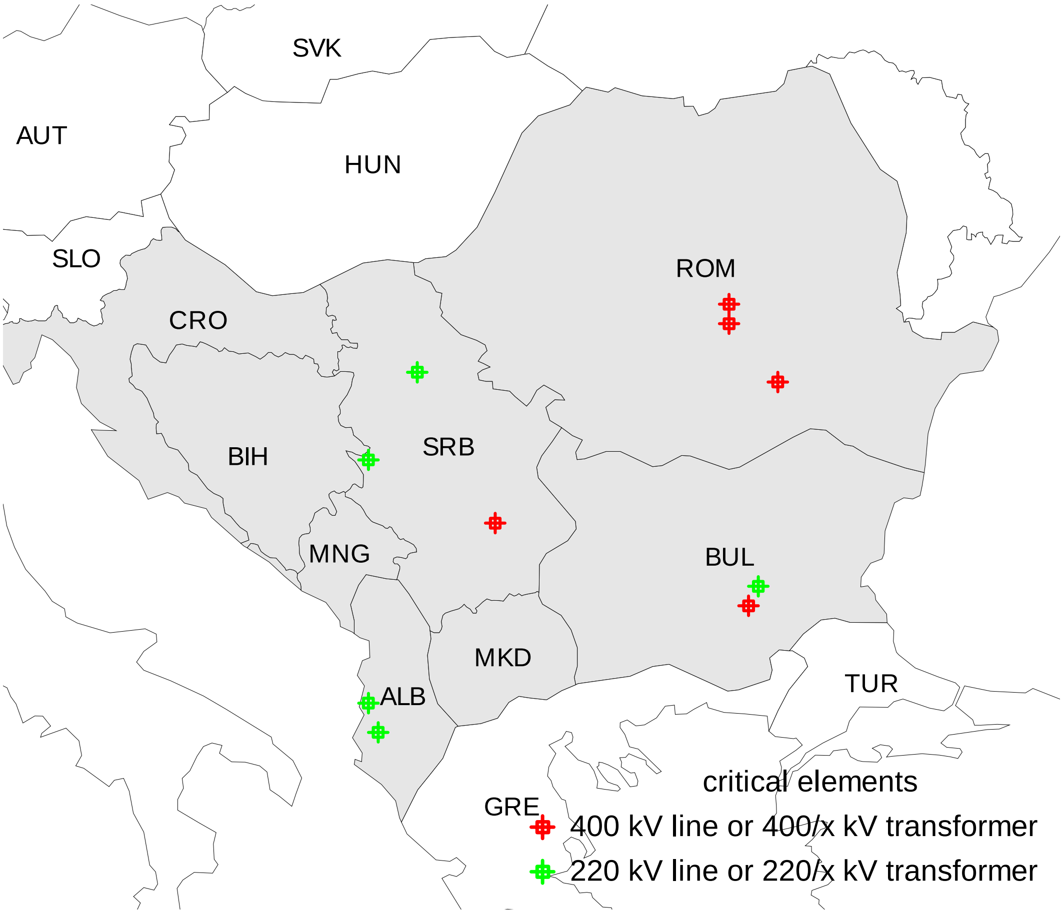


Figure 5.1.6 - Geographical positions of the critical elements for 2010-sensitivity case-average hydrology-import 1500 MW scenario

5.2 Scenario 2010 – average hydrology – high load

This part of the Study presents the results of static load flow and voltage profile analyses that are conducted for complete network topology and (n-1) contingencies in the scenario which is denoted as GTmax run for year 2010 - average hydrology – high load and with new generation facilities implemented. High load conditions denotes high load growth rate scenario. This scenario (higher growth rate) is analyzed in order to evaluate network performance for "heavy" load conditions.

5.2.1 Lines loadings

Figure 5.2.1 shows power exchanges between areas for 2010-average hydrology high load scenario. Power flows along interconnection lines in the region together with balances of the systems are shown in Figure 5.2.2. Area totals are shown in Table 5.2.1 and comparison of the average hydro regimes with normal load projection and high load projection is shown in

Table 5.2.2. As it can be seen, increase of load level for around 3.61% on regional level, causes network losses to rise for up to 177 MW or 24%. This is consequence of higher network load and somewhat lower voltage levels.

Figure 5.2.3 shows histogram of tie lines loadings. It can be concluded that the most of the tie lines are loaded less than 25% of their thermal limits.

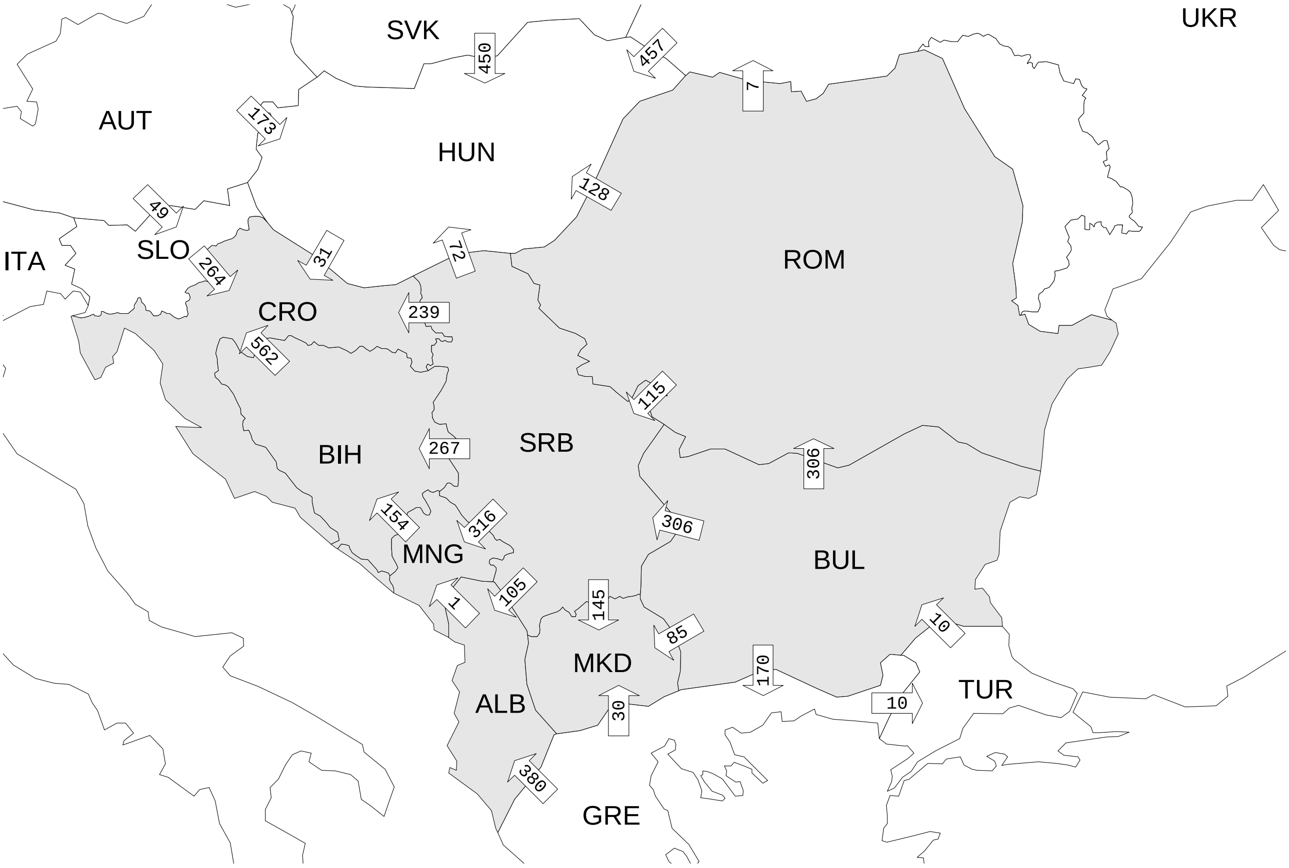


Figure 5.2.1 - Area exchanges in analyzed electric power systems for 2010-average hydrology high load scenario – 2010 topology

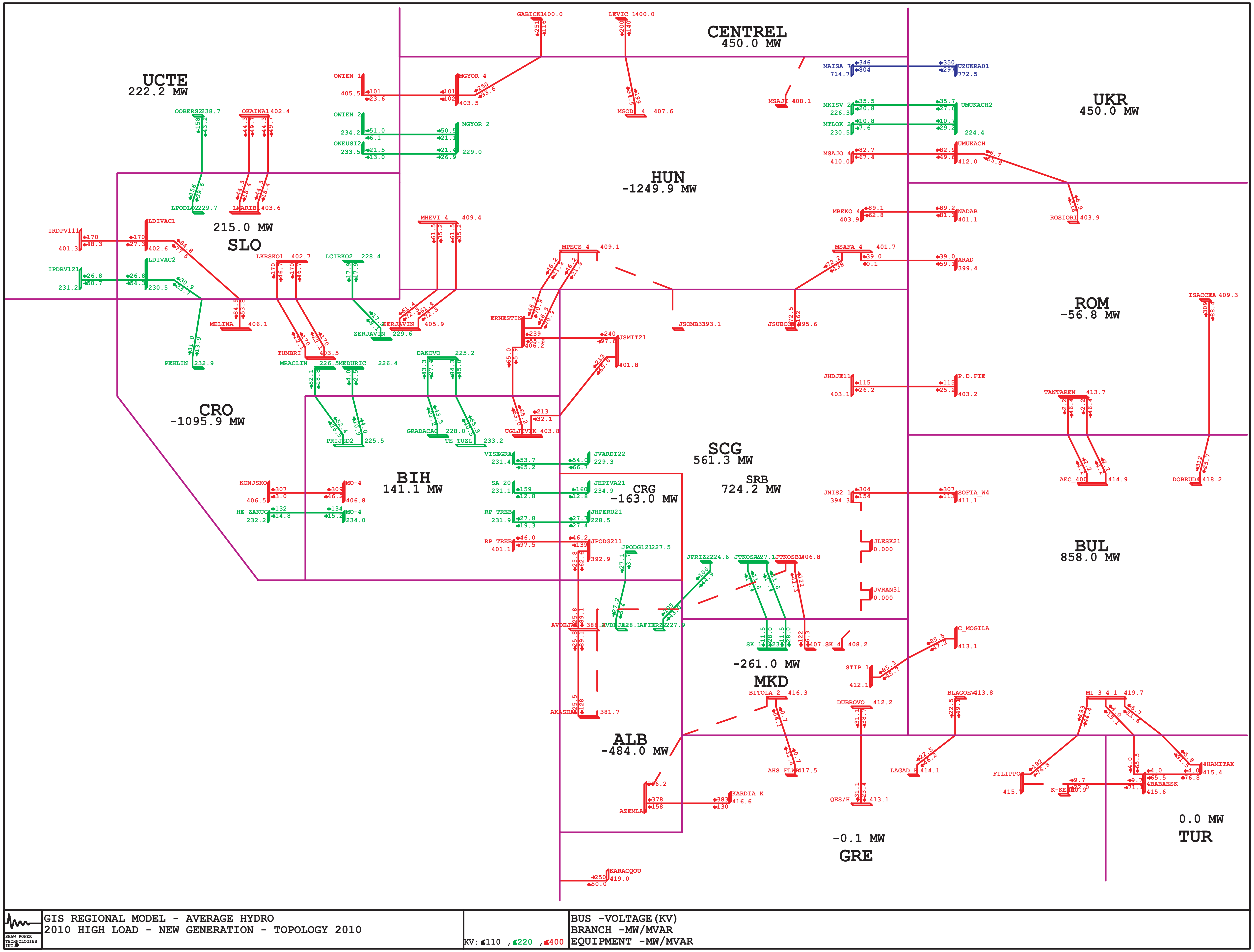


Figure 5.2.2 - Power flows along interconnection lines in the region with balances of the systems for 2010-average hydrology high load scenario – 2010 topology

Table 5.2.1 - Area totals in analyzed electric power systems for 2010- average hydrology high load scenario – 2010 topology

AREA	GENERATION	LOAD	LOSSES	INTERCHANGE
ALBANIA	931.7	1358	57.7	-484
BULGARIA	7282.5	6278	146.5	858
BIH	2202.8	2004	57.8	141.1
CROATIA	2254.6	3295	55.4	-1095.9
MACEDONIA	991.1	1234	18.1	-261
ROMANIA	7113.3	6859.4	310.6	-56.7
SERBIA	8103.8	7131	248.6	724.2
MONTENEGRO	542.3	686	19.2	-163
TOTALS	29422.1	28845.4	913.9	-337.3

Table 5.2.2 – Comparison of Area totals in analyzed electric power systems for 2010- average hydrology versus average hydrology high load scenario – 2010 topology

AREA	LOAD			LOSSES		
	normal load	high load		normal load	high load	
ALBANIA	1287.3	1358	5.49%	50.4	57.7	14.48%
BULGARIA	5977.3	6278	5.03%	121.6	146.5	20.48%
BIH	1971.3	2004	1.66%	58.6	57.8	-1.37%
CROATIA	3136.7	3295	5.05%	49	55.4	13.06%
MACEDONIA	1198.2	1234	2.99%	20.1	18.1	-9.95%
ROMANIA	6728.3	6859.4	1.95%	201.2	310.6	54.37%
SERBIA	6873.1	7131	3.75%	220.8	248.6	12.59%
MONTENEGRO	669.2	686	2.51%	15.5	19.2	23.87%
TOTALS	27841.4	28845.4	3.61%	737.1	913.9	23.99%

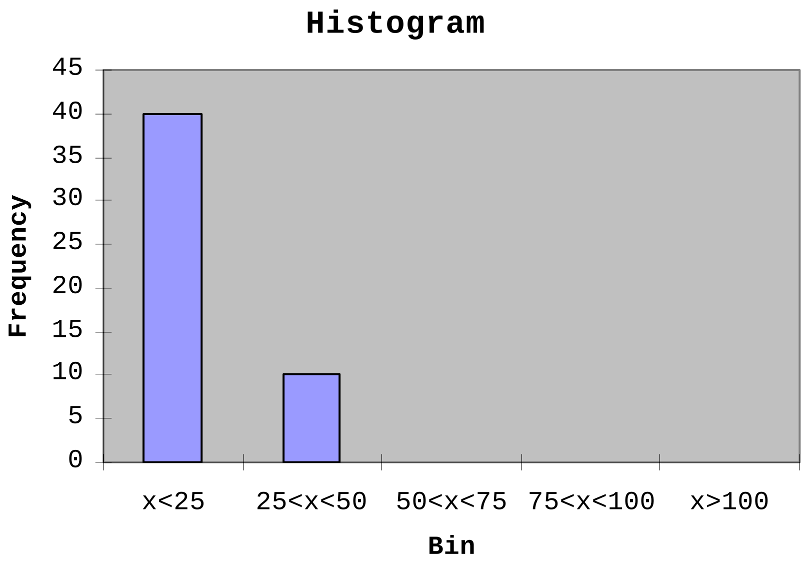


Figure 5.2.3 - Histogram of interconnection lines loadings for 2010- average hydrology high load scenario – 2010 topology ("Frequency" denotes number of lines and "Bin" denotes loading range in % of thermal limit)

Table 5.2.3 shows all network elements loaded over 80% of their thermal limits. As it can be seen some lines 220 kV voltage level in Albania, Romania and Serbia are loaded over 80%. Also, most of the elements loaded over 80% are transformers in some substations, again, in Albania, Romania and Serbia. Figure 5.2.4 shows histogram of branch loadings in the system.

As for the conclusion regarding thermal loadings in this scenario it can be said that most of the network elements are loaded up to 75% of their thermal limits, but there are some elements highly loaded, even overloaded. It can be concluded that overall load of the system is higher than by normal load projection. Higher load-demand level causes that increase of load of the elements which supply large consumption areas are is higher than increase of load-demand level. This goes especially for transformer units over which large consumption areas are connected to high voltage network. Also, most of the elements loaded over 80% are transformers in some substations, and loading of these elements is higher than in case of normal load projection. There are some elements that are overloaded (220 kV lines Targu Jiu – Paroseni and Urechesti-Targu Jiu in Romania, and 220/110 kV transformers in Fier substation in Albania), and this load is higher than in case of normal load projection. Like in previous scenarios analyzed, higher engagement of TPP Paroseni resolves this overloads of the 220 kV lines Targu Jiu – Paroseni and Urechesti-Targu Jiu and decreases the load of the 400/220 transformer in Urechesti substation. Also, it is expected that transformers in Fierza substation will be replaced with more powerful transformer units.

Table 5.2.3 - Network elements loaded over 80% of their thermal limits for 2010-average hydrology high load scenario – 2010 topology

BRANCH LOADINGS ABOVE 80.0 % OF RATING:

AREA	ELEMENT	LOADING MVA	RATING MVA	PERCENT
	Lines			
ROM	HL 220kV P.D.F.A-RESITA 1	226.8	277.4	81.7
	HL 220kV P.D.F.A-RESITA 2	226.8	277.4	81.7
	HL 220kV TG.JIU-PAROSEN 1	277.8	208.1	133.5
	HL 220kV URECHESI-TG.JIU 1	277.8	277.4	100.1
	Transformers			
ALB	TR 220/110 kV AFIER 1	122.2	120	101.8
	TR 220/110 kV AFIER 2	100.1	90	111.3
	TR 220/110 kV AFIER 3	95.6	90	106.2
ROM	TR 400/220 kV URECHE 1	344.4	400	86.1
	TR 220/110 kV FUNDE2 1	178.6	200	89.3
SRB	TR 220/110 kV JTKOSA 2	131.5	150	87.7
	TR 220/110 kV JTKOSA 3	133.9	150	89.3
	TR 220/110 kV JZREN2 2	120.2	150	80.1
	TR 400/220 kV JBGD8 1	326.3	400	81.6

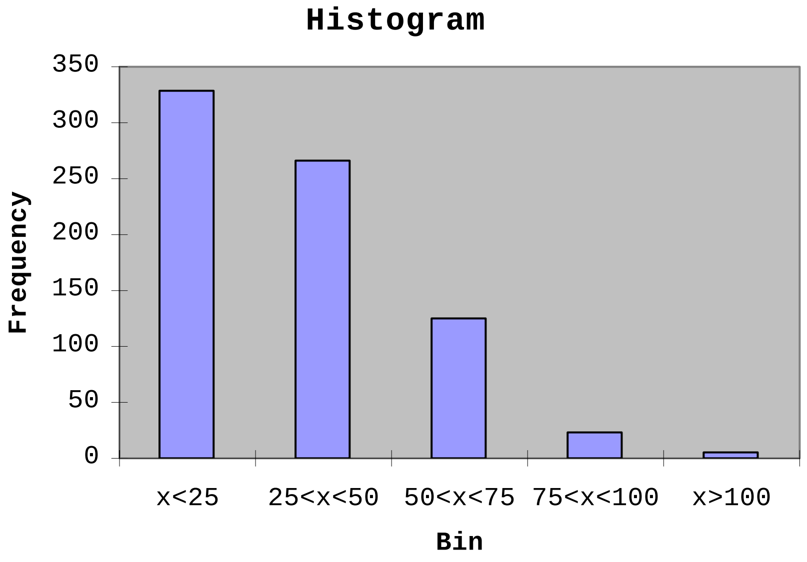


Figure 5.2.4 - Histogram of branch loadings for 2010- average hydrology high load scenario – 2010 topology ("Frequency" denotes number of lines and "Bin" denotes loading range in % of thermal limit)

5.2.2 Voltage Profile in the Region

Figure 5.2.5 shows histogram of voltages in monitored substations. Voltages in almost all monitored substations are found within permitted limits. Voltage profile in network of Albania is somewhat near low limits, but this can be resolved by changing of the setting of the tap changing transformers in some substations. Also, voltage levels are somewhat lower comparing to normal load projection scenario. Higher load of network elements, which is consequence of the higher demand level, causes voltage drops along network elements to be higher.

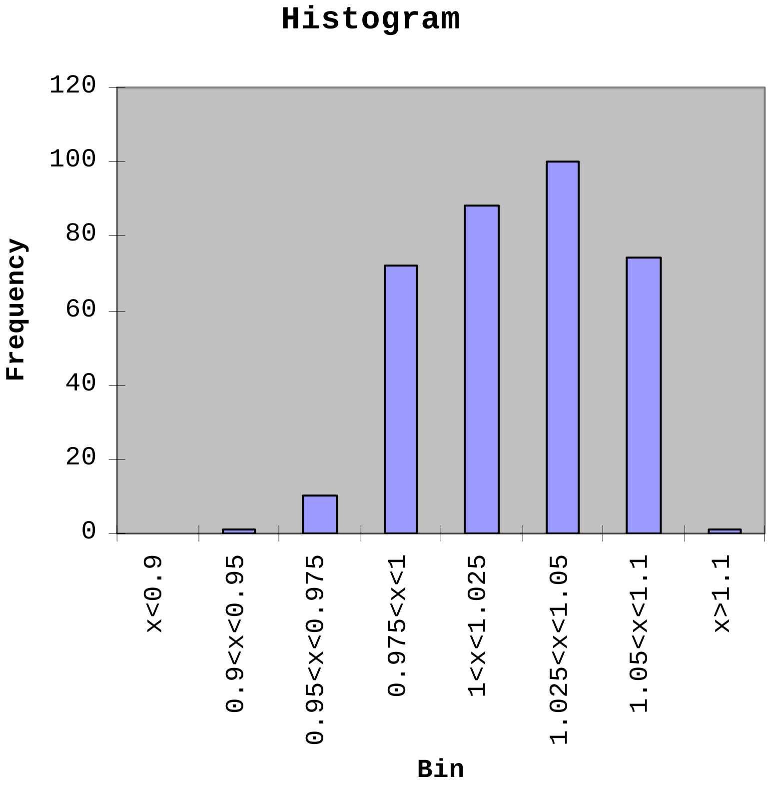


Figure 5.2.5 - Histogram of voltages in monitored substations for 2010- average hydrology high load scenario – 2010 topology ("Frequency" denotes number of busses and "Bin" denotes voltage range in p.u.)

5.2.3 Security (n-1) analysis

Results of security (n-1) analysis for 2010-average hydrology high load scenario and expected topology for 2010 are presented in Table 5.2.4. Figure 5.2.6 shows the geographical position of the critical elements in monitored systems.

It can be concluded that all identified insecure situations are located in internal networks that belong to monitored power systems of Albania, Romania and Serbia. In most critical case in Romanian system, the critical elements are 220 kV lines Targu Jiu – Paroseni and Urechesti-Targu Jiu and 400/220 kV transformer in Urechesti substation, but these elements are overloaded in case of full topology also, which is the main reason why they appear as critical by most outages analyzed. As it has been stated before, this can be resolved by higher engagement of the TPP Paroseni. Compared to the normal load projection (chapter 4.1) it can be concluded that the critical elements are almost the same. The only difference is overload of the 400/110 kV transformer unit in SS Pancevo. This is cosequence of higher load of these transformers in full network topology compared to the normal demand scenario.

