THE BLACK SEA REGIONAL TRANSMISSION PLANNING PROJECT: Loadflow and Dynamic Modeling Report for 2015 & 2020

Black Sea Regional Transmission Planning Project Phase II
Balkans and Regional Energy Market Partnership Program
Cooperative Agreement EEE-A-00-02-00054-00

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THE BLACK SEA REGIONAL TRANSMISSION PLANNING PROJECT: Loadflow and Dynamic Modeling Report for 2015 & 2020

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Table of Contents

Abbreviations

ENTSO-E- European Network of Transmission System Operators for Electricity (former UCTE)
AGC- Automatic Generation Control
LFC- Load Frequency Control

Introduction

This report details the accomplishments, findings and recommendations of phase II of the Black Sea Regional Transmission Planning Project (BSTP).

BSTP was established in 2004 to foster regional cooperation in transmission planning and analysis. It results from a desire among the Transmission System Operators (TSOs) in the region to identify investments necessary to improve regional system security and to take advantage of the potential for east-west electricity trade with neighboring markets in Southeast Europe and the UCTE system.

Though integrated at the borders, the Black Sea electrical network is currently an amalgamation of three electric power systems. Until recently, communication between the TSOs within these systems had been restricted primarily to daily operational matters with little, if any; focus on longer term planning issues related to system expansion, security and the facilitation of trade and exchanges.

Within the context of this project, Armenia, Georgia, Moldova, Russia and Ukraine are members of the synchronous IPS/UPS system. Since the early 1990s national transmission system operators (TSOs) within IPS/UPS have operated relatively independently. The Southeast European Black Sea nations of Bulgaria and Romania, acceded to the European Union on January 1, 2007, are members of ENTSO-E, and are signatories of the Energy Community of Southeast Europe Treaty. They adhere to ENSTO-E procedures and protocols. Turkey is the third element of the Black Sea electrical network and is in the final stages of trials for synchronous connection to ENTSO-E.

Though tempered by the current economic downturn, emerging electricity markets in the Energy Community of Southeast Europe and increasing demand in Central & Eastern Europe present long term opportunities for increasing electricity exports from the Black Sea region. Identifying and capitalizing on opportunities for further integration with the Energy Community and ENTSO-E requires enhanced technical coordination, cooperative planning and institutional capacity to analyze bulk power flows in the region and with neighboring regions.

In response to these developments the Black Sea TSOs signed the Sofia Memorandum of Understanding in 2004. The MOU outlines the goals and objectives of the Project, provides a framework for Project governance and details the rights and responsibilities of participating organizations. Current signatories of the Sofia MOU, which was updated in 2007 at the beginning of Phase II, include:

- Energy Research Institute of Armenia
- Electro Power System Operator of Armenia
- National Dispatching ESO EAD of Bulgaria
- Georgia State Electrosytem
- Moldelectrica of Moldova
- Transelectric of Romania
- System Operator United Power System (SO-UPS) of Russia
- Turkish Electricity Transmission Company
- National Energy Company (NEK) Ukrenergo
- United States Agency for International Development
- United States Energy Association

Project Goals & Objectives

The MOU provides the basis for project organization and coordination, details the Project methodology, timelines, schedules and deliverables, the rights and responsibilities of the TSOs, the role of Transelectrica as the Technical Coordinator, the role of EKC as regional model integrator and the support provided by USAID and USEA.

The goals and objectives contained in the MOU are to:

- Promote regional cooperation on transmission planning among Black Sea TSOs
- Identify priority investments in transmission systems and interconnections to improve reliability of the regional power system
- Propose possibilities to enhance electric power trade in the Black Sea Region
- Harmonize transmission planning principles, methods and perhaps methodologies
- Create a working group with experts trained in transmission planning issues and well informed about the characteristics of participating power systems
- Develop a common platform (common database, common software and consistent principles) for transmission system analysis among the TSOs in the Black Sea Region
- Provide training in the use of transmission planning software (PSS/E)
- Promote the results of the analysis to a wide audience of policy and regulatory authorities

The MOU established a Working Group composed of two transmission engineers from each TSO. A Steering Committee comprised of senior officials from each TSO, USAID and USEA oversees the work plans and activities of the Working Group. The Steering Committee provides a mechanism for IFIs and regional organizations to provide input to the Project. Transelectrica is the Technical Coordinator of the project. The Electricity Coordination Center (EKC) of Belgrade is the regional model integrator.

Activities & Accomplishments

Training and Modeling for Dynamic Mode The major task in phase II of the BSTP was to maintain and update the static model for 2010 developed during the first phase of the project, and to develop static and dynamic models for the years 2015 and 2020.

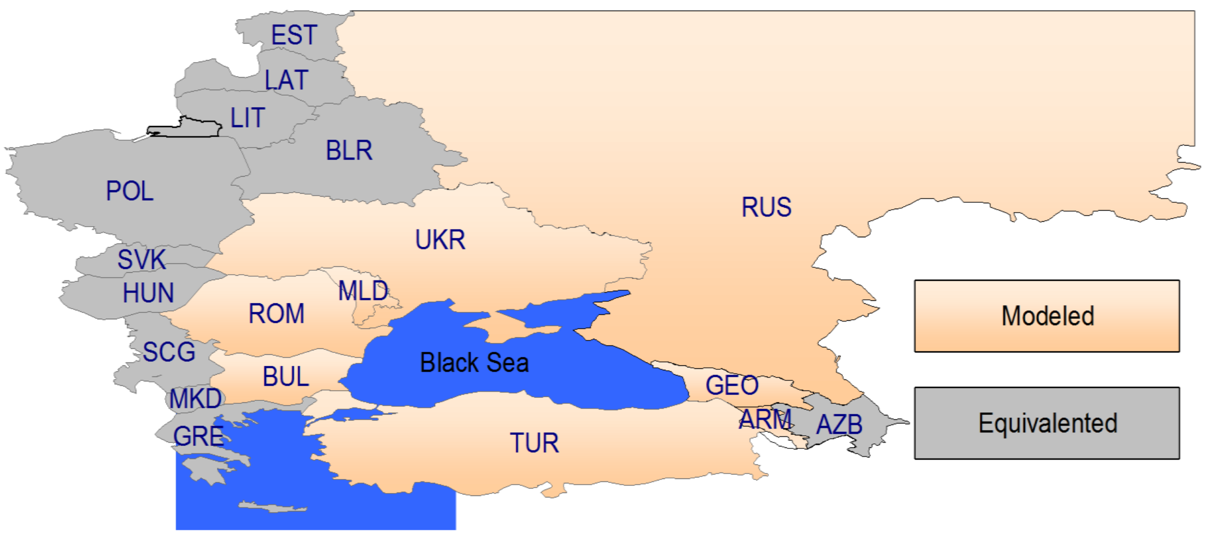
A five day training course on the use and application of the Power System Simulator Software for Engineers (PSS/E) for dynamic mode modeling and calculations was conducted in Varna, Bulgaria in March 2007. Two representatives from each of the BSTSOs participated, bringing the total number of BSTP trainees to a combined 43 for both steady state and dynamic mode training. During the training, the Working Group agreed to model the system for the following three operating regimes:

- Winter peak load at 16:00 GMT
- Summer peak load at 16:00 GMT
- Summer off-peak load at 01:00 GMT

The regional model was constructed by integrating national models prepared by each TSO following the training using the PSS/E software provided by the project. The model integrator (EKC) connected the national models into a single regional model. EKC also had responsibility to:

- Harmonize the data for interconnection lines
- Develop external equivalents for Western, Central and Southern Europe's networks
- Checking all national models and the regional model for errors
- Testing the accuracy of the model

The regional models contain the voltages: 750kV, 500kV, 400kV, 330kV, 220kV, 150kV and 110kV. The main generator units are modeled at their nominal voltage level with corresponding step-up transformers. All new substations and lines that are expected to be operational by 2020 (according to the long term development plans provided by the TSOs) are modeled as well.



Modeled and equivalent parts of the system

For the 2015 analysis, the models assume the following synchronous operation areas:

- ENTSO-E countries of Romania and Bulgaria operating synchronously with Europe and Turkey;
- IPS/UPS countries of Russia, Ukraine, Moldova, Georgia, Armenia and Azerbaijan.

The project team has a high degree of confidence in the 2015 model data due to a high level of certainty that lines, generation and loads included in this model are a sound estimate of conditions that will exist in 2015. However, due to increasing levels of economic uncertainty in the region, the same level of certainty does not extend to the 2020 planning horizon. As a result analysis of the regional network was restricted to the 2015 horizon during this phase of the project.

Survey of Transmission Planning Criteria and Methodologies Employed in the Black Sea Region:

The participating TSOs prepared a survey to benchmark similarities and differences in the planning criteria used in their national planning processes. The Turkish Electricity Transmission Company (TEIAS) acted as a lead in developing the survey instrument and in collecting and analyzing the responses. Three topical areas were reviewed: the role and interaction between TSOs and regulators in the planning process; technical criteria employed by the TSO in the planning process; and economic and financial criteria used to evaluate potential projects. The survey reveals significant commonalities found throughout the planning processes, which provide a basis for enhanced collaboration on a regional basis, including potential harmonization of grid codes among system operators. The survey results are found in Annex Two of this report.

Training for Economic and Financial Analysis of Transmission Projects: The project conducted a training workshop on Economic and Financial Analysis of Transmission Planning Projects in Kiev on July 7-8, 2009. The course provided an introduction to fundamental principles and techniques for financial and economic analysis of transmission projects, including discounted cash flow, calculating internal rates of return, and cost benefit analysis. The World Bank and European Bank for Reconstruction and Development also participated in the workshop by presenting information on their respective project cycles and the financial appraisal of national and regional transmission projects. The training revealed the extent to which the economic and financial criteria are used. They are applied only to evaluate financial return on investments in new lines on a national basis. Market oriented transmission investments and investments that may have value from a regional perspective, either to improve security or promote trade, are not employed. These findings have informed our recommendations for next steps in the follow-up phase of the project.

Acknowledgements

USAID and USEA wish to acknowledge the invaluable contributions of all participating organizations to the success of the Project. The successful completion of this phase of the project would not be possible without the tremendous collaborative effort contributed by both the senior management and technical staff of the TSOs and resource organizations involved. The dedication to the objectives of the project by all involved is illustrated by the countless hours of volunteer labor contributed as a cost share to the project.

The TSOs graciously contributed the pro-bono labor of skilled system planners who worked diligently to develop their national models, spent countless hours coordinating with their counterparts by phone and email, and collaborated so effectively at the five two-day regional Working Group meetings. In addition to their labor contributions, they are to be recognized for sharing the cost of travel to the Working Group meetings by funding airfare and other expenses.

A special acknowledgement goes to Transelectrica, which volunteered to serve as Technical Project Coordinator in 2004. Since then Dan Preotescu has served as the Project Coordinator, deftly leading the Working Group and Steering Committee. Thanks to Transelectrica’s excellent management, the Project has produced a sophisticated regional transmission planning model and system analyses.

The Electricity Coordination Center of Belgrade is to be recognized for its professionalism and technical support in the development of the eight national models, the creation of the regional model, training on PSS/E and UCTE calculations, and the system analysis calculations. The assistance provided by EKC was “above and beyond” all expectations. A special debt of gratitude must be paid to TEIAS, who on a pro-bono basis to prepare and the Survey of Planning Criteria.

Organization of the Report

The report is organized as follows:

- The national transmission network descriptions are contained in Chapter Two of this report;
- A description of the regional load flow and dynamic models can be found in Chapter Three;
- Chapter Four is an analysis of the network in the 2015 steady state and dynamic modes;
- Chapter Five provides conclusions and a set of recommendations for the next phase of the project;
- Annex One is an inventory of generation and transmission network projects on a country by country basis up to 2020;
- Annex Two is the Survey of Planning Criteria and Principles among the Black Sea Regional Transmission System Operators.

Power Systems Data

This chapter includes the characteristic data for each system that is in Black Sea Region.

Armenia

The power transmission network of Armenia consists of 220 kV and 110 kV lines. Figure 2.1 shows the map of Armenian network and Table 2.1 shows main data about Armenian transmission network.

Table 2.1 – Armenia - network overview

Lines		Transformers	
Voltage level	Length of the overhead lines and cables	Voltage level	Installed capacities
(kV)	(km)	(kV/kV)	(MVA)
220	1527	220/x	2715
110	3083	110/x	5700
total	4610		8415

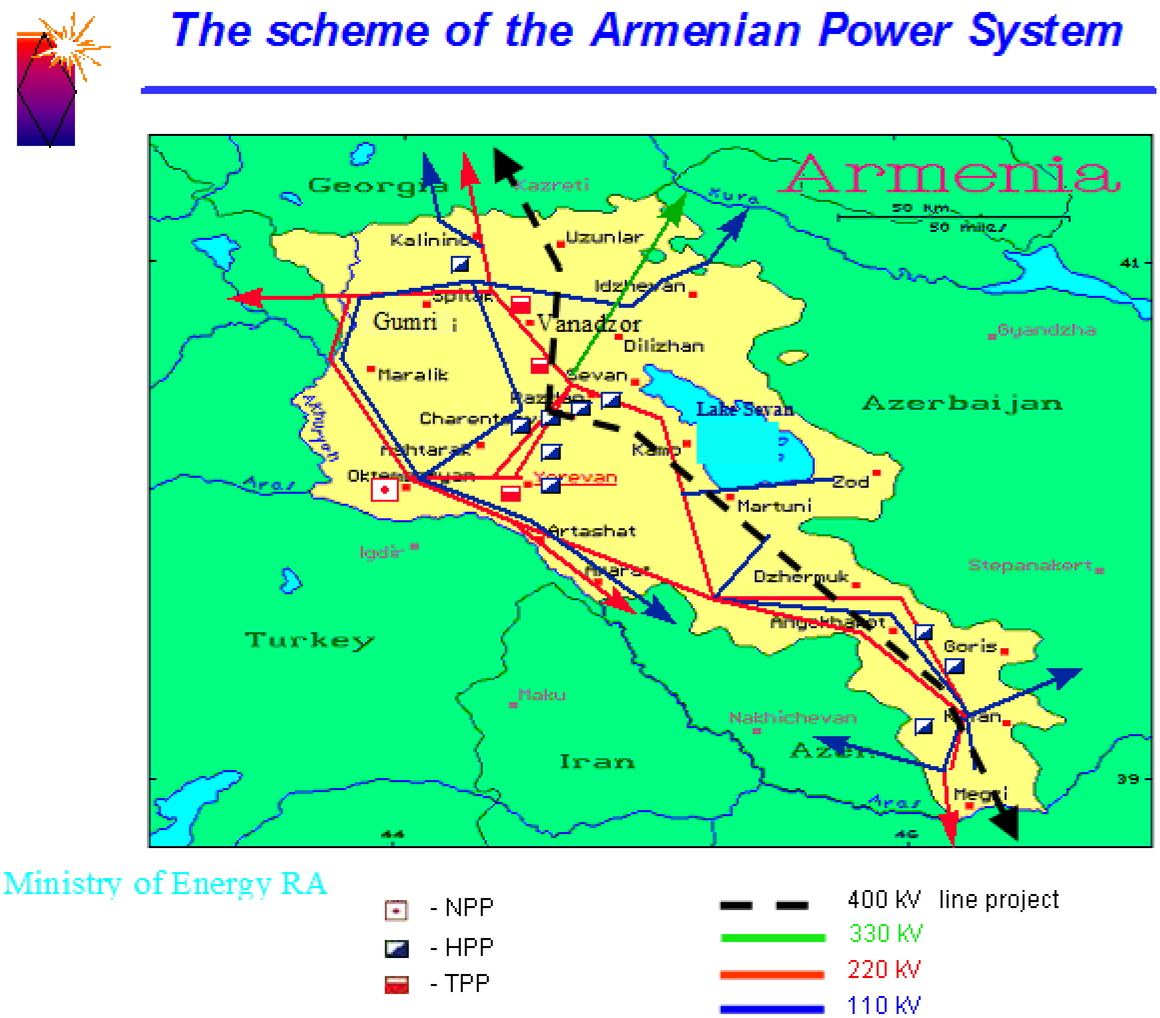


Figure 2.1 – Armenia - network map

Armenia is connected through interconnection lines with all neighboring countries:

Table 2.2 – Armenia – interconnection lines

OL name and nominal voltage (kV)	Substations		Length (km)		Capacity (MW)	Actual Condition
	Armenia	Foreign countries	Total	In Armenia		
Meghri 220	Shinuhair	Agar/ Iran	176.8	83	440	commercial operation
Alaverdi 220	Alaverdi	Tbilisi TPP/ Georgia	63.5	29.5	250	commercial operation
Ashotsk 110	Ashotsk	Ninotsminda/ Georgia	35.8	13.2	80	radial regime
Lalvar 110	Alaverdi-2	Sadakhlo/ Georgia	30	26.1	80	radial regime
Ghars 220	Giumri-2	Ghars/ Turkey	80	9.5	300	out of operation
Atabekian 330	Hrazdan TPP	Akstafa/ Azerbaijan	108	92	400	out of operation
Babek 220	Aarat-2	Babek/ Nakhijevan	99.6	19.5	250	breakdown state
Norashen 110	Ararat-2	Norashen/ Nakhijevan	98	16.6	80	breakdown state
Ordoubad 110	Agarak	Ordoubad/ Nakhijevan	30	9	80	breakdown state

Installed generation capacity in Armenia exceeds consumption, and Armenia is capable of exporting large quantities of energy.

Armenian NPP	815(440) MW
Hrazdan TPP	810 MW
Yerevan TPP	600 MW
Sevan-Hrazdan cascade of HPPs	561 MW
Vorotan cascade of HPPs	400 MW
Small HPPs	140 MW

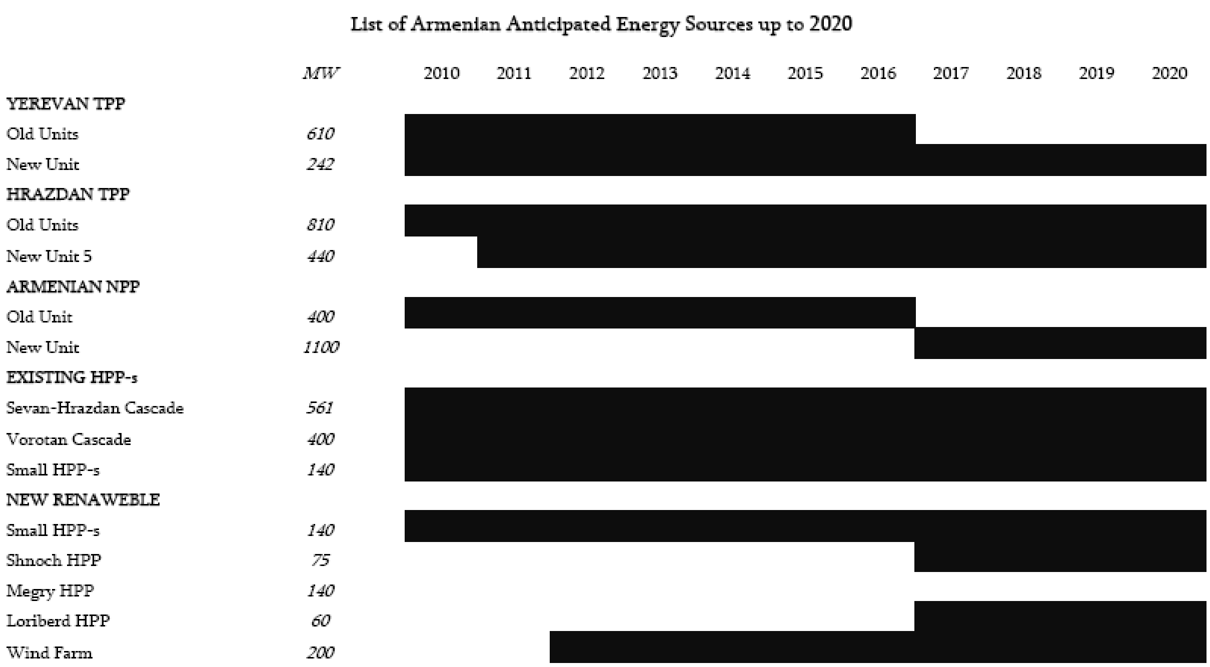


Figure 2.2 – Armenia – generation expansion plan

Table 2.3 – Armenia – Demand Forecasts

Item	Scenario	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Generation for Domestic Needs (GWh)	Low	6653	6790	6929	7071	7216	7364	7460	7550	7640	7732	7825
	Reference	6981	7240	7507	7785	8073	8372	8548	8727	8906	9084	9257
	High	7497	7816	8148	8495	8853	9225	9502	9787	1008 1	1038 3	1069 5
Domestic Consumption (GWh)	Low	4987	5107	5229	5354	5482	5613	5705	5792	5881	5971	6063
	Reference	5240	5454	5676	5907	6147	6398	6555	6717	6879	7041	7200
	High	5635	5898	6172	6459	6758	7069	7309	7557	7813	8077	8351
Gross Peak Demand (MW)	Low	1528	1559	1591	1624	1657	1691	1712	1733	1753	1774	1795
	Reference	1582	1636	1692	1750	1809	1870	1904	1938	1971	2004	2035
	High	1684	1747	1813	1880	1950	2022	2072	2123	2175	2228	2282

Source: The 2006 Updated Least Cost Generation Plan (LCGP). USAID EPP-I-00-03-00008-00, Task Order 800 /Armenia Program to Strengthen Reform and Enhance Energy Security in Armenia/ PA Consulting Group

Table 2.4 – Armenia – Import/Export balance plans

Item	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Domestic Consumption	5955	6190	6435	6690	6954	7229	7399	7572	7746	7920	8090
Supplied to Distribution Company from Small HPP-s	360	380	420	480	540	600	600	600	600	600	600
Supplied to Transmission Network for Domestic Consumption	5680	5899	6107	6304	6512	6730	6902	7079	7255	7431	7604
Import/Export to Regional Market	2030	4568	4569	4568	5482	5482	6091	8122	8833	8832	8833
* Iran	2000	3000	3000	3000	3900	3900	4500	4500	5200	5200	5200
* Turkey	0	1500	1500	1500	1500	1500	1500	3500	3500	3500	3500
* Georgia	0	0	0	0	0	0	0	0	0	0	0
NET GENERATIO N	8070	1084 7	1109 5	1135 3	1253 4	1281 2	1359 4	1580 0	1668 8	1686 4	1703 6

Source: Energy Scientific Research Institute CJSC" estimation based on "The 2006 Updated Least Cost Generation Plan (LCGP)" reference scenario and "Energy Sector Development Strategies in the Context of Economic Development in Armenia" adopted by the Government of Armenia at June 23 2005

Planned Network Reinforcements

Table 2.5 shows planed network reinforcements in forthcoming period.