Like by normal demand scenario (chapter 4.1), some of the overloadings identified can be relieved by certain dispatch actions (splitting busbars, changing lower voltage network topology in order to redistribute load-demand or change of generation units engagement).

All in all, certain reinforcement of internal network is necessary in order to make this regime more secure. Especially, taking into consideration that higher demand causes higher load of transformer units in whole monitored region.

Table 5.2.4 - Network overloadings for 2010- average hydrology high load scenario , single outages – 2010 topology

Area	contingency	Area	overloadings / out of limits voltages	#	limit / Unom	Flow / Voltage	rate / volt.dev.
1	2	3	4	5	6	7	8
	BASE CASE	RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	285.6MVA	133.5%
AL	OHL 220kV AELBS12 -AFIER 2 1	AL	HL 220kV AKASHA2-ARRAZH2	1	270MVA	289.9MVA	112.2%
RO	OHL 220kV P.D.F.A -RESITA 1	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	301.5MVA	106.1%
		RO	HL 220kV P.D.F.A-RESITA	2	277.4MVA	331.5MVA	122.8%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	301.5MVA	141.4%
RO	OHL 220kV RESITA -TIMIS 1	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	295.7MVA	103.9%
		RO	HL 220kV RESITA-TIMIS	2	277.4MVA	348.7MVA	127.0%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	295.7MVA	138.5%
RO	OHL 220kV PESTIS -MINTIA A 1	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	296.3MVA	104.8%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	290.4MVA	139.7%
RO	OHL 220kV CLUJ FL -AL.JL 1	RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	271MVA	126.4%
RO	OHL 220kV AL.JL -GILCEAG 1	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	308.8MVA	109.1%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	308.8MVA	145.4%
RO	OHL 400kV TANTAREN-URECHESI 1	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	292.5MVA	102.6%
RO	OHL 400kV TANTAREN-BRADU 1	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	300.1MVA	105.9%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	300.1MVA	141.1%
RO	OHL 400kV TANTAREN-SIBIU 1	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	331.1MVA	117.3%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	331.1MVA	156.4%
RO	OHL 400kV URECHESI-P.D.FIE 1	RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	268.7MVA	124.5%
RO	OHL 400kV URECHESI-DOMNESTI 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	400.6MVA	100.1%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	305.6MVA	107.7%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	305.6MVA	143.6%
RO	OHL 400kV MINTIA -ARAD 1	RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	263.1MVA	123.1%
RO	OHL 400kV MINTIA -SIBIU 1	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	326.2MVA	115.5%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	326.2MVA	153.9%
RO	OHL 400kV DOMNESTI-BRAZI 1	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	296.2MVA	104.0%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	296.2MVA	138.7%
RO	OHL 400kV SMIRDAN -GUTINAS 1	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	296.9MVA	104.5%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	296.9MVA	139.3%
RO	OHL 400kV BRASOV -BRADU 1	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	296.3MVA	104.3%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	296.3MVA	139.0%
CS	OHL 220kV JBGD172 -JBGD8 22 1	CS	HL 220kV JBGD172-JBGD8 22	2	365.8MVA	453.5MVA	129.0%
CS	OHL 400kV JBOR 21 -JHDJE11 1	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	300.9MVA	106.1%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	300.9MVA	141.4%
CS	OHL 400kV JHDJE11 -JTDRMN1 1	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	315.8MVA	111.9%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	315.8MVA	149.1%
CS	OHL 400kV JNSAD31 -JSUBO31 1	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	304.1MVA	107.2%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	304.1MVA	142.8%
RO	TR 400/110 BRASOV 1	RO	TR 400/110kV/kV DIRSTE	1	250MVA	353.9MVA	141.6%
RO	TR 400/110 DIRSTE 1	RO	TR 400/110kV/kV BRASOV	1	250MVA	350MVA	140.0%
CS	TR 400/110 JNIS2 1	CS	TR 400/110kV/kV JNIS2 1	2	300MVA	323.1MVA	107.7%
CS	TR 400/110 JPANC2 1	CS	TR 400/110kV/kV JPANC21	2	300MVA	318.8MVA	106.3%

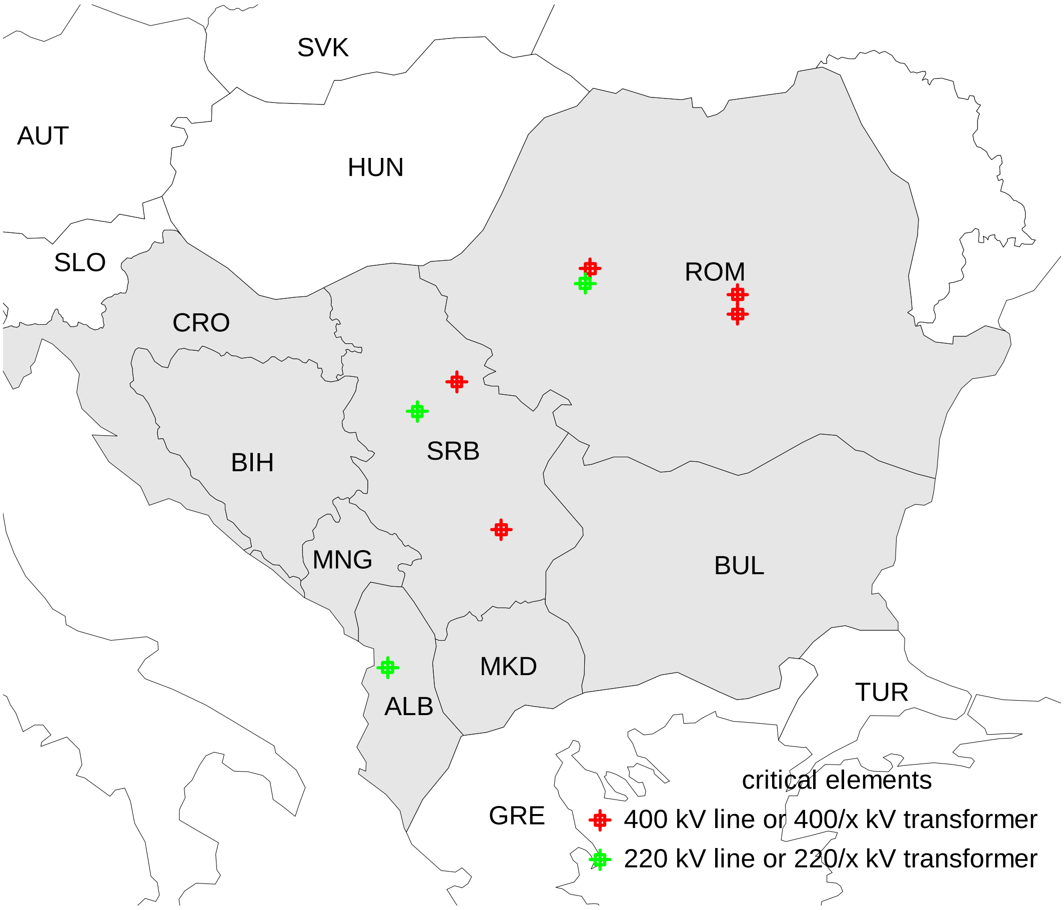


Figure 5.2.6 – geographical position of critical elements for 2010- average hydrology high load scenario – 2010 topology

5.3 Scenario 2015 – average hydrology – import/export – 2010 topology

This part of the Study presents results of static load flow and voltage profile analyses that are conducted for complete network topology and (n-1) contingencies in the scenario which is denoted as Scenario 2015 – sensitivity case – average hydrology – import 1500 MW – topology 2010.

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

- Import 750 MW from UCTE
- Import 500 MW from Turkey
- Export 500 MW to Greece
- Import 750 MW from Ukraine

Calculations on the model characterized by the 2010 network topology, appropriate GTMax generation dispatch, predicted load level in 2015 and power import/export as explained above, could not lead to a convergent load flow solution due to reactive power problems. Lack of reactive power in the analyzed situation is visible especially in the power system of Albania.

If the power plants reactive limits are ignored in the model, a convergent solution is found and the following can be concluded:

- There is a permanent lack of reactive power for analyzed generation dispatch, load level and power import/export in the power system of Albania. Generators in power plants Balsh, Fierza and Vau Dejes exceed their Var limits in order to keep nominal voltages. This proves the necessity to install compensation devices or new power plants in the Albanian power system, or to construct new interconnection lines to make network connections stronger.

- Generators in Bulgarian power system, which are dispatched in the analyzed scenario and whose reactive power limits are exceeded, are operated mostly in the under-excitation area below their minimum Var limits. This means that there is a sufficient reactive power reserve, but problems with high voltages may be expected especially in lower bus loading conditions (nights, summer).

- Reactive power problems in the analyzed situation are not detected in the power systems of Bosnia and Herzegovina, Croatia and Macedonia.

- In the power system of Romania, the generator Var limits are occasionally exceeded in both directions (some generators work in the over-excitation area and some in the under-excitation one) in order to achieve scheduled (mostly nominal) voltages in the analyzed situation. The Var limits are not significantly exceeded when observing all dispatched generators in Romania.

- Certain lack of reactive power is visibly present in the power system of Serbia and UNMIK. Ten power plants are operated slightly above their maximum Var limits.

- Smaller lack of reactive power also exists in the power system of Montenegro that is affected by the poor voltage profile in Albania.

To provide deeper insight into the voltage problems which are obviously present in the analyzed export/import scenario in 2015, but on the network topology predicted to exist in 2010, it is necessary to conduct more comprehensive and thorough analysis. It is assumed that the utilisation 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.

If new interconnection lines predicted to exist in 2015 are included in the model, Vranje (Serbia) – Skopje 4 (Macedonia), Zemlak (Albania) – Bitola 2 (Macedonia), and V. Dejes (Albania) – Kosovo B (UNMIK), a convergent solution is found. Power flow solution is explained in the following Chapter.

A convergent solution for the 2010 network topology is found when only 400 kV line V.Dejes (Albania) – Kosovo B (UNMIK) is included in the model, but without satisfactory network voltage profile. Two 400 kV nodes in Albania (Elbassan and Tirana) and five 400 kV nodes in Romania (Domnesti, Dirste, Brazi, Brasov, Bradu) have small voltage values (between 374 kV and 379 kV). Two 220 kV nodes in Albania (Fier and Babic) have also small voltage values (193 kV and 196 kV respectively). Sixty two 110 kV nodes, mostly in Albania, have low voltages, ranging between 80 kV and 99 kV.

Convergent solution on network topology in 2010 is found also if only 400 kV line Zemlak (Albania) – Bitola (Macedonia) is included on the model, but voltage profile in the network is unsatisfactory again. Two 400 kV nodes in Albania (Elbassan and Tirana) and five 400 kV nodes in Romania (Domnesti, Dirste, Brazi, Brasov, Bradu) have small voltage values (between 373 kV and 379 kV). Two 220 kV nodes in Albania (Fier and Babic) have small voltage values also (192 kV and 195 kV respectively). Seventy five 110 kV nodes, mostly in Albania, have low voltages, ranging between 78 kV and 99 kV.

To conclude, the analyzed scenario which is characterized by large power import in 2015, but on the 2010 network topology, can not be supported from a transmission network viewpoint due to voltage problems. Their existence is the most obvious in the power system of Albania due to scarce reactive power sources. To mitigate such problems it is necessary to construct at least one new 400 kV interconnection line between Albania and UNMIK or Macedonia.

5.4 Scenario 2015 – average hydrology – import/export – 2015 topology

This part of the Study presents results of static load flow and voltage profile analyses that are conducted for complete network topology and (n-1) contingencies in the scenario which is denoted as Scenario 2015 – sensitivity case – average hydrology – import 1500 MW – topology 2015.

5.4.1 Lines loadings

Area totals and power exchanges for the 2015-sensitivity case-average hydrology-import 1500 MW-topology 2015 scenario are shown in Figure 5.4.1. Power flows along interconnection lines in the region together with balances of the systems are shown in Figure 5.4.2. Area totals are shown in Table 5.4.1. Table 5.4.2 shows power flows along regional interconnection lines for 2015-sensitivity case-average hydrology-import 1500 MW-topology 2015 scenario

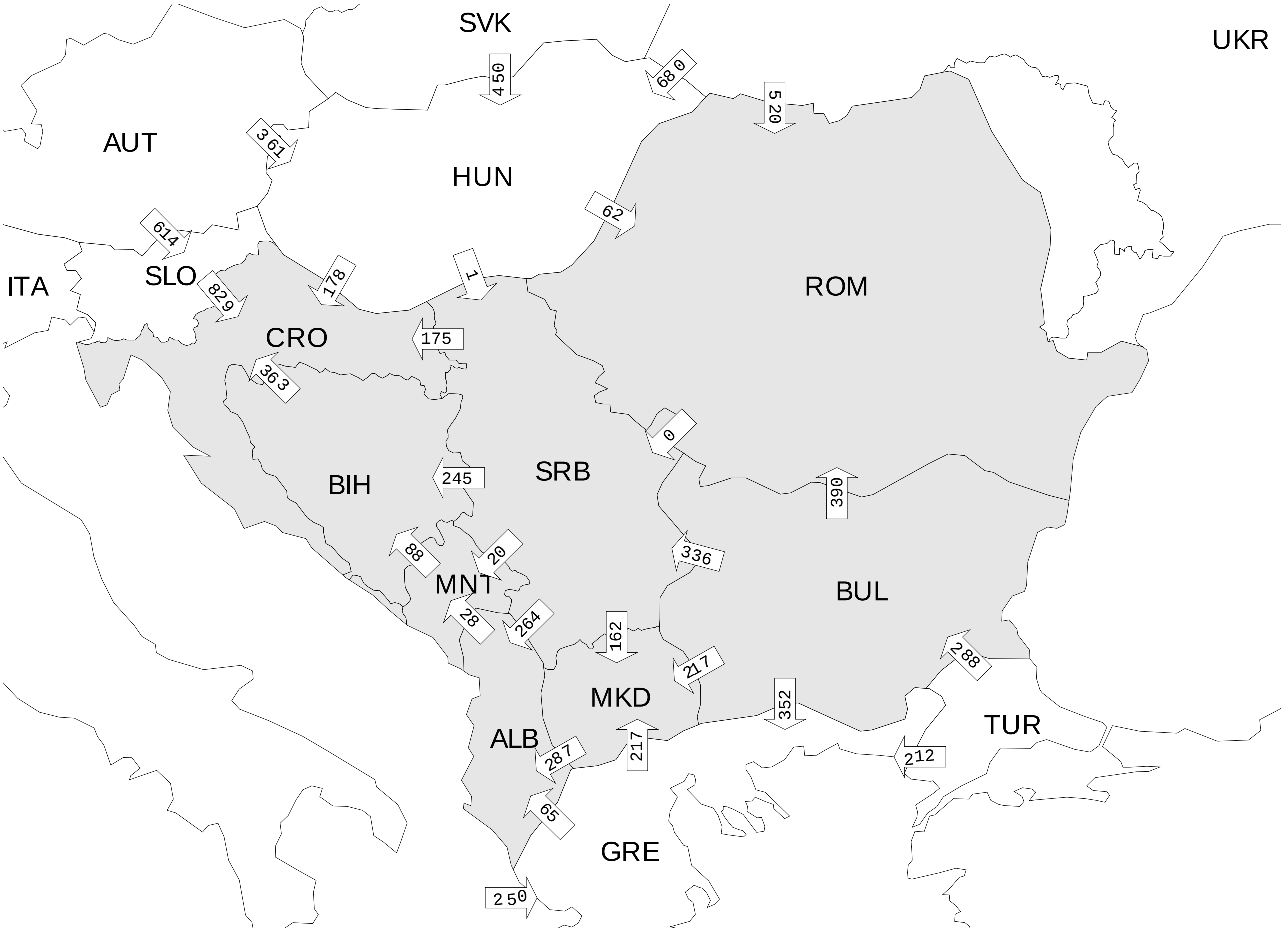


Figure 5.4.1 - Area exchanges in analyzed electric power systems for 2010-sensitivity case-average hydrology-import 1500 MW-topology 2015 scenario

Table 5.4.1 - Area totals in analyzed electric power systems for 2015-sensitivity case-average hydrology-import 1500 MW-topology 2015 scenario

Country	Generation (MW)	Load (MW)	Bus Shunt (Mvar)	Line Shunt (Mvar)	Losses (MW)	Net Interchange (MW)
Albania	1027.5	1544.0	0	0	71.5	-588.0
Bulgaria	7582.2	6418.9	0	14.6	142.7	1006.0
Bosnia and Herzegovina	2394.9	2293.8	0	0	70.1	31.0
Croatia	2173.9	3660.1	0	0	58.8	-1545.0
Macedonia	1076.3	1393.7	0	0	22.5	-340.0
Romania	7187.7	7831.2	0	74.6	253.9	-972.0
Serbia and UNMIK	8029.8	7270.7	0	14.1	215.1	530.0
Montenegro	731.9	675.0	0.6	1.8	15.6	39.0
TOTAL - SE EUROPE	*30204.2*	*31087.4*	*0.6*	*105.0*	*850.3*	*-1839.0*

By comparing the average hydrology situation in 2015 and balanced SE Europe power system to the average hydrology situation and 1500 MW of power import, a significant increase of the power flows is noticed along the Slovenian-Croatian and Ukrainian-Romanian interfaces. However, the interconnection lines are not jeopardized since their loading levels fall far below their thermal ratings. In the same time, power flows through other interfaces between countries in the SE Europe are mostly decreased.

Power losses, in comparison to the situation of balanced SE Europe power system, are increased only in the power system of Macedonia (5%). In other power systems power losses are decreased, the most significantly in the power systems of Romania (-26%) and Montenegro (-23%). Power losses are decreased (-16%) in the region when analyzing the additional power import.

Figure 5.4.3 shows that all tie lines in the region are loaded less than 50% of their thermal limits for the analyzed import/export scenario in year 2015. Among total number of fifty two 400 kV and 220 kV interconnection lines in the region only ten are loaded between 25% and 50% of their thermal ratings. Other tie lines are loaded less than 25% of their thermal ratings.

Table 5.4.3 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 in some substations and internal 110 kV and 220 kV lines. 110 kV lines which are loaded over 80% $I_{thermal}$ are not shown in the table. Certain internal network reinforcements are necessary to sustain given load-demand level and production pattern including import of 1500 MW from analyzed directions.

Figure 5.4.4 shows histogram of 400 kV and 220 kV regional internal lines and 400/x kV and 220/x kV transformers loadings. Some 40% of observed branches are loaded below 25% of their thermal ratings, 36% are loaded between 25% and 50%, 20% are loaded between 50% and 75% and 5% of observed branches are loaded between 75% and 100% of their thermal ratings. Four branches (transformers 220/110 kV Fierze in Albania, 102% - 106% S_n and 220/110 kV transformer in Fundeni substation in Romania) are overloaded when all branches are in operation.

By comparing the average hydrology situation in 2015 and balanced SE Europe power system to the average hydrology situation and 1500 MW of power import, it is noticed that power system of Romania becomes slightly relieved while some highly loaded branches are present in the power systems of Albania, Serbia and Bulgaria. Distribution of internal branches loading is slightly changed because a number of branches loaded between 25% and 75% of their thermal ratings is increased compared to the situation characterized by balanced SE Europe power system.

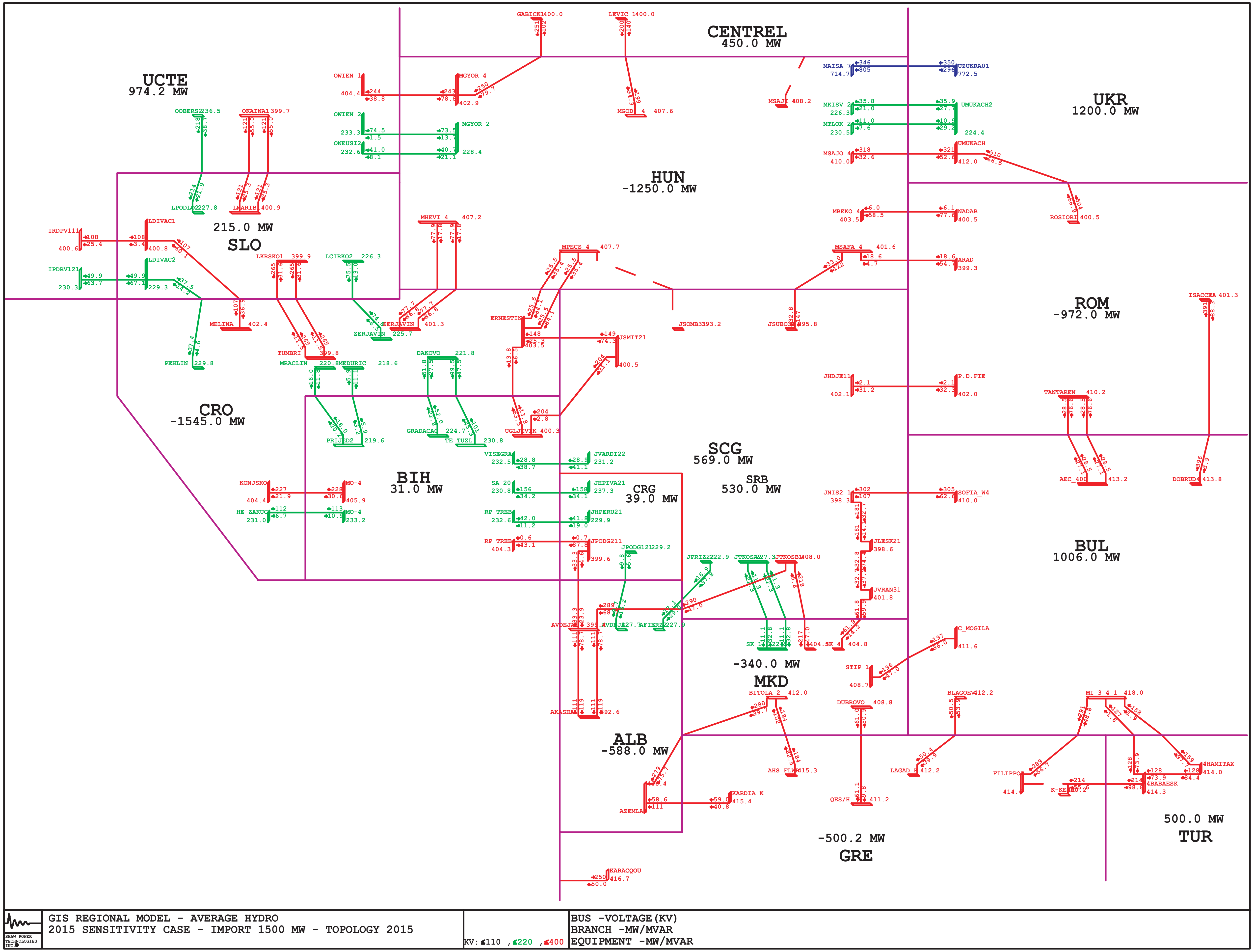


Figure 5.4.2 - Power flows along interconnection lines in the region for 2015-sensitivity case-average hydrology-import 1500 MW-topology 2015 scenario