Table 2.5 – Armenia - Planned network reinforcements

TYPE	SUBSTATION1		SUBSTATION2		VOLTAGE LEVEL	number of circuits /units	CAPACITY		MATERIAL OR TRANSFORMER TYPE	CROS SECTION	LENGTH			DATE OF COMMISSION	STATUS
								limited			BR1	BR2	TOTAL		
					kV/kV		A or MVA	A or MVA		mm2	km	km	km		
1	2	3	2	3	4	5	6	7	8	9	10	11	12	13	14
SS	AM	Hrazdan TPP			400/220	2	2x500	2x500						2015	Under negotiation
OHL	AM	Hrazdan TPP	IR	Tavriz	400	2	2x1800	2x1900	ACSR	2x(2x500)	332	100	432	2015	Under negotiation
OHL	AM	Shinuhayr	AM	Ararat 2	220	1	1100	1400	ACSR	2x300	90	80	170	2014	Under negotiation
OHL	AM	Hrazdan TPP	GE	Ksani	400	1	1100	1400	ACSR	2x300	90	80	170	2014	Under negotiation
SS	AM	Agarak 2			220/110	1	63		OTC					2015	Under negotiation
OHL	AM	Agarak 2	AM	Agarak 1	110	1			ACSR					2014	Under negotiation
SS	AM	Noravan			400/220	2	2x200							2015	Under negotiation
OHL	AM	Noravan	AM	Hrazdan TPP	400	2	1445		ACSR	2x300				2015	Under negotiation
OHL	AM	NPP Medzamor	AM	Hrazdan TPP	400	2	1445		ACSR	2x300				2015	Under negotiation

1. Type of project (OHL - overhead line, K - kable, SK - submarin kable, SS - substation, BB - back to back system...)
2. Country (ISO code)
3. Substation name
4. Installed voltage (for lines nominal voltage, for transformers ratio in voltages)
5. number of circuits/units
6. Conventional transmission capacity of elements for OHL in Amps, for transformers in MVA
7. Conventional transmission capacity limited by transformers or substations
8. Type of conductor or transformer (ACSR - Aluminum Cross section Steel Reinforced, or code of conductor, PS - phase shift transformer...)
9. Cross section (number of ropes in bundle x cross section/cross section of reinforcement rope)
10. Length till border of first state
11. Length till border of second state
12. Total length
13. Date of commissioning (estimate)
14. Status of project (Idea, Feasibility study, Construction, Damaged, out of service, Decommissioned...)

Table 2.6 – Armenia - Planned new generation units

TYPE	SUBSTATION1		VOLTAGE LEVEL		CAPACITY		DATE OF COMMISSIONING	STATUS
			kV	kV	MW	MVA	year	
1	2	3	4	5	6	7	8	9
CCHP	AM	Yerevan TPP new unit	18	110	208	240	2009	Tendering
TPP	AM	Hrarzdan TPP unit 5	15.75	220	440	510	2009	Partly Constructed
NPP	AM	NPP Medzamor	24	400	2x500	2x588	2017	
HPP	AM	Shnoch			75	85	2017	
HPP	AM	Megri			140	165	2017	
HPP	AM	Loriberd			60	71	2017	
SHPP	AM				140	189	2010	
WPP	AM				200	220	2012	

1. Type of plant (HPP - Hydropower plant, TPP - Thermal power plant, PSHPP - Pump Storage Hydro Power Plant, CCHP - Combined Cycle Heating Plant...)
2. Country
3. Substation name
4. Generator voltage level
5. Network voltage level
6. Installed active power
7. Installed apparent power
8. Date of commissioning (estimate)
9. Status of the project (Idea, Feasibility study, Construction...)

Bulgaria

Power transmission network of Bulgaria consists of 400 kV, 220 kV and 110 kV lines. Figure 2.3 shows the map of the Bulgarian network and Table 2.7 shows the main data regarding the Bulgarian transmission network.

Installed generation capacity comprises about 5400 MW of thermal units, 2000 MW of nuclear units, and 2600 MW of hydro units. Thermal power plants produce about 50 % of the total energy, nuclear units produce about 40 %, and hydro units cover 10 %.

Table 2.7 – Bulgaria - network overview

lines		transformers	
Voltage level	Length of the overhead lines and cables	Voltage level	Installed capacities
(kV)	(km)	(kV/kV)	(MVA)
400	2451	400/x	-
220	2805	220/x	-
110	9954	110/x	-
total	15210		15888

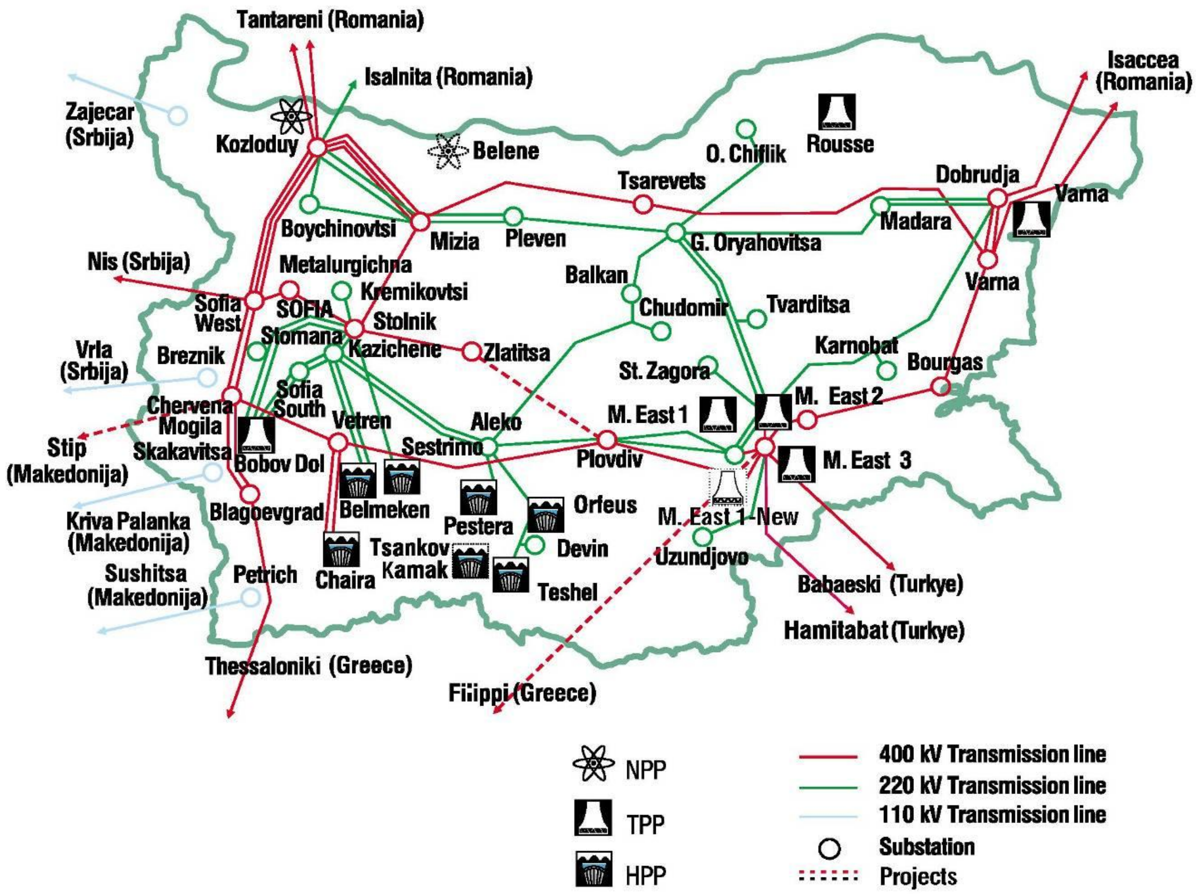


Figure 2.3 – Bulgaria - network map

Interconnection lines between the Bulgarian EPS and neighboring countries and the grid operation data for 2005 are shown in Table 2.8

Table 2.8 – Bulgaria – interconnection lines

Interconnection Lines between the Republic of Bulgaria and Neighbour Countries

Country	Substation	Voltage кV	Number of lines	Length km	Cross Section mm^2
Romania	NPP Kozloduy (BG) - Tantareni (RO)	400	2	115.7 (14)	2ACO 500
Romania	NPP Kozloduy (BG) - Isalnita (RO)	220	1	98.1 (18.6)	ACO 500
Romania	Varna (BG) - Isaccea (RO)	400	1	235.4 (85)	5ACO 300
Romania	Dobrudja (BG) - Isaccea (RO)	400	1	230.6 (80.3)	3ACO 400
Turkey	TPP Maritsa East 3 (BG) - Babaeski (TR)	400	1	136.6 (59.5)	2ACO 500
Turkey	TPP Maritsa East 3 (BG) - GPP Hamitabat (TR)	400	1	150 (59)	3ACO 400
Greece	Blagoevgrad (BG) - Thessaloniki (GR)	400	1	174.7 (72.7)	2AC 500
Macedonia	Petrich (BG) - Sushitsa (MK)	110	1	49.3 (21.5)	ACO 400
Macedonia	Skakavitsa (BG) - Kriva Palanka (MK)	110	1	12.7 (5.3)	ACO 400
Macedonia	Chervena Mogila (BG) - Stip (MK)	400		under construction	
Serbia	Sofia West (BG) - Nis (SER)	400	1	122.6 (37)	2ACO 500
Serbia	Breznik (BG) - Vurla (SER)	110	1	64.1 (41.1)	AC 185
Serbia	Kula (BG) - Zajecar (SER)	110	1	21 (11.8)	AC 185

(...) - On the territory of the Republic of Bulgaria

The gross power demand forecast for Bulgaria was developed on the assumption that there would be a 51% reduction of electricity intensity over the period 2008-2030 in a minimum scenario and 41% in a maximum scenario. Figure 2.4 shows gross power demand.

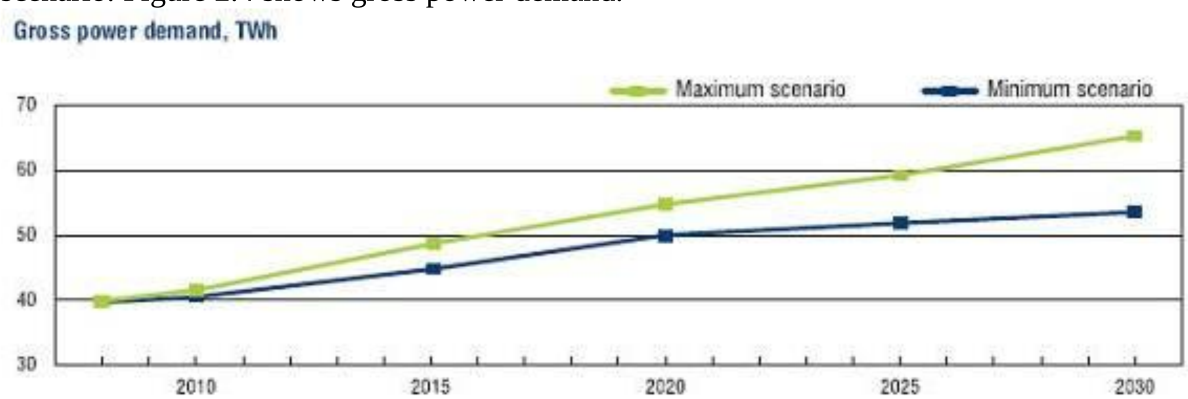


Figure 2.4 – Bulgaria - Demand forecasts

Planned Network Reinforcements

Table 2.9 shows planed network reinforcements in forthcoming period.

Table 2.9 – Bulgaria - Planned network reinforcements

TYPE	SUBSTATION1		SUBSTATION2		VOLTAGE LEVEL	Number Of Circuits /units	CAPACITY		MATERIAL OR TRANSFORMER TYPE	CROSS	LENGTH			DATE OF COMMISSIONING	STATUS
								limited			BR1	BR2	TOTAL		
					kV/kV		A or MVA	A or MVA		mm2	km	km	km		
1	2	3	2	3	4	5	6	7	8	9	10	11	12	13	14
OHL	BG	M.East	GR	Nea Santa	400	1	1700	-	ACSR	3X400	-	-	-	2015	Project
OHL	BG	Zlatitsa	BG	Plovdiv	400	1	1700	-	ACSR	3X400	-	-	75	2010	Commissioning
OHL	BG	M.East1	BG	Plovdiv	400	1	1700	-	ACSR	3X400	-	-	93	2013	Project
OHL	BG	M.East1	BG	M.East3	400	1	1700	-	ACSR	3X400	-	-	13	2010	Construction
OHL	BG	M.East1	BG	Burgas	400	1	1700	-	ACSR	3X400	-	-	135	2017	Project
OHL	BG	HPP Aleko	BG	Plovdiv	220	2	720	-	ACSR	500	-	-	2x40=80	2015	Project
OHL	BG	Karnobat	BG	Dobrudja	220	1	360	-	ACSR	500	-	-	90	2017	Project
OHL	BG	Dobrich	BG	Majak	110	1	180	-	ACSR	500	-	-	140	2012	Project
OHL	BG	Kavarna	BG	Varna	110	2	360	-	ACSR	500	-	-	2x90=180	2013	Project
Substation	BG	Krushari	BG		400/110				ACSR					2020	Project
Substation	BG	Vidno	BG		400/110				ACSR					2020	Project
OHL	BG	Krushari	BG	Vidno	400	2	2x1700	-	ACSR	3x400	-	-	2x115=230	2020	Project

1. Type of project (OHL - overhead line, K - kable, SK - submarin kable, SS - substation, BB - back to back system...)
2. Country (ISO code)
3. Substation name
4. Installed voltage (for lines nominal voltage, for transformers ratio in voltages)
5. number of circuits/units
6. Conventional transmission capacity of elements for OHL in Amps, for transformers in MVA
7. Conventional transmission capacity limited by transformers or substations
8. Type of conductor or transformer (ACSR - Aluminum Crossection Steel Reinforced, or code of conductor, PS - phase shift transformer...)
9. Crossection (number of ropes in bundle x cross section/cross section of reinforcement rope)
10. Length till border of first state
11. Length till border of second state
12. Total length
13. Date of commissioning (estimate)
14. Status of project (Idea, Feasibility study, Construction, Damaged, out of service, Decommissioned...)

Table 2.10 – Bulgaria - Planned new generation units

TYPE	SUBSTATION1		VOLTAGE LEVEL		CAPACITY		DATE OF COMMISSIONING	STATUS
			kV	kV	MW	MVA	year	
1	2	3	4	5	6	7	8	9
NPP	BG	Belene	24	400	2x1000	2x1111	2017,2017	Project
CCGT	BG	TPP Varna New unit 1	19	220	280	336	2016	Project
CCGT	BG	TPP Varna New unit 2	19	220	280	336	2016	Project
CCGT	BG	TPP Varna New unit 3	19	110	312	336	2016	Project
TPP	BG	TPP Galabovo, U1	20	400	335	436	2010	Commissioning
TPP	BG	TPP Galabovo, U2	20	400	335	436	2011	Commissioning
TPP	BG	TPP Maritsa East4	?	400	700	?	2018	Project
HPP	BG	HPP Cankov Kamak, U1	10.5	110	40	50	2010	Commissioning
HPP	BG	HPP Cankov Kamak, U2	10.5	110	40	50	2011	Commissioning
HPP	BG	HPP Gorna Arda	?	110	174	?	2018	Project
TPP	BG	TPP Ruse	13.8	110	100	137.5	2014	Project
HPP	BG	HPP Nikopol	?	110	440	?	2020,2021	Project
HPP	BG	HPP Silistra	?	110	130	?	2020,2021	Project
WPP	BG	Wind PP	?	110	1519	?	2015	Project
CHPP	BG	GPP Haskovo	11	110	256	284	2012,2013	Project
CHPP	BG	GPP Mramor	11.5	110	250	312	2011,2012	Project

1. Type of plant (HPP - Hydropower plant, TPP - Thermal power plant, PSHPP - Pump Storage Hydro Power Plant, CCHP - Combined Cycle Heating Plant...)
2. Country
3. Substation name
4. Generator voltage level
5. Network voltage level
6. Installed active power
7. Installed apparent power
8. Date of commissioning (estimate)
9. Status of the project (Idea, Feasibility study, Construction...)

Georgia

Figure 2.5 shows the Georgian transmission system. The chart maps a 500 kV East-West line that represents the backbone of Georgia's high voltage network. Together with 220 kV lines in parallel, 110kV and 35 kV in radial (spurs) operation, it completes the Georgian transmission system. Table 2.11 shows the main characteristics of the Georgian network.

Table 2.11 – Georgia - network overview

lines		transformers	
Voltage level	Length of the overhead lines and cables	Voltage level	Installed capacities
(kV)	(km)	(kV/kV)	(MVA)
500	573	500/220	5995
330	21	330/x	480
220	1536	220/x	7275
110	3925	110/x	4125
total	6055		3200

Figure 2.5 – Georgia - network map

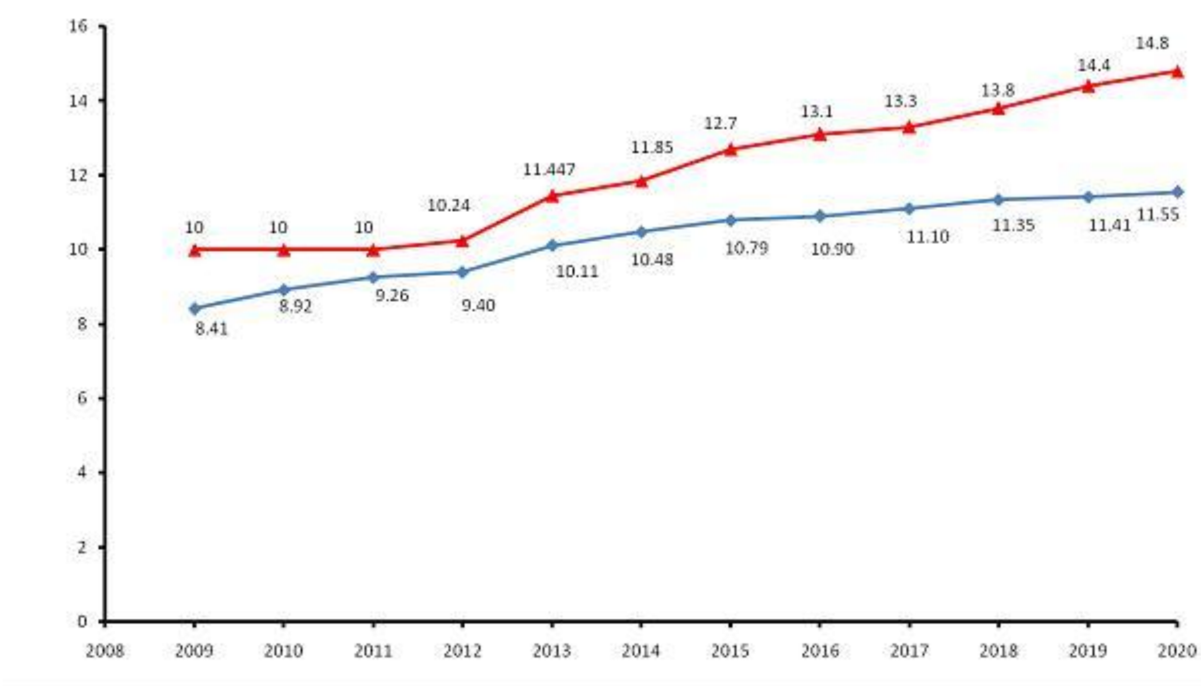


Figure 2.6 – Georgia - Demand forecasts (TWh)

Planned Network Reinforcements

Figure 2.5 illustrates the planned network reinforcements in Georgia. The main goal is to reinforce the Georgia-Russia-Azerbaijan loop, close the 500 kV loop internally, and build a new connection to Turkey to increase transfer capacity.

Table 2.12 – Georgia - Planned network reinforcements

TYPE	SUBSTATION1		SUBSTATION2		VOLTAGE LEVEL	number of circuits /units	CAPACITY	limited	MATERIAL OR TRANSFORMER TYPE	CROSSECTION	LENGTH BR1	BR2	TOTAL	DATE OF COMMISSION	STATUS
					kV/kV		A or MVA	A or MVA		mm2	km	km	km		
1	2	3	2	3	4	5	6	7	8	9	10	11	12	13	14
SS	GE	Qsani			500/400	1	3X267		LTC					2009	Feasibility study
OHL	GE	Qsani	AM	TPP Hrazdan	400	1	1100	1400	ACSR	2x300	80	90	170	2009	Feasibility study
OHL	GE	Mukharani	AZ	AZ TPP	330	1							283		
SS	GE	Akhaltske			500/400	1									
BB	GE	Akhaltske			400	1									
OHL	GE	Akhaltske		Marneuli	500	1									
OHL	GE	Marneuli		Gardabani	500	1									
OHL	GE	Akhaltske		Menji	500	1									
OHL	GE	Menji		Kudoni	500	1									
OHL	GE	Akhaltske		Zestaponi	500	1							71		
OHL	GE	Akhaltske	TR	Borcka	400	1							130		
OHL	GE	Gardabani	AR	Atarbeksan	330	1									
OHL	GE	Enguri	RU	Centralna(Sochi)	500	1							450		

1. Type of project (OHL - overhead line, K - kable, SK - submarin kable, SS - substation, BB - back to back system...)
2. Country (ISO code)
3. Substation name
4. Installed voltage (for lines nominal voltage, for transformers ratio in voltages)
5. number of circuits/units
6. Conventional transmission capacity of elements for OHL in Amps, for transformers in MVA
7. Conventional transmission capacity limited by transformers or substations
8. Type of conductor or transformer (ACSR - Aluminum Crossection Steel Reinforced, or code of conductor, PS - phase shift transformer...)
9. Crossection (number of ropes in bundle x cross section/cross section of reinforcement rope)
10. Length till border of first state
11. Length till border of second state
12. Total length
13. Date of commissioning (estimate)
14. Status of project (Idea, Feasibility study, Construction, Damaged, out of service, Decommissioned...)

Moldova

The backbone of the Moldovan network is the 330 kV system that covers the country from north to south. Together with 110 kV system that operates in parallel with the 330 kV network, it forms the national grid. Figure 2.7 illustrates the Moldovan transmission grid. Table 2.13 shows the main characteristics of the Moldovan network.