Table 5.4.2 - Power flows along regional interconnection lines for 2015-sensitivity case-average hydrology-import 1500 MW-topology 2015 scenario

Interconnection line			**Power Flow**		**% of thermal rating**
			MW	**Mvar**	
OHL 400 kV	Zemlak (ALB)	Kardia (GRE)	-58.6	-110.9	9
OHL 220 kV	Fierze (ALB)	Prizren (SER)	17.1	29.0	14
OHL 220 kV	V.Dejes (ALB)	Podgorica (MON)	-9.7	-15.2	6
OHL 400 kV	V.Dejes (ALB)	Podgorica (MON)	33.3	-23.9	3
OHL 400 kV	Ugljevik (B&H)	Ernestinovo (CRO)	-13.8	-63.5	5
OHL 400 kV	Mostar (B&H)	Konjsko (CRO)	228.5	-30.6	17
OHL 400 kV	Ugljevik (B&H)	S. Mitrovica (SER)	-203.8	-2.8	16
OHL 400 kV	Trebinje (B&H)	Podgorica (MON)	-0.6	43.1	7
OHL 220 kV	Trebinje (B&H)	Plat (CRO)	-104.8	40.0	36
OHL 220 kV	Prijedor (B&H)	Mraclin (CRO)	16.0	-20.2	8
OHL 220 kV	Prijedor (B&H)	Medjuric (CRO)	5.9	3.2	4
OHL 220 kV	Gradacac (B&H)	Djakovo (CRO)	52.0	22.8	20
OHL 220 kV	Tuzla (B&H)	Djakovo (CRO)	100.8	45.3	37
OHL 220 kV	Mostar (B&H)	Zakucac (CRO)	113.4	-10.9	36
OHL 220 kV	Visegrad (B&H)	Vardiste (SER)	-28.8	38.7	16
OHL 220 kV	Sarajevo 20 (B&H)	Piva (MON)	-156.5	-34.2	41
OHL 220 kV	Trebinje (B&H)	Perucica (MON)	42.0	11.2	15
OHL 400 kV	Blagoevgrad (BUL)	Thessaloniki (GRE)	50.5	-53.9	10
OHL 400 kV	M.East 3 (BUL)	Filippi (GRE)	290.6	-48.8	41
OHL 400 kV	M.East 3 (BUL)	Babaeski (TUR)	-127.3	-1.6	12
OHL 400 kV	M.East 3 (BUL)	Hamitabat (TUR)	-158.4	1.9	10
OHL 400 kV	C.Mogila (BUL)	Stip (MCD)	197.4	-36.0	28
OHL 400 kV	Dobrudja (BUL)	Isaccea (ROM)	396.1	3.9	29
OHL 2x400 kV ckt.1	Kozloduy (BUL)	Tantarena (ROM)	28.5	27.1	6
OHL 2x400 kV ckt.2	Kozloduy (BUL)	Tantarena (ROM)	28.5	27.1	6
OHL 400 kV	Sofia West (BUL)	Nis (SER)	304.5	62.6	44
OHL 2x400 kV ckt.1	Zerjavinec (CRO)	Heviz (HUN)	-77.7	-86.8	9
OHL 2x400 kV ckt.2	Zerjavinec (CRO)	Heviz (HUN)	-77.7	-86.8	9
OHL 2x400 kV ckt.1	Ernestinovo (CRO)	Pecs (HUN)	-25.5	-84.1	7
OHL 2x400 kV ckt.2	Ernestinovo (CRO)	Pecs (HUN)	-25.5	-84.1	7
OHL 2x400 kV ckt.1	Tumbri (CRO)	Krsko (SLO)	-264.6	11.5	23
OHL 2x400 kV ckt.2	Tumbri (CRO)	Krsko (SLO)	-264.6	11.5	23
OHL 400 kV	Melina (CRO)	Divaca (SLO)	-106.6	22.8	11
OHL 400 kV	Ernestinovo (CRO)	S.Mitrovica (SER)	-148.4	25.3	12
OHL 220 kV	Zerjavinec (CRO)	Cirkovce (SLO)	-74.8	6.5	25
OHL 220 kV	Pehlin (CRO)	Divaca (SLO)	-37.4	4.6	12
OHL 400 kV	Dubrovo (MCD)	Thessaloniki (GRE)	-61.0	-50.9	5
OHL 400 kV	Bitola (MCD)	Florina (GRE)	-183.9	-101.9	17
OHL 400 kV	Skopje (MCD)	Kosovo B (UNMIK)	-216.8	-47.0	16
OHL 2x220 kV ckt.1	Skopje (MCD)	Kosovo A (UNMIK)	-11.1	-32.8	11
OHL 2x220 kV ckt.2	Skopje (MCD)	Kosovo A (UNMIK)	-11.1	-32.8	11
OHL 400 kV	Arad (ROM)	Sandorfalva (HUN)	-18.6	-54.7	5
OHL 400 kV -	Nadab (ROM)	Bekescaba (HUN)	6.1	-77.6	6
OHL 400 kV	Rosiori (ROM)	Mukacevo (UKR)	-503.9	-68.9	43
OHL 400 kV	Portile De Fier (ROM)	Djerdap (SER)	-2.1	-32.3	2
OHL 400 kV	Subotica (SER)	Sandorfalva (HUN)	-32.8	-147.1	11
OHL 400 kV	Ribarevine (MON)	Kosovo B (UNMIK)	-148.4	-17.0	11
OHL 220 kV	Pljevlja (MON)	Bajina Basta (SER)	-11.3	9.6	9
OHL 220 kV	Pljevlja (MON)	Pozega (SER)	75.9	40.3	29
OHL 400 kV*	Skopje 4 (MCD)	Vranje (SER)	61.9	14.2	6
OHL 400 kV*	Zemlak (ALB)	Bitola (MCD)	-279.2	-75.7	21
OHL 400 kV*	V.Dejes (ALB)	Kosovo B (UNMIK)	-289.3	-68.7	22

* new lines planned till 2015

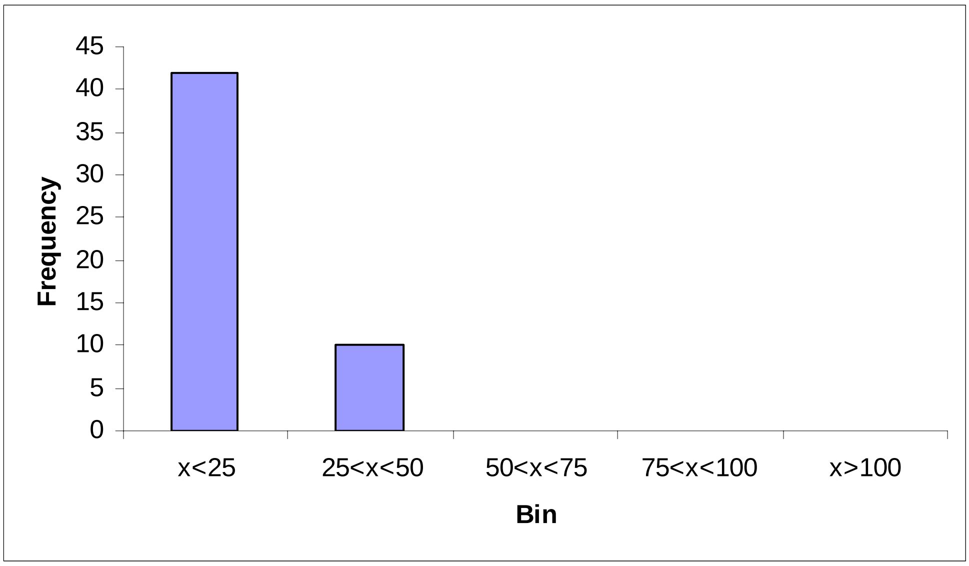


Figure 5.4.3 - Histogram of interconnection lines loadings for 2015-sensitivity case-average hydrology-import 1500 MW-topology 2015 scenario ("Frequency" denotes number of lines and "Bin" denotes loading range in % of thermal limit)

Table 5.4.3 - Network elements loaded over 80% of thermal limits for 2015-sensitivity case-average hydrology-import 1500 MW-topology 2015 scenario

AREA	ELEMENT	LOADING MVA	RATING MVA	PERCENT
Lines				
ALB	OHL 220 kV AKASHA2-ARRAZH2	235.7	270.0	87.3
BUL	OHL 220 kV MI_2_220-ST ZAGORA	191.0	228.6	83.5
	OHL 400 kV PLOVDIV4-MI_400	605.2	692.8	87.4
ROM	OHL 220 kV BRADU-TIRGOVI	246.9	302.6	81.6
	OHL 220 kV P.D.F.A-CETATE1	204.3	208.1	98.2
	OHL 220 kV BUC.S-B-FUNDENI	266.0	320.0	83.1
SRB	OHL 220 kV JBGD3 21-JOBREN2	277.4	301.0	92.2
Transformers				
ALB	TR 220/110 kV AFIERZ2-AFIERZ5 ckt.1	50.9	60.0	84.8
	TR 220/110 kV AFIERZ2-AFIERZ5 ckt.2	50.9	60.0	84.8
	TR 220/110 kV ABURRE2-ABURRL5 ckt. 1	49.1	40.0	81.8
	TR 220/110 kV ABURRE2-ABURRL5 ckt. 2	49.1	40.0	81.8
	TR 220/110 kV ABURRE2-ABURRL5 ckt. 3	49.1	40.0	81.8
	TR 220/110 kV AELBS12-AELBS15 ckt.1	74.0	90.0	82.2
	TR 220/110 kV AELBS12-AELBS15 ckt.2	74.0	90.0	82.2
	TR 220/110 kV AELBS12-AELBS15 ckt.3	79.5	90.0	88.3
	TR 220/110 kV AKASHA2-AKASH25 ckt.1	82.9	100.0	82.9
	TR 220/110 kV AKASHA2-AKASH25 ckt.2	82.9	100.0	82.9
	TR 220/110 kV AFIER 2-AFIER 5 ckt.1	130.7	120.0	108.9
	TR 220/110 kV AFIER 2-AFIER 5 ckt.2	107.1	90.0	119.0
	TR 220/110 kV AFIER 2-AFIER 5 ckt.3	102.2	90.0	113.6
B&H	TR 400/110 kV UGLJEVIK	256.3	300.0	85.4
ROM	TR 400/110 kV BRASOV	202.5	250.0	81.0
	TR 220/110 kV FUNDENI	181.0	200.0	90.5
	TR 220/110 kV FUNDENI-FUNDE2B	214.4	200.0	107.2
SRB	TR 220/110 kV JBGD3 21-JBGD 351	169.4	200.0	84.7
	TR 220/110 kV JBGD3 22-JBGD 352	126.8	150.0	84.5
	TR 220/110 kV JZREN22-JZREN25	121.5	150.0	81.0

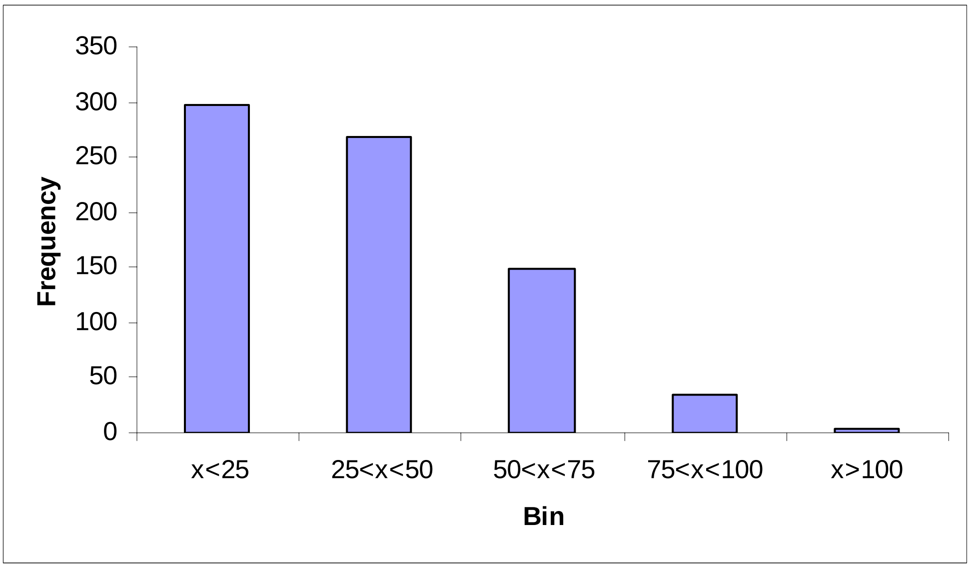


Figure 5.4.4 - Histogram of 400 kV and 220 kV regional branches loadings for 2015-sensitivity case-average hydrology-import 1500 MW-topology 2015 scenario ("Frequency" denotes number of lines and "Bin" denotes loading range in % of thermal limit)

5.4.2 Voltage Profile in the Region

Voltage profile in the region within this scenario which is defined by given generation pattern and power import is seen as satisfactory because there are no voltages outside permitted limits. Figure 5.4.5 shows histogram of voltages in monitored 400 kV and 220 kV substations.

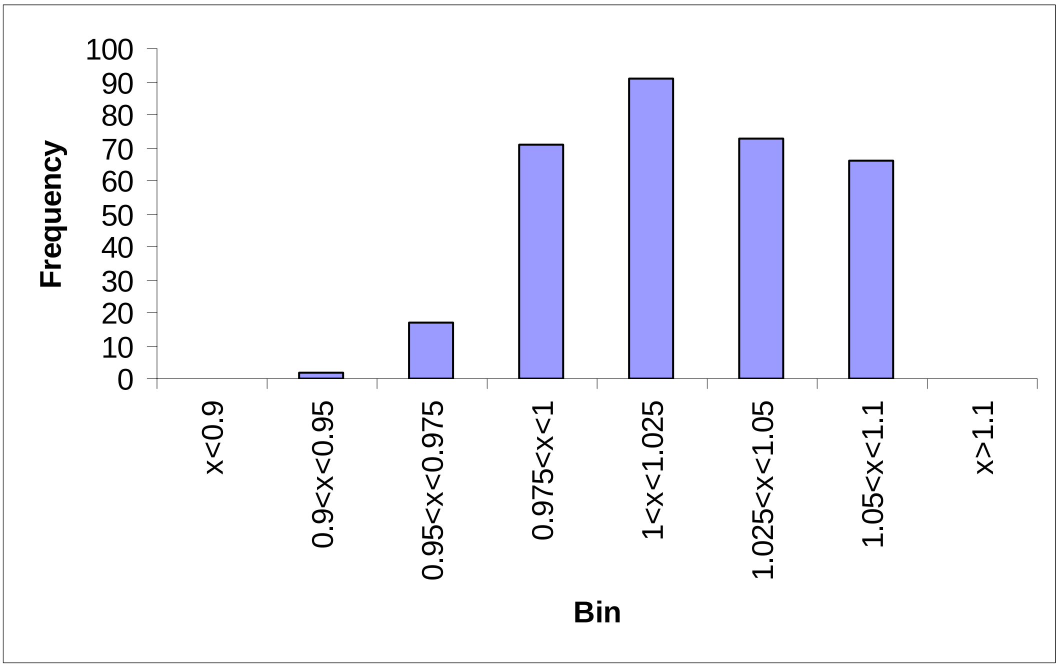


Figure 5.4.5 - Histogram of voltages in monitored substations for 2015-sensitivity case-average hydrology-import 1500 MW-topology 2015 scenario ("Frequency" denotes number of busses and "Bin" denotes voltage range in p.u.)

5.4.3 Security (n-1) analysis

Results of security (n-1) analysis for the 2015-sensitivity case-average hydrology-import 1500 MW-topology 2015 scenario are presented in Tables 5.3.4 - 5.3.5.

Insecure system situations for given generation pattern and power import are detected in the power systems of Albania, Bulgaria, Bosnia and Herzegovina, Croatia, Romania and Serbia. Some possible actions for transmission system relief during certain contingency cases are previously described while the transformer overloadings in Zerjavinec (Croatia), Nis and Pancevo (Serbia) substations may be removed by system operator actions.

Figure 5.4.6 shows geographical positions of critical elements in the analyzed scenario. A green colour reveals 220 kV elements (line 220 kV or transformer 220/x kV), while a red one reveals 400 kV elements (line 400 kV or transformer 400/x kV).

According to the obtained and presented results, it may be concluded that certain reinforcements in the internal networks of Romania, Bulgaria, Albania and Serbia are necessary shall this generation pattern and 1500 MW of power import be made more secure. None of the identified congestions is located at the border lines.

Table 5.4.4 - Lines overloadings for 2015-sensitivity case-average hydrology-import 1500 MW scenario-topology 2015, single outages

Outage	**Overloaded line(s)**	**Loadings**		**Country**
		MVA	**%**	
OHL 220 kV AELBS12-AFIER 2	OHL 220 kV AKASHA2-ARRAZH2	351.1	136.4	ALBANIA
OHL 400 kV BURGAS-MI_2_400	OHL 400 kV PLOVDIV4-MI_400	742.9	104.9	BULGARIA
OHL 220 kV G_ORIAH-MI_2_220	OHL 220 kV MI_2_220-ST.ZAGORA	255.1	105.0	
OHL 400 kV VISEGRA-HE VG	OHL 220 kV RP KAKAN-KAKANJ5	335.1	102.3	B&H
OHL 400 kV TANTAREN-BRADU	OHL 220 kV BUC.S-B-FUNDENI	312.8	103.4	ROMANIA
OHL 400 kV DOMNESTI-BRAZI	OHL 220 kV BUC.S-B-FUNDENI	319.8	103.1	
OHL 220 kV P.D.F.A-CALAFAT	OHL 220 kV P.D.F.A-CETATE1	257.9	125.0	
OHL 220 kV P.D.F.A-RESITA ckt.1	OHL 220 kV P.D.F.A-RESITA ckt.2	273.3	100.9	
OHL 220 kV FUNDENI-BUC.S-B	OHL 220 kV BUC.S-B-FUNDENI	342.7	110.2	
TR 400/220 kV ROSIORI	OHL 400 kV GADALIN-CLUJ E	242.2	105.7	
TR 400/220 kV BRAZI	OHL 220 kV BRADU-TIRGOVI	285.9	105.9	
	OHL 220 kV BUC.S-B-FUNDENI	355.6	118.4	
TR 400/220 kV JBGD8 ckt.2	OHL 220 kV JBGD3 21-JOBREN2	307.4	104.7	SERBIA
TR 400/220 kV JBGD8 ckt.1	OHL 220 kV JBGD3 21-JOBREN2	329.2	112.9	
	OHL 220 kV JBGD3 22-JBGD8 22	373.7	107.3	
OHL 400 kV JBGD8 1-JOBREN11	OHL 220 kV JBGD3 21-JOBREN2	468.7	167.2	
OHL 400 kV JHDJE11-JTDRMN1	OHL 220 kV JBGD3 21-JOBREN2	321.3	109.1	
OHL 400 kV JPANC21-JTDRMN1	OHL 220 kV JBGD3 21-JOBREN2	302.0	103.1	
OHL 220 kV JBBAST2-JBGD3 21	OHL 220 kV JBGD3 21-JOBREN2	304.8	103.6	
OHL 220 kV JBGD3 22-JBGD8 21	OHL 220 kV JBGD3 21-JOBREN2	300.2	102.0	
OHL 220 kV JBGD172-JBGD8 22 ckt.1	OHL 220 kV JBGD172-JBGD8 22 ckt.2	464.7	132.6	

Table 5.4.5 - Transformer overloadings for 2015-sensitivity case-average hydrology-import 1500 MW scenario-topology 2015, single outages

Outage	Overloaded branch(es)	Loadings		Country
		MVA	%	
OHL 400 kV BLUKA 6-TS TUZL	TR 400/110 kV UGLJEVIK	302.7	100.9	B&H
TR 400/110 kV ZERJAVIN ckt.1	TR 400/110 kV ZERJAVIN ckt.2	300.8	100.3	CROATIA
OHL 400 kV BRASOV-DIRSTE	TR 400/110 kV BRASOV	253.8	101.5	ROMANIA
OHL 220 kV BUC.S-B-FUNDENI	TR 400/220 kV BRAZI	418.6	104.6	
TR 400/220 kV BUC.S ckt.1	TR 400/220 kV BUC.S ckt.2	505.1	126.3	
TR 400/110 kV BRASOV	TR 400/110 kV DIRSTE	434.5	173.8	
TR 400/110 kV DIRSTE	TR 400/110 kV BRASOV	423.8	169.5	
TR 400/110 kV NIS ckt.1	TR 400/110 kV NIS ckt.2	304.8	101.6	SERBIA
TR 400/110 kV PANCEVO ckt.1	TR 400/110 kV PANCEVO ckt.2	305.8	101.9	

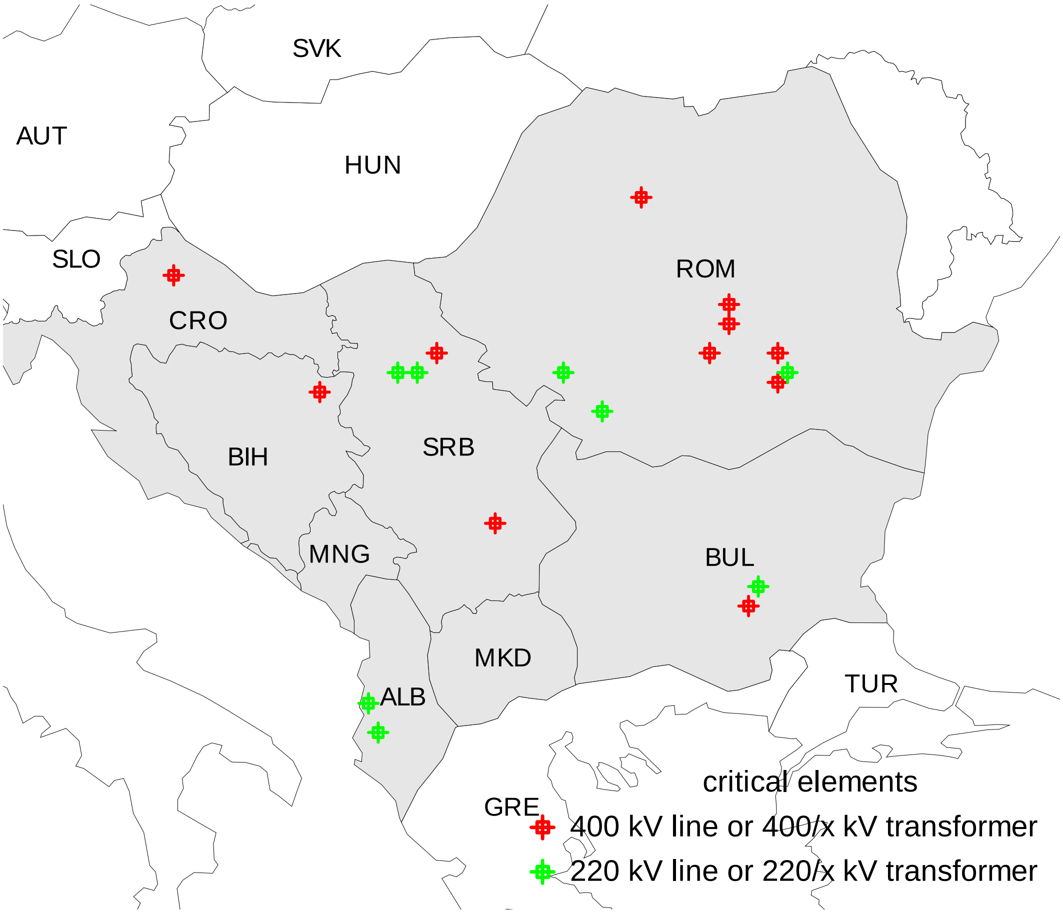


Figure 5.4.6 – Geographical positions of the critical elements for 2015-sensitivity case-average hydrology-import 1500 MW-topology 2015 scenario

5.4.4 Summary of Impacts - 2015 topology versus 2010 topology

Compared to the expected topology 2010, analyzed in previous chapter, it can be seen that planned investments make analyzed generation, demand and power import scenario feasible. This scenario could not be solved on 2010 topology because lack of reactive power support especially in the power system of Albania. Construction of at least one new interconnection line from Albania (V.Dejes or Zemlak) to UNMIK (Kosovo B) or Macedonia (Bitola) makes this scenario feasible but voltage profile in Albania, Montenegro and Serbia is poor. If all planned new lines are in operation voltage profile is satisfactory but some internal reinforcements will be necessary to make this generation pattern and power import more secure.