Table 2.13 – Moldova - network overview

lines		transformers	
Voltage level	Length of the overhead lines and cables	Voltage level	Installed capacities
(kV)	(km)	(kV/kV)	(MVA)
400	214	400/330	500
330	532.4	330/x	2525
110	5231.1	110/x	3687
total	5977.5		6712

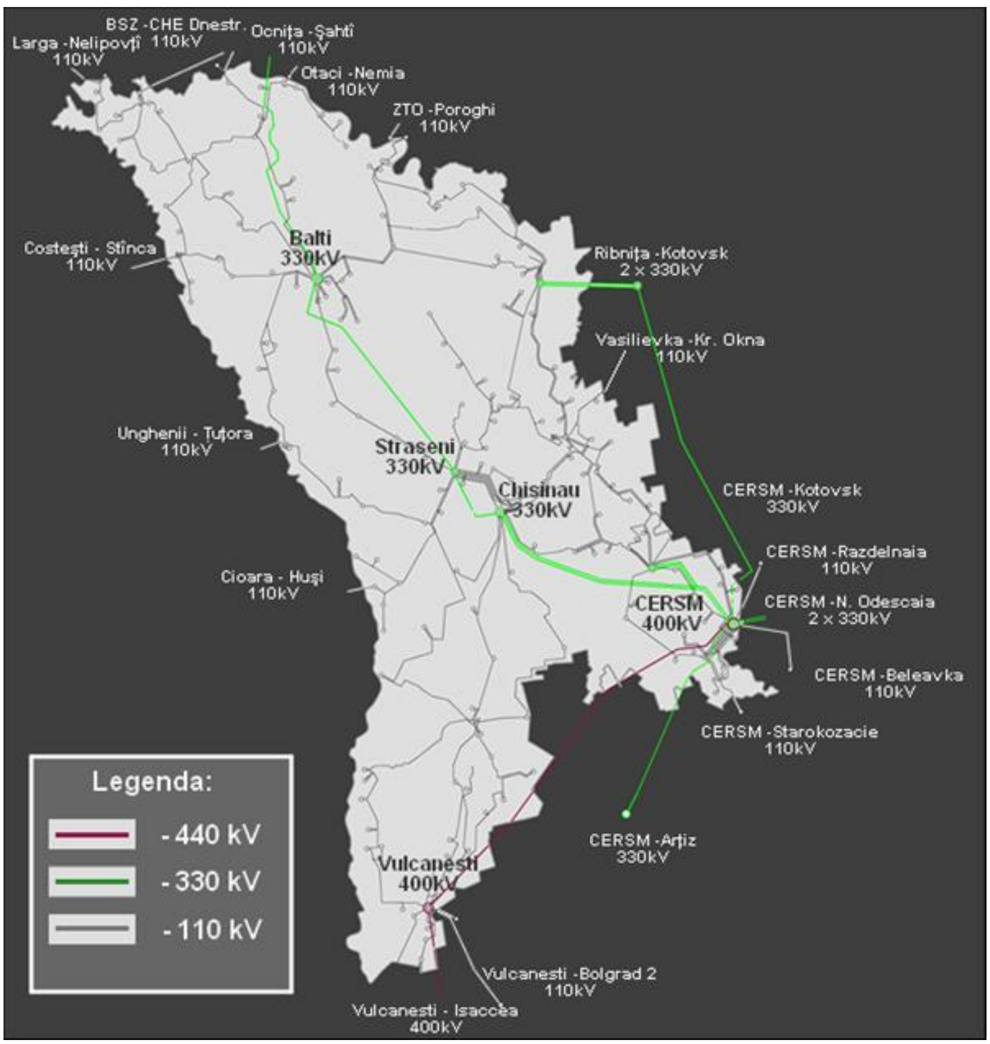


Figure 2.7 – Moldova - network map

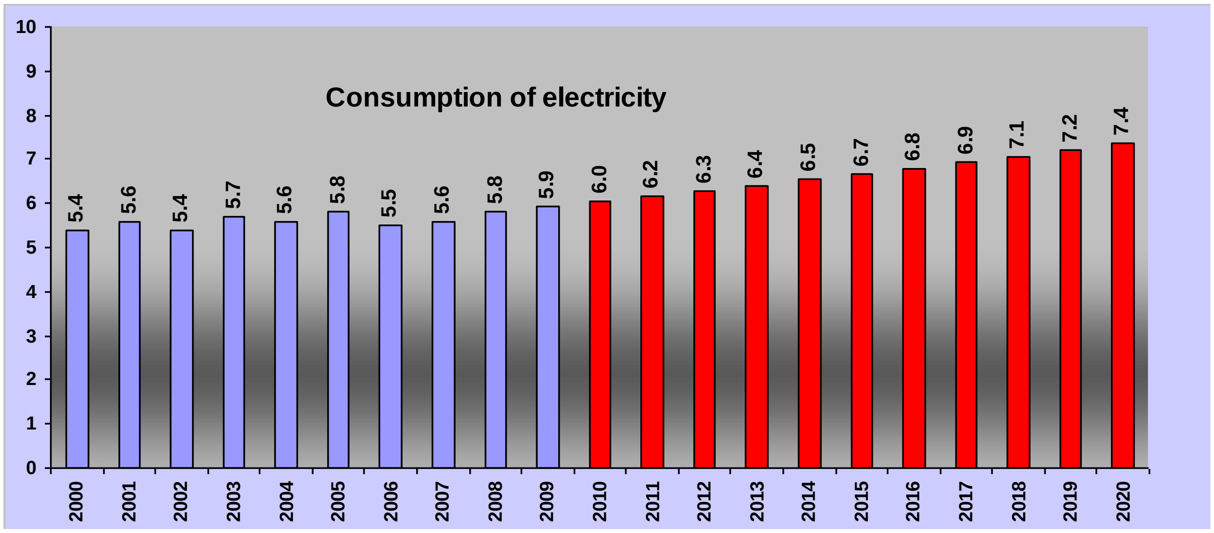


Figure 2.8 – Moldova – Demand forecast

Currently, Moldova operates in parallel operation and is highly integrated with the Ukrainian national grid. The 110 kV connections to Romania are operated only in island mode, and 400 kV line to Bulgaria is out of service. Due to configuration of the high voltage network, Ukraine has a large influence on the system operation of the Moldavian network.

Planned Network Reinforcements

Table 2.14 – Moldova - Planned network reinforcements

TYPE	SUBSTATION1		SUBSTATION2		VOLTAGE LEVEL kV/kV	Number Of Circuits /units	CAPACITY A or MVA	CAPACITY limited A or MVA	MATERIAL OR TRANSFORMER TYPE	CROSSECTION mm2	LENGTH BR1 km	LENGTH BR2 km	LENGTH TOTAL km	DATE OF COMMISSIONING
1	2	3	2	3	4	5	6	7	8	9	10	11	12	13
OHL	MD	Balti	UA	Dnestrovsca HPP	330	1	1670	-			88	32	120	2020
OHL	MD	Balti	MD	Straseni	330	1	1380	-			102.8		102.8	2020
OHL	MD	Straseni	MD	Chisinau	330	1	1380	-			36.4	-	36.4	2020
OHL	MD	Balti	MD	Ribnita	330	1	1380	-			82.5	-	82.5	2020
OHL	MD	Straseni		Ribnita	330	1	1380	-			75	-	75	2020
SS	MD	Balti			400/330	1	630	-	IPC					2015
OHL	MD	Balti	RO	Suceava	400	1	1750	-			55	-		2015
OHL	MD	Ungheni	RO	Iasi	400	2	1750	-			10	-		2020
OHL	MD	Ungheni	MD	Balti	400	1	1750	-			86.1	-		2020
OHL	MD	Ungheni	MD	Straseni	400	1	1750	-			113.9	-		2020
SS	MD	Straseni			400/330	1	630	-	IPC					2020

1. Type of project (OHL - overhead line, K - kable, SK - submarin kable, SS - substation, BB - back to back system...)
2. Country (ISO code)
3. Substation name
4. Installed voltage (for lines nominal voltage, for transformers ratio in voltages)
5. number of circuits/units
6. Conventional transmission capacity of elements for OHL in Amps, for transformers in MVA
7. Conventional transmission capacity limited by transformers or substations
8. Type of conductor or transformer (ACSR - Aluminum Crossection Steel Reinforced, or code of conductor, PS - phase shift transformer...)
9. Crossection (number of ropes in bundle x cross section/cross section of reinforcement rope)
10. Length till border of first state
11. Length till border of second state
12. Total length
13. Date of commissioning (estimate)
14. Status of project (Idea, Feasibility study, Construction, Damaged, out of service, Decommissioned...)

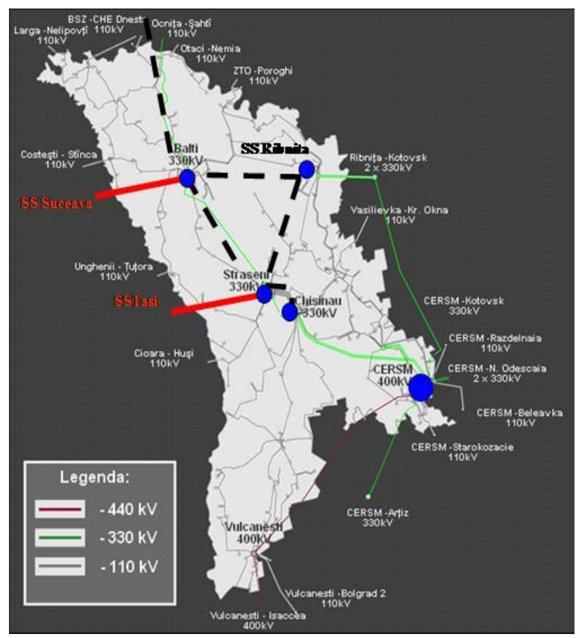


Table 2.15 – Moldova - Planned new generation units

TYPE	SUBSTATION1		VOLTAGE LEVEL kV	kV	CAPACITY MW	MVA	DATE OF COMMISSIONING year	STATUS	COMMENT
1	2	3	4	5	6	7	8	9	10
CCHP	MD	KSPP-2	15.75	110	from 240 to 440		2020	Reconstruction and extension of existing plant	CCHP
TPP	MD	Chisinau	22	400	350		2020		TPP

1. Type of plant (HPP - Hydropower plant, TPP - Thermal power plant, PSHPP - Pump Storage Hydro Power Plant, CCHP - Combined Cycle Heating Plant...)
2. Country
3. Substation name
4. Generator voltage level
5. Network voltage level
6. Installed active power
7. Installed apparent power
8. Date of commissioning (estimate)
9. Status of the project (Idea, Feasibility study, Construction...)

Romania

The transmission network of Romania consists of a mesh of 400, 220 and 110 kV lines. From the regional system point of view, the Romanian transmission system has a strong configuration with multiple internal loops at 400 kV. However, there are very few interconnections with surrounding countries. The main characteristics of Romanian network are presented in Table 2.16 below.

Table 2.16 – Romania - network overview

lines		transformers	
Voltage level	Length of the overhead lines and cables	Voltage level	Installed capacities
(kV)	(km)	(kV/kV)	(MVA)
750	154.6	750/400	2500
400	4740.3	400/x	15250
220	4095.9	220/x	16900
110	6473.5	110/x	14580
total	15464.3		49230

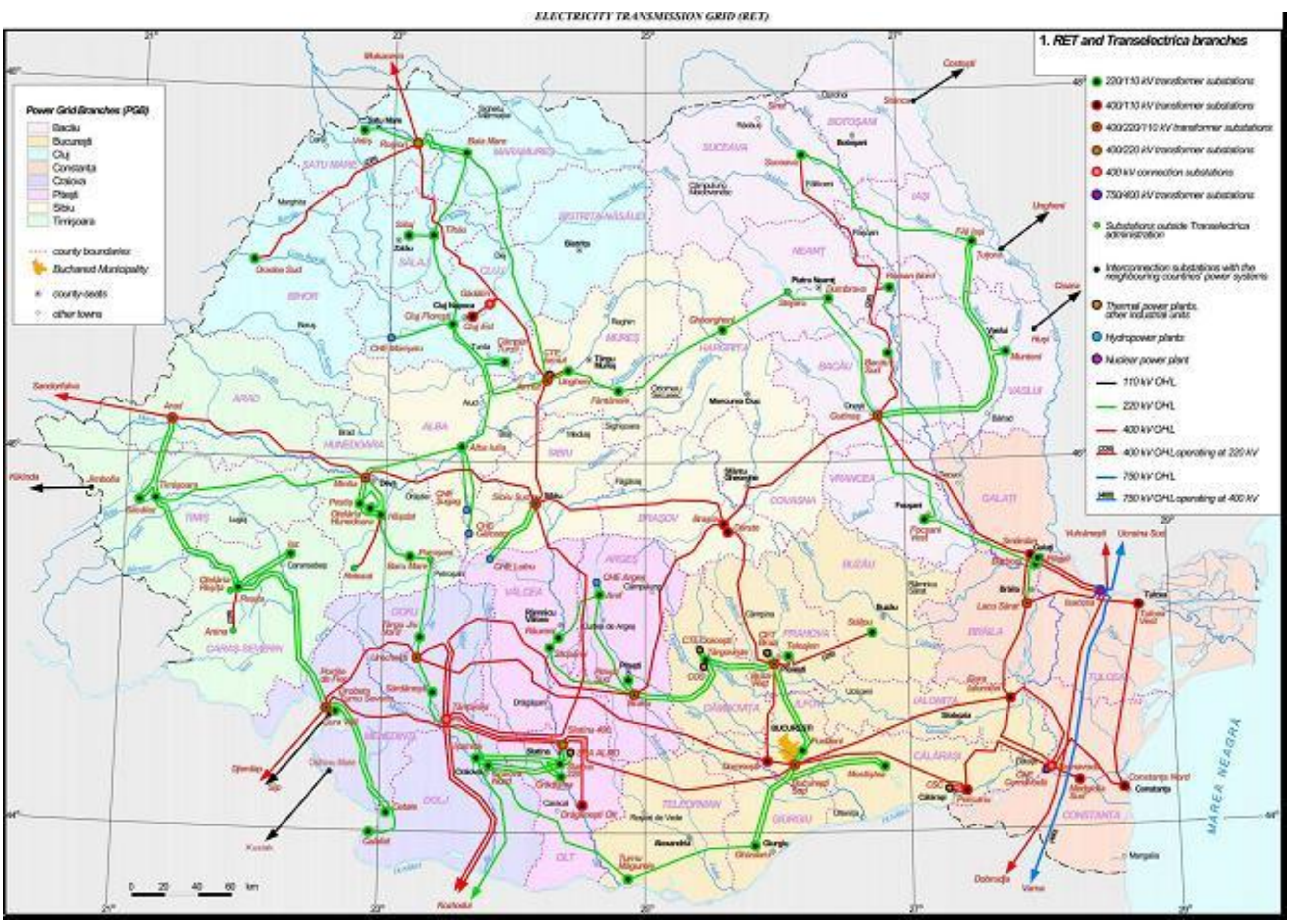


Figure 2.9 – Romania - network map

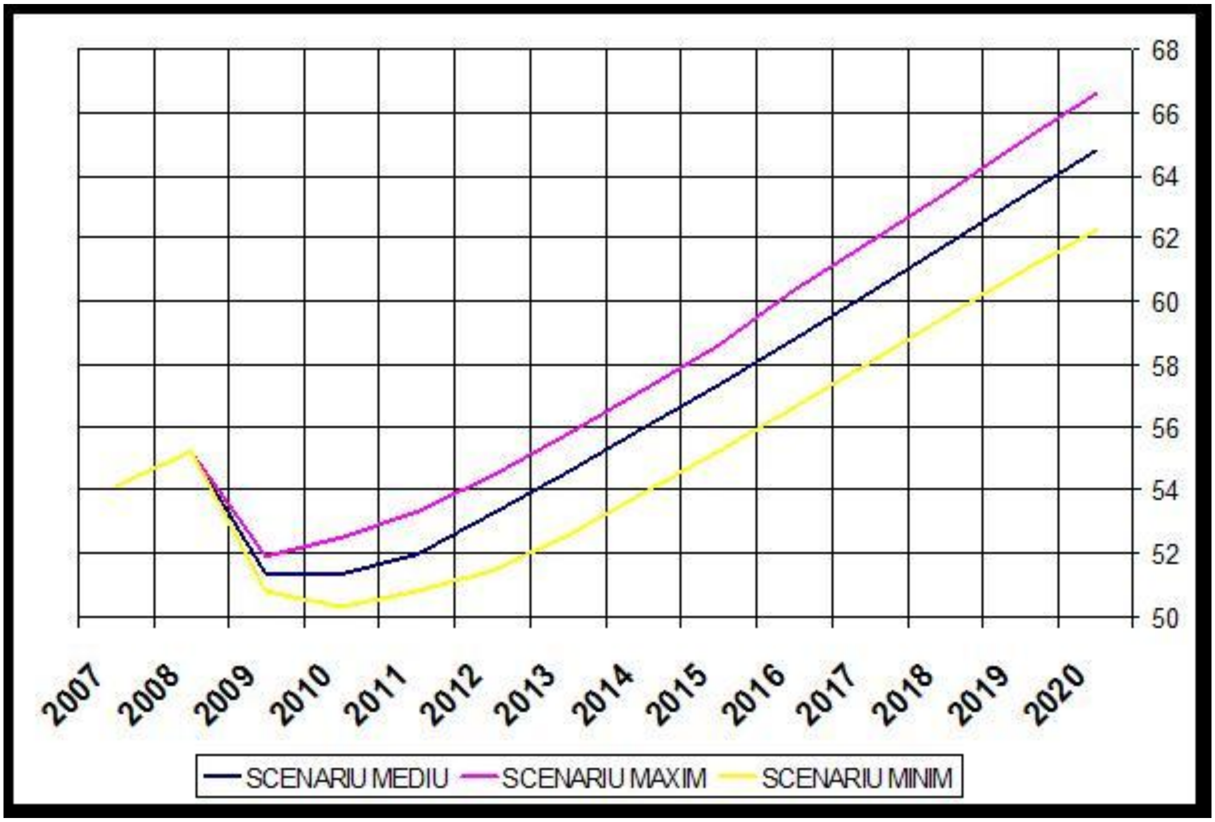


Figure 2.10 – Romania – Demand Forecast (TWh)

Planned Network Reinforcements

The present development plan is to: increase border lines capacities by diverting Dobrudja (Bulgaria)-Vulkanesti (Moldova) line to Isaccea (Romania) substation; rehabilitate the existing 750 kV line Isaccea (Romania)-Pivdenoukrainskaya (Ukraine); installing the Back-to-Back system; building 400 kV lines Oradea (Romania) - Becescaba (Hungary) and Suceava (Romania)-Balti (Moldova), and upgrading parts of the Romanian network from 220 kV to 400 kV. These lines are already built for 400 kV but currently operate at the 220 kV level. The construction of the new 400 kV lines will increase transmission and reserve capacity of the network. The objective is to close the 400kV ring in the Romanian network, and increase the security of supply of the main consumption region in the Bucharest 400kV ring.

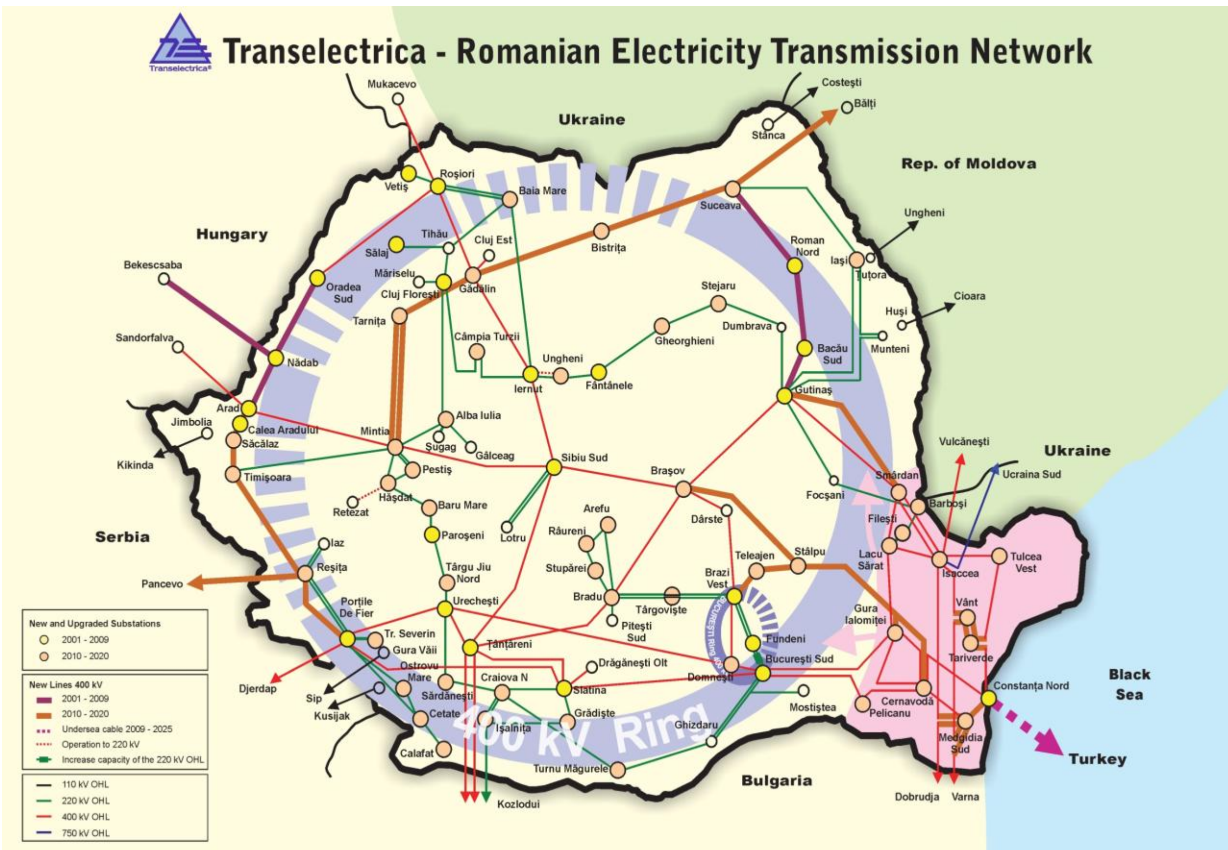


Table 2.17 – Romania – Planned network reinforcements

TYPE	SUBSTATION1		SUBSTATION2		VOLTAGE LEVEL kV/kV	Number Of Circuits /units	CAPACITY A or MVA	CAPACITY limited A or MVA	MATERIAL OR TRANSFORMER TYPE	CROSS mm2	LENGTH BR1 km	LENGTH BR2 km	LENGTH TOTAL km	DATE OF COMMISSION	STATUS	COMMENT
1	2	3	2	3	4	5	6	7	8	9	10	11	12	13	14	13
SS	RO	Portile de Fier II			220/110	2	2*200		2 windings					2008	completed	
OHL	RO	Portile de Fier II	RO	Cetate	220	1	875		Ol-Al	450			80	2008	completed	
OHL	RO	Portile de Fier II	RO	Portile de Fier I	220	1	875		Ol-Al	450			71	2008	completed	
CSS	RO	Nadab		-	400										completed	
OHL	RO	Oradea	RO	Nadab	400	1	1997		Ol-Al	3x300			75		completed	
OHL	RO	Arad	RO	Nadab	400	1	1997		Ol-Al	3x300			35		completed	
OHL	RO	Nadab	HU	Bekescsaba Border	400	1	1750		Ol-Al	3x300			23	2008	completed	
OHL	HU	Bekescsaba Border	HU	Bekescsaba	400	1	1750		Ol-Al	2x500			37	2010	completed	
SS	RO	Resita			400/220	1	400		2 windings					2014		
SS	RO	Resita			400/110	1	250		2 windings					2014		
OHL	RO	Portile de Fier I	RO	Resita	400	1	1997		Ol-Al	3x300			117	2014		new 400kV OHL
SS	RO	Timisoara			400/220	1	400		2 windings					2014		
OHL	RO	Timisoara	RO	Resita	400	1	1997		Ol-Al	3x300			73	2014		upgrade from 220 kV
OHL	RO	Timisoara	RO	Arad	400	1	1997		Ol-Al	3x300			55	2014		upgrade from 220 kV
OHL	RO	Timisoara	RS	Pancevo	400	1	1750		Ol-Al	3x300			100	2014		
SS	RO	Suceava			400/110	2	250		2 windings					2010		
OHL	RO	Suceava	MD	Balti	400	1	1750		Ol-Al	3x300	40	55	95	2019		
SS	RO	Bacau			400/220	1	400		2 windings					2014		
SS	RO	Roman			400/220	1	400		2 windings					2014		
OHL	RO	Suceava	RO	Roman	400	1	1700		Ol-Al	3x300			100	2014		upgrade from 220 kV
OHL	RO	Roman	RO	Bacau	400	1	1700		Ol-Al	3x300			58.8	2014		upgrade from 220 kV
OHL	RO	Bacau	RO	Gutinas	400	1	1700		Ol-Al	3x300			55.3	2014		upgrade from 220 kV
SS	RO	Bistrica			400/110	1	250		2 windings					2020		
OHL	RO	Suceava	RO	Bistrica	400	1	1700		Ol-Al	3x300				2020		upgrade from 220 kV
OHL	RO	Gadalin	RO	Bistrica	400	1	1700		Ol-Al	3x300				2020		upgrade from 220 kV
SS	RO	Vant			400/110	2	250		2 windings					2014		
OHL	RO	Isaccea	RO	Vant	400	1	1800		Ol-Al	3x300				2014	Constr.	to line Isaccea-Dobrudja
OHL	RO	Medgidia	RO	Vant	400	1	1800		Ol-Al	3x300				2014	Constr	to line Isaccea-Dobrudja
OHL	BG	Dobrudja	RO	Medgidia	400	1	1800		Ol-Al	3x300				2012	Constr	to line Isaccea-Dobrudja
SS	RO	Tariverde			400/110	2	250		2 windings					2011	Constr	
OHL	RO	Tulcea west	RO	Tariverde	400	1	1800		Ol-Al	3x300				2011	Constr	to line Tulcea-

																Constanta
OHL	RO	Constanta	RO	Tariverde	400	1	1800		Ol-Al	3x300				2011	Constr	to line Tulcea-Constanta
OHL	RO	Isaccea	RO	Medgidia	400	1	1800		Ol-Al	3x300				2014		to line Isaccea-Varna
OHL	BG	Varna	RO	Medgidia	400	1	1800		Ol-Al	3x300				2014		to line Isaccea-Varna
OHL	RO	Constanta	RO	Medgidia	400	1	1800		Ol-Al	3x300			21	2014		new 400kV OHL
DC	RO	Constanta			400		600 MW							2020		DC Converter station
SK	RO	Constanta	TR	Pasakoy	400	1	600 MW				200	200	400	2020		
SS	RO	Iasi			400/220									2020		
OHL	RO	Iasi	MD	Chisinau	400	1	1750		Ol-Al	3x300				2020		

1. Type of project (OHL - overhead line, K - kable, SK - submarin kable, SS - substation, BB - back to back system...)
2. Country (ISO code)
3. Substation name
4. Installed voltage (for lines nominal voltage, for transformers ratio in voltages)
5. number of circuits/units
6. Conventional transmission capacity of elements for OHL in Amps, for transformers in MVA
7. Conventional transmission capacity limited by transformers or substations
8. Type of conductor or transformer (ACSR - Aluminum Crossection Steel Reinforced, or code of conductor, PS - phase shift transformer...)
9. Crossection (number of ropes in bundle x cross section/cross section of reinforcement rope)
10. Length till border of first state
11. Length till border of second state
12. Total length
13. Date of commissioning (estimate)
14. Status of project (Idea, Feasibility study, Construction, Damaged, out of service, Decommissioned...)

Table 2.18 – Romania – Planned new generation units

TYPE	SUBSTATION1		VOLTAGE LEVEL kV	kV	CAPACITY MW	MVA	DATE OF COMMISSIONING year	STATUS	COMMENT
1	2	3	4	5	6	7	8	9	10
CCHP	RO	Brazi	20	400	2x305	4x288	2010	construction	
CCHP	RO	Brazi	20	220	315	4x288	2010	construction	
TPP	RO	Galati	24	400	800		2014	construction	
TPP	RO	Braila	24	400	880		2016	construction	
NPP	RO	Cernavoda	24	400	2x720	2x800	2016	construction	
HPP	RO	Tarnita	15.75	400	4x256	4x288	2016	Project	

1. Type of plant (HPP - Hydropower plant, TPP - Thermal power plant, PSHPP - Pump Storage Hydro Power Plant, CCHP - Combined Cycle Heating Plant...)
2. Country
3. Substation name
4. Generator voltage level
5. Network voltage level
6. Installed active power
7. Installed apparent power
8. Date of commissioning (estimate)
9. Status of the project (Idea, Feasibility study, Construction...)

Russia

The power industry in Russia developed stepwise by: incorporating regional power systems, working in parallel, and forming interregional electric power pools, which merged to form a single Power Grid.

Figure 2.11 – Russia – network map (western part)

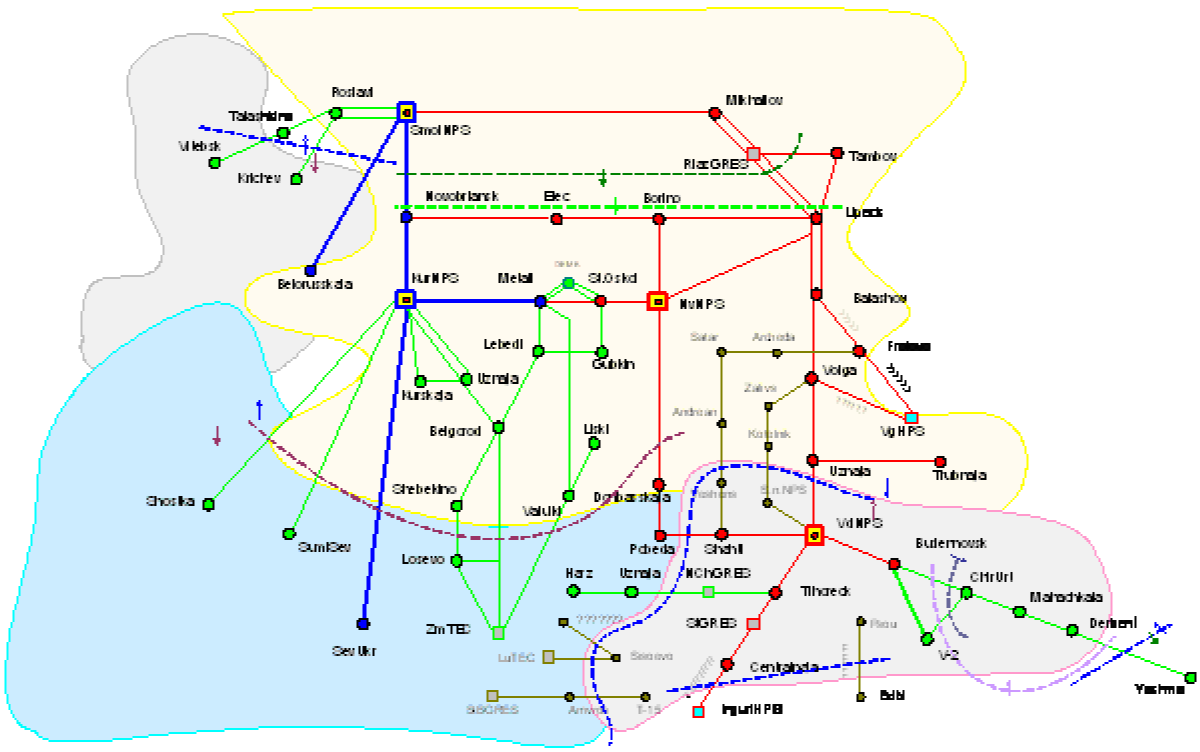


Figure 2.12 – Russia – network map (modeled part in Black Sea regional model)

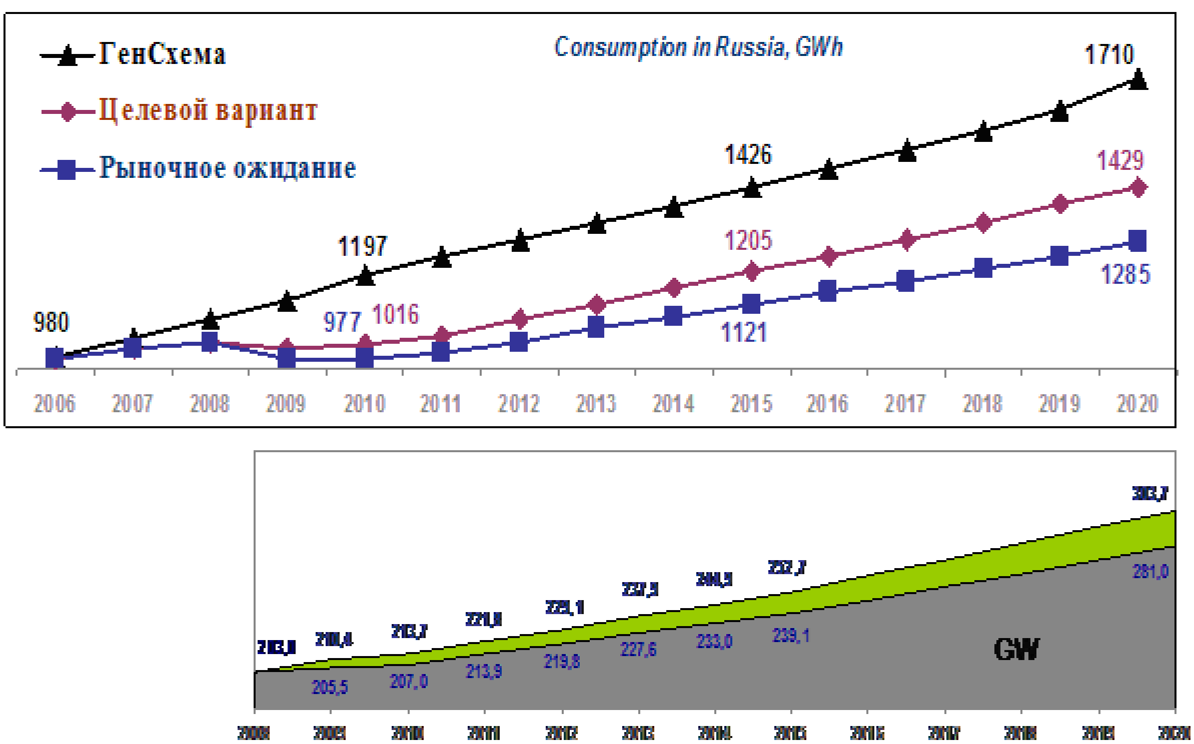


Figure 2.13 – Russia – Demand forecast

Planned Network Reinforcements

Table 2.19 – Russia – Planned network reinforcements

TYPE	SUBSTATION1		SUBSTATION2		VOLTAGE LEVEL kV/kV	Number Of Circuits /units	CAPACITY A or MVA	limited A or MVA	MATERIAL OR TRANSFORMER TYPE	CROSS mm2	LENGTH BR 1 km	BR 2 km	TOTAL km	DATE OF COMMISSION	STATUS	COMMENT
1	2	3	2	3	4	5	6	7	8	9	10	11	12	13	14	13
OHL	RU	Centralna(Sochi)	GE	Enguri	500									2015		450 km, single circuit
SS	RU	Rostov			500/220									2011		-
OHL	RU	Rostov		Sahti 30	500									2011		single circuit
OHL	RU	Rostov		Frolovska	500									2011		single circuit
OHL	RU	Rostov		R20	220									2011		single circuit
SS	RU	Krimskaya II			500/220									2015		-
OHL	RU	Krimskaya II		Tihoreck	500									2015		single circuit
SS	RU	Senaya			220									2015		-
OHL	RU	Krimskaya II		Senaya	220									2015		single circuit
OHL	RU	Krimskaya II		Slavyansk	220									2015		single circuit
OHL	RU	Slavyansk		Senaya	220									2015		single circuit
SS	RU	Nevinomysk			500/220									2010		-
OHL	RU	Nevinomysk		Volgodonska	500									2010		single circuit
SS	RU	Mozdok			500/220									2012		-
OHL	RU	Nevinomysk		Mozdok	500									2012		single circuit
SS	RU	Alagir			330/110									2015		-
OHL	RU	Nalcik		Alagir	330									2015		single circuit
OHL	RU	V2		Alagir	330									2015		single circuit
SS	RU	Kizljar			330/110									2015		on 330 kV Budenovsk-Chirjurt
SS	RU	Grozniy			330/110									2015		on 330 kV V2-Chirjurt
SS	RU	Artem			330/110									2010		on 330 kV Mahachkala-Chirjurt
OHL	RU	Mozdok		Artem	330									2010		single circuit
OHL	RU	HPP Irganskaya		Artem	330									2010		single circuit
OHL	RU	Derbent		Artem	330									2010		single circuit
OHL	RU	Derbent	AZ	Apsheron	330									2010		single circuit

1. Type of project (OHL - overhead line, K - kable, SK - submarin kable, SS - substation, BB - back to back system...)
2. Country (ISO code)
3. Substation name
4. Installed voltage (for lines nominal voltage, for transformers ratio in voltages)
5. number of circuits/units
6. Conventional transmission capacity of elements for OHL in Amps, for transformers in MVA
7. Conventional transmission capacity limited by transformers or substations
8. Type of conductor or transformer (ACSR - Aluminum Crossection Steel Reinforced, or code of conductor, PS - phase shift transformer...)
9. Crossection (number of ropes in bundle x cross section/cross section of reinforcement rope)
10. Length till border of first state
11. Length till border of second state
12. Total length
13. Date of commissioning (estimate)
14. Status of project (Idea, Feasibility study, Construction, Damaged, out of service, Decommissioned...)

Table 2.20 – Russia – Planned new generation units

TYPE	SUBSTATION1		VOLTAGE LEVEL kV	kV	CAPACITY MW	MVA	DATE OF COMMISSIONING year	STATUS	COMMENT
1	2	3	4	5	6	7	8	9	10
NPP	RU	Leningrad2	24	500	2x1150	2x1278	2010	CONSTR.	old plant decommissioned
NPP	RU	Leningrad2	24	750	2x1150	2x1278	2011	CONSTR.	old units decommissioned
NPP	RU	Novovoronez	24	500	2x1150	2x1278	2015	CONSTR.	
NPP	RU	Kostromska	24	500	2x1150	2x1278	2020	CONSTR.	
NPP	RU	Nizhegorodskaya	24	500	2x1150	2x1278	2020	CONSTR.	
NPP	RU	Kaliningrad	24	500	2x1150	2x1278	2015	CONSTR.	
NPP	RU	Kola2	24	500	1150	1278	2015	CONSTR.	
NPP	RU	Seversk	24	500	2x1150	2x1278	2020	CONSTR.	
HPP	RU	Boguchanskaya		330	3000		2020		Krasnoyarsk area
HPP	RU	Evenky		330	1000		2020		Krasnoyarsk area
HPP	RU	Motiginskaya		330	757		2020		Krasnoyarsk area
PHPP	RU	Leningrad		330	4x390		2015		Sankt-Petersburg area
PHPP	RU	Zagorsk-2		330	2x420		2015		Moscow region
PHPP	RU	Zelenchuk		330	1x140		2015		Karachay-Cherkessia
HPP	RU	Zaramagskaya		330			2010		
HPP	RU	Cherkeskaya II		330			2010		
NPP	RU	Volgodonskaya	24	500	1000	1111	2010	CONSTR.	unit 2
CCGT	RU	Stavropol	15.75	500	2x400	2x440	2012	PLANNING	
CCGT	RU	Nevinnomyssk	15.75	500	410	450	2010	CONSTR.	
CCHP	RU	Sochi	10.5	110	80	90	2010	CONSTR.	
CCHP	RU	Tuapce	15.75	110	150	170	2011	CONSTR.	
CCHP	RU	Tuapce	15.75	110	180	200	2012	CONSTR.	
CCHP	RU	Adler	15.75	110	2x180	2x200	2012	CONSTR.	
CCHP	RU	Olimpic	15.75	110	2x180	2x200	2012	CONSTR.	

1. Type of plant (HPP - Hydropower plant, TPP - Thermal power plant, PSHPP - Pump Storage Hydro Power Plant, CCHP - Combined Cycle Heating Plant...)
2. Country
3. Substation name
4. Generator voltage level
5. Network voltage level
6. Installed active power
7. Installed apparent power
8. Date of commissioning (estimate)
9. Status of the project (Idea, Feasibility study, Construction...)

Turkey

The Turkish Power Grid consists of lines of 400, 220, 150, 66 kV. Table 2.21 shows the total length of the transmission lines by voltage levels. The 400 kV system network is shown in Figure 2.15.

Turkey's power system's high quality of service and reliability are up to par with the Western European standards. Hydro potential and lignite are important primary energy resources of the country. Large loads are concentrated in the areas of İstanbul, İzmir and Ankara. Most of the hydro resources and a large lignite fields are located in Eastern Turkey, so power has to be transmitted across the country via 400 kV lines.

Table 2.21 – Turkey – network overview

lines		transformers	
Voltage level	Length of the overhead lines and cables	Voltage level	Installed capacities
(kV)	(km)	(kV/kV)	(MVA)
400	14350.8	400/x	24240
220	84.6	220/x	300
150	31500.9	154/x	46979
66	550	66/x	678
total	46485.7		84333

Location of the power generation and the long distances involved are a challenge to the transmission grid during the maximum hydroelectric dispatch operation. Most of the power produced by the large HPPs in the East has to be transferred to the North-West regions and partly to the South-West regions, where the energy consumption is higher. Consequently, the planned lines connecting the Western and the Eastern areas of the country, have the necessary power carrying capacity and stability margins.

In the eastern Black Sea region, the group of large HPPs planned for commissioning in 2005-2007, has an aggregate capacity of 2010 MW, they are Borçka HPP (300 MW), Deriner HPP (670 MW), Muratlı HPP (115 MW), Artvin HPP (332 MW) and Yusufeli HPP (540 MW). Borçka and Muratlı HPPs have been commissioned recently.

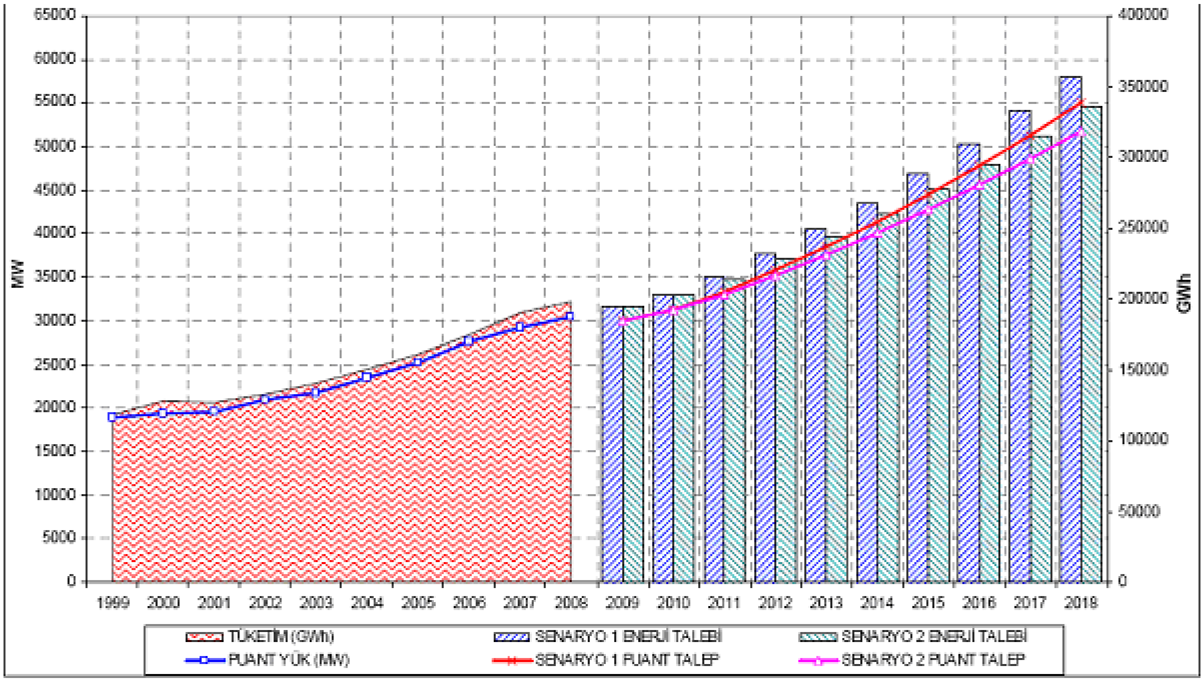


Figure 2.14 – Turkey – Demand forecast

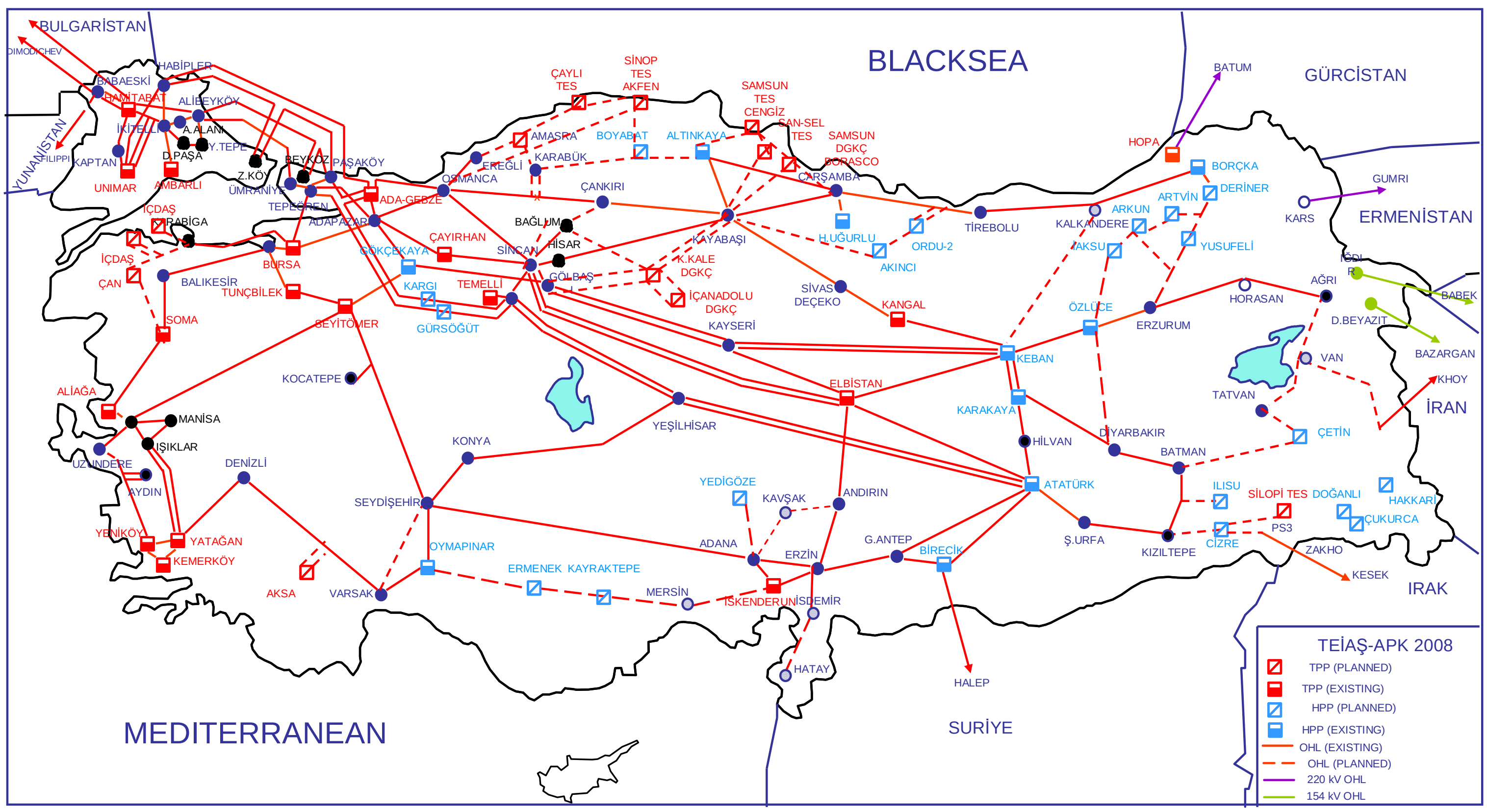


Figure 2.15 – Turkey – network map

Planned Network Reinforcements

Table 2.22 – Turkey – Planned network reinforcements

TYPE		SUBSTATION1		SUBSTATION2	VOLTAGE LEVEL	Number of circuits /units	CAPACITY		MATERIAL OR TRANSFORMER TYPE	CROSS	LENGTH			DATE OF COMMISSION	STATUS	COMMENT
								limited			BR1	BR2	TOTAL			
					kV/kV		A or MVA	A or MVA		mm2	km	km	km			
1	2	3	2	3	4	5	6	7	8	9	10	11	12	13	14	15
OHL	TR	Hpp oymapinar		Hpp ermenek	400	1			Acsr	3bx1272					Constr	
OHL	TR	Mersin		Hpp ermenek	400	1			Acsr	3bx1272					Constr	
SS	TR	Mersin			400/150		2x250								Constr	
DC	TR	Alibeykoy			400		600 mw								Idea	Dc converter station
SC	TR	Alibeykoy	Ro	Constanta	400	1	600 mw				200	200	400		Idea	Dc cable
OHL	TR	Gercuz-ilisu		Cizre-sinir	400	2			Acsr	3bx954	30	100	130		Planning	Planning
OHL	TR	Agri		Van	400	1			Acsr	3bx1272					Planning	
OHL	TR	Batman-siirt		Van	400	1			Acsr	3bx1272	65	205	270		Planning	
OHL	TR	Van		Baskale	400	1			Acsr	3bx954					Planning	
OHL	TR	Hpp boyabat		Hpp altinkaya	400	1			Acsr	3bx1272					Planning	
OHL	TR	Seydisehir		Varsak	400	1			Acsr	3bx1272			130		Constr	
OHL	TR	Temelli		Afyon2	400	1			Acsr	3bx1272					Constr	
OHL	TR	Afyon2		Denizli	400	1			Acsr	3bx1272			180		Constr	
OHL	TR	Bursa ngccpp		Bursa san	400	2			Acsr	3bx954					Planning	
OHL	TR	Icdas		Bursa san	400	1			Acsr	3bx954					Planning	
OHL	TR	Soma		Manisa	400	1			Acsr	3bx1272			50		Constr	
OHL	TR	Ozluce		Diyarbakir	400	1			Acsr	3bx1272			100		Constr	
SS	TR	Konya			400/150		150								Constr	Capacityadd
SS	TR	Adana			400/150		250								Constr	
SS	TR	Eskisehir			400/150		2x250								Constr	
SS	TR	Catalca			400/150		2x250								Planning	
SS	TR	Kucukbakkalkoy gis			400/150		2x250								Constr	
SS	TR	Kucukbakkalkoy gis			400/33		2x125								Constr	
C	TR	Umraniye		Kucukbakkalkoy	400					2000mm2			6.3		Constr	
SS	TR	Van			400/150		2x250								Planning	
SS	TR	Uzundere			400/33		125								Planning	
SS	TR	Yenibosna gis			400/150		2x250								Constr	
SS	TR	Yenibosna gis			400/33		2x125								Constr	
C	TR	Yenibosna gis		Davutpasa	400					2000mm2			6.98		Constr	
SS	TR	Afyon2			400/150		2x250								Constr	Capacityadd
SS	TR	Viransehir			400/150		250+150								Constr	
SS	TR	Diyarbakir			400/33		125								Constr	
SS	TR	Usak			400/150		250								Planning	

1. type of project (ohl - overhead line, k - kable, sk - submarin kable, ss - substation, bb - back to back system...)
2. Country (ISO code)
3. Substation name
4. Installed voltage (for lines nominal voltage, for transformers ratio in voltages)
5. number of circuits/units
6. Conventional transmission capacity of elements for OHL in Amps, for transformers in MVA
7. Conventional transmission capacity limited by transformers or substations
8. Type of conductor or transformer (ACSR - Aluminium Crossection Steel Reinforced, or code of conductor, PS - phase shift transformer...)
9. Crossection (number of ropes in bundle x cross section/cross section of reinforcement rope)
10. Length till border of first state
11. Length till border of second state
12. Total length
13. Date of commissioning (estimate)
14. Status of project (Idea, Feasibility study, Construction, Damaged, out of service, Decommissioned...)