5.5 Scenario 2015 – average hydrology – high load – 2010 topology

This part of the Study presents the results of static load flow and voltage profile analyses that are conducted for complete network topology and (n-1) contingencies in the scenario which is denoted as GTmax run for year 2015 - average hydrology high load and expected network topology for 2010 with new generation facilities implemented.

5.5.1 Lines loadings

Figure 5.5.1 shows power exchanges between areas for 2015-average hydrology high load scenario and 2010 topology. Power flows along interconnection lines in the region together with balances of the systems are shown in Figure 5.5.2. Area totals are shown in Table 5.5.1 and comparison of the average hydro regimes with normal load projection and high load projection is shown in Table 5.5.2. Difference of load-demand level for these two regimes for 2015 is around 8.11% on regional level. As a consequence of this high load level, network losses are increased by 262 MW or 25%. Further differences are explained in detail in following chapter.

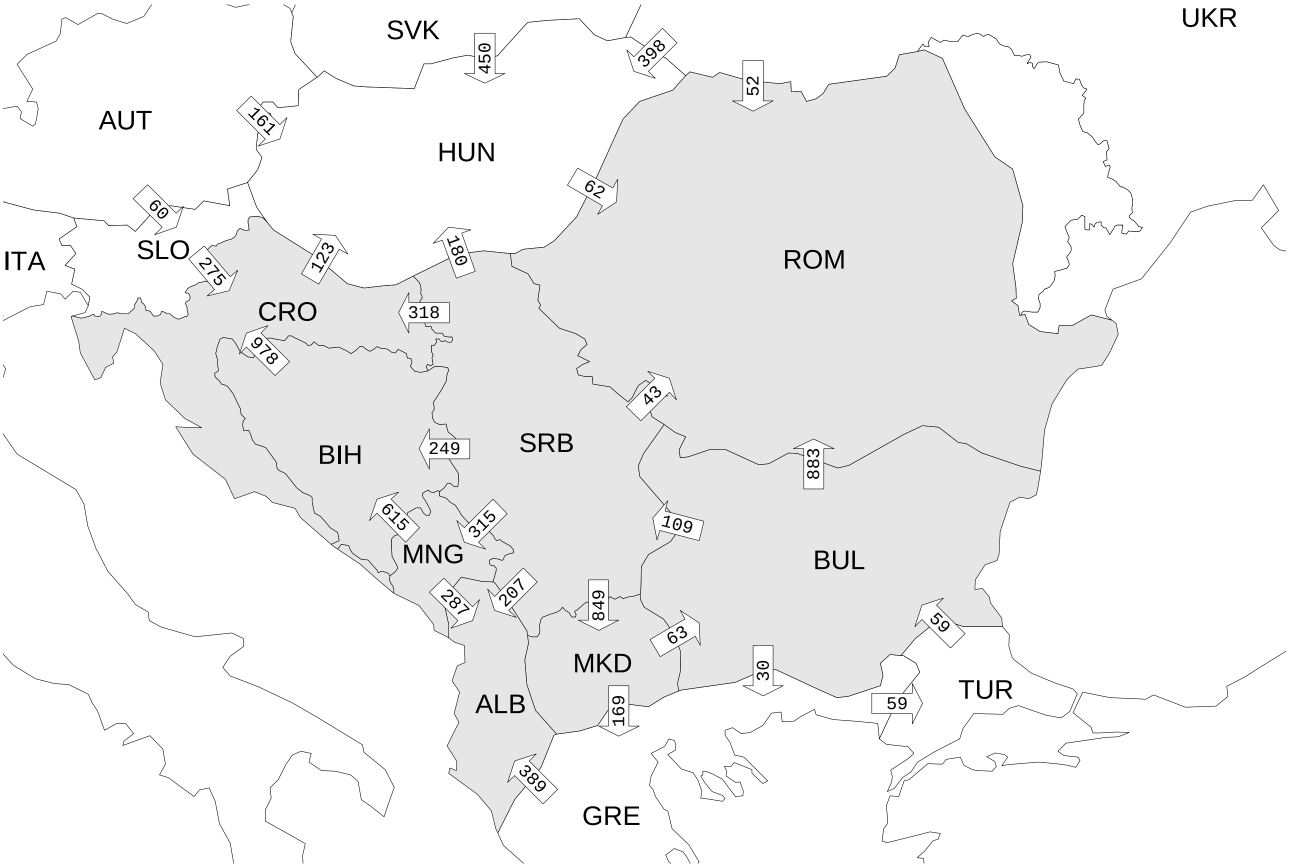
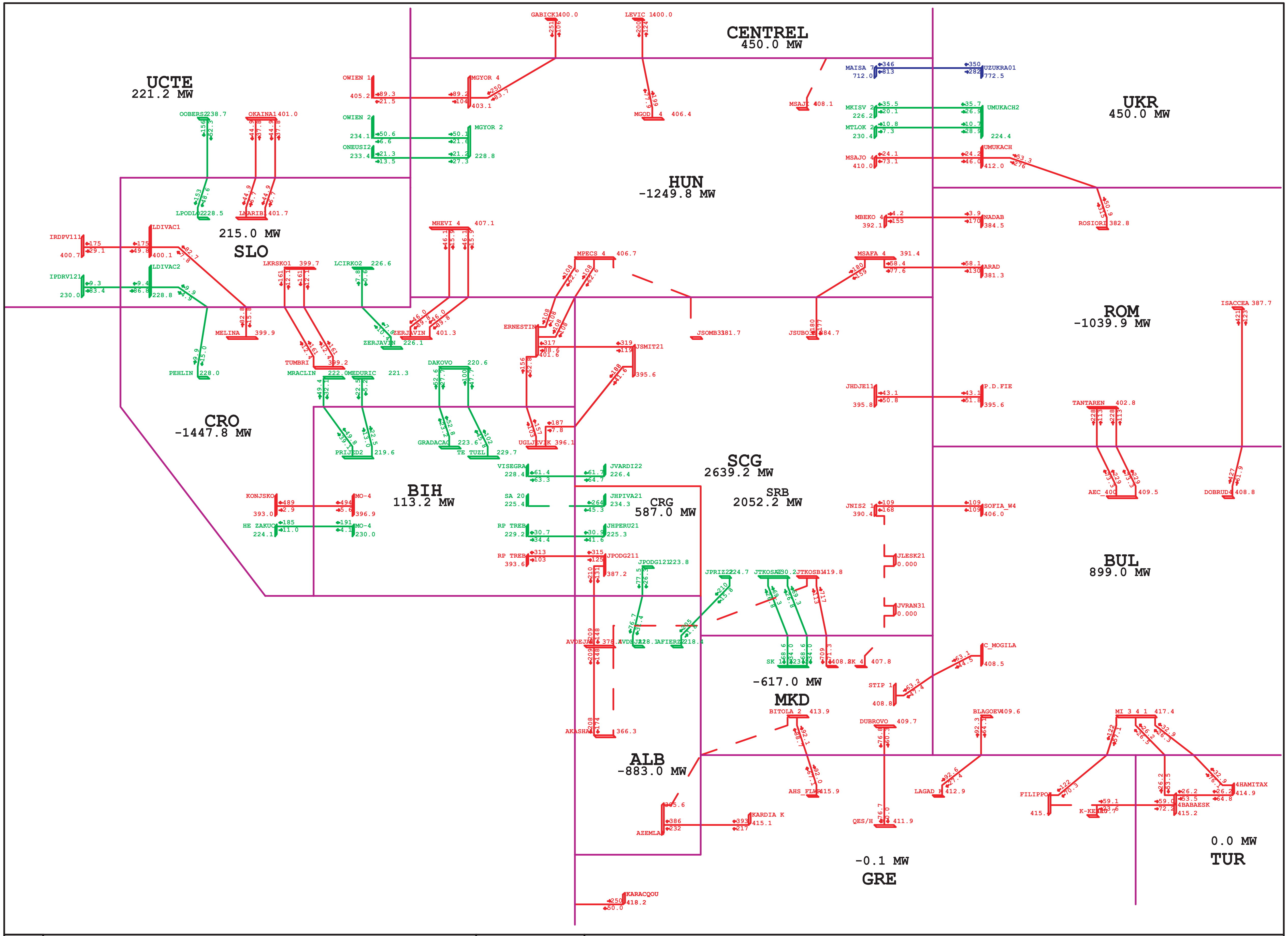


Figure 5.5.1 - Area exchanges in analyzed electric power systems for 2015-average hydrology high load scenario – topology 2010

Figure 5.5.3 shows histogram of tie lines loadings. It is concluded that most of the tie lines are loaded less than 50% of their thermal limits, but there are some that are loaded up to 75% of their thermal limit like the 220 kV line from Pizren (Serbia-UNMIK)-Fierza (Albania).



GIS REGIONAL MODEL - AVERAGE HYDRO
2015 HIGH LOAD - NEW GENERATION - TOPOLOGY 2010

KV: ≤110 , ≤220 , ≤400

BUS - VOLTAGE (KV)
BRANCH - MW/MVAR
EQUIPMENT - MW/MVAR

Figure 5.5.2 - Power flows along interconnection lines in the region with balances of the systems for 2015-average hydrology high load scenario – 2010 topology

Table 5.5.1 - Area totals in analyzed electric power systems for 2015-average hydrology high load scenario – 2010 topology

AREA	GENERATION	LOAD	LOSSES	INTERCHANGE
ALBANIA	896.1	1680	99	-883
BULGARIA	8157.8	7083	175.8	899
BIH	2479.4	2274	92.2	113.2
CROATIA	2591	3959	79.8	-1447.8
MACEDONIA	895	1489	23	-617
ROMANIA	7684.5	8269.8	454.5	-1039.8
SERBIA	10024.2	7635	337	2052.2
MONTENEGRO	1324.6	702	35.6	587
TOTALS	34052.6	33091.8	1296.9	-336.2

Table 5.5.2 - Comparison of Area totals in analyzed electric power systems for 2015- average hydrology versus average hydrology high load scenario – 2010 topology

AREA	LOAD			LOSSES		
	normal load	high load		normal load	high load	
ALBANIA	1531	1680	9.73%	81.2	99	21.92%
BULGARIA	6483	7083	9.25%	150.7	175.8	16.66%
BIH	2279	2274	-0.22%	78.7	92.2	17.15%
CROATIA	3657	3959	8.26%	63.4	79.8	25.87%
MACEDONIA	1407	1489	5.83%	20	23	15%
ROMANIA	7317.4	8269.8	13.02%	347.4	454.5	30.83%
SERBIA	7263	7635	5.12%	268.7	337	25.42%
MONTENEGRO	671	702	4.62%	25	35.6	42.4%
TOTALS	30608.4	33091.8	8.11%	1035.1	1296.9	25.29%

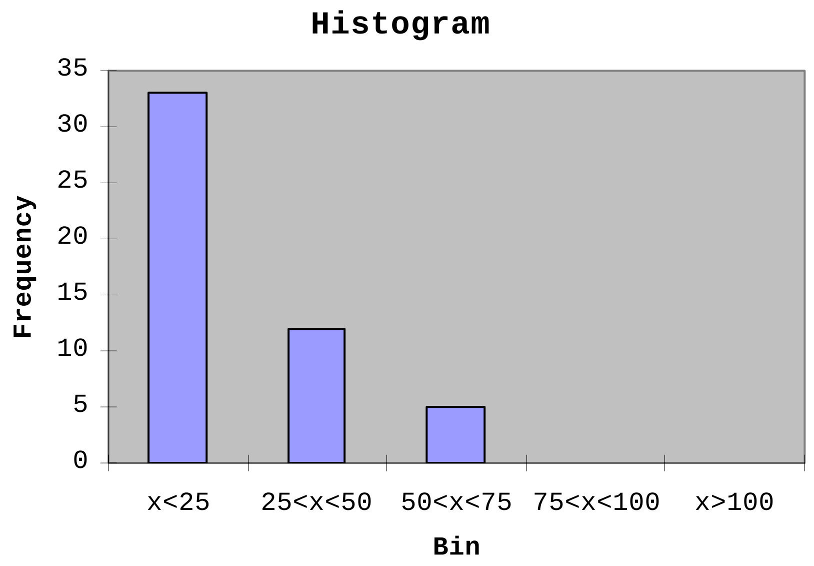


Figure 5.5.3 - Histogram of interconnection lines loadings for 2015- average hydrology high load scenario – topology 2010 ("Frequency" denotes number of lines and "Bin" denotes loading range in % of thermal limit)

Following Table 5.5.3 lists all network elements loaded over 80% of their thermal limits. As it can be seen large number of lines 220 kV voltage level in Albania, Romania and Serbia are loaded over 80%. It can be concluded that overall load level of the transmission network increased, especially in parts of the network that supply major consumption areas (Tirana in Albania, Bucharest and Timisoara in Romania, Belgrade in Serbia and Pristina in Serbia-UNMIK). Most of the elements loaded over 80% are 220 kV lines in Romania, but also transformers in some substations that supply the major consumption areas.

There are some elements that are overloaded (220 kV lines Targu Jiu – Paroseni and Urechesti – Targu Jiu in Romania and 220/110 kV transformers in Fierza and Elbasan 1 substation in Albania, and 400/220 kV and 220/110 kV transformers in Kosovo B and Kosovo A substations in Serbia-UNMIK. This leads to conclusion that transmission network is not able to sustain this load-demand level and this production pattern.

Table 5.5.3 - Network elements loaded over 80% of their thermal limits for 2015-average hydrology high load scenario – 2010 topology

BRANCH LOADINGS ABOVE 80.0 % OF RATING:

AREA	ELEMENT	LOADING MVA	RATING MVA	PERCENT
Lines				
ALB	HL 220kV AKASHA2-ARRAZH2 1	287.7	270	106.6
ROM	HL 220kV BRADU-TIRGOVI 1	285.4	302.6	94.3
	HL 220kV BUC.S-B-FUNDENI 1	309.4	320	96.7
	HL 220kV FILESTI-BARBOSI 1	248.3	277.4	89.5
	HL 220kV L.SARAT-FILESTI 1	241	277.4	86.9
	HL 220kV P.D.F.A-CETATE1 1	207.2	208.1	99.6
	HL 220kV P.D.F.A-RESITA 1	266.9	277.4	96.2
	HL 220kV P.D.F.A-RESITA 2	266.9	277.4	96.2
	HL 220kV P.D.F.II-CETATE1 1	271.1	277.4	97.7
	HL 220kV PAROSEN-BARU M 1	227.6	277.4	82
	HL 220kV RESITA-TIMIS 1	229.6	277.4	82.8
	HL 220kV RESITA-TIMIS 2	229.6	277.4	82.8
	HL 220kV TG.JIU-PAROSEN 1	320.7	208.1	154.1
	HL 220kV URECHESI-TG.JIU 1	320.4	277.4	115.5
	HL 400kV GADALIN-CLUJ E 1	208.4	238.3	87.5
SRB	HL 220kV JBGD3 21-JOBREN2 1	291	301	96.7
Transformers				
ALB	TR 220/110 kV ABURRE 1	49.5	60	82.5
	TR 220/110 kV ABURRE 2	49.5	60	82.5
	TR 220/110 kV ABURRE 3	49.5	60	82.5
	TR 220/110 kV AELBS1 1	87.7	90	97.5
	TR 220/110 kV AELBS1 2	87.7	90	97.5
	TR 220/110 kV AELBS1 3	94.2	90	104.7
	TR 220/110 kV AFIER 1	149	120	124.1
	TR 220/110 kV AFIER 2	122.1	90	135.7
	TR 220/110 kV AFIER 3	116.5	90	129.5
	TR 220/110 kV AFIERZ 1	58	60	96.7
	TR 220/110 kV AFIERZ 2	58	60	96.7
	TR 220/110 kV AKASHA 1	93.4	100	93.4
	TR 220/110 kV AKASHA 2	93.4	100	93.4
	TR 220/110 kV ARRAZH 1	87.7	100	87.7
	TR 220/110 kV ARRAZH 2	87.7	100	87.7
	TR 220/110 kV ATIRAN 2	97.5	120	81.3
	TR 220/110 kV ATIRAN 3	102.2	120	85.2
BIH	TR 400/110 kV UGLJEV 1	258.8	300	86.3
CRO	TR 220/110 kV TESISA 1	178.8	200	89.4
ROM	TR 220/110 kV BARBOS 1	167.1	200	83.6
	TR 220/110 kV FUNDE2 1	240.8	200	120.4
	TR 220/110 kV FUNDEN 1	203.9	200	101.9
	TR 220/110 kV TIMIS 1	171.7	200	85.9
	TR 400/110 kV BRASOV 1	231.5	250	92.6
	TR 400/110 kV CLUJ E 1	208.4	250	83.4
	TR 400/110 kV DIRSTE 1	221	250	88.4
	TR 400/220 kV BUC.S 1	378.4	400	94.6
	TR 400/220 kV BUC.S 2	378.4	400	94.6
	TR 400/220 kV IERNUT 1	408.1	400	102
	TR 400/220 kV URECHE 1	486.6	400	121.6
SRB	TR 220/110 kV JBGD3 1	174.9	200	87.5
	TR 220/110 kV JBGD3 2	137.1	150	91.4
	TR 220/110 kV JPRIS4 1	137	150	91.3
	TR 220/110 kV JPRIS4 2	137	150	91.3
	TR 220/110 kV JTKOSA 2	151.3	150	100.9
	TR 220/110 kV JTKOSA 3	154	150	102.7
	TR 220/110 kV JZREN2 2	133.8	150	89.2
	TR 400/110 kV JJAGO4 A	245.8	300	81.9
	TR 400/220 kV JBGD8 1	332.2	400	83
	TR 400/220 kV JTKOSB 1	411.6	400	102.9

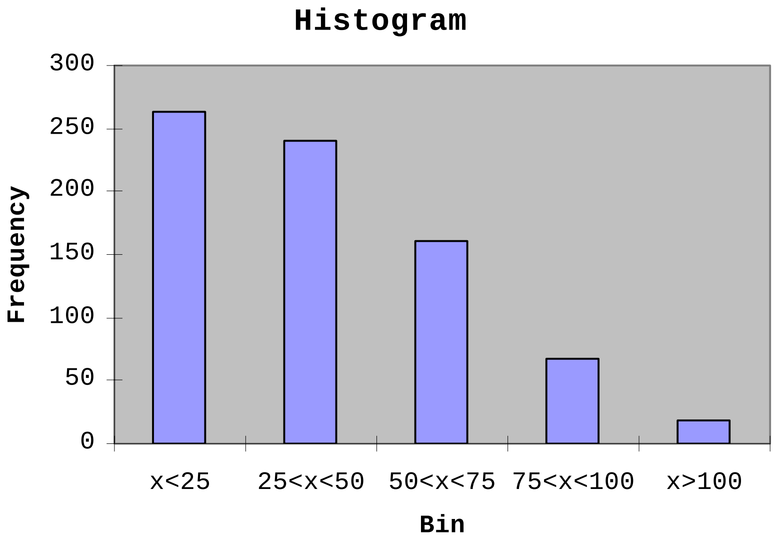


Figure 5.5.4 - Histogram of branch loadings for 2015-average hydrology high load scenario – 2010 topology ("Frequency" denotes number of lines and "Bin" denotes loading range in % of thermal limit)

5.5.2 Voltage Profile in the Region

Figure 5.5.5 shows histogram of voltages in monitored substations. Overall voltage profile is not adequate. In most of the network, especially in major consumption areas of Albania and Romania, voltages in some monitored substations are below limits. Using of voltage control devices (tap changing transformers, shunt devices) in Albania and Romania is not analyzed, but especially Albania, these devices have very limited abilities for improving voltage profile. All in all it can be concluded that conditions in some parts of the transmission network in this regime are dangerously close to voltage collapse.