Table 2.23 – Turkey – Planned generation units

TYPE	SUBSTATION1		VOLTAGE LEVEL		CAPACITY		DATE OF COMMISSIONING	STATUS	COMMENT
			kV	kV	MW	MVA	year		
1	2	3	4	5	6	7	8	9	10
HPP	TR	Ermenek		400	320		2010	CONSTR	
HPP	TR	OBRUK		400	4x50		2010	CONSTR	
HPP	TR	Borçka		400	300		2010	FINISHED	
HPP	TR	Deriner		400	670		2010	CONSTR	
TPP	TR	TEREN		400	2X600		2015	PLANNED	Coal fired TPP
HPP	TR	TIREB		400	300		2015	PLANNED	Equivalent of lots of HPPs in the river basin, most of them run of river type
HPP	TR	KALKANDERE		400	3X200		2015	PLANNED	Equivalent of lots of HPPs in the river basin, most of them run of river type
HPP	TR	YUSUFELI		400	4x135		2015	PLANNED	Equivalent of lots of HPPs in the river basin, most of them run of river type
CCGT	TR	TBANDRMA		400	1000		2015	PLANNED	NGCCPP(Private company)
CCGT	TR	AMBARLI		400	2X270		2015	PLANNED	NGCCPP. Extension of existing Ambarlı NGCCPP
CCGT	TR	AKSA ANTALIA		400	1000		2015	PLANNED	NGCCPP(Private company)
TPP	TR	SUGOZU		400	700		2015	PLANNED	Coal fired. Extension of existing Sugozu TPP
CCGT	TR	DENIZLI		400	1000		2015	PLANNED	NGCCPP(Private company)
HPP	TR	BOYABAT		400	3X180		2015	PLANNED	HPP(Private company)
TPP	TR	GALATA		400	2X135		2015	PLANNED	TPP (oil fired)
CCGT	TR	MAKINA		400	2X300		2015	PLANNED	NGCCPP(Private company)
HPP	TR	ALKUMRU		400	3X80		2015	PLANNED	HPP(Private company)
CCGT	TR	RASA		400	80		2015	PLANNED	NGCCPP(Private company)
TPP	TR	SILOPITES		150	135		2015	PLANNED	TPP (oil fired)
HPP	TR	INCIR		150	122		2015	PLANNED	HPP(Private company)
HPP	TR	AKDAM		400	300		2015	PLANNED	Equivalent of lots of HPPs in the river basin, most of them run of river type
CCGT	TR	EGEMER		400	6X300		2015	PLANNED	NGCCPP+ Coal fired(Private company)
WPP	TR	GELI		400	300		2015	PLANNED	Equivalent of lots of WPPs in the region
WPP	TR	CAN		400	300		2015	PLANNED	Equivalent of lots of WPPs in the region
TPP	TR	BASAT		400	2X150		2015	PLANNED	Coal fired TPP
TPP	TR	ORTA		400	2X150		2015	PLANNED	Coal fired TPP
TPP	TR	ATLAS		400	600		2015	PLANNED	Coal fired TPP
TPP	TR	KARASU		400	2X600		2015	PLANNED	Coal fired TPP
HPP	TR	ILISU		400	6x200		2015	PLANNED	
NPP	TR	Akkuyu Bay		400	5x1100		2020	PLANNED	

1. Type of plant (HPP - Hydropower plant, TPP - Thermal power plant, PSHPP - Pump Storage Hydro Power Plant, CCHP - Combined Cycle Heating Plant...)
2. Country
3. Substation name
4. Generator voltage level
5. Network voltage level
6. Installed active power
7. Installed apparent power
8. Date of commissioning (estimate)
9. Status of the project (Idea, Feasibility study, Construction...)

Ukraine

Ukraine's transmission system consists of a 800 kV DC line; a basic infrastructure of 750 kV single circuit AC system that overlays an extensive 330 kV (single and double circuit) network. This network feeds into the 220 kV and 110 kV systems, as well as 500 kV and 400 kV AC systems in some parts of the country. Figure 2.18 demonstrates the transmission network of Ukraine and Table 2.24 is an overview of the transmission network.

Table 2.24 – Ukraine –network overview

lines		transformers	
Voltage level	Length of the overhead lines and cables	Voltage level	Installed capacities
(kV)	(km)	(kV/kV)	(MVA)
800	100	750	16613
750	4120	500	1753
400-500	715	400	1609
330	13330	330	48453
220	4010	220	9609
110	540		
35	100		
total	22910		78037

The southwestern part of the Ukrainian system called Burstyn Island, including Burstinskaya TPP, is part of 220 kV network. The Mukachevo substation is separated from the main Ukrainian system and operates in a synchronous and parallel mode with ENTSO-E main grid. This was done in order to identify the export from Ukraine to Western Europe.

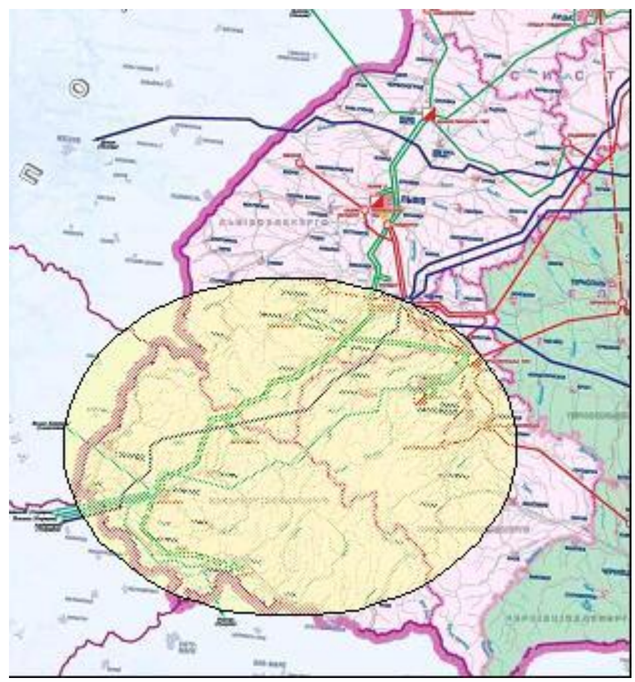


Figure 2.16 – Ukraine – Bustin Island

Figure 2.17 shows the forecasted demand and generation level. Ukraine plans to export up to 2.5TWh. The primary fuel for most of the production comes from Russia, due to the nature of production facilities and Ukraine’s large deficit in control reserve. As a result, most of the new planned generation units are PHPP stations.

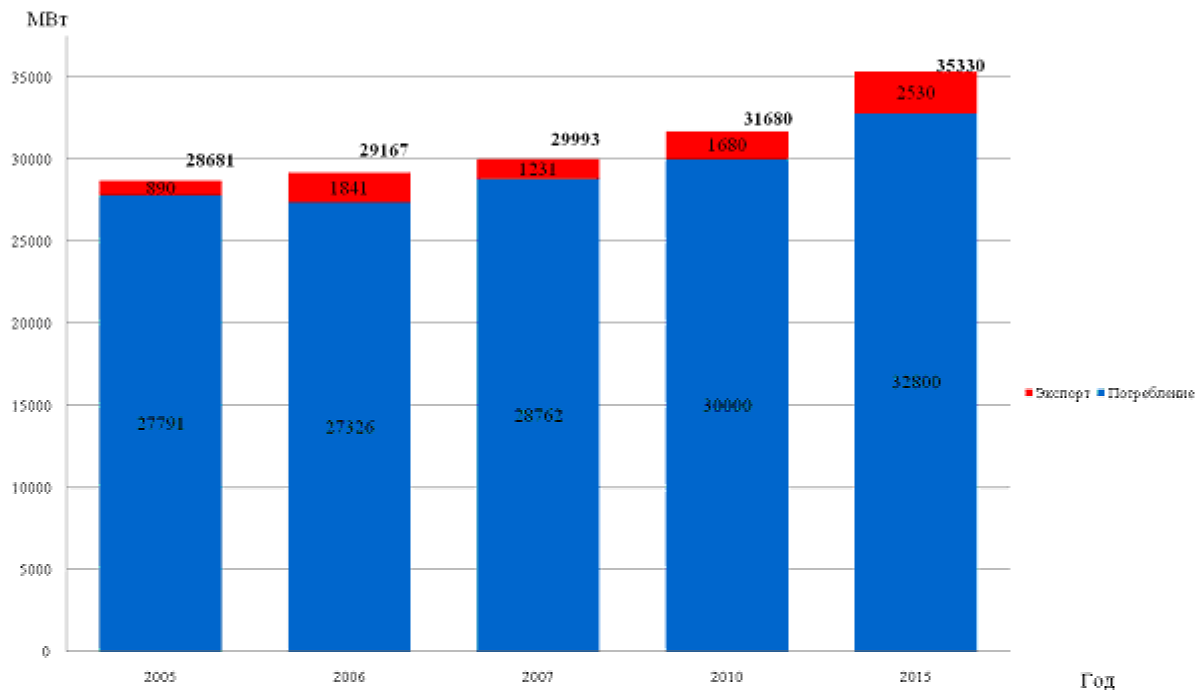


Figure 2.17 – Ukraine – Demand forecast

Figure 2.18 – Ukraine – network map

Planned Network Reinforcements

Table 2.25 – Ukraine – Network reinforcements till 2015

TYPE		SUBSTATION1		SUBSTATION2	VOLTAGE LEVEL kV/kV	number of circuits /units	CAPACITY A or MVA	CAPACITY limited A or MVA	MATERIAL OR TRANSFORMER TYPE	CROSS mm2	LENGTH BR1 km	LENGTH BR2 km	LENGTH TOTAL km	DATE OF COMMISSIONING	STATUS	COMMENT
1	2	3	2	3	4	5	6	7	8	9	10	11	12	13	14	15
OHL	UA	Novoodeska	UA	Artsyz	330	1	1670 A	-	ACSR	400*2	140	0	140	2012	project	
OHL	UA	Adgalyk	UA	Usatovo	330	1	1670 A	-	ACSR	400*2	124	0	124	2010	Construction	second line
OHL	UA	Zarya	UA	Mirna	330	1	1380 A	-	ACSR	300*2	14	0	14	2010	Construction	second line
SS	UA	Simferopol			330	1			SVC					2011	project	SVC
OHL	UA	Simferopol	UA	Sevastopol	330	1	1670 A	-	ACSR	400*2	70	0	70	2010	finished	upgrade from 220kV to 330 kV
OHL	UA	Dgankoj	UA	Melitopol–Simferopol	330	1	1380 A	-	ACSR	400*2	16	0	16	2008	finished	Connectors of Dgankoj SS to OHL Melitopol–Simferopol
OHL	UA	Zapadnokrymskaya	UA	Sevastopol	330	1	1670 A	-	ACSR	400*2				2014	Idea	
OHL	UA	Zapadnokrymskaya	UA	Kahovska	330	1	1670 A	-	ACSR	400*2				2015	Idea	
SS	UA	Kyivska			750/330	1	1000 MVA	-	PST	-	-	-	-	2009	finished	I stage
OHL	UA	Pivnichnoukrainska	UA	Kyivska	750	1	4000 A	-	ACSR	400*5	292	0	292	2015	Idea	
OHL	UA	Rivnenska NPP	UA	Kyivska	750	1	4000 A	-	ACSR	400*5	370	0	370	2012	Construction	
OHL	UA	Zahidnoukrainska	UA	Bogorodchani	330	1	1670 A	-	ACSR	400*2	111	0	111	2013	project	
OHL	UA	NPP Rivne	BY	Mikashevichi	330	1	1670 A	-	ACSR	400*2				2015	Idea	
SS	UA	Novodonbaska			500/220			-		-	-	-	-	2015	feasibility	Reconstruction 500 кV SS "Novodonbasskaya" with construction 2 OHL 500 кV, AT 500/220 кV and 5 OHL 220 кV
SS	UA	Primorska			750/330	1	1000 MVA	-	PST	-	-	-	-	2015	feasibility	
OHL	UA	Pivdenoukrainskaya	RO	Isaccea	750	1	4000 A	-	ACSR	400*5	406	3	409	2015	Feasibility study	Restoration. Voltage level to be defined
OHL	UA	Dnistrovska PSHPP	UA	Bar	330	1	1670 A	-	ACSR	400*2	95	0	95	2010	Construction	
OHL	UA	Dnistrovska PSHPP	UA		750	1	4000 A	-	ACSR	400*5				2015	project	To existing line Zapadnoukrainskaya – Vinnitsa
OHL	UA	K.Podolska (Chernovcy)	UA	Ternopil	330	1	1670 A	-	ACSR	400*2	150	0	150	2015	Feasibility study	
OHL	UA	Lutsk Pivnichna	UA	Ternopil	330	1	1670 A	-	ACSR	400*2	180	0	180	2011	project	
OHL	UA	HPP Dnistrovska	MD	Balti	330	1	1670 A	-	ACSR	400*2	120	0	120	2015	Idea	second line
SS	UA	Kahovska			750/330	2	1000 MVA	-	PST	-	-	-	-	2012	project	
OHL	UA	Zaporizka NPP	UA	Kahovska	750	1	4000 A	-	ACSR	400*5	190	0	190	2012	project	
SS	UA	Zaporizka NPP			750/330	1	1000 MVA	-	PST	-	-	-	-	2017	Idea	second transformer
SS	UA	Dnieprovska			750/330	1	1000 MVA	-	PST	-	-	-	-	2016	finished	third transformer
OHL	UA	Novoodeska	UA	Artsyz	330	1	1670 A	-	ACSR	400*2	140	0	140	2012	project	
OHL	UA	Adgalyk	UA	Usatovo	330	1	1670 A	-	ACSR	400*2	124	0	124	2010	Construction	second line
OHL	UA	Zarya	UA	Mirna	330	1	1380 A	-	ACSR	300*2	14	0	14	2010	Construction	second line
SS	UA	Simferopol			330	1			SVC					2011	project	SVC

1. Type of project (OHL - overhead line, K - kable, SK - submarin kable, SS - substation, BB - back to back system...)
2. Country (ISO code)
3. Substation name
4. Installed voltage (for lines nominal voltage, for transformers ratio in voltages)
5. number of circuits/units
6. Conventional transmission capacity of elements for OHL in Amps, for transformers in MVA
7. Conventional transmission capacity limited by transformers or substations
8. Type of conductor or transformer (ACSR - Aluminium Crossection Steel Reinforced, or code of conductor, PS - phase shift transformer...)
9. Crossection (number of ropes in bundle x cross section/cross section of reinforcement rope)

10. Length till border of first state
11. Length till border of second state
12. Total length
13. Date of commissioning (estimate)
14. Status of project (Idea, Feasibility study, Construction, Damaged, out of service, Decommissioned...)

Table 2.26 – Ukraine – New production units

TYPE	SUBSTATION1		VOLTAGE LEVEL		CAPACITY		DATE OF COMMISSIONING	STATUS	COMMENT
			kV	kV	MW	MVA	year		
1	2	3	4	5	6	7	8	9	10
PSHPP	UA	Dnistrovska	15.75	330	360/390	420	2009	in operation	unit 1
PSHPP	UA	Dnistrovska	15.75	330	360/390	420	2012	Construction	unit 2
PSHPP	UA	Dnistrovska	15.75	330	360/390	420	2015	Construction	unit 3
PSHPP	UA	Dnistrovska	15.75	330	4x360/4x390	420	2015-2020	Construction	units 4-7
CCHP	UA	Kyivska 6	20	330	300	353	2015	Construction	unit 3
PSHPP	UA	Tashlykska	15.75	330	2x151/2x233	307	2008	in operation	units 1 and 2
PSHPP	UA	Tashlykska	15.75	330	2x151/2x233	307	2015	Construction	units 3 and 4
NPP	UA	Khmelinskaya	24	750	2x1000		2016-2020	PLANNED	
TPP	UA	Dobrotvirska	15.75	220	3x225		2020	PLANNED	
PSHPP	UA	Kanev	15.75	330	4x250/4x260	4x263/4x273	2030	PLANNED	

1. Type of plant (HPP - Hydropower plant, TPP - Thermal power plant, PSHPP - Pump Storage Hydro Power Plant, CCHP - Combined Cycle Heating Plant...)
2. Country
3. Substation name
4. Generator voltage level
5. Network voltage level
6. Installed active power
7. installed apparent power
8. Date of commissioning (estimate)
9. Status of the project (Idea, Feasibility study, Construction...)

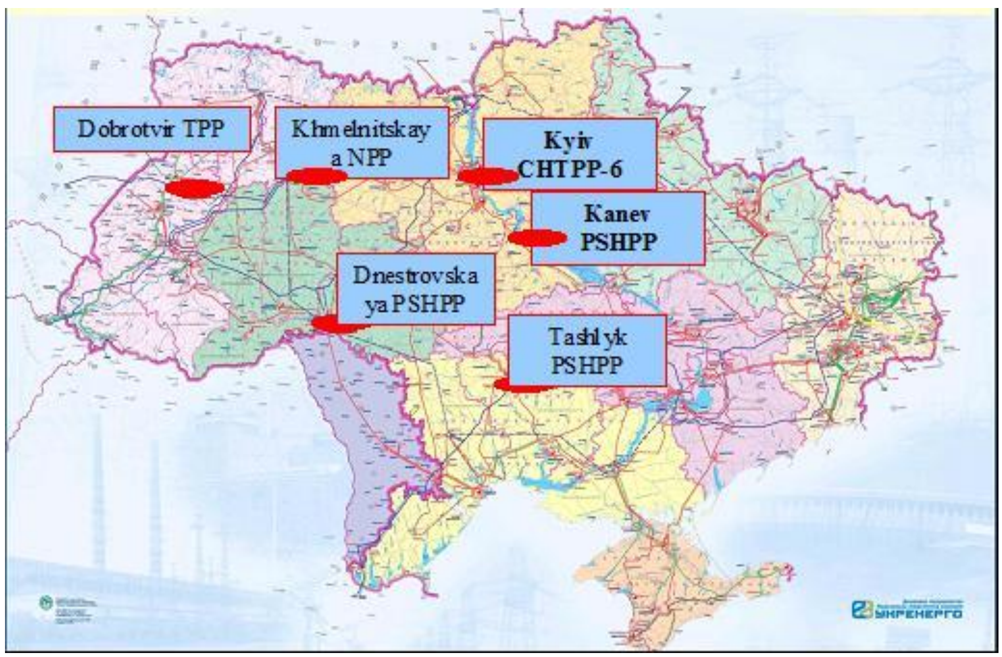


Figure 2.19 – Ukraine – new generation capacities

Network capacities

Following figure shows network import/export capabilities.

Table 2.27 – Ukraine – Network capacities

Figure 2.20 – Ukraine – network border capacities

Dynamic Models

In the previous phase of the project the 2010 static model developed by the TSOs revealed certain system deficiencies and weak points. To further analyze the capacity of the regional network to support enhanced trade an exchange of electricity while maintaining security and reliability, it is necessary to investigate system response to disturbances that cause large and sudden changes in the power system. In other words, one of major conclusions from Phase I of this project is that dynamic stability is of major concern in the region and system stability is major limiting factor for system operation and high electricity exchange level, therefore there is necessity to analyze dynamic system behavior. In order to perform this kind of analyses, development of adequate regional dynamic model is necessary. So, upon the development of the load flow model, an upgrade of this regional model for dynamic analyses has been conducted.

Dynamic Models Construction Procedure

All the machines connected to the high voltage network and represented in Load Flow model are represented individually with appropriate data set that consists of following parts:

- Generator data
- Excitation system data
- Turbine and governor data

Model integrator, EKC has prepared an extensive questionnaire for dynamic data collection and each project participant has completed the survey accordingly. Using this data, the Model integrator constructed a database that is employed for the dynamic model preparation. For all new generator units and units for which data is not available, the integrator applied the typical parameters or production unit construction data (if available).

Based on the constructed database, each project participant prepared a dynamic model of their national system and provided it to model integrator to develop the regional dynamic model.

Obligations of model integrator concerning this item are as follows:

- Review all collected data to check that it conforms to the agreed numbering systems for the areas, zones, busses, and the questionnaire format
- Provide consultancy for the isolated model development to the project participants
- Review and test operation of respective isolated models for each system
- Merge all model data in order to form a regional model
- Test the operation of the regional model
- Prepare a regional model report that consist of:
    - Summary data for regional model
    - Characteristics of the regional model
    - Dynamic database
- Present the verified and developed regional model to all participants

The regional dynamic model and the database are prepared based on the Load Flow model for winter peak regimes that also correspond to the summer regimes for following years:

- 2010
- 2015
- 2020

Dynamic Regional model consist of the following parts:

- Load flow model in PSS/E format (*.sav file)
- Dynamic model data base (collected questionnaires)
- Dynamic model in PSS/E format (*.dyr file) that corresponds to Load flow file
- Auxiliary PSS/E files necessary for model running (*.dll, *.flx or other)

The Dynamic model is developed in the latest PSS/E version 31. USAID and USEA provided the full PSS/E program support to all project participants in order to develop national models. To identify the tasks defined in Terms of References, it was necessary to use PSS/E Graphical Model Builder in order to develop user defined models that correspond to Russian and Ukrainian building excitation systems. The PSS/E model database does not have the appropriate solutions. EKC experts have built dynamic models for these generator units that can and will be used by all participating parties in the project.