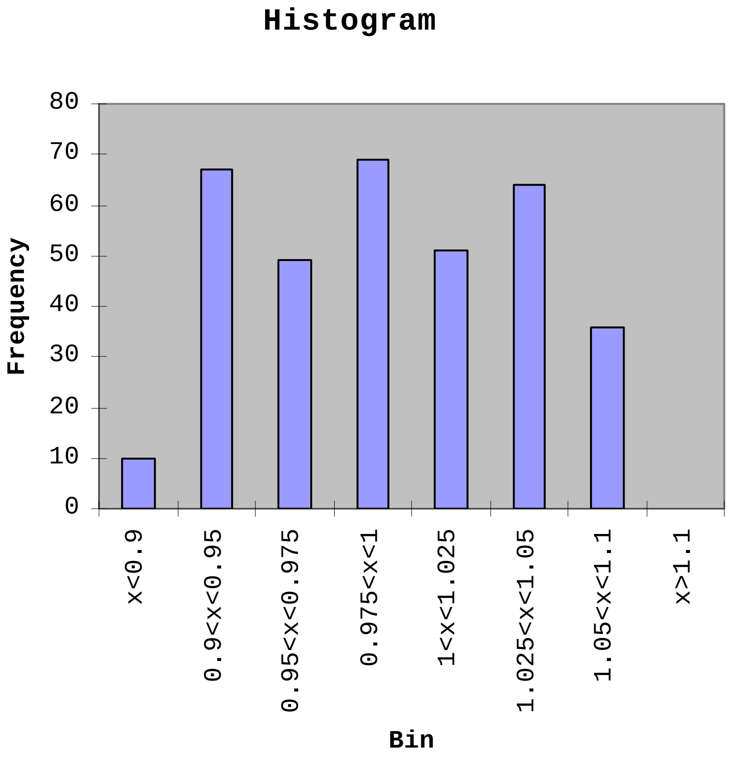


Figure 5.5.5 - Histogram of voltages in monitored substations for 2015-dry hydrology scenario – 2010 topology ("Frequency" denotes number of busses and "Bin" denotes voltage range in p.u.)

5.5.3 Security (n-1) analysis

Results of security (n-1) analysis for 2015-average hydrology high load scenario and expected topology for 2010 are presented in Table 5.5.4. Figure 5.5.6 shows the geographical position of the critical elements in monitored systems. As it can be seen, by lot of investigated contingencies, insecure states are identified. Almost all elements that are loaded over 80% in base case (Table 5.5.3), represent critical elements in n-1 analyses. Furthermore, for lot of contingency cases (losing of major interconnection and internal lines) results could not be presented because of mathematical instability of the model. This indicates that all these cases are not feasible in reality, and that these contingencies can lead to voltage collapse and partial black outs in some parts of the monitored network.

Table 5.5.4 - Network overloadings for 2015-dry hydrology scenario , single outages – 2010 topology

Area	contingency	Area	overloadings / out of limits voltages	#	limit / Unom	Flow / Voltage	rate / volt.dev.
1	2	3	4	5	6	7	8
	BASE CASE	AL	HL 220kV AKASHA2-ARRAZH2	1	270MVA	263MVA	106.6%
		RO	TR 400/220kV/kV URECHESI	1	400MVA	483.6MVA	120.9%
		RO	HL 220kV LOTRU-SIBIU	1	277.4MVA	275.6MVA	102.1%
		RO	HL 220kV LOTRU-SIBIU	2	277.4MVA	275.6MVA	102.1%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	307.7MVA	115.5%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	298.9MVA	154.1%
		CS	TR 400/220kV/kV JTKOSB1	1	400MVA	432MVA	108.0%
		CS	TR 400/220kV/kV JTKOSB1	2	400MVA	451.4MVA	112.9%
		CS	TR 400/220kV/kV JTKOSB1	3	400MVA	451.4MVA	112.9%
AL	OHL 220kV AVDEJA2 -ATIRAN2 1	AL	HL 220kV AKASHA2-ARRAZH2	1	270MVA	275.2MVA	123.9%
AL	OHL 220kV ATIRAN2 -AKASHA2 1	AL	HL 220kV AKASHA2-ARRAZH2	1	270MVA	274.6MVA	111.1%
IN	OHL 400kV KONJSKO -MO-4 1	HR	HL 220kV XRA_ZA21-HE ZAKUC	1	297MVA	343.9MVA	115.1%
IN	OHL 400kV ISACCEA -DOBRUD4 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	506.7MVA	126.7%
RO	OHL 220kV STUPARE -BRADU 1	RO	HL 220kV AREF-RIURENI	1	277.4MVA	252.6MVA	106.6%
RO	OHL 220kV URECHESI-SARDANE 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	455.2MVA	113.8%
RO	OHL 220kV URECHESI-TG.JIU 1	RO	HL 400kV MINTIA-SIBIU	1	381.1MVA	387.2MVA	116.9%
		RO	HL 220kV P.D.F.A-RESITA	1	277.4MVA	269.1MVA	108.8%
		RO	HL 220kV P.D.F.A-RESITA	2	277.4MVA	269.1MVA	108.8%
		RO	HL 220kV PESTIS-MINTIA A	1	277.4MVA	256.1MVA	105.5%
RO	OHL 220kV P.D.F.A -CALAFAT 1	RO	HL 220kV P.D.F.A-CETATE1	1	208.1MVA	259.6MVA	129.9%
RO	OHL 220kV P.D.F.A -RESITA 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	504MVA	126.0%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	325.7MVA	123.6%
		RO	HL 220kV P.D.F.A-RESITA	2	277.4MVA	355.4MVA	145.4%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	315.2MVA	165.0%
RO	OHL 220kV RESITA -TIMIS 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	494.2MVA	123.6%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	317.8MVA	119.9%
		RO	HL 220kV RESITA-TIMIS	2	277.4MVA	351.8MVA	136.8%
RO	OHL 220kV CRAIOV A-TR. MAG 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	464.8MVA	116.2%
RO	OHL 220kV CRAIOV B-ISALNI A 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	499.6MVA	124.9%
RO	OHL 220kV TG.JIU -PAROSEN 1	RO	HL 400kV MINTIA-SIBIU	1	381.1MVA	386.7MVA	117.0%
		RO	HL 220kV P.D.F.A-RESITA	1	277.4MVA	269.1MVA	109.0%
		RO	HL 220kV P.D.F.A-RESITA	2	277.4MVA	269.1MVA	109.0%
		RO	HL 220kV PESTIS-MINTIA A	1	277.4MVA	257.2MVA	106.3%
RO	OHL 220kV PESTIS -MINTIA A 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	507.3MVA	126.8%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	326MVA	124.6%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	313.5MVA	166.4%
RO	OHL 220kV MINTIA B-AL.JL 1	RO	HL 400kV GADALIN-CLUJ E	1	238.3MVA	216.3MVA	101.8%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	296.3MVA	111.1%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	288.2MVA	148.3%
RO	OHL 220kV FUNDENI -BUC.S-B 1	RO	HL 220kV BRADU-TIRGOVI	1	302.6MVA	273.6MVA	108.2%
		RO	HL 220kV BUC.S-B-FUNDENI	1	320MVA	389.3MVA	134.8%
RO	OHL 220kV STEJARU -GHEORGH 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	495.9MVA	124.0%
		RO	TR 400/220kV/kV IERNUT	1	400MVA	487.2MVA	121.8%
RO	OHL 220kV GHEORGH -FINTINE 1	RO	TR 400/220kV/kV IERNUT	1	400MVA	412.5MVA	103.1%
RO	OHL 220kV CLUJ FL -MARISEL 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	497MVA	124.3%
RO	OHL 220kV CLUJ FL -AL.JL 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	471.7MVA	117.9%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	294.1MVA	110.1%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	286.3MVA	146.9%
RO	OHL 220kV AL.JL -GILCEAG 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	514.1MVA	128.5%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	333MVA	127.8%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	320.8MVA	170.6%
RO	OHL 220kV BRAZI A-TELEAJEN 1	RO	HL 220kV BUC.S-B-FUNDENI	1	320MVA	307.4MVA	105.4%
RO	OHL 220kV TELEAJEN-STILPU 1	RO	HL 220kV BUC.S-B-FUNDENI	1	320MVA	307.8MVA	105.6%
RO	OHL 400kV TANTAREN-URECHESI 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	467.2MVA	116.8%
RO	OHL 400kV TANTAREN-SLATINA 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	559.7MVA	139.9%
		RO	HL 220kV BRADU-TIRGOVI	1	302.6MVA	272.9MVA	104.1%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	292.5MVA	112.9%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	284.5MVA	150.6%

Area	contingency	Area	overloadings / out of limits voltages	#	limit / Unom	Flow / Voltage	rate / volt.dev.
1	2	3	4	5	6	7	8
RO	OHL 400kV URECHESI-P.D.FIE 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	451.1MVA	112.8%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	290.7MVA	108.8%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	282.7MVA	145.2%
RO	OHL 400kV URECHESI-DOMNESTI 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	551.6MVA	137.9%
		RO	HL 220kV BRADU-TIRGOVI	1	302.6MVA	274.9MVA	106.9%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	329.2MVA	125.9%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	318.2MVA	168.0%
RO	OHL 400kV MINTIA -ARAD 1	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	295.6MVA	113.4%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	283.8MVA	151.7%
RO	OHL 400kV MINTIA -SIBIU 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	527.9MVA	132.0%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	355.6MVA	135.8%
		RO	HL 220kV P.D.F.A-RESITA	1	277.4MVA	262.9MVA	103.9%
		RO	HL 220kV P.D.F.A-RESITA	2	277.4MVA	262.9MVA	103.9%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	343.2MVA	181.2%
RO	OHL 400kV P.D.FIE -SLATINA 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	518.9MVA	129.7%
RO	OHL 400kV DOMNESTI-BUC.S 1	RO	HL 220kV BUC.S-B-FUNDENI	1	320MVA	327.2MVA	110.4%
RO	OHL 400kV DOMNESTI-BRAZI 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	505.8MVA	126.4%
		RO	TR 400/220kV/kV BUC.S	1	400MVA	436MVA	109.0%
		RO	TR 400/220kV/kV BUC.S	2	400MVA	436MVA	109.0%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	323.6MVA	123.6%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	312.2MVA	165.0%
		RO	HL 220kV BUC.S-B-FUNDENI	1	320MVA	374.2MVA	131.0%
RO	OHL 400kV GR.IAL -L.SARAT 1	RO	HL 220kV BUC.S-B-FUNDENI	1	320MVA	304.5MVA	103.3%
RO	OHL 400kV GR.IAL -CERNAV 1	RO	HL 400kV GR.IAL-CERNAV	2	791.2MVA	775.9MVA	102.0%
RO	OHL 400kV GR.IAL -CERNAV 2	RO	HL 400kV GR.IAL-CERNAV	1	791.2MVA	773.4MVA	101.6%
RO	OHL 400kV BACAU -ROMAN 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	493.8MVA	123.5%
RO	OHL 400kV BRASOV -BRADU 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	498.6MVA	124.7%
		RO	HL 220kV BRADU-TIRGOVI	1	302.6MVA	304.9MVA	114.7%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	319.2MVA	121.2%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	309MVA	161.7%
RO	OHL 400kV IERNUT -GADALIN 1	RO	HL 400kV MINTIA-SIBIU	1	381.1MVA	345.1MVA	102.9%
		RO	TR 400/220kV/kV IERNUT	1	400MVA	413.3MVA	103.3%
CS	OHL 220kV JBBAST2 -JBGD3 21 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	314.9MVA	110.0%
CS	OHL 220kV JBGD172 -JBGD8 22 1	CS	HL 220kV JBGD172-JBGD8 22	2	365.8MVA	488.5MVA	144.0%
CS	OHL 220kV JBGD3 22-JBGD8 21 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	308.5MVA	107.6%
CS	OHL 220kV JBGD3 22-JBGD8 22 2	CS	TR 400/220kV/kV JBGD8 1	1	400MVA	425.8MVA	106.5%
CS	OHL 220kV JHIP 2 -JPANC22 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	296.7MVA	103.4%
CS	OHL 220kV JLESK22 -JNIS 22 1	CS	TR 400/220kV/kV JTKOSB1	1	400MVA	443.8MVA	111.0%
		CS	TR 400/220kV/kV JTKOSB1	2	400MVA	463.8MVA	115.9%
		CS	TR 400/220kV/kV JTKOSB1	3	400MVA	463.8MVA	115.9%
CS	OHL 220kV JNSAD32 -JOBREN2 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	303.6MVA	105.2%
CS	OHL 220kV JNSAD32 -JZREN22 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	303.6MVA	106.0%
CS	OHL 220kV JOBREN2 -JVALJ32 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	291MVA	100.8%
CS	OHL 220kV JTKOSA2 -JTKOSB2 1	CS	HL 220kV JTKOSA2-JTKOSB2	2	365.8MVA	453.9MVA	119.0%
CS	OHL 400kV JBGD8 1 -JOBREN11 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	490.7MVA	187.1%
		CS	HL 220kV JBGD3 22-JBGD8 22	2	365.8MVA	337MVA	108.2%
CS	OHL 400kV JBGD8 1 -JBGD201 A	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	298.4MVA	104.1%
CS	OHL 400kV JBOR 21 -JHDJE11 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	494.5MVA	123.6%
CS	OHL 400kV JNIS2 1 -JJAGO41 A	RO	TR 400/220kV/kV URECHESI	1	400MVA	496.6MVA	124.1%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	319.6MVA	121.0%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	309.6MVA	161.5%
		CS	TR 400/220kV/kV JTKOSB1	1	400MVA	444.6MVA	111.1%
		CS	TR 400/220kV/kV JTKOSB1	2	400MVA	464.6MVA	116.1%
		CS	TR 400/220kV/kV JTKOSB1	3	400MVA	464.6MVA	116.1%
CS	OHL 400kV JNSAD31 -JSUBO31 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	511.8MVA	128.0%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	331.7MVA	126.7%
		RO	HL 220kV P.D.F.A-RESITA	1	277.4MVA	266.3MVA	106.1%
		RO	HL 220kV P.D.F.A-RESITA	2	277.4MVA	266.3MVA	106.1%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	320.3MVA	169.1%
CS	OHL 400kV JOBREN12-JTKOLB1 A	RO	TR 400/220kV/kV URECHESI	1	400MVA	501MVA	125.3%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	323.4MVA	122.9%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	313MVA	164.0%
CS	OHL 400kV JPANC21 -JTDRMN1 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	313MVA	110.1%
CS	OHL 400kV JRPMLA1 -JSMIT21 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	497MVA	124.2%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	318.6MVA	120.6%
BG	TR 400/110 CAREVEC 1	BG	TR 400/110kV/kV CAREVEC	2	275MVA	281.3MVA	102.3%
CS	TR 400/110 JBGD20 A	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	289.5MVA	100.6%
CS	TR 400/110 JKRAG2 1	CS	TR 400/110kV/kV JKRAG21	2	300MVA	314.1MVA	104.7%
CS	TR 400/110 JNIS2 1	CS	TR 400/110kV/kV JNIS2 1	2	300MVA	353.3MVA	117.8%
CS	TR 400/110 JPANC2 1	CS	TR 400/110kV/kV JPANC21	2	300MVA	327.4MVA	109.1%
CS	TR 400/110 JPEC A	CS	TR 400/220kV/kV JTKOSB1	1	400MVA	472.2MVA	118.1%
		CS	TR 400/220kV/kV JTKOSB1	2	400MVA	493.4MVA	123.4%
		CS	TR 400/220kV/kV JTKOSB1	3	400MVA	493.4MVA	123.4%
BG	TR 400/110 PLOVDIV 1	BG	TR 400/110kV/kV PLOVDIV4	2	275MVA	284.4MVA	103.4%
MK	TR 400/110 SK 1 1	CS	TR 400/220kV/kV JTKOSB1	1	400MVA	448.2MVA	112.0%
		CS	TR 400/220kV/kV JTKOSB1	2	400MVA	468.3MVA	117.1%
		CS	TR 400/220kV/kV JTKOSB1	3	400MVA	468.3MVA	117.1%
RO	TR 400/110 SMIRDAN 1	RO	HL 220kV L.SARAT-FILESTI	1	277.4MVA	302.2MVA	113.5%
RO	TR 400/220 BRAZI 1	RO	TR 400/220kV/kV BUC.S	1	400MVA	447MVA	111.8%
		RO	TR 400/220kV/kV BUC.S	2	400MVA	447MVA	111.8%
		RO	HL 220kV BRADU-TIRGOVI	1	302.6MVA	302.8MVA	123.3%
		RO	HL 220kV FUNDENI-BUC.S-B	1	320MVA	290.1MVA	104.0%

Area	contingency	Area	overloadings / out of limits voltages	#	limit / Unom	Flow / Voltage	rate / volt.dev.
1	2	3	4	5	6	7	8
		RO	HL 220kV BUC.S-B-FUNDENI	1	320MVA	387.2MVA	138.6%
RO	TR 400/220 BUC.S 1	RO	TR 400/220kV/kV BUC.S	2	400MVA	577.8MVA	144.4%
CS	TR 400/220 JBGD8 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	340.4MVA	120.3%
		CS	HL 220kV JBGD3 22-JBGD8 22	2	365.8MVA	398.3MVA	118.3%
CS	TR 400/220 JBGD8 2	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	315.3MVA	110.4%
CS	TR 400/220 JNIS2 1	CS	TR 400/220kV/kV JTKOSB1	1	400MVA	447.5MVA	111.9%
		CS	TR 400/220kV/kV JTKOSB1	2	400MVA	467.6MVA	116.9%
		CS	TR 400/220kV/kV JTKOSB1	3	400MVA	467.6MVA	116.9%
CS	TR 400/220 JTKOSB 1	CS	TR 400/220kV/kV JTKOSB1	2	400MVA	610MVA	152.5%
		CS	TR 400/220kV/kV JTKOSB1	3	400MVA	610MVA	152.5%
RO	TR 400/220 MINTIA 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	501.5MVA	125.4%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	323MVA	122.7%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	311.7MVA	163.7%
RO	TR 400/220 SIBIU 1	RO	TR 400/220kV/kV SIBIU	2	400MVA	490.9MVA	122.7%
RO	TR 400/220 SLATINA 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	518.8MVA	129.7%
		RO	TR 400/220kV/kV SLATINA	2	400MVA	460.5MVA	115.1%

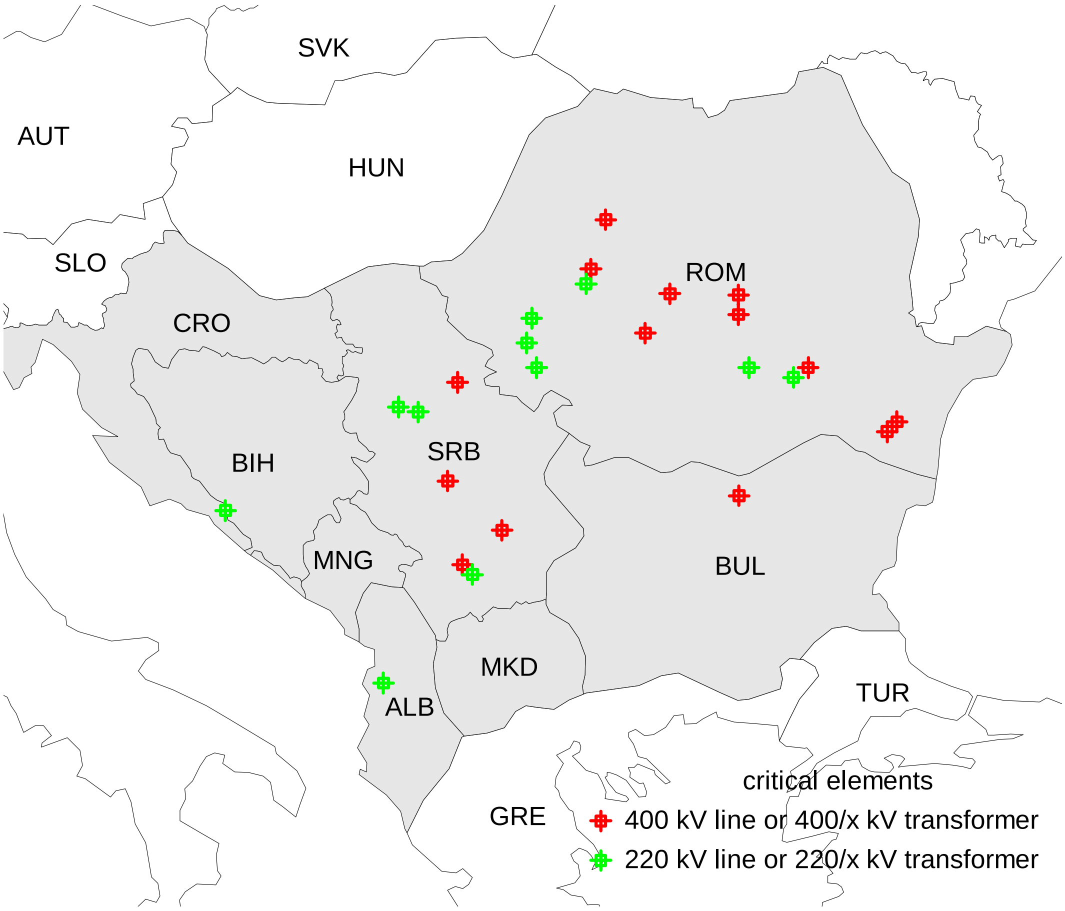


Figure 5.5.6 – geographical position of critical elements for 2015-average hydrology high load scenario – topology 2010

Some of these problems identified are connected to the problem of new generation units implemented in the model. For some, there is great insecurity how these units will be connected to the transmission network, especially in the case of new generation capacities in Kosovo B region (Serbia-UNIMK). In this regime new 3000 MW generation capacity is analyzed. Problem of feasible connection of such a large generation capacity is not in the scope of this study and separate study, that will analyze this problem alone is necessary to give right answer to this question.

All in all, it can be concluded that this regime is not feasible without major reinforcement of transmission network.

5.6 Scenario 2015 – average hydrology – high load – topology 2015

This part of the Study presents the results of static load flow and voltage profile analyses that are conducted for complete network topology and (n-1) contingencies in the scenario which is denoted as GTmax run for year 2015 - average hydrology high load scenario and expected network topology for 2015 and new planned generation capacities implemented.

5.6.1 Lines loadings

Figure 5.6.1 shows power exchanges between areas for 2015-average hydrology high load scenario. Power flows along interconnection lines in the region together with balances of the systems are shown in Figure 5.6.2. Area totals are shown in Table 5.6.1 and comparison of the average hydro regimes with normal load projection and high load projection is shown in Table 5.6.2. Difference of load-demand level for these two regimes is around 8.11% on regional level. As a consequence of this high load level, network losses are increased by 251 MW or 25%. Figure 5.6.3 shows histogram of tie lines loadings. It is concluded that most of the tie lines are loaded less than 50% of their thermal limits.

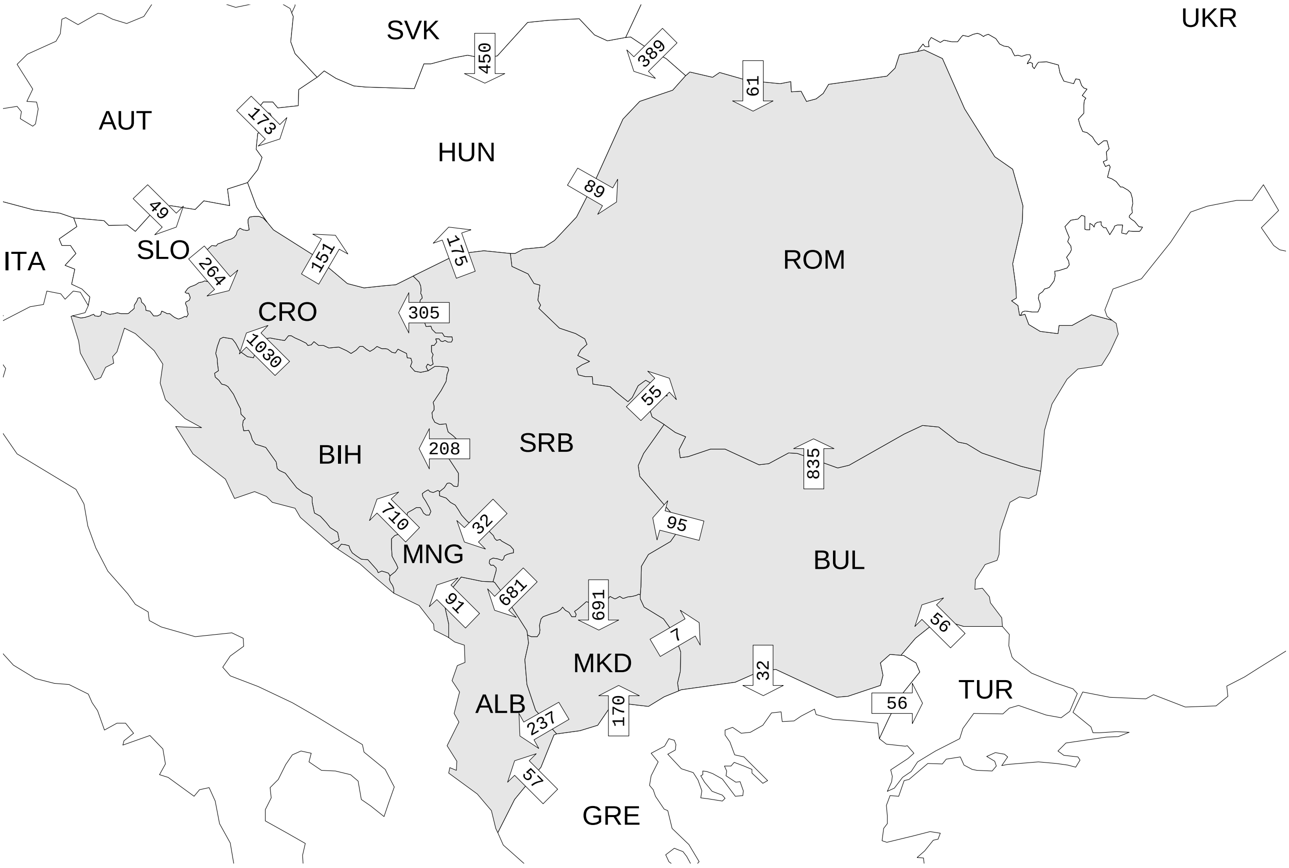


Figure 5.6.1 - Area exchanges in analyzed electric power systems for 2015-average hydrology high load scenario – 2015 topology

As it can be seen, new elements that are expected to be build till 2015 cause totally different distribution of power flows in the southern part of the region (Albania, FYR of Macedonia, Serbia and Montenegro). Compared to the expected topology 2010, analyzed in previous chapter, it can be seen that the network losses are decreased as a consequence of building of new elements for 2015 network topology, especially in the cases of Albania, Serbia and Montenegro. Overall reduction of loses is around 39 MW.

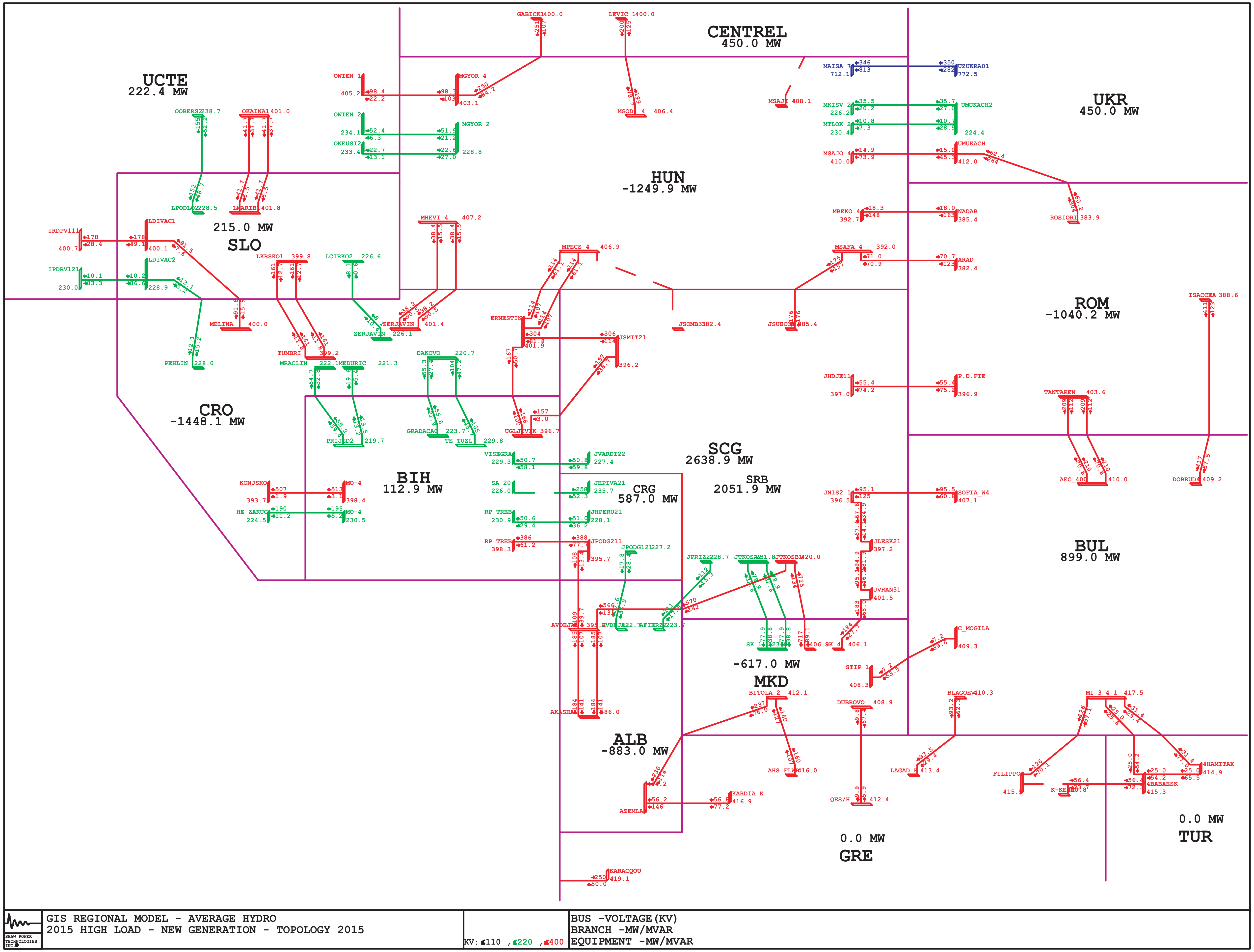


Figure 5.6.2 - Power flows along interconnection lines in the region with balances of the systems for 2015-dry hydrology scenario

Table 5.6.1 - Area totals in analyzed electric power systems for 2015-average hydrology high load scenario – 2015 topology

AREA	GENERATION	LOAD	LOSSES	INTERCHANGE
ALBANIA	897.7	1684	96.7	-883
BULGARIA	8157.4	7083	175.4	899
BIH	2479.7	2272	94.7	112.9
CROATIA	2592.1	3959	81.1	-1448.1
MACEDONIA	895.7	1489	23.7	-617
ROMANIA	7676.4	8269.8	446.7	-1040.1
SERBIA	10023.9	7660	311.9	2051.9
MONTENEGRO	1322.6	708	27.6	587
TOTALS	34045.5	33124.8	1257.8	-337.4

Table 5.6.2 - Comparison of Area totals in analyzed electric power systems for 2015- average hydrology versus average hydrology high load scenario –2015 topology

AREA	LOAD			LOSSES		
	normal load	high load		normal load	high load	
ALBANIA	1541	1684	9.28%	73.1	96.7	32.28%
BULGARIA	6483	7083	9.25%	150.9	175.4	16.24%
BIH	2279	2272	-0.31%	79.2	94.7	19.57%
CROATIA	3657	3959	8.26%	64	81.1	26.72%
MACEDONIA	1407	1489	5.83%	21.4	23.7	10.75%
ROMANIA	7317.4	8269.8	13.02%	343.1	446.7	30.2%
SERBIA	7279	7660	5.23%	254.4	311.9	22.6%
MONTENEGRO	676	708	4.73%	20.3	27.6	35.96%
TOTALS	30639.4	33124.8	8.11%	1006.4	1257.8	24.98%

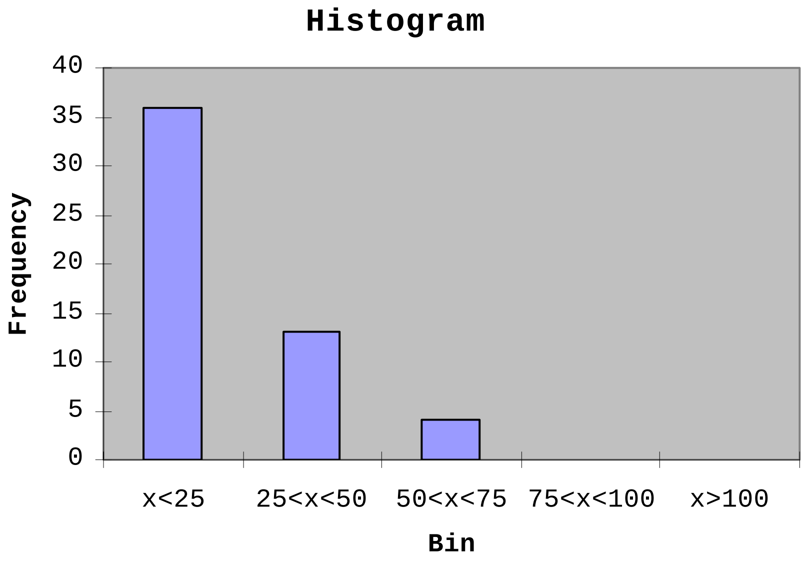


Figure 5.6.3 - Histogram of interconnection lines loadings for 2015-average hydrology high load scenario – 2015 topology ("Frequency" denotes number of lines and "Bin" denotes loading range in % of thermal limit)

Following Table 5.6.3 shows all network elements loaded over 80% of their thermal limits. Histogram of branch loadings in the system is shown in Figure 5.6.4. As it can be seen large number of lines 220 kV voltage level in Albania, Romania and Serbia are loaded over 80% for the reasons described in previous chapter in detail. It can be concluded that new expected network topology for 2015 compared to 2010 topology has small influence in overall load level of the transmission network. Almost the same elements are found critical as for topology 2010, especially in parts of the network that supply major consumption areas (Tirana in Albania, Bucharest and Timisoara in Romania, Belgrade in Serbia and Pristina in Serbia-UNMIK).

Table 5.6.3 - Network elements loaded over 80% of their thermal limits for 2015-average hydrology high load scenario – 2015 topology

BRANCH LOADINGS ABOVE 80.0 % OF RATING:

AREA	ELEMENT	LOADING MVA	RATING MVA	PERCENT
	Lines			
ALB	HL 220kV AKASHA2-ARRAZH2 1	290.4	270	107.6
ROM	HL 220kV BRADU-TIRGOVI 1	283.9	302.6	93.8
	HL 220kV BUC.S-B-FUNDENI 1	307.5	320	96.1
	HL 220kV FILESTI-BARBOSI 1	245.8	277.4	88.6
	HL 220kV L.SARAT-FILESTI 1	239	277.4	86.2
	HL 220kV LOTRU-SIBIU 1	281.2	277.4	101.4
	HL 220kV LOTRU-SIBIU 2	281.2	277.4	101.4
	HL 220kV P.D.F.A-CETATE1 1	206.3	208.1	99.1
	HL 220kV P.D.F.A-RESITA 1	262.1	277.4	94.5
	HL 220kV P.D.F.A-RESITA 2	262.1	277.4	94.5
	HL 220kV P.D.F.II-CETATE1 1	269.9	277.4	97.3
	HL 220kV RESITA-TIMIS 1	225	277.4	81.1
	HL 220kV RESITA-TIMIS 2	225	277.4	81.1
	HL 220kV TG.JIU-PAROSEN 1	313.8	208.1	150.8
	HL 220kV URECHESI-TG.JIU 1	313.5	277.4	113
SRB	HL 220kV JBGD3 21-JOBREN2 1	292	301	97
	Transformers			
ALB	TR 220/110 kV ABURRE 1	52.2	60	87
	TR 220/110 kV ABURRE 2	52.2	60	87
	TR 220/110 kV ABURRE 3	52.2	60	87
	TR 220/110 kV AELBS1 1	87.8	90	97.6
	TR 220/110 kV AELBS1 2	87.8	90	97.6
	TR 220/110 kV AELBS1 3	94.4	90	104.8
	TR 220/110 kV AFIER 1	151.7	120	126.4
	TR 220/110 kV AFIER 2	124.4	90	138.2
	TR 220/110 kV AFIER 3	118.7	90	131.9
	TR 220/110 kV AFIERZ 1	59.9	60	99.8
	TR 220/110 kV AFIERZ 2	59.9	60	99.8
	TR 220/110 kV AKASHA 1	94.7	100	94.7
	TR 220/110 kV AKASHA 2	94.7	100	94.7
	TR 220/110 kV ARRAZH 1	87.5	100	87.5
	TR 220/110 kV ARRAZH 2	87.5	100	87.5
	TR 220/110 kV ATIRAN 2	96.4	120	80.3
	TR 220/110 kV ATIRAN 3	100.6	120	83.9
BIH	TR 220/110 kV MO-4 3	124.4	150	83
	TR 400/110 kV UGLJEV 1	256.1	300	85.4
CRO	TR 220/110 kV TESISA 1	179.4	200	89.7
ROM	TR 220/110 kV BARBOS 1	166.6	200	83.3
	TR 220/110 kV FUNDE2 1	239.8	200	119.9
	TR 220/110 kV FUNDEN 1	203	200	101.5
	TR 220/110 kV TIMIS 1	170.4	200	85.2
	TR 400/110 kV BRASOV 1	230.2	250	92.1
	TR 400/110 kV CLUJ E 1	206.4	250	82.6
	TR 400/110 kV DIRSTE 1	219.6	250	87.8
	TR 400/220 kV BUC.S 1	376.5	400	94.1
	TR 400/220 kV BUC.S 2	376.5	400	94.1
	TR 400/220 kV IERNUT 1	404.8	400	101.2
	TR 400/220 kV URECHE 1	479.7	400	119.9
SRB	TR 220/110 kV JBGD3 1	174.8	200	87.4
	TR 220/110 kV JBGD3 2	137.5	150	91.7
	TR 220/110 kV JTKOSA 2	133.5	150	89
	TR 220/110 kV JTKOSA 3	135.9	150	90.6
	TR 220/110 kV JZREN2 2	133.8	150	89.2
	TR 400/220 kV JBGD8 1	330.3	400	82.6
	TR 400/220 kV JTKOSB 1	351.9	400	88
	TR 400/220 kV JTKOSB 2	367.7	400	91.9
	TR 400/220 kV JTKOSB 3	367.7	400	91.9
MNG	TR 220/110 kV JTPLJE 1	102.4	125	82

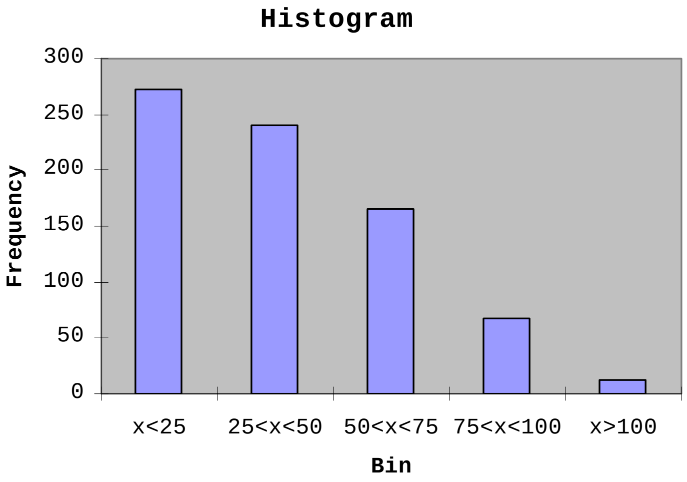


Figure 5.6.4 - Histogram of branch loadings for 2015-average hydrology scenario – 2015 topology ("Frequency" denotes number of lines and "Bin" denotes loading range in % of thermal limit)

This leads to conclusion that planned network reinforcements compared to network topology 2010, reduce loading of some elements in southern part of Serbia, and that in order for transmission network to sustain this load-demand level and this production pattern, additional network reinforcements are necessary, especially in increasing transformer capacity in substations that supply major consumption areas in Albania, Romania and Serbia.

5.6.2 Voltage Profile in the Region

Figure 5.6.5 shows histogram of voltages in monitored substations. Like for the investigated topology 2010, overall voltage profile is not adequate, but comparing to 2010 topology voltage profile is much better in monitored parts of Albanian and Serbian network. In some parts of the network, especially in major consumption areas of Romania, voltages in some monitored substations are below allowed limits. Using of voltage control devices (tap changing transformers, shunt devices) can improve voltage profile in this region, but it can be concluded that conditions in some parts of the transmission network of Romania are dangerously close to voltage collapse. Since this is local problem, detailed analyses is necessary to analyze this situation.

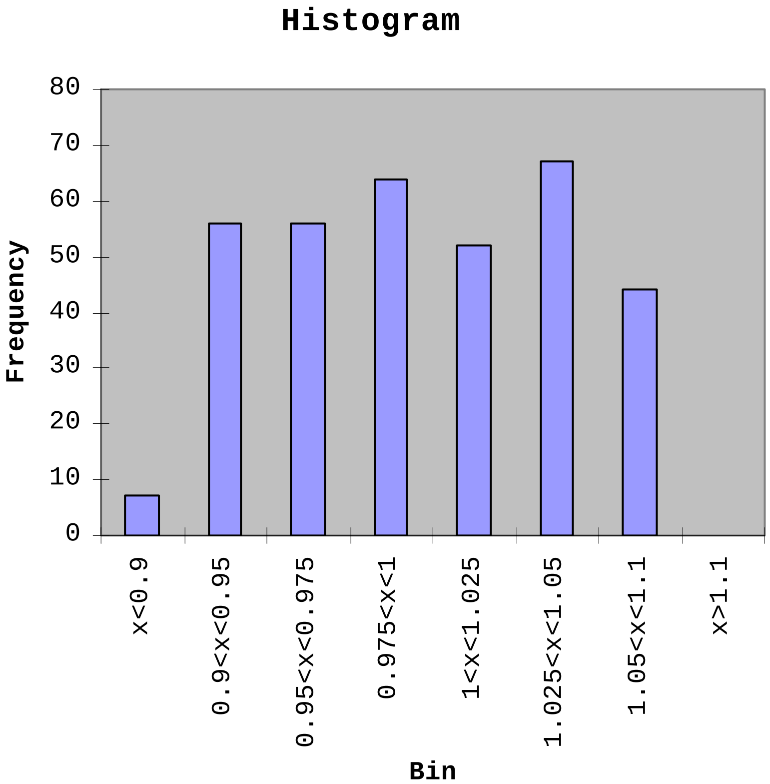


Figure 5.6.5 - Histogram of voltages in monitored substations for 2015-average hydrology high load scenario – 2015 topology ("Frequency" denotes number of busses and "Bin" denotes voltage range in p.u.)

5.6.3 Security (n-1) analysis

Results of security (n-1) analysis for 2015-average hydrology high load scenario and expected network topology for 2015 are presented in Table 5.6.4. Figure 5.6.6 shows the geographical position of the critical elements in monitored systems.

Like for expected topology 2010 (previous chapter), it can be concluded that all identified insecure situations are located in internal networks that belong to monitored power systems of Albania, Romania and Serbia. Also, the planned network reinforcements till 2015 resolve some of the noticed critical contingencies, especially in southern part of Serbia. Compared to the similar scenario with normal load projection, it can be concluded that higher load-demand projected and new production capacities modeled, increase the overload level of some critical elements. The rest of the conclusions are the same as in case of the analyzed normal load projection and expected topology 2015, and that is that certain level of network reinforcement is necessary to make this regime more secure.