The Dynamic model consists of the following characteristics: 395GW production modeled (156GW in equivalents of ENTSO-E and part of Russia, 239GW real power plants, of which 7.1GW come from wind power) in 1183 generators.

Training for Dynamic Model Construction

In order to accomplish this part of the project, it was necessary to upgrade and increase the abilities of the working group members. Creating the Dynamic regional model required training in the use of the PSS/E software for dynamic modeling and the construction of detailed technical databases.

In the scope of the project, EKC experts prepared and organized a four day training session on the use of the PSS/E software for the development of national transmission models in the dynamic mode.

Following the training, the TSOs started a discussion on the parameters of the model, started the data collection and the development of a common technical database, and finagling the realization of the dynamic model.

Dynamic Models

The conventional method adopted in dynamic stability analyses is via time domain simulation on adequate mathematical models. The complete system is modeled with configuration of non-linear differential equations that describe the behavior of the individual system components.

Generator models

Almost all generators in the system are represented with two types of models from PSS/E dynamic model library:

GENSAL - salient pole dynamic model (hydro power plant) *Figure* 3.1

GENROU - round rotor dynamic model (thermal power plants turbo generators) Figure 3.2

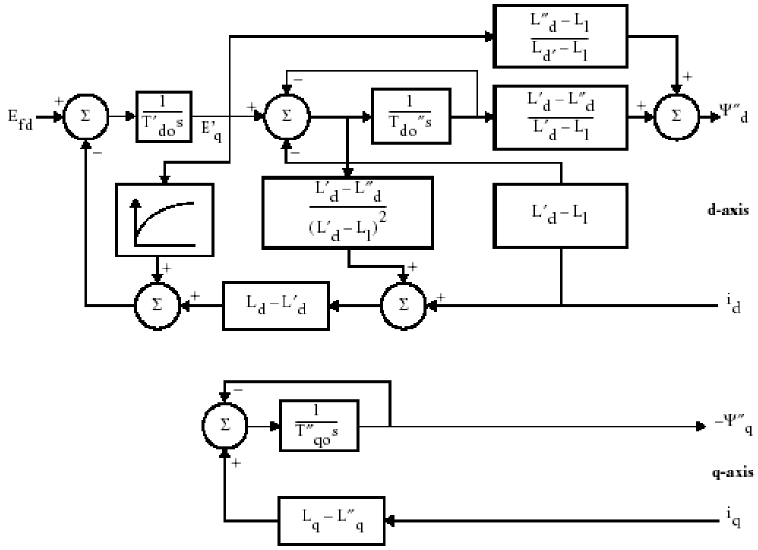


Figure 3.1 - *GENSAL model of salient pole synchronous generator*

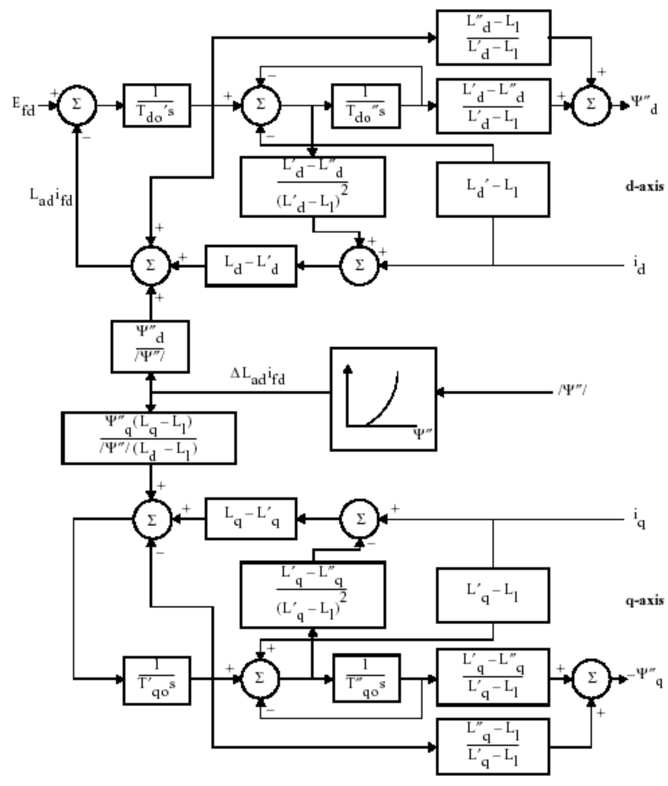


Figure 3.2 - GENROU model of round rotor synchronous generator

Excitation systems

A wide variety of excitation systems are used depending on the equipment producer and type for modeling. For modeling old and obsolete DC excitation systems, either IEEET1 (*Figure* 3.3) or DC1A (*Figure* 3.4) model is used.

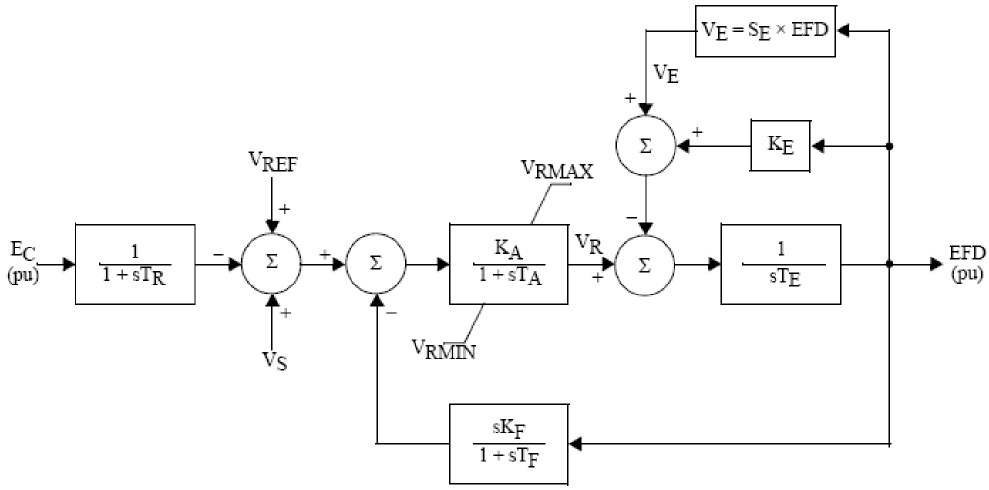


Figure 3.3 – IEEET1 DC excitation system

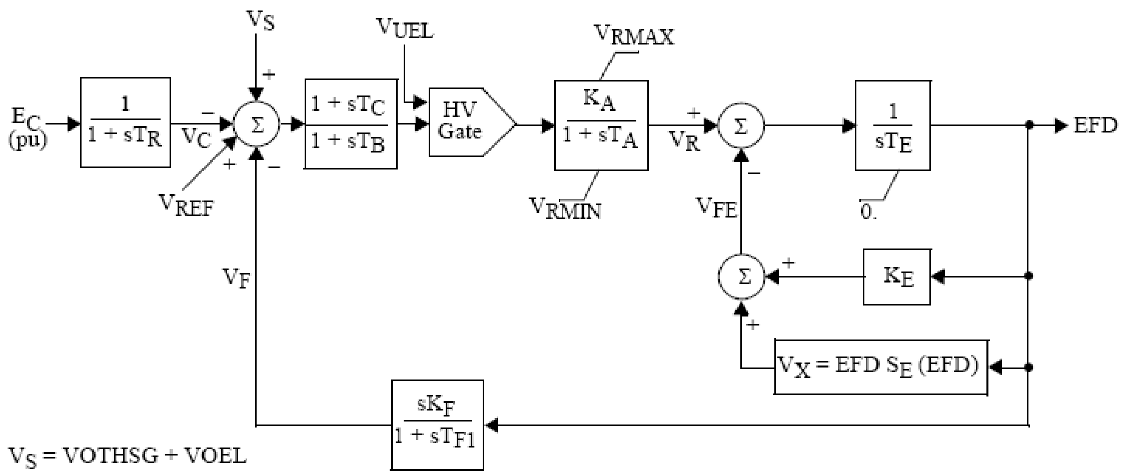
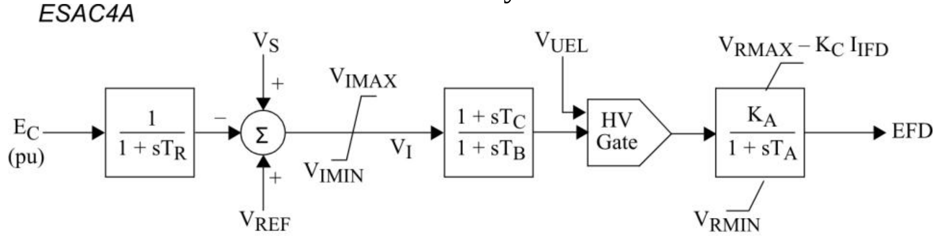


Figure 3.4 – DC1A DC excitation system

For modeling more advanced and newer AC excitation systems

ESAC4A



V_S = VOTHSG + VOEL

Figure 3.5 – AC4A AC excitation system

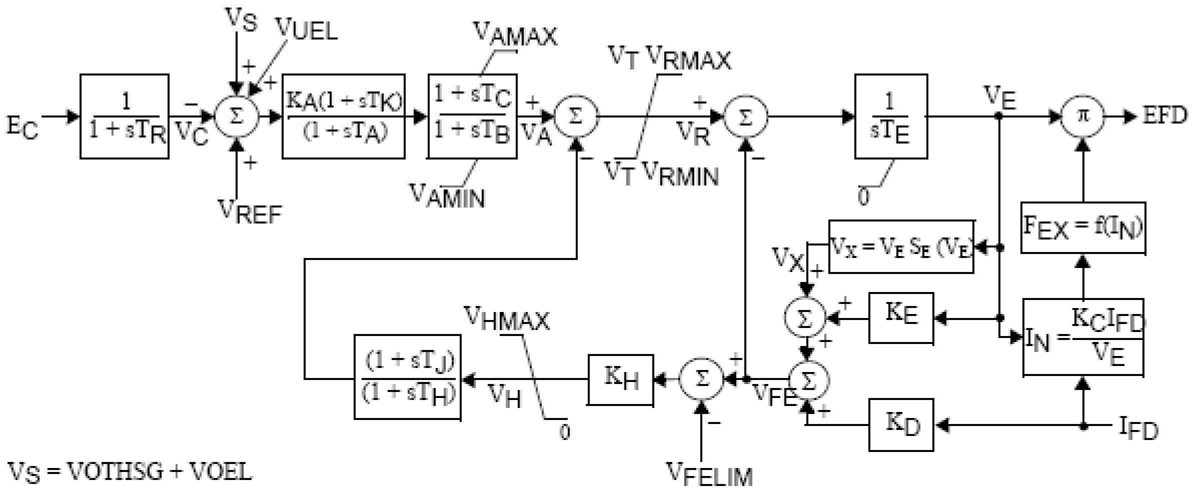


Figure 3.6 – AC6A AC excitation system

For modeling advanced excitation systems with digital regulators, the following models have been applied:

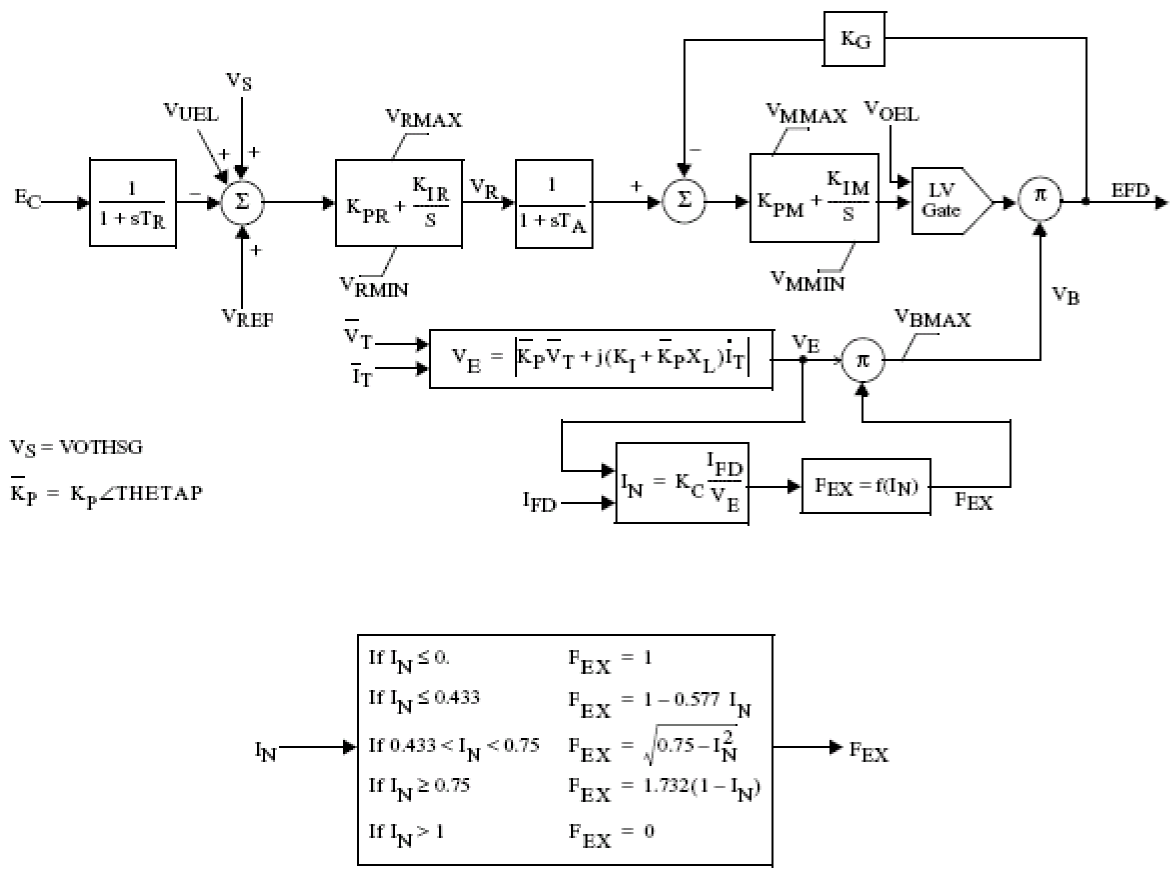


Figure 3.7 – ST4B Static excitation system

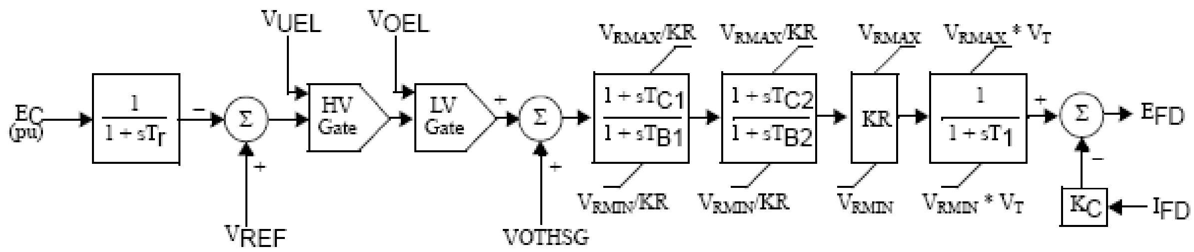


Figure 3.8 – ST5B Simplified Static excitation system

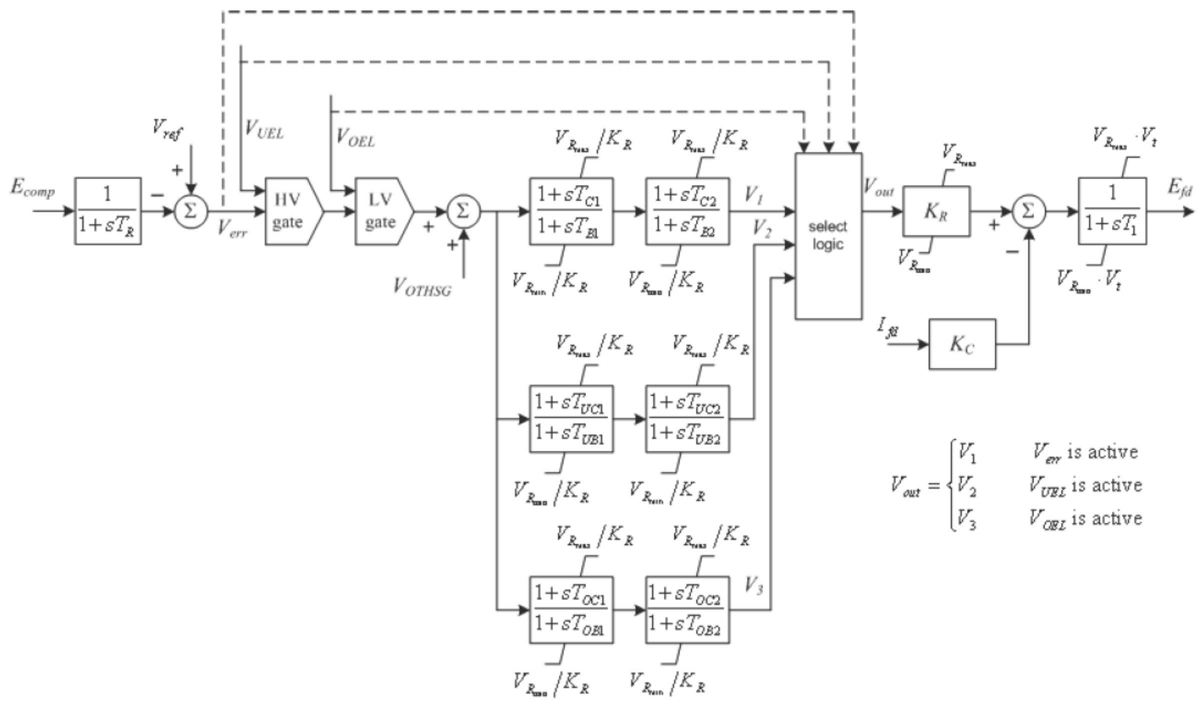


Figure 3.9 – ST5B Static excitation system

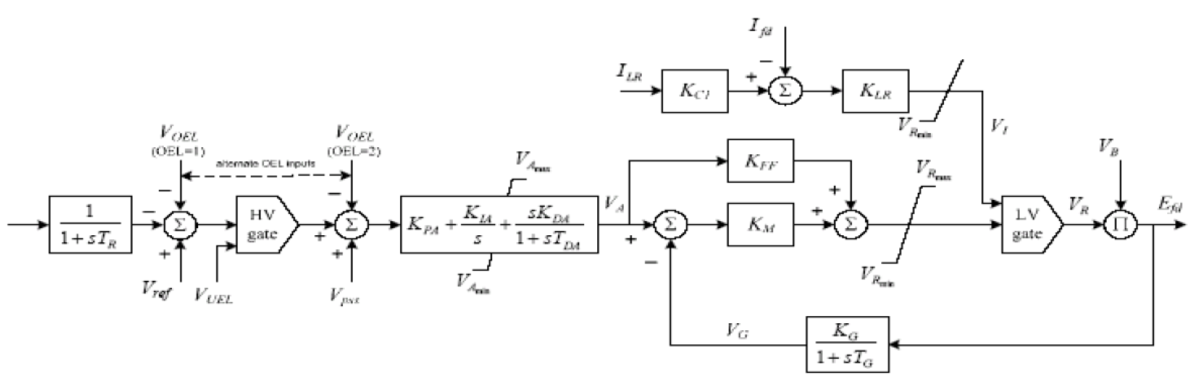


Figure 3.10 – ST6B Static excitation system

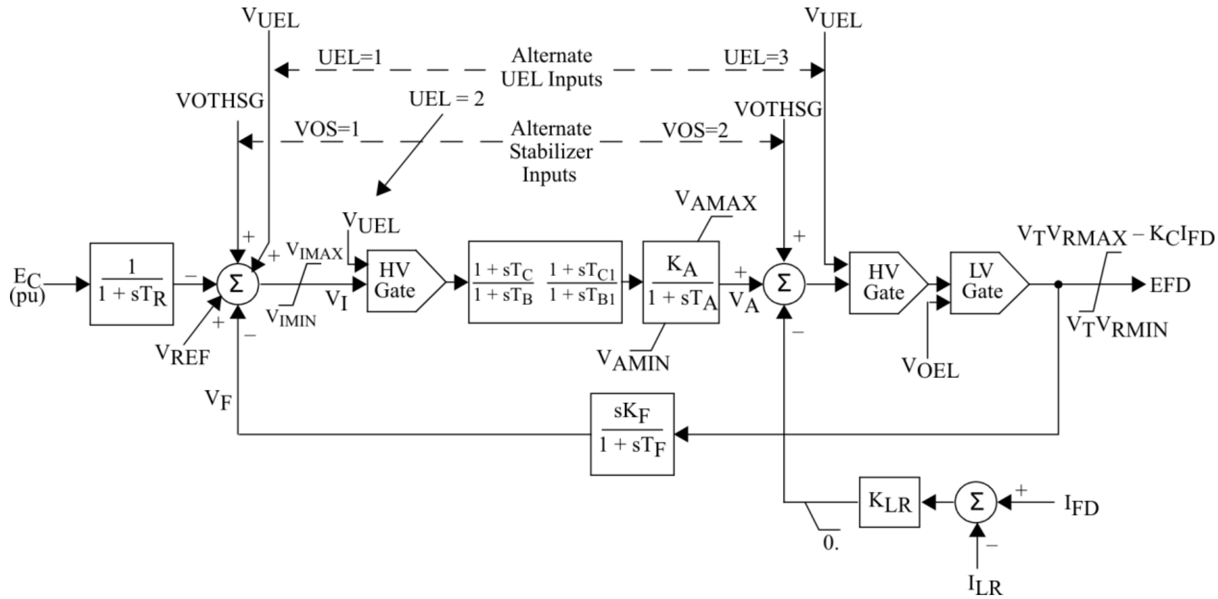


Figure 3.11 – ST1A Static excitation system

For modeling Russian excitation systems (multivariable excitation systems) in most cases, a combination of ST1 (Figure 3.12) static excitation system and the PSS1A (Figure 3.14) are used for implementing additional controls. The ST2A (Figure 3.13) in combination with PSS1A are employed in cases where the brushless excitation system is implemented. The parameters are recalculated in order for these systems to behave the same as the actual ones.