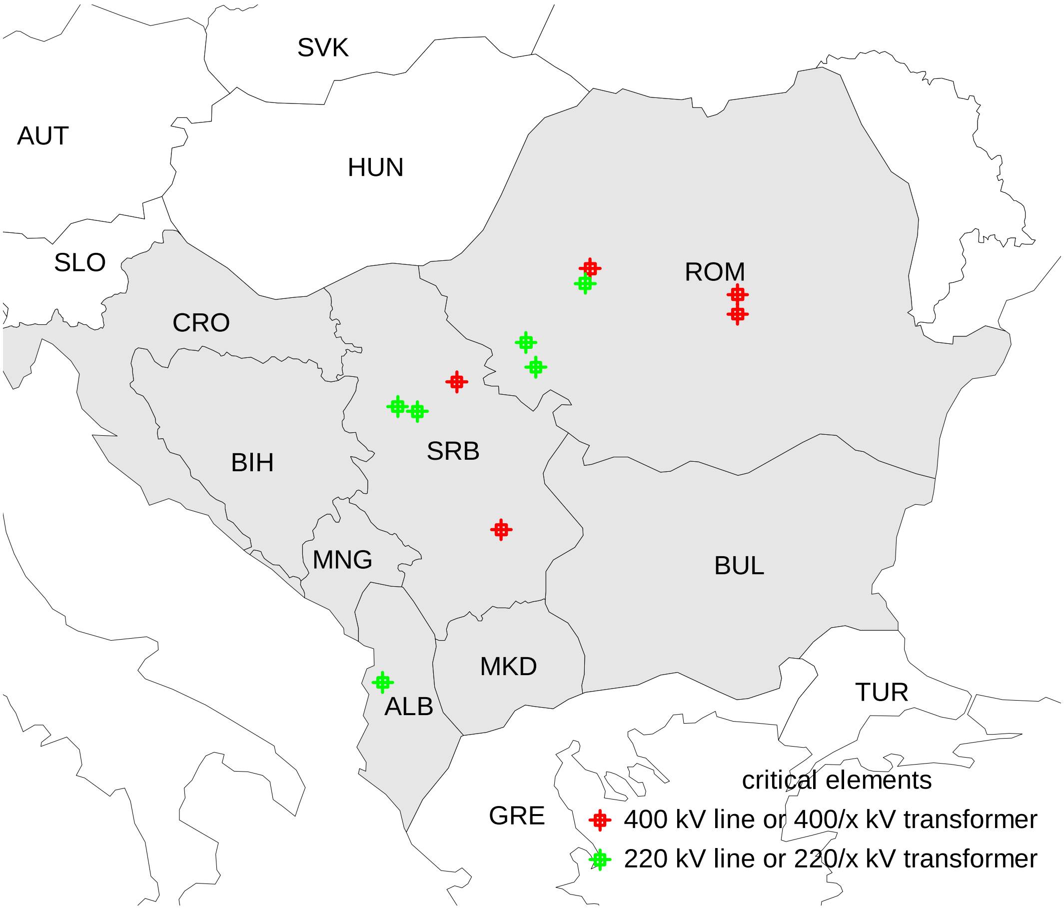


Figure 5.6.6 – geographical position of critical elements for 2015-average hydrology high load scenario – 2015 topology

Table 5.6.4 - Network overloadings for 2015-average hydrology high load scenario , single outages – 2015 topology

Area	contingency	Area	overloadings / out of limits voltages	#	limit / Unom	Flow / Voltage	rate / volt.dev.
1	2	3	4	5	6	7	8
	BASE CASE	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	285.6MVA	100.1%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	285.6MVA	133.5%
AL	OHL 220kV AELBS12 -AFIER 2 1	AL	HL 220kV AKASHA2-ARRAZH2	1	270MVA	289.9MVA	112.2%
RO	OHL 220kV P.D.F.A -RESITA 1	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	301.5MVA	106.1%
		RO	HL 220kV P.D.F.A-RESITA	2	277.4MVA	331.5MVA	122.8%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	301.5MVA	141.4%
RO	OHL 220kV RESITA -TIMIS 1	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	295.7MVA	103.9%
		RO	HL 220kV RESITA-TIMIS	2	277.4MVA	348.7MVA	127.0%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	295.7MVA	138.5%
RO	OHL 220kV PESTIS -MINTIA A 1	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	296.3MVA	104.8%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	290.4MVA	139.7%
RO	OHL 220kV CLUJ FL -AL.JL 1	RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	271MVA	126.4%
RO	OHL 220kV AL.JL -GILCEAG 1	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	308.8MVA	109.1%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	308.8MVA	145.4%
RO	OHL 400kV TANTAREN-URECHESI 1	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	292.5MVA	102.6%
RO	OHL 400kV TANTAREN-BRADU 1	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	300.1MVA	105.9%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	300.1MVA	141.1%
RO	OHL 400kV TANTAREN-SIBIU 1	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	331.1MVA	117.3%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	331.1MVA	156.4%
RO	OHL 400kV URECHESI-P.D.FIE 1	RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	268.7MVA	124.5%
RO	OHL 400kV URECHESI-DOMNESTI 1	RO	TR 400/220kV/kV URECHESI	1	400MVA	400.6MVA	100.1%
		RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	305.6MVA	107.7%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	305.6MVA	143.6%
RO	OHL 400kV MINTIA -ARAD 1	RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	263.1MVA	123.1%
RO	OHL 400kV MINTIA -SIBIU 1	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	326.2MVA	115.5%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	326.2MVA	153.9%
RO	OHL 400kV DOMNESTI-BRAZI 1	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	296.2MVA	104.0%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	296.2MVA	138.7%
RO	OHL 400kV SMIRDAN -GUTINAS 1	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	296.9MVA	104.5%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	296.9MVA	139.3%
RO	OHL 400kV BRASOV -BRADU 1	RO	HL 220kV URECHESI-TG.JIU	1	277.4MVA	296.3MVA	104.3%
		RO	HL 220kV TG.JIU-PAROSEN	1	208.1MVA	296.3MVA	139.0%
CS	OHL 220kV JBGD172 -JBGD8 22 1	CS	HL 220kV JBGD172-JBGD8 22	2	365.8MVA	453.5MVA	129.0%
CS	OHL 400kV JBGD8 1 -JOBREN11 1	CS	HL 220kV JBGD3 21-JOBREN2	1	301MVA	293.8MVA	102.6%
RO	TR 400/110 BRASOV 1	RO	TR 400/110kV/kV DIRSTE	1	250MVA	353.9MVA	141.6%
RO	TR 400/110 DIRSTE 1	RO	TR 400/110kV/kV BRASOV	1	250MVA	350MVA	140.0%
CS	TR 400/110 JNIS2 1	CS	TR 400/110kV/kV JNIS2 1	2	300MVA	323.1MVA	107.7%
CS	TR 400/110 JPANC2 1	CS	TR 400/110kV/kV JPANC21	2	300MVA	318.8MVA	106.3%
RO	TR 400/220 BUC.S 1	RO	TR 400/220kV/kV BUC.S	2	400MVA	405.6MVA	101.4%
RO	TR 400/220 IERNUT 1	RO	HL 220kV STEJARU-GHEORGH	1	208.1MVA	196.5MVA	106.0%

5.6.4 Summary of Impacts - 2015 topology versus 2010 topology

Compared to the expected topology 2010, analyzed in previous chapter, it can be seen that the network losses are smaller as a consequence of building of new elements for 2015 network topology, especially in the cases of Albania, Serbia and Montenegro. Overall reduction of loses is around 39 MW.

Also, planned network reinforcements compared to network topology 2010, reduce load of some elements in southern part of Serbia. Compared to the 2010 topology, voltage profile is somewhat better, especially in southern and central part of Serbia, as well as in Albania. This is direct consequence of the building of the new 400 kV line Nis-Leskovac-Vranje-Skopje and substation 400/110 kV Vranje. However, voltage profile is still not satisfying.

Realization of the planed investments till 2015 has impact on secure operation of the network. Some of the insecure states identified with 2010 topology are relieved and do not exist with expected 2015 network topology.

Main conclusion can be that even with 2015 topology, this load-generation regime is not feasible enough and additional network reinforcements are necessary, especially in the major consumption area.

6 ANALYSES SUMMARY AND RECOMMENDATIONS

In this chapter, comparison of the all analyzed scenarios is presented. Main issues are impact of different generation patterns and planed network investments on system losses and system security. The authors tried to give main indicators how to resolve some insecure states identified, based on prerequisites and assumptions presented in Chapter 2 and only results of the analyses of scenarios. Deeper impacts of the proposed remedies are not analyzed whether they are or not in compliance with long term investments plans of the countries in the region.

6.1 Reference cases

Reference cases consist of nine cases. Three different hydrology scenarios are analyzed (average, dry and wet) for years 2010 and 2015. Also, for each of these generation-load patterns in year 2015 two cases are analyzed (first for 2010 topology, i.e. without any new line or transformer planned for commissioning between 2010 and 2015 and second for expected topology in year 2015).

6.1.1 Analyses comparison

Main focus of this subchapter is to analyze influence of different generation patterns and planed network investments on overall network performance and system losses.

Table 6.1.1 shows overview of losses on regional level. It can be seen that new elements planned for commissioning between 2010 and 2015 influence reduction of losses in analyzed region, no matter of hydrology. This reduction of losses is between 30 and 40 MW.

Table 6.1.1: Peak Hour - Regional Losses (MW)

Topology	Year 2010			Year 2015		
	Dry	Average	Wet	Dry	Average	Wet
2010	756.9	737.1	741.5	951.6	1,035.1	976.6
2015	-	-	-	909.6	1,006.4	941.8

These changes are consequence of better voltage profile in analyzed region, especially in areas directly influenced by the new elements. For example, new interconnection line Nis-Leskovac-Vranje-Skopje greatly improves voltage profile in southern part of Serbia and new interconnection lines Podgorica – V.Dejes – Kashar – Elbasan and Kosovo B – V.Dejes – Kashar – Elbasan greatly improve voltage profile in Albania. Higher voltages and reduction of load of some elements that are highly influenced by the new elements, reduce power losses mainly in Albania, Southern Serbia, and in the region as whole.

Table 6.1.2 shows overview of area summaries for analyzed reference cases. Comparing cases with different hydrology (for the same year and topology) it can be concluded following:

- Since analyzed region is balanced, deficit of power produced by hydro power plants is compensated by greater power produced by thermal power plants. Different hydrology causes different generation and interchange patterns.
- Because of different generation and interchange patterns, power flows are different and this cause different level of losses, but it is not possible to establish clear connection between these factors.
- Level of intersystem interchanges is much higher than in present or history. It has to be stated that networks of single systems are developed mainly to cover their demand with their own production capacities, so this kind of power plant engagement and level of interchanges cause power flows and network status that are different from ones recorded. This goes especially Albanian and Serbian system.

Table 6.1.2: Overview of area summaries for analyzed reference cases (in MW)

Year	Hydrology	Topology	Data type	Albania	B & H	Bulgaria	Croatia	Macedonia	Montenegro	Romania	Serbia	*Total (SE Europe)*
2010	Average	2010	Generation	896.7	2266.1	6900.4	1502.9	950.3	539.8	7939.9	7355.9	28351.9
			Load	1287.3	1971.3	5977.3	3136.7	1198.2	669.2	6728.3	6873.1	27841.4
			Losses	50.4	58.6	121.6	49.0	20.1	15.5	201.2	220.8	737.1
			Interchange	-441.0	236.2	787.0	-1682.8	-268.0	-147.0	930.4	248.4	-336.7
	Dry	2010	Generation	953.3	2842.4	6709.6	2294.6	1021.1	467.8	6742.0	7311.7	28342.5
			Load	1290.5	1989.0	5970.0	3147.0	1206.0	671.0	6703.8	6944.0	27921.3
			Losses	46.8	60.3	133.6	41.6	18.1	16.9	238.0	201.6	756.9
			Interchange	-384.0	793.0	606.0	-894	-203.0	-220.0	-199.9	166.0	-335.9
	Wet	2010	Gen	898.6	2037.1	6940.4	1735.4	1081.8	586.3	7342.4	7406.2	28028.1
			Load	1287.3	1961.1	5966.2	3136.7	1194.0	669.2	6423.7	6875.1	27513.3
			Losses	50.3	57.0	120.9	50.7	19.8	15.9	206.6	220.4	741.5
			Interchange	-439.0	19.0	839.0	-1452.0	-132.0	-101.0	632.1	297.1	-336.7
2015	Average	2010	Generation	1116.1	2316.6	7332.7	2316.3	1087.0	735.0	7712.8	8687.6	31304.1
			Load	1531.0	2279.0	6483.0	3657.0	1407.0	671.0	7317.4	7263.0	30608.4
			Losses	81.2	78.7	150.7	63.4	20.0	25.0	347.4	268.7	1035.1
			Interchange	-496.0	-41.1	699.0	-1404.1	-340.0	39.0	47.9	1156.0	-339.3
		2015	Generation	1118.1	2317.2	7332.9	2317.0	1088.4	735.2	7708.6	8689.4	31306.8
			Load	1541.0	2279.0	6483.0	3657.0	1407.0	676.0	7317.4	7279.0	30639.4
			Losses	73.1	79.2	150.9	64.0	21.4	20.3	343.1	254.4	1006.4
			Interchange	-496.0	-41.0	699.0	-1404.0	-340.0	39.0	48.1	1156.0	-338.9
	Dry	2010	Generation	894.7	3140.9	7363.9	2636.7	985.1	586.3	7724.6	8397.9	31730.1
			Load	1521.9	2304.0	6450.0	3665.0	1410.0	672.0	7798.4	7296.0	31117.3
			Losses	92.7	78.2	147.9	58.2	19.1	22.1	295.5	237.9	951.6
			Interchange	-720.0	758.8	766.0	-1086.4	-444.0	-107.7	-369.2	864.0	-338.5
		2015	Generation	893.6	3141.2	7363.9	2637.7	985.2	586.3	7722.9	8396.3	31727.1
			Load	1542.0	2305.0	6450.0	3665.0	1409.0	678.0	7798.4	7308.0	31155.4
			Losses	71.6	77.1	147.8	58.7	20.2	16.4	293.5	224.3	909.6
			Interchange	-720.0	759.0	766.0	-1085.9	-444.0	-108.0	-368.9	864.0	-337.8
	Wet	2010	Generation	1124.5	2154.2	7553.2	2799.9	869.5	778.7	7953.9	8413.1	31646.9
			Load	1528.9	2278.6	6446.1	3660.4	1407.6	669.8	7704.0	7209.2	30904.6
			Losses	85.8	74.8	137.4	60.9	18.9	21.6	298.9	278.4	976.6
			Interchange	-490.1	-199.3	955.0	-921.3	557.0	85.0	-123.3	912.7	-338.3
		2015	Generation	1111.0	2155.1	7553.3	2800.9	870.8	774.1	7950.3	8398.5	31613.9
			Load	1528.9	2278.6	6446.1	3660.4	1407.6	669.8	7704.0	7209.2	30904.6
			Losses	72.1	75.6	137.5	61.6	20.2	16.9	294.8	263.2	941.8
			Interchange	-490.0	-199.0	955.0	-921.1	-557.0	85.0	-123.0	913.0	-337.2

Table 6.1.3: Overview of high loaded elements in analyzed reference cases

LOAD LEVEL			2010						2015											
HYDROLOGY			average		dry		wet		average				dry				wet			
TOPOLOGY									2010		2015		2010		2015		2010		2015	
AREA	ELEMENT	RATING MVA	LOAD MVA	%	LOAD MVA	%	LOAD MVA	%	LOAD MVA	%	LOAD MVA	%	LOAD MVA	%	LOAD MVA	%	LOAD MVA	%	LOAD MVA	%
Lines																				
ALB	OHL 220 kV AKASHA2-ARRAZH2	270							250	92.6	238	88	275	102	243	89.9	259	96	237	87.8
BUL	OHL 220 kV MI_2_220-ST ZAGORA	228.6															191	83.5	190	83.3
ROM	OHL 220 kV MINTIA-SIBIU	381.1							268	96.5	268	96.4					324	85.1	313	82.2
	OHL 220 kV P.D.F.II-CETATE1	277.4							205	98.6	205	98.5					269	97	268	96.8
	OHL 220 kV P.D.F.A-CETATE1	208.1							236	85.2	232	83.7					206	99	206	98.8
	OHL 220 kV P.D.F.A-RESITA ckt.1	277.4							236	85.2	232	83.7					239	86.2	236	84.9
	OHL 220 kV P.D.F.A-RESITA ckt.2	277.4															239	86.2	236	84.9
	OHL 220 kV LOTRU-SIBIU ckt.1	277.4					276	99.5									304	109	303	109
	OHL 220 kV LOTRU-SIBIU ckt.2	277.4					276	99.5									304	109	303	109
	OHL 220 kV URECHESI-TG.JIU	277.4							278	100	273	98.3					280	101	275	99.3
	OHL 220 kV TG.JIU-PAROSEN	208.1					182	87.3	278	134	273	131					280	135	275	132
	OHL 220 kV BUC.S-B-FUNDENI	320											261	81.6	261	81.4	285	89.2	285	88.9
SRB	OHL 220 kV JBGD3 21-JOBREN2	301							261	86.7	262	87	294	97.5	295	97.9	313	104	313	104
Transformers																				
ALB	TR 220/110 kV AFIERZ2-AFIERZ5 ckt.1	60							51.9	86.5	50.3	83.8	59	98.3	52.1	86.9	54.6	91.1	50.2	83.7
	TR 220/110 kV AFIERZ2-AFIERZ5 ckt.2	60							51.9	86.5	50.3	83.8	59	98.3	52.1	86.9	54.6	91.1	50.2	83.7
	TR 220/110 kV AELBS12-AELBS15 ckt.1	90							78	86.6	74.3	82.5	84.7	94.1	75.4	83.8	81.4	90.5	74.8	83.2
	TR 220/110 kV AELBS12-AELBS15 ckt.2	90							78	86.6	74.3	82.5	84.7	94.1	75.4	83.8	81.4	90.5	74.8	83.2
	TR 220/110 kV AELBS12-AELBS15 ckt.3	90							83.8	93.1	79.8	88.7	91	101	81	90	87.5	97.2	80.4	89.3
	TR 220/110 kV AKASHA2-AKASH25 ckt.1	100							84.1	84.1	82.1	82.1	90.8	90.8	83.5	83.5	87.2	87.2	82.3	82.3
	TR 220/110 kV AKASHA2-AKASH25 ckt.2	100							84.1	84.1	82.1	82.1	90.8	90.8	83.5	83.5			82.3	82.3
	TR 220/110 kV AFIER 2-AFIER 5 ckt.1	120	117	93.7	107	89	117	97.1	138	115	135	113	147	122	137	114	141	118	135	112
	TR 220/110 kV AFIER 2-AFIER 5 ckt.2	90	95.7	106	87.5	97.2	95.5	106	113	126	111	123	120	134	112	125	116	129	110	123
	TR 220/110 kV AFIER 2-AFIER 5 ckt.3	90	91.4	102	83.5	92.8	91.1	101	108	120	106	117	115	128	107	119	110	123	105	117
	TR 220/110 kV ARRAZH 1	100											84.7	84.7			80.3	80.3		
	TR 220/110 kV ARRAZH 2	100											84.7	84.7			80.3	80.3		
	TR 220/110 kV ATIRAN 3	120											98.2	81.9						
B&H	TR 400/110 kV UGLJEVIK	300	255	84.9					255	84.9	253	84.2	242	80.8	241	80.2	270	90	268	89.2
ROM	TR 400/220 kV URECHESI	400							395	98.9	391	97.7					414	104	410	103
	TR 400/220 kV BUC.S-BUC.S-B ckt.1	400															340	85	339	84.8
	TR 400/220 kV BUC.S-BUC.S-B ckt.2	400															340	85	339	84.8
	TR 220/110 kV FUNDE2 1	200	173	86.6	168	84.1	169	84.4	193	96.7	193	96.5	200	99.9	200	99.8	209	104	208	104
	TR 220/110 kV FUNDEN 1	200							163	81.4	163	81.3	169	84.2	168	84.1	176	88	176	87.8
	TR 400/220 kV MINTIA-MINTIA B	400	386	96.4																
	TR 400/220 kV IERNUT 1	400							320	80.1			325	81.3	324	81.1				
SRB	TR 400/220 kV JBGD8 1	400															338	84.5	335	83.7
	TR 220/110 kV JBGD3 1	200							167	83.4	167	83.3	171	85.6	171	85.5	197	98.6	197	98.3
	TR 220/110 kV JBGD3 2	150							126	83.7	126	83.9	130	86.5	130	86.6	135	89.7	134	89.6
	TR 220/110 kV JZREN2 2	150							124	82.4	124	82.3					122	81.3	122	81
	TR 220/110 kV JTKOSA 2	150							131	87.1			133	88.9			132	87.9		
	TR 220/110 kV JTKOSA 3	150							133	88.7			136	90.5			134	89.5		
	TR 400/220 kV JTKOSB 1	400											323	80.8						
	TR 400/220 kV JTKOSB 2	400							326	81.4			338	84.4			325	81.1		
	TR 400/220 kV JTKOSB 3	400							326	81.4			338	84.4			325	81.1		
	TR 220/110 kV JPRIS4 1	150											122	81.1						
	TR 220/110 kV JPRIS4 2	150											122	81.1						
	TR 400/110 kV JJAGO4	300															247	82.5		

Table 6.1.3 shows summary for elements loaded over 80% of their thermal limits. In network planning practice, this is used as one of the main indicators which parts of the transmission network represent weak spots and what network reinforcements are necessary in sense of generation and supply, without taking into consideration the security aspects. Analysis of these results leads to conclusion that transmission network is capable of transferring power from generation facilities to major consumption areas, and network reinforcement is not necessary (without taking n-1 criterion into consideration). But, in some substations, there is not enough transformer capacity to supply demand from transmission network, since the load of these elements do not depend on generation pattern and level of system interchange, but only on load level in these substations. This is problem of local supply, and this should be studied as program of local not regional system development. Increase of transformer installed capacity is needed in substations 220/110 kV Fier, Elbasan, Fierza and Kashar in Albania, 400/110 kV Ugljevik in Bosnia and Herzegovina.

Also, it should be noted that level of reactive power consumption in load flow model of Albania is very high comparing to the other systems and not realistic. This is one of the reasons why voltage profile in Albanian network is very close to voltage collapse in some investigated scenarios. Because of the problem with unrealistic reactive power demand new reactive power demand forecast is needed.

Influence of voltage control equipment was not tested on regional level, and therefore it is not possible to give answer weather there is possibility to better voltage profile in certain regimes. Also, no light load regimes were analyzed, so there is no possibility to analyze effect of new reactive power control devices.

6.1.2 Overview on possible solutions for system relief

In this subchapter, security aspects of network performance in analyzed scenarios are presented. As it has been concluded in Chapter 4, in all investigated scenarios, some elements are highly loaded even in case of full topology. Most of the elements loaded over 80% are transformers in some substations and also there are some overloaded elements (Table 6.1.3).

Based on full topology and n-1 contingency analyses, some internal network reinforcements are necessary to sustain analyzed load-demand level and production pattern. In other words, optimum GTMax dispatch, according to analyzed generation and load scenarios, is not possible to achieve with desired level of network security. Internal network reinforcements are necessary in order to achieve such optimal dispatch.

Most of the identified critical network elements in Romania can be relieved by dispatching actions (change of network topology or production units engagement). Re-dispatching actions, mostly in the power system of Romania (power plants DEVA 1, LOTRU CIUNGET, PORTILE 1, PAROSENI and ROVINARI) will be necessary to keep desired network security level according to the (n-1) criterion. Also, installing a new transformer unit 400/110 kV in Brasov is planned and helps resolving some critical states in Romanian network. Upgrading the Timisoara substation to 400 kV level and supplying this area from 400 kV network instead from 220 kV would resolve some problems in Romanian network.

Reinforcement of local network in vicinity of Belgrade is necessary, but as it has been stated before, this is local development. Problem of supplying Belgrade area must be part of more complex and thorough analyses.

Central part of the 400 kV network in Serbia is heavy loaded due to large energy transits from Romania, Bulgaria and south of Serbia (Kosovo and Metohija) to Croatia and Hungary. Strengthening of the 400 kV corridor from Romania through Serbia to Croatia (East-West), by building 400 kV lines Romania (e.g. new proposed substation Timisoara)-(Vrsac)-Drmno and Belgrade-Obrenovac can relieve this problem.

For all of this, more thorough analyses are needed and only adequate feasibility studies can give the proper answer to the question about the level and type of network reinforcements.

Final conclusions concerning year 2010 are:

- **expected network topology in year 2010 is sufficient for all investigated generation and load pattern for year 2010, except in South Serbia and Belgrade area;**
- **building of the 400 kV corridor Nis-Leskovac-Vranje-Skoplje before 2010 resolves all insecure states identified in network of southern Serbia for investigated regimes in 2010;**
- **network reinforcement in Belgrade area is necessary;**
- **level of reactive power consumption in load flow model of Albania is very high comparing to the other systems and not realistic and this causes some overloads due to low voltage profile in Albanian network;**
- **high loads and overloads of elements in Romania can be relieved by operational methods.**

Expected network topology for 2015 generally improves network performance, especially in the cases of Albanian and Serbian network. But, additional network reinforcements are necessary, especially in increasing transformer capacities in mentioned substations, over which large consumption areas are supplied. In case of Romania, it is hard to say what reinforcements are necessary, since most of the identified insecure states can be relieved with production redispatch and network topology changes.