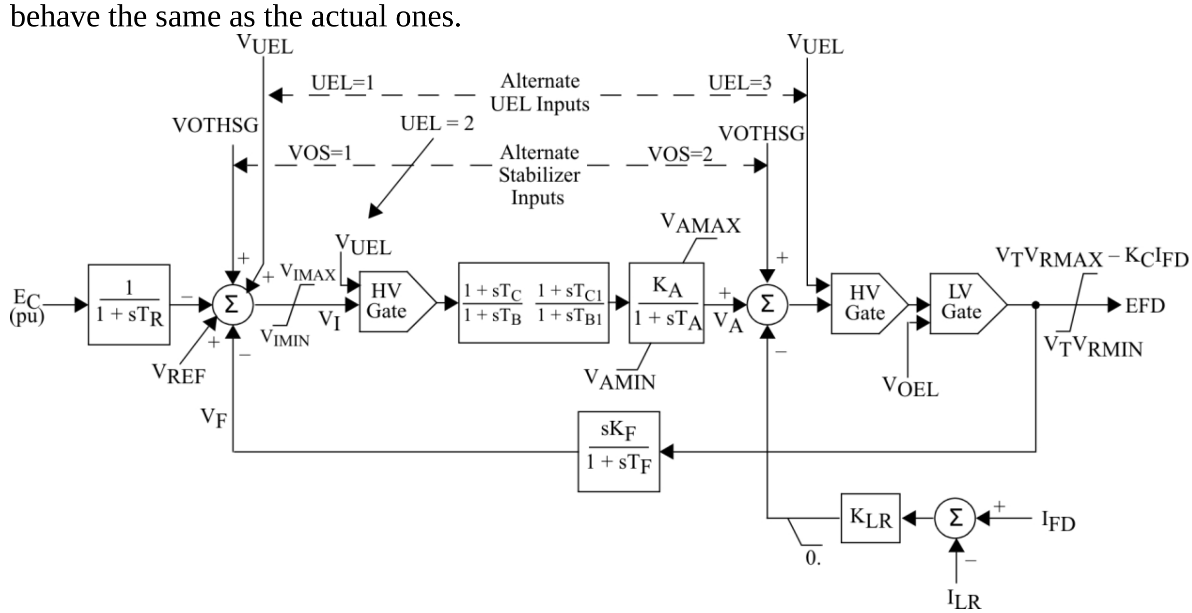


Figure 3.12 – ST1A static excitation system

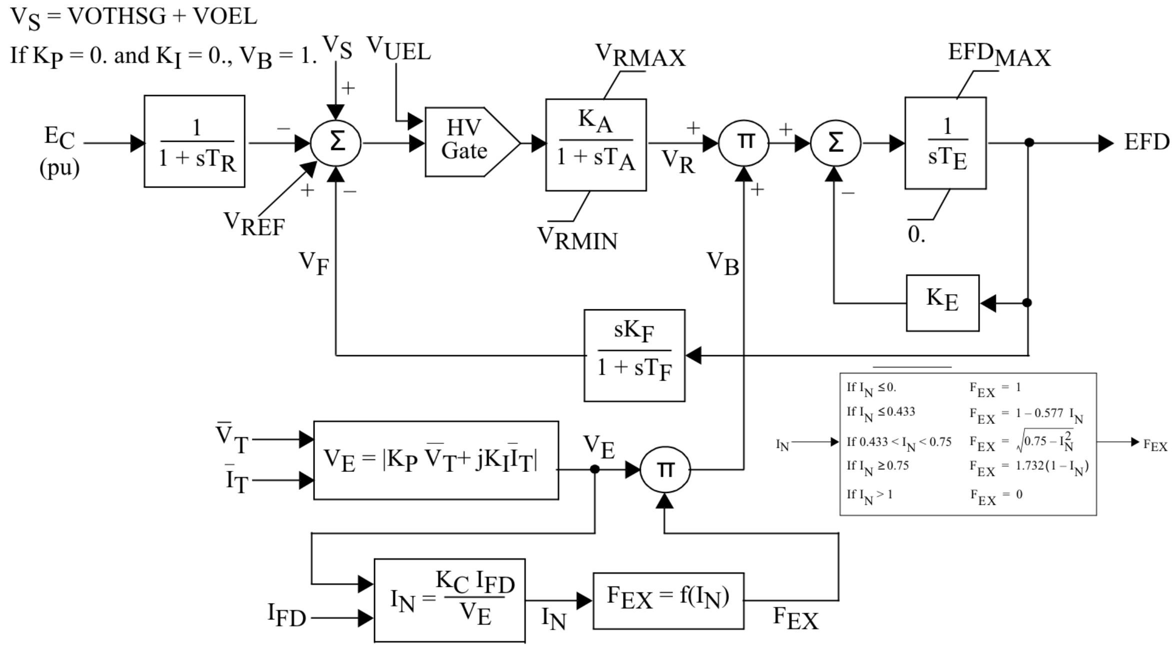


Figure 3.13 – ST2A static excitation system

For modeling stabilizing loops in certain excitation systems, especially for newer models, PSS devices have been modeled using following models:

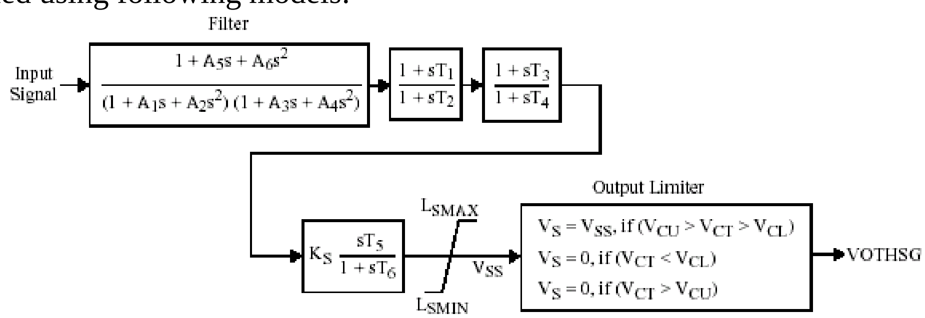


Figure 3.14 – PSS1A power system stabilizer

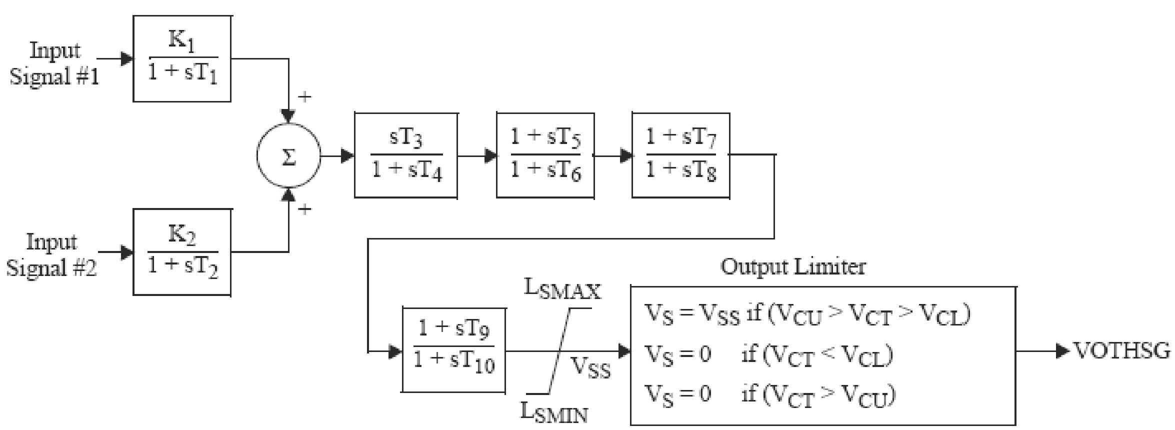


Figure 3.15 – PSS1A power system stabilizer with two inputs

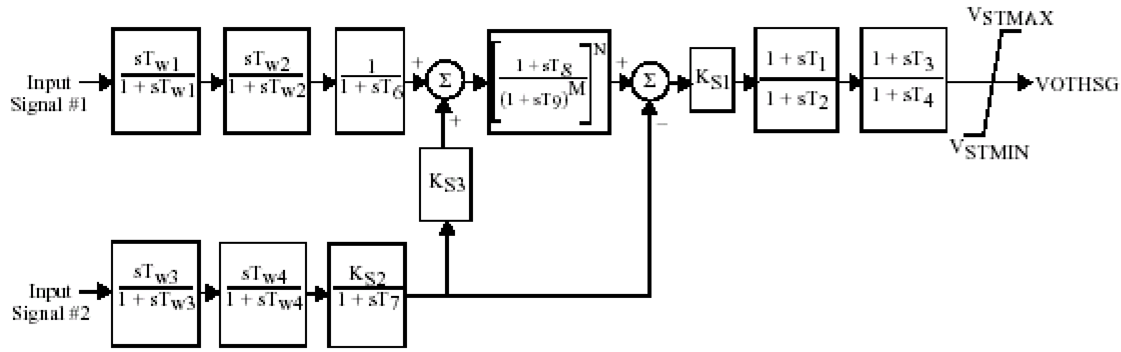


Figure 3.16 – PSS2A power system stabilizer

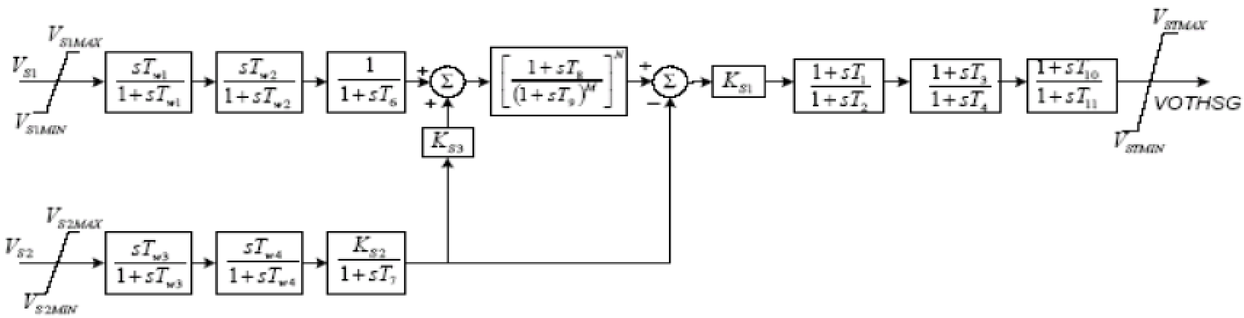


Figure 3.17 – PSS2B power system stabilizer

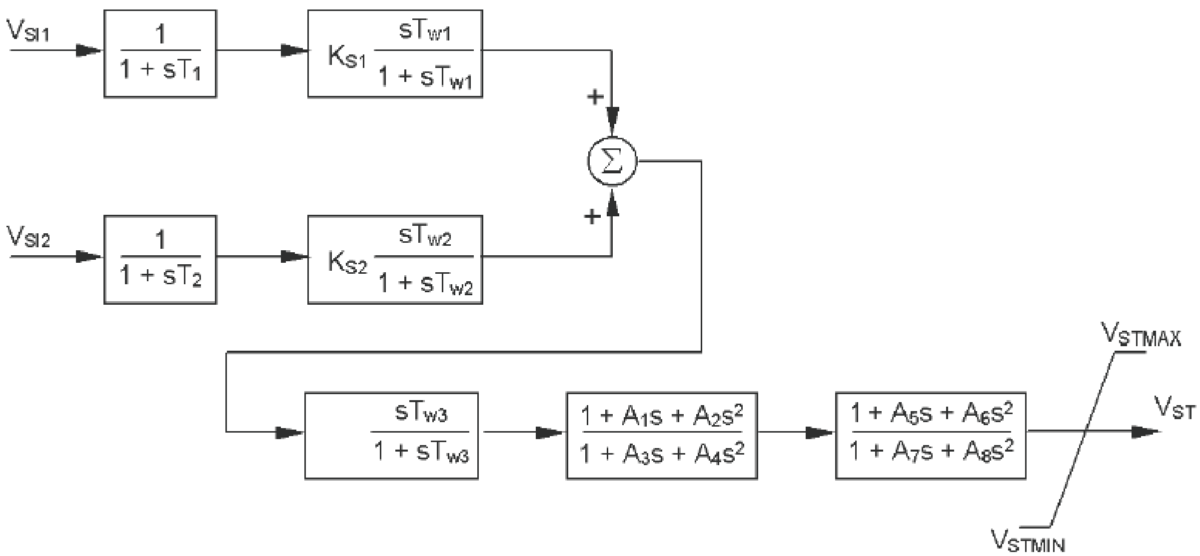


Figure 3.18 – PSS3B power system stabilizer

Turbine and governors

Hydro turbine and governors in the model are represented either with IEEEG3 (*Figure* 3.19), HYGOV (Figure 3.20) or WSHYGP (

Figure 3.21) depending on the level of parameter detail. First two are for electromechanical devices and the third one is for more advanced and modern installations.

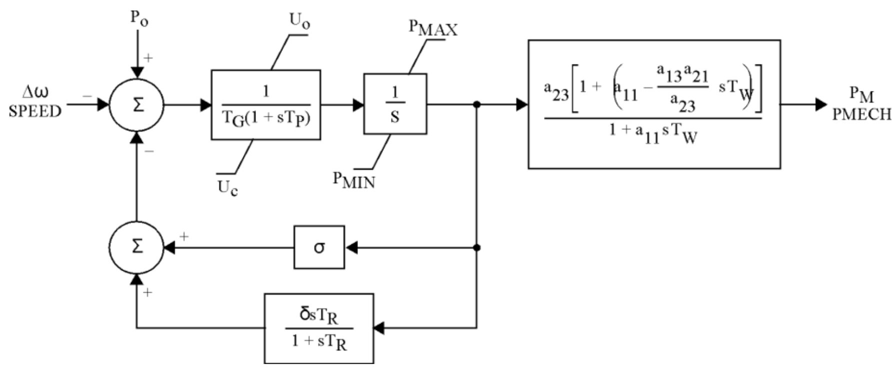


Figure 3.19 – IEEEG3 linearized hydro turbine and governor model

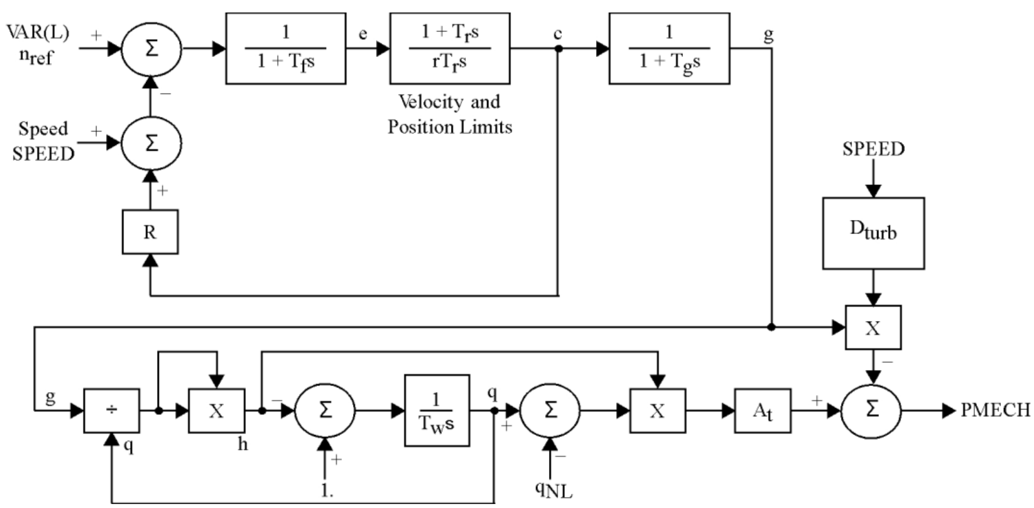


Figure 3.20 – HYGOV standard hydro turbine and governor model

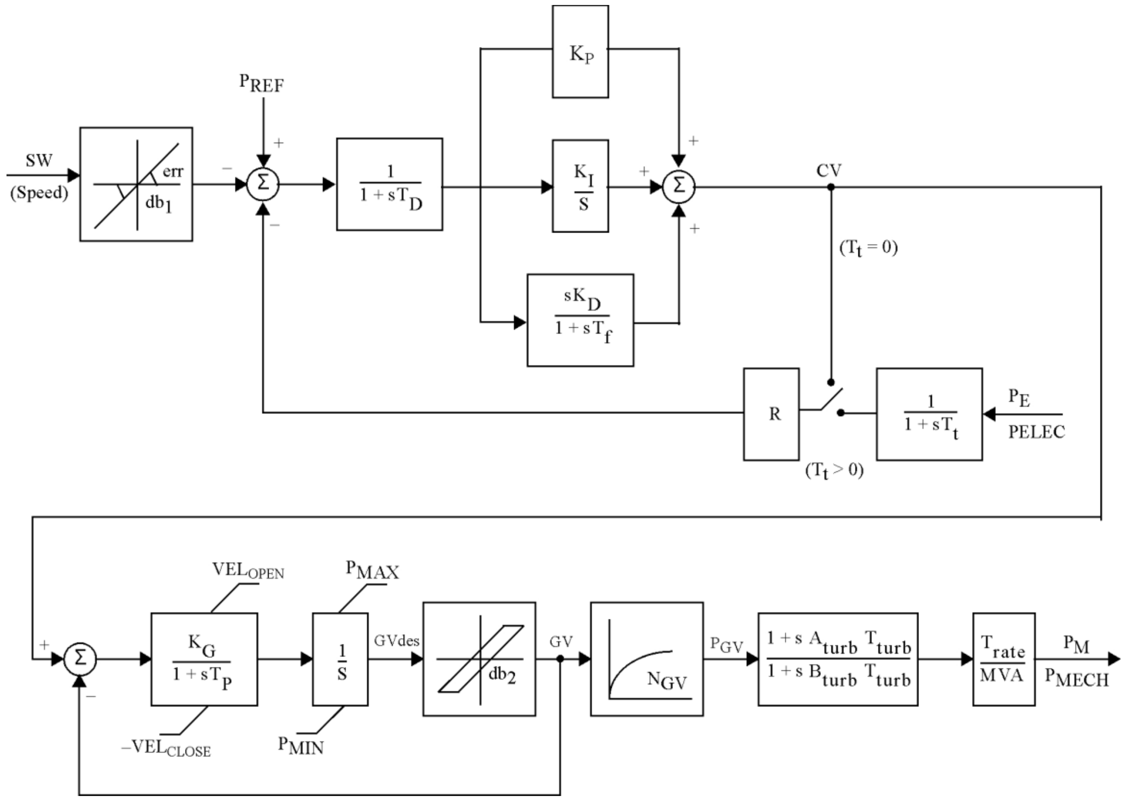


Figure 3.21 – WSHYGP digital PID hydro turbine and governor model

Thermal power plants that operate on coal or nuclear power utilize one of two models depending on whether the insensitivity zone (dead band) is implemented on the machine: IEEEG1 (Figure 3.23) and WSIEG1 (Figure 3.22). The second one is commonly used to model Russian built nuclear units. Smaller units, as well as gas fired thermal units, are modeled with simpler TGOV1 (Figure 3.24).

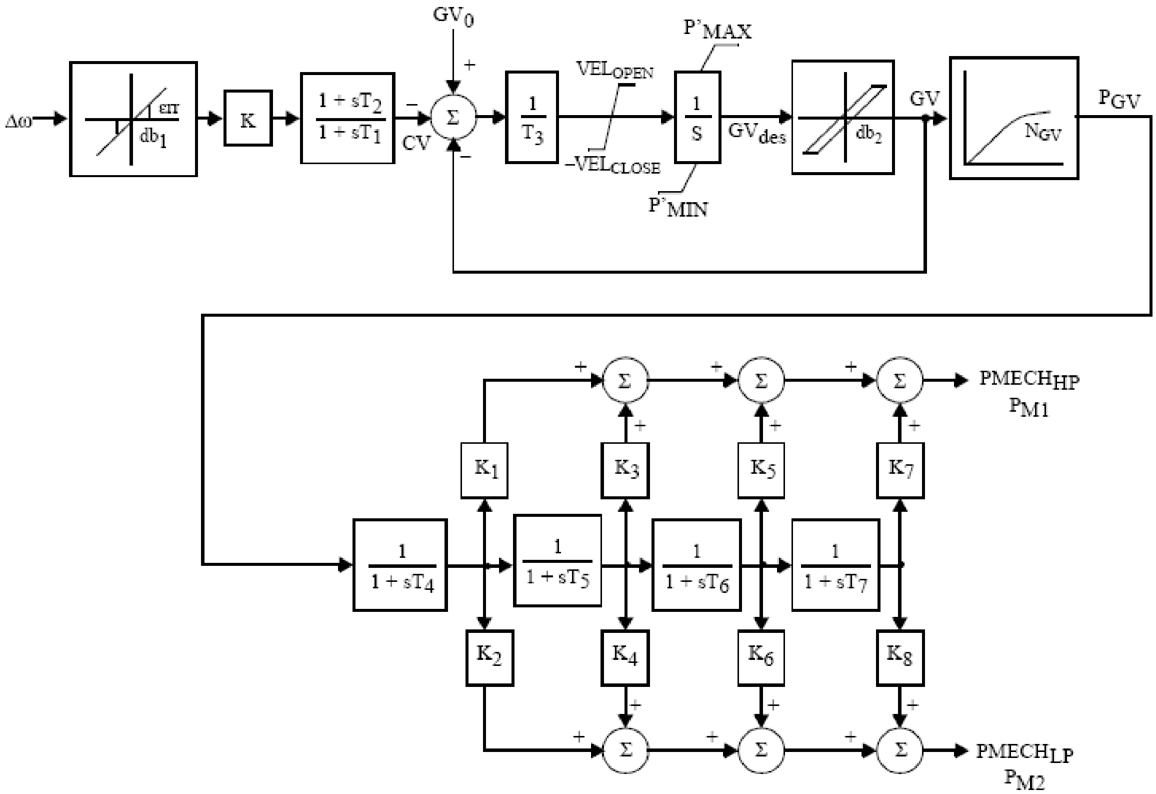


Figure 3.22 – WSIEG1 standard thermal turbine and governor model

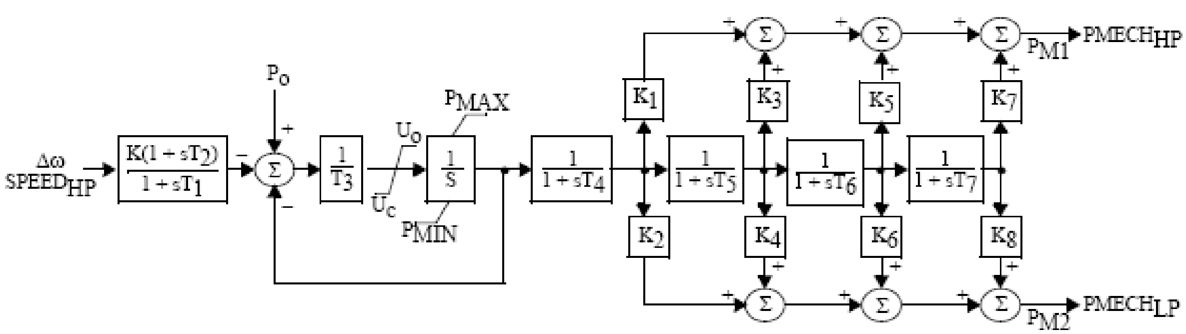


Figure 3.23 – IEEEG1 standard thermal turbine and governor model

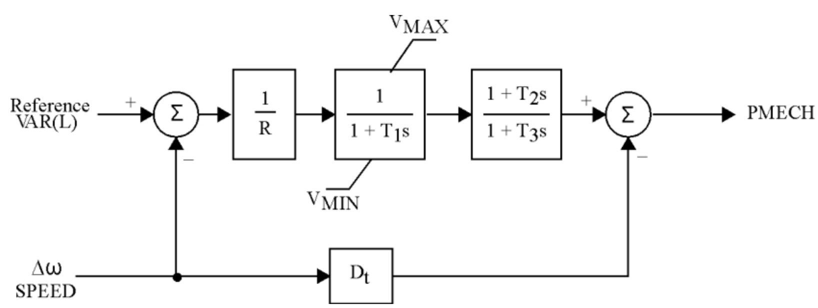


Figure 3.24 – TGOV1 standard thermal turbine and governor model

Gas turbines are modeled using the following models depending on the size of the unit, the producer and type of governor: GAST (Figure 3.25), GAST2A (Figure 3.26), GASTWD (Figure 3.27) and GGOV1 (Figure 3.28)

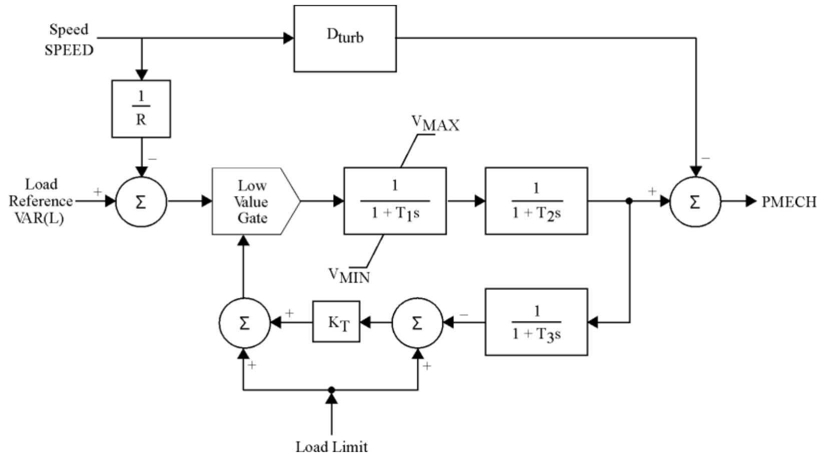
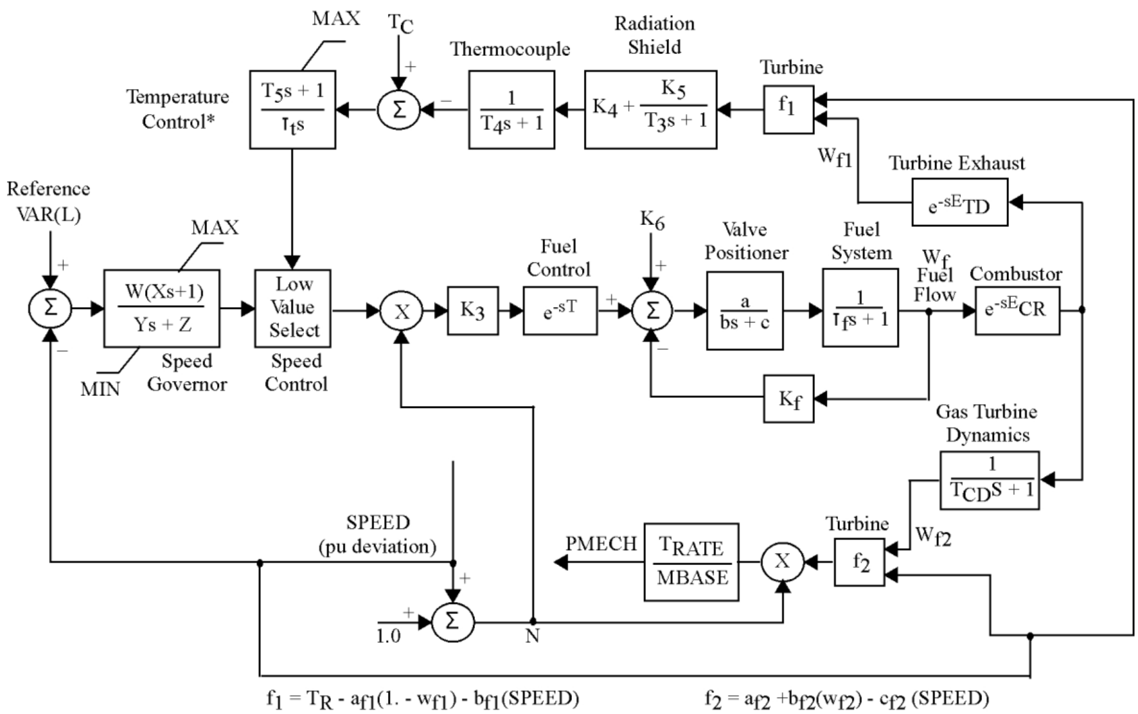


Figure 3.25 – GAST simplified gas turbine and governor model



*Temperature control output is set to output of speed governor when temperature control input changes from positive to negative.

Figure 3.26 – GAST2A gas turbine and governor model

*Temperature control output is set to output of speed governor when temperature control input changes from positive to negative.

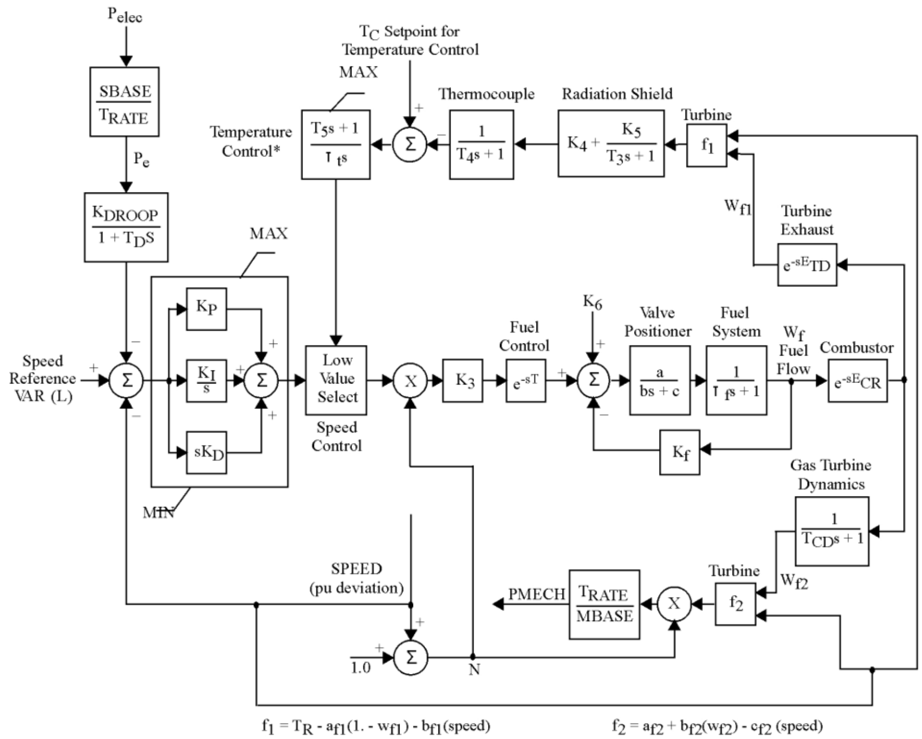


Figure 3.27 – GASTWD gas turbine and governor model with PID regulator

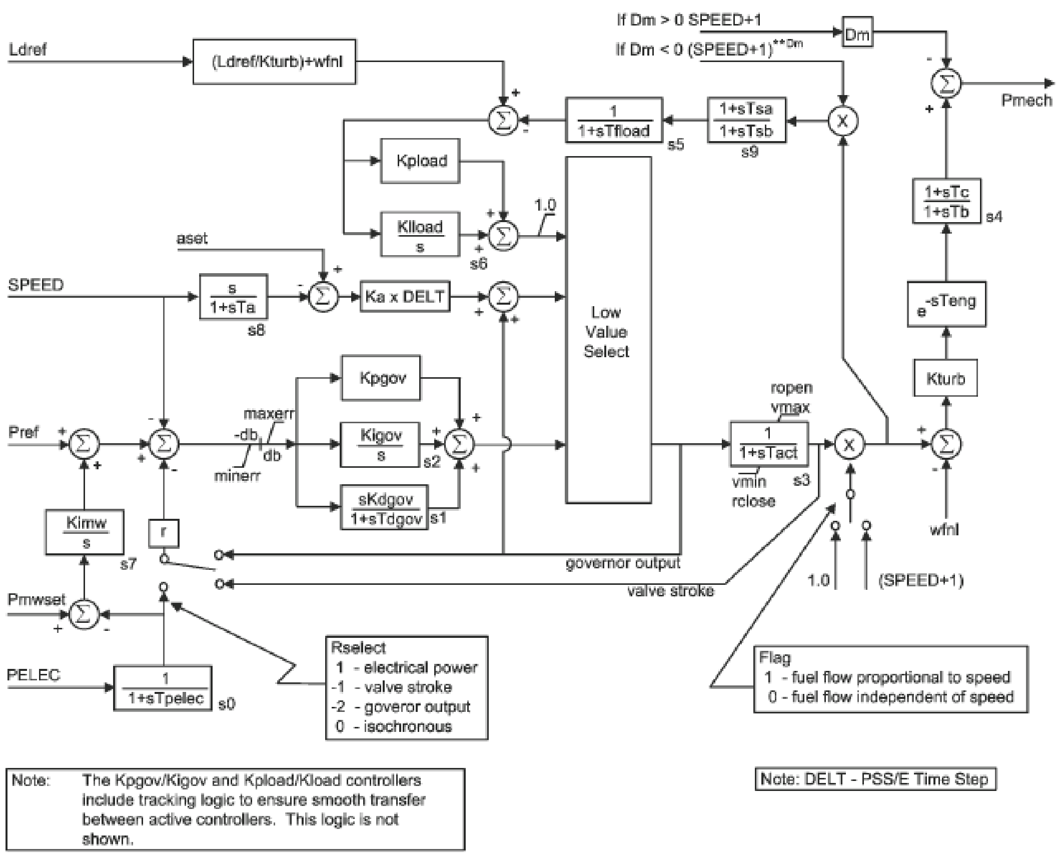


Figure 3.28 – GGOV1 GE gas turbine and governor model

Combined Cycled Gas Turbines (CCGT) are modeled with after the gas turbine model with the addition of the steam turbine model, which is connected to the gas turbine over the Heat Recovery Steam Generator using TGOV1 model (Figure 3.24). For single-shaft systems (GT turbine+ST turbine-generator) URCSCT (GAST2A+IEEEG1) model is used.

Wind Generation: When modeling wind generations the following approach utilized: Instead of modeling each generator, wind parks are modeled as one generator for the entire wind park. The power plant generator model of asynchronous generator CIMTR4 from the PSS/E dynamic model library is used with typical parameters adjusted to correspond to the installed capacity of the power plant.

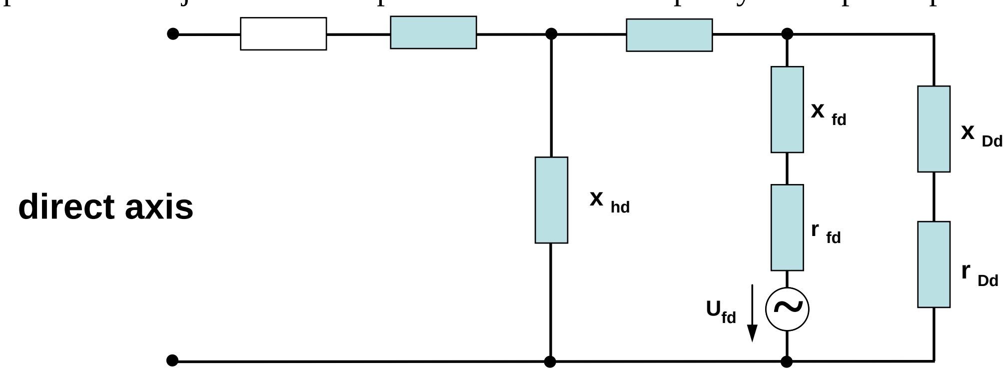


Figure 3.29 - *CIMTR4 model of double cage asynchronous generator*

Turbine-governor system for a wind power plant is usually adapts to current wind conditions, rather than the system. In this case, the constant mechanical torque model is used. This is achieved by using the TGOV1 turbine governor model (Figure 3.24), with the drop set to a large value (1000) in order to block the speed governing response, and decreasing the set to -1, thus allowing the model to adjust output power according to the system frequency.

Small hydro generation: The current systems have a small installed capacity; all are modeled as a negative load in the dynamic model of load with parameters that correspond to the generator behavior.

Equivalensing: Three type of equivalenting have been implemented in the regional dynamic model:

- Small machines modeling
- Machines bellow 50MW installed capacity are modeled as negative load with dynamic model of load with parameters that are in accordance with the generator behavior.
- Power plant modeling
- Machines bellow 50MW installed capacity is modeled by grouping machines with same characteristics into large equivalent machines – power plant models. These models have a generator model, excitation system model and a turbine governing system model.
- Equivalent system modeling
- Parts of the systems that are not modeled in detail (outside of Black Sea region *Figure* 3.30) are presented with equivalents. In order to model dumping effects by rotating masses that exist in this non modeled part of interconnected system, dynamic equivalents are implemented.

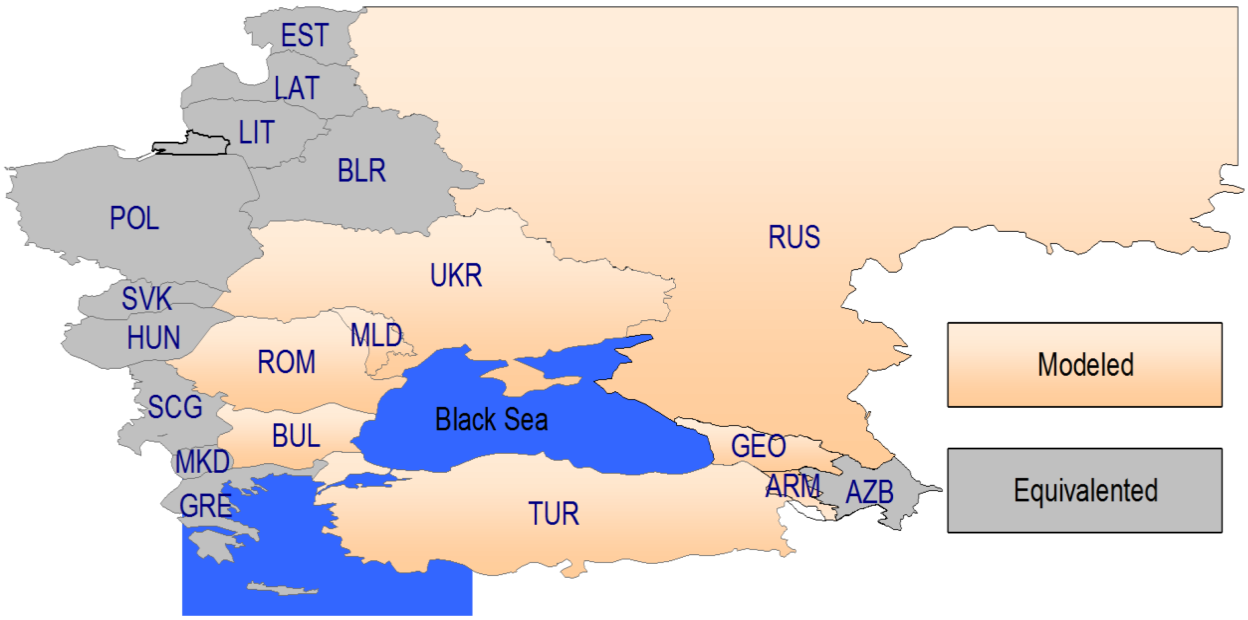


Figure 3.30 – *Modeled and equivaleted parts of the system*

For the influence of the equivalent parts of the systems on the excitation systems is neglected, and modeled through generator parameters (model of "mighty" network). The dynamic behavior of the above is modeled through dynamic equivalent models that consist of two parts:

- An equivalent generator
- The GENROU model is selected, and parameters of this equivalent generator are selected so short-circuit power contribution is the same as full system model that is implemented. The dynamic parameters are selected so inertia of the equivalent corresponds to overall inertia of the full model. (MVAbase/Inertia ratio of the equivalent=average MVAbase/Inertia ratio of real system machines)
- An equivalent turbine-governor
- Parameters of this turbine governor are selected to reflect behavior of the system according to recorded values and rules.

Analyses Results, Findings and Conclusions

Currently, the Black Sea region operates in three synchronous zones as illustrated below (*Figure 4.1*).

Figure 4.1 – *Black Sea region – synchronous operation 2010*

By 2015, Turkey is expected to be officially accepted as a full member of ENTSO-E, operating synchronously and in parallel. As a result, the Black Sea region will operate in two synchronous zones (*Figure 4.2*):

- West (Romania, Bulgaria, Turkey) with ENTSO-E
- East (Ukraine, Russia, Moldova, Georgia, Armenia, Azerbaijan)

Figure 4.2 – Black Sea region – synchronous operation 2015

Regional Balance Analyses

Figure 4.3 below shows the 2015 winter peak power balance along with the total regional balance for each TSO. This chart illustrates that Russia, Ukraine, Romania, Bulgaria and Armenia have excess power in the winter peak operation that can be exported. Moldova and Georgia are balanced with no export or import, while Turkey has a winter peak deficit. In total, the region has significant potential to export power outside of the Black Sea Region.

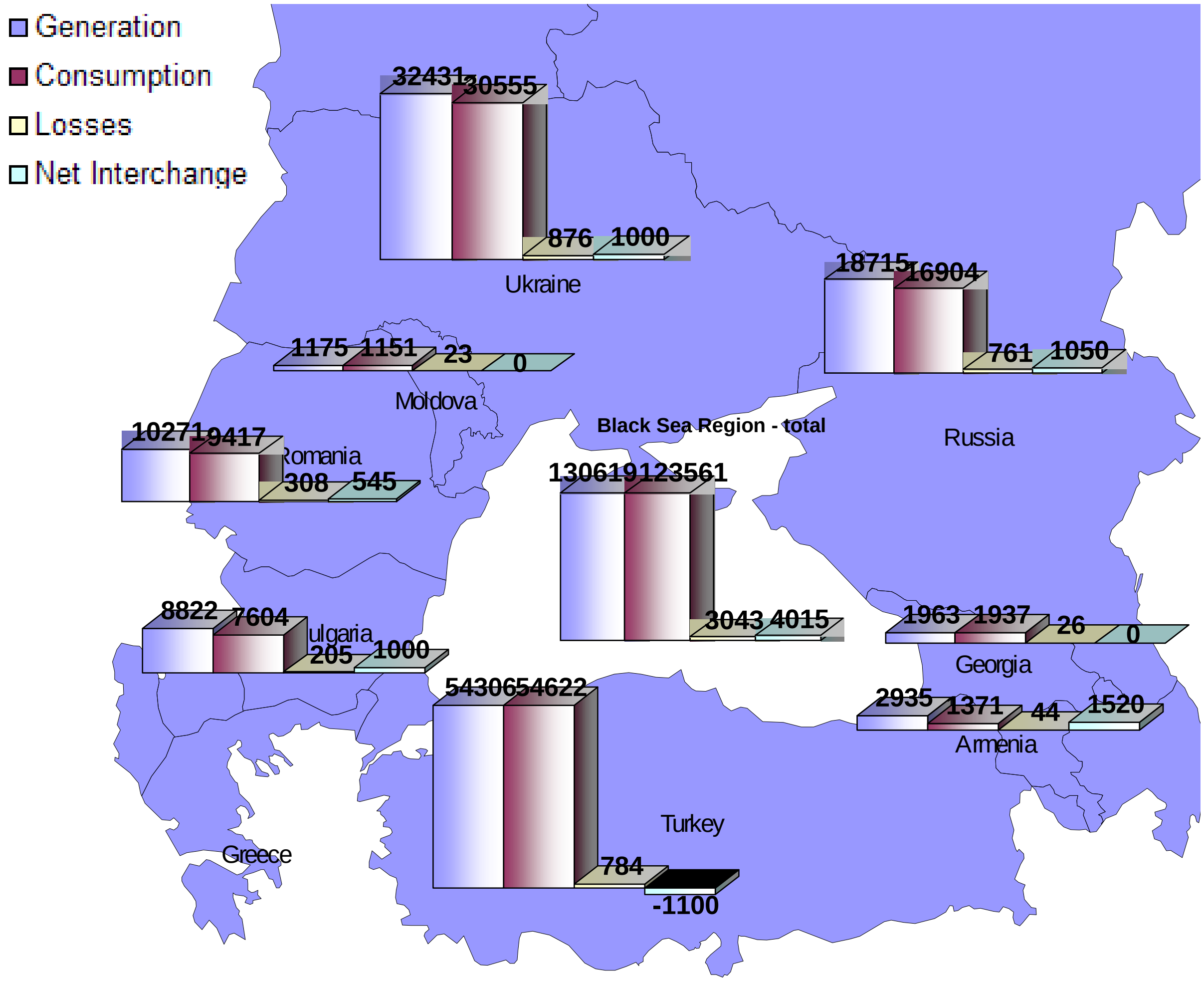


Figure 4.3 – *Black Sea region – winter 2015 balances*

Figure 4.4 below shows the 2015 summer peak power balance as well as the total regional balance for each country. This chart shows that the Net Interchange quantities are similar to the Winter Peak data with the exception of Georgia, which also reveals excess power. Its total available power for export is higher than during the winter peak operation.

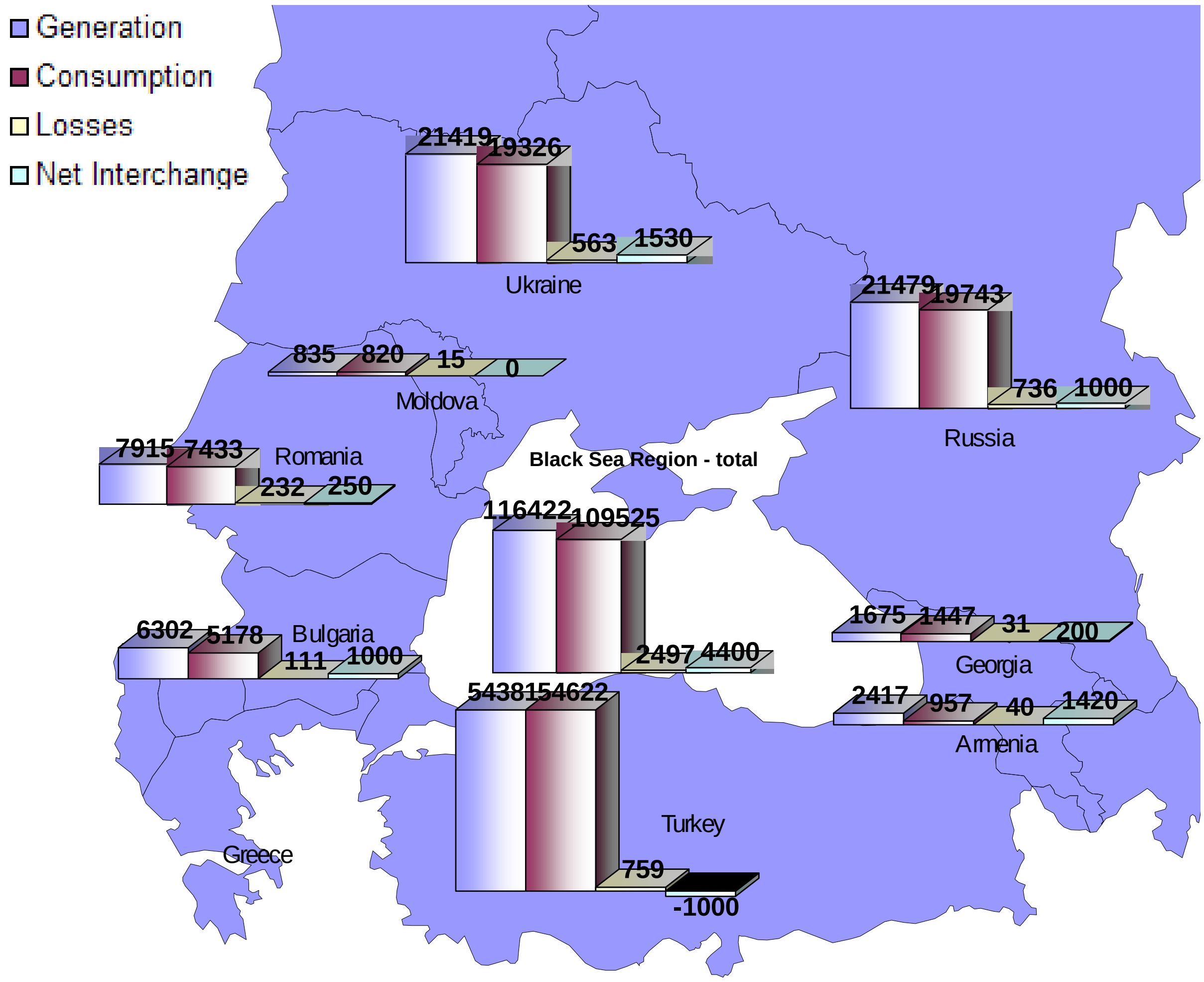


Figure 4.4 – Black Sea region – summer 2015 balances

When analyzing electricity exchanges, the Black Sea region can be divided into three major sub regions:

- North (Ukraine, Russia, Moldova)
- South (Caucasus region - Georgia, Armenia, Azerbaijan)
- West (Romania, Bulgaria, Turkey)

Countries in the west (Romania