New proposed lines (Visegrad – Pljevlja, Tumbri – Banja Luka and Pecs – Sombor) do not resolve any of the identified insecure states, since these lines are electrically far from these critical network elements, and therefore do not have significant influence. But, they do increase transfer capabilities of interconnected network.

Final conclusions concerning year 2015 are:

- **new lines commissioned to come into operation between 2010 and 2015 greatly reduce losses in analyzed region, regardless of hydrology;**
- **expected network topology in year 2015 is sufficient for all investigated generation and load pattern for year 2010, except in Belgrade area;**
- **building of the 400 kV corridor Nis-Leskovac-Vranje-Skoplje resolves all insecure states identified in network of southern Serbia for investigated regimes in 2015;**
- **network reinforcement in east-west corridor in Serbia is necessary (this includes Belgrade area also);**
- **level of reactive power consumption in load flow model of Albania is very high comparing to the other systems and not realistic and this causes some overloads due to low voltage profile in Albanian network;**
- **high loads and overloads of elements in Romania can be relieved by operational methods;**
- **proposed interconnection lines candidates do not resolve any of the identified problems.**

6.2 Sensitivity cases

Sensitivity cases consist of six scenarios. In all of these cases average hydrology is used. Two different scenarios are analyzed (first 1500 MW of import plus 500 MW of transit and second high load growth) for years 2010 and 2015. Also, for each of these scenarios in year 2015 two cases are analyzed (first for 2010 topology, i.e. without any new line or transformer planned for commissioning between 2010 and 2015 and second for expected topology in year 2015).

6.2.1 Analyses comparison

Main focus of this subchapter is to analyze influence of high load growth rate and import/export regime on system losses and overall network performance.

Table 6.2.1 shows overview of losses on regional level. It can be seen that new elements planned for commissioning between 2010 and 2015 influence reduction of losses in analyzed region, no matter of hydrology. This reduction of losses is between 30 and 40 MW.

Table 6.2.1: Peak Hour - Regional Losses (MW) under Average Hydrologic Conditions

Case	Year 2010	Year 2015	
	2010*	2010*	2015*
Reference Case	737.1	1,035.1	1,006.4
Imports/Exports	684.8	NA	850.3
High Load Forecast	913.9	1,296.9	1,257.8

*topogy

These changes are consequence of better voltage profile in analyzed region, especially in areas directly influenced by the new elements. For example, new interconnection line Nis-Leskovac-Vranje-Skopje greatly improves voltage profile in southern part of Serbia and new interconnection lines Podgorica – V.Dejes – Kashar – Elbasan and Kosovo B – V.Dejes – Kashar – Elbasan greatly improve voltage profile in Albania. Higher voltages and reduction of load of some elements that are highly influenced by the new elements, reduce power losses mainly in Albania, Southern Serbia, and in the region as whole.

Table 6.2.2 shows overview of area summaries for analyzed reference cases and Table 6.2.3 shows overview of high loaded elements in analyzed sensitivity cases.

Import/export sensitivity scenarios

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

- Import 750 MW from UCTE
- Import 500 MW from Turkey
- Export 500 MW to Greece
- Import 750 MW from Ukraine

Large imports from analyzed directions cause significant increase of power flows along Slovenian-Croatian, Ukrainian-Romanian and Bosnian-Montenegrin interfaces in 2010, but interconnection lines are not jeopardised since they are loaded far below their thermal ratings.

Power losses on network topology in 2010, compared to the situation of balanced SE Europe power system, are increased in the power systems of Bulgaria (7.9 %) and Montenegro (9 %). In other power systems these losses are decreased, with the most significant drop in Romania (-16 %) and Serbia and UNMIK (-10.1 %). Regional power losses are decreased (-7.1 %) when the situation includes additional power import. It can be concluded that for this exchange scenario, power flows and voltage profile are such that transmission network is better utilized, and as a consequence losses are smaller.

By comparing the average hydrology situation in 2010 and balanced SE Europe power system to the average hydrology situation and 1500 MW of power import, it may be noticed that some critical contingencies in the Romanian power system disappear, especially those connected with Mintia substation, while some new contingencies appear in the power system of Bulgaria (lines around Maritsa East substation). This is due to different dispatching conditions of DEVA 1 power plant in Romania (disconnected in import/export scenario, dispatched with 850 MW in the base case) and power import through Turkish-Bulgarian interface that goes through Maritsa East 3 substation.

The analyzed scenario which is characterized by large power import in 2015, but on the 2010 network topology, can not be supported from a transmission network viewpoint due to voltage problems. Their existence is the most obvious in the power system of Albania due to scarce reactive power sources. To mitigate such problems it is necessary to construct at least one new 400 kV interconnection line between Albania and UNMIK or Macedonia.

Large imports from analyzed directions in 2015 cause significant increase of the power flows along the Slovenian-Croatian and Ukrainian-Romanian interfaces. However, the interconnection lines are not jeopardized since their loading levels fall far below their thermal ratings.

Power losses, in comparison to the situation of balanced SE Europe power system, are increased only in the power system of Macedonia (5%). In other power systems power losses are decreased, the most significantly in the power systems of Romania (-26%) and Montenegro (-23%). Power losses are decreased (-16%) in the region when analyzing the additional power import.

Certain reinforcements in the internal networks of Romania, Bulgaria, Albania and Serbia till 2015 are necessary shall analyzed generation pattern and 1500 MW of power import be made more secure. None of the identified congestions is located at the border lines.

High load growth rate

Pessimistic (high) load growth rate is more close to load forecast made by electric power utilities in analyzed region.

In case of high load growth rate power flows through lines and transformers are greater. This cause greater level of losses, increased number of elements loaded over 80 % and overloaded elements also and greatly decreased level of system security (Table 6.2.3).

In case of year 2015 and 2010 topology it is not feasible to realize this generation-load pattern due to network constraints in Albania, but in Serbia and Romania also.

As it has been concluded in Chapter 5, in all investigated scenarios, some elements are highly loaded even in case of full topology. Most of the elements loaded over 80% are transformers in some substations and also there are some overloaded elements (Table 6.2.3).

Table 6.2.2: Overview of area summaries for analyzed sensitivity cases (in MW)

Year	Case	Topology	Data type	Albania	B & H	Bulgaria	Croatia	Macedonia	Montenegro	Romania	Serbia	*Total (SE Europe)*
2010	Reference case Average hydrology	2010	Generation	896.7	2266.1	6900.4	1502.9	950.3	539.8	7939.9	7355.9	28351.9
			Load	1287.3	1971.3	5977.3	3136.7	1198.2	669.2	6728.3	6873.1	27841.4
			Losses	50.4	58.6	121.6	49.0	20.1	15.5	201.2	220.8	737.1
			Interchange	-441.0	236.2	787.0	-1682.8	-268.0	-147.0	930.4	248.4	-336.7
	Import/export Average hydrology	2010	Generation	898.2	2398.3	6827.0	1705.2	965.5	542.1	6877.4	6591.7	26805.4
			Load	1288.5	1965.0	5967.5	3143.3	1178.3	670.2	6733.1	6901.7	27847.6
			Losses	49.7	54.3	131.2	44.9	20.1	16.9	169.1	198.6	684.8
			Interchange	-440.0	379.0	714.0	-1483.0	-233.0	-147.0	-104.8	-521.9	-1836.7
	High load Average hydrology	2010	Generation	931.7	2202.8	7282.5	2254.6	991.1	542.3	7113.3	8103.8	29422.1
			Load	1358.0	2004	6278.0	3295.0	1234.0	686.0	6859.4	7131.0	28845.4
			Losses	57.7	57.8	146.5	55.4	18.1	19.2	310.6	248.6	913.9
			Interchange	-484.0	141.1	858.0	-1095.9	-261.0	-163	-56.7	724.2	-337.3
2015	Reference case Average hydrology	2010	Generation	1116.1	2316.6	7332.7	2316.3	1087.0	735.0	7712.8	8687.6	31304.1
			Load	1531.0	2279.0	6483.0	3657.0	1407.0	671.0	7317.4	7263.0	30608.4
			Losses	81.2	78.7	150.7	63.4	20.0	25.0	347.4	268.7	1035.1
			Interchange	-496.0	-41.1	699.0	-1404.1	-340.0	39.0	47.9	1156.0	-339.3
		2015	Generation	1118.1	2317.2	7332.9	2317.0	1088.4	735.2	7708.6	8689.4	31306.8
			Load	1541.0	2279.0	6483.0	3657.0	1407.0	676.0	7317.4	7279.0	30639.4
			Losses	73.1	79.2	150.9	64.0	21.4	20.3	343.1	254.4	1006.4
			Interchange	-496.0	-41.0	699.0	-1404.0	-340.0	39.0	48.1	1156.0	-338.9
	Import/export Average hydrology	2010	Generation	*	*	*	*	*	*	*	*	*
			Load	*	*	*	*	*	*	*	*	*
			Losses	*	*	*	*	*	*	*	*	*
			Interchange	*	*	*	*	*	*	*	*	*
		2015	Generation	1027.5	2394.9	7582.2	2173.9	1076.3	731.9	7187.7	8029.8	30204.2
			Load	1544.0	2293.8	6418.9	3660.1	1393.7	675.0	7831.2	7270.7	31087.4
			Losses	71.5	70.1	142.7	58.8	22.5	15.6	253.9	215.1	850.3
			Interchange	-588.0	31.0	1006.0	-1545.0	-340.0	39.0	-972.0	530.0	-1839.0
	High load Average hydrology	2010	Generation	896.1	2479.4	8157.8	2591.0	895.0	1324.6	7684.5	10024.2	34052.6
			Load	1680.0	2274.0	7083.0	3959.0	1489.0	702.0	8269.8	7635.0	33091.8
			Losses	99.0	92.2	175.8	79.8	23.0	35.6	454.5	337.0	1296.9
			Interchange	-883.0	113.2	899.0	-1447.8	-617.0	587.0	-1039.8	2052.2	-336.2
		2015	Generation	897.7	2479.7	8157.4	2592.1	895.7	1322.6	7676.4	10023.9	34045.5
			Load	1684.0	2272.0	7083.0	3959.0	1489.0	708.0	8269.8	7660.0	33124.8
			Losses	96.7	94.7	175.4	81.1	23.7	27.6	446.7	311.9	1257.8
			Interchange	-883.0	112.9	899.0	-1448.1	-617.0	587.0	-1040.1	2051.9	-337.4

* convergent load flow solution was not found

Table 6.2.3: Overview of high loaded elements in analyzed sensitivity cases

year			2010						2015											
regime			average		imp/exp		high load		average				imp/exp				high load			
topology									2010		2015		2010*		2015		2010		2015	
AREA	ELEMENT	RATING MVA	LOAD MVA	%	LOAD MVA	%	LOAD MVA	%	LOAD MVA	%	LOAD MVA	%	LOAD MVA	%	LOAD MVA	%	LOAD MVA	%	LOAD MVA	%
Lines																				
ALB	HL 220kV AKASHA2-ARRAZH2 1	270							250	92.6	238	88			236	87.3	288	107	290	108
BUL	HL 220 kV M.EAST-ST.ZAGORA	228.6			189	82.6									191	83.5				
ROM	HL 220kV BRADU-TIRGOVI 1	302.6													247	81.6	285	94.3	284	93.8
	HL 220kV BUC.S-B-FUNDENI 1	320													266	83.1	309	96.7	308	96.1
	HL 220kV FILESTI-BARBOSI 1	277.4															248	89.5	246	88.6
	HL 220kV L.SARAT-FILESTI 1	277.4															241	86.9	239	86.2
	HL 220kV LOTRU-SIBIU 1	277.4																	281	101
	HL 220kV LOTRU-SIBIU 2	277.4																	281	101
	HL 220kV P.D.F.A-CETATE1 1	208.1							205	98.6	205	98.5			204	98.2	207	99.6	206	99.1
	HL 220kV P.D.F.A-RESITA 1	277.4					227	81.7	236	85.2	232	83.7					267	96.2	262	94.5
	HL 220kV P.D.F.A-RESITA 2	277.4					227	81.7									267	96.2	262	94.5
	HL 220kV P.D.F.II-CETATE1 1	277.4							236	85.2	232	83.7					271	97.7	270	97.3
	HL 220kV PAROSEN-BARU M 1	277.4															228	82		
	HL 220kV RESITA-TIMIS 1	277.4															230	82.8	225	81.1
	HL 220kV RESITA-TIMIS 2	277.4															230	82.8	225	81.1
	HL 220kV TG.JIU-PAROSEN 1	208.1					278	134	278	134	273	131					321	154	314	151
	HL 220kV URECHESI-TG.JIU 1	277.4					278	100	278	100	273	98.3					320	116	314	113
	HL 220 kV MINTIA-SIBIU	381.1							268	96.5	268	96.4								
SRB	HL 220kV JBGD3 21-JOBREN2 1	301							261	86.7	262	87			277	92.2	291	96.7	292	97
Transformers																				
ALB	TR 220/110 kV ABURRE 1	60													49.1	81.8	49.5	82.5	52.2	87
	TR 220/110 kV ABURRE 2	60													49.1	81.8	49.5	82.5	52.2	87
	TR 220/110 kV ABURRE 3	60													49.1	81.8	49.5	82.5	52.2	87
	TR 220/110 kV AELBS1 1	90							78	86.6	74.3	82.5			74	82.2	87.7	97.5	87.8	97.6
	TR 220/110 kV AELBS1 2	90							78	86.6	74.3	82.5			74	82.2	87.7	97.5	87.8	97.6
	TR 220/110 kV AELBS1 3	90			117	97.6	122	102	83.8	93.1	79.8	88.7			79.5	88.3	94.2	105	94.4	105
	TR 220/110 kV AFIER 1	120	117	93.7	96	107	100	111	138	115	135	113			131	109	149	124	152	126
	TR 220/110 kV AFIER 2	90	95.7	106	91.6	102	95.6	106	113	126	111	123			107	119	122	136	124	138
	TR 220/110 kV AFIER 3	90	91.4	102					108	120	106	117			102	114	117	130	119	132
	TR 220/110 kV AFIERZ 1	60							51.9	86.5	50.3	83.8			50.9	84.8	58	96.7	59.9	99.8
	TR 220/110 kV AFIERZ 2	60							51.9	86.5	50.3	83.8			50.9	84.8	58	96.7	59.9	99.8
	TR 220/110 kV AKASHA 1	100							84.1	84.1	82.1	82.1			82.9	82.9	93.4	93.4	94.7	94.7
	TR 220/110 kV AKASHA 2	100							84.1	84.1	82.1	82.1			82.9	82.9	93.4	93.4	94.7	94.7
	TR 220/110 kV ARRAZH 1	100															87.7	87.7	87.5	87.5
	TR 220/110 kV ARRAZH 2	100															87.7	87.7	87.5	87.5
	TR 220/110 kV ATIRAN 2	120															97.5	81.3	96.4	80.3
	TR 220/110 kV ATIRAN 3	120															102	85.2	101	83.9
BIH	TR 220/110 kV MO-4 3	150																	124	83
	TR 400/110 kV UGLJEV 1	300	255	84.9					255	84.9	253	84.2			256	85.4	259	86.3	256	85.4
CRO	TR 220/110 kV TESISA 1	200															179	89.4	179	89.7
ROM	TR 220/110 kV BARBOS 1	200			174	86.9											167	83.6	167	83.3
	TR 220/110 kV FUNDE2 1	200	173	86.6			179	89.3	193	96.7	193	96.5			214	107	241	120	240	120
	TR 220/110 kV FUNDEN 1	200							163	81.4	163	81.3			181	90.5	204	102	203	102
	TR 220/110 kV TIMIS 1	200															172	85.9	170	85.2
	TR 400/110 kV BRASOV 1	250													203	81	232	92.6	230	92.1
	TR 400/110 kV CLUJ E 1	250															208	83.4	206	82.6
	TR 400/110 kV DIRSTE 1	250															221	88.4	220	87.8
	TR 400/220 kV BUC.S 1	400															378	94.6	377	94.1
	TR 400/220 kV BUC.S 2	400															378	94.6	377	94.1
	TR 400/220 kV IERNUT 1	400							320	80.1							408	102	405	101
	TR 400/220 kV URECHE 1	400					344	86.1	395	98.9	391	97.7					487	122	480	120
	TR 400/220 kV MINTIA	400	386	96.4																
SRB	TR 220/110 kV JBGD3 1	200							167	83.4	167	83.3			169	84.7	175	87.5	175	87.4
	TR 220/110 kV JBGD3 2	150							126	83.7	126	83.9			127	84.5	137	91.4	138	91.7
	TR 220/110 kV JPRIS4 1	150															137	91.3		
	TR 220/110 kV JPRIS4 2	150															137	91.3		
	TR 220/110 kV JTKOSA 2	150					132	87.7	131	87.1							151	101	134	89
	TR 220/110 kV JTKOSA 3	150					134	89.3	133	88.7							154	103	136	90.6
	TR 220/110 kV JZREN2 2	150					120	80.1	124	82.4	124	82.3			122	81	134	89.2	134	89.2
	TR 400/110 kV JJAGO4 A	300															246	81.9		
	TR 400/220 kV JBGD8 1	400					326	81.6									332	83	330	82.6
	TR 400/220 kV JTKOSB 1	400															412	103	352	88
	TR 400/220 kV JTKOSB 2	400							326	81.4							430	108	368	91.9
	TR 400/220 kV JTKOSB 3	400							326	81.4							430	108	368	91.9
MNG	TR 220/110 kV JTPLJE 1	125																	102	82

*convergent load flow solution was not found

As it has been said above, in some substations there is not enough transformer capacity to supply demand from transmission network, since the load of these elements do not depend on generation pattern and level of system interchange, but only on load level in these substations, particularly in this case.

This is problem of local supply. It should be pointed out that load patterns (in all reference and sensitivity cases) have the greatest influence to identified problems.

6.2.2 Overview on possible solutions for system relief

Security aspects of network performance in analyzed scenarios are presented in this subchapter.

It has to be said, that new generation facilities in UNMIK area, are too large to be investigated as they were. Over 3000 MW of new production were connected to only one substation, Kosovo B. It is almost certain, that installing such large capacities demands different and more detailed solution, as well as large changes in internal network of UNMIK area, in order to supply this energy to consumers. Also, large changes in internal network of Serbia are necessary too, since installing of these 3000 MW causes great changes in energy flows in region, and therefore different supply routes in internal network. That is why, more detailed analysis is necessary in order to draw conclusions that will give right indices about eventual congestions and necessary network reinforcements. One of possible solutions is building of 400 kV ring (Kosovo B – Pristina 4 – Kosovo C) that will connect new production facilities with existing substations Kosovo B and new substation 400 kV Pristina 4. The other is to connect the all new plants to existing 400 kV substation Kosovo B radial through new 400 kV lines (as it was analyzed in this study). This solution is better from network point of view, but from generation point of view is less reliable and secure.

More thorough analyses is needed and only adequate feasibility studies can give the proper answer to the question about the level and type of network reinforcements, especially in the case of the new generation facilities proposed.

Concerning internal network reinforcements, same conclusions can be made as in previous chapter.

Additional conclusions concerning year 2010 are:

- **level of power losses for import/export scenario are significantly lower as consequence of better utilization of the transmission network. It should be pointed out that this scenario is more close to recorded system behavior, since Greece is one of the major regional importers**
- **level of load of high loaded and overloaded elements is greater, especially in case of high load scenario;**
- **building of the 400 kV corridor Nis-Leskovac-Vranje-Skoplje before 2010 resolves has much greater significance.**

Additional conclusions concerning year 2015 are:

- **expected network topology in year 2015 is not sufficient in case of high load scenario;**
- **operational methods in network of Romania can relieve some of identified problems, but in case of high load scenario network reinforcement should be analyzed also;**
- **new production units in UNMIK area require detailed analysis related to connection of these units to power system network.**

6.3 List of priorities

Based on main conclusions above lists of priorities are given in Table 6.3.1 and Table 6.3.2. It should be pointed out that these elements are not ranked according to some criteria, but presented according commissioning date and approved development plans from each responsible power company in the region. Realization of all of these projects is necessary for secure and reliable operation of regional transmission network (as described in previous subchapters).

Table 6.3.1: List of priorities until year 2010

Interconnection line	Interconnected countries	Year of commissioning
Ugljevik - S. Mitrovica	BA - SER	2005/06
Kashar - Podgorica	AL - MN	2006/07
C. Mogila - Stip	BG - MK	2006/07
Florina - Bitola	GR - MK	2006/07
Maritsa Istok - Filipi	BG - GR	2007/08
Ernestinovo - Pecs (double)	HR - HU	2007/08
(Filipi) - Kehros - Babaeski	GR - TR	2007/08
Bekescaba - Nadab (Oradea)	HU - RO	2008

Table 6.3.2: List of priorities between 2010 and 2015

Interconnection line	Interconnected countries	Year of commissioning
Zemlak - Bitola	AL - MK	2010/15
Kashar (V. Dejes) - Kosovo B	AL – CS	2010/15
(Nis) – (Leskovac) – Vranje - Skopje	CS – MK	2010/15

It also should be pointed out that local networks also need to be reinforced to satisfy security and reliability criteria, but this is not problem of transmission network then local supply problem. In case of new production units, especially in UNMIK area, detailed analysis related to connection of these units to power system network is required.

In Table 6.3.3 and Table 6.3.4 are presented some recommendations that would make operation of regional transmission network more reliable and secure.

Table 6.3.3 – Recommendation for new transformers in new substations

Country	Line	Voltage	Length (km)
Romania	Arad-Timisoara	400 kV	55
Serbia	Obrenovac-Belgrade ?-Pancevo	400 kV	80
	Drmno-Vrsac	400 kV	50
UNMIK	TPP Kosovo NEW-Pristina	400 kV	20
	TPP Kosovo NEW-Kosovo B	400 kV	20
Interconnection	Timisoara (ROM)-Vrsac (SCG)	400 kV	80

Table 6.3.4 – Recommendation for new transformers in new substations

Country	Name of substation	Voltage levels kV/kV	New transformers MVA
Romania	Timisoara	400/110	2x300
Serbia	Vrsac	400/110	2x300
	Beograd ?	400/110	2x300
UNMIK	Pristina	400/110	2x300

It should be pointed out that these recommendations are not according to the long term development plans of power utilities in the region, but just ideas of authors that can resolve some of the identified problems in regional network. They should be taken into consideration in future studies and analyses. Without detailed analyses it is not possible to rank these recommendations.

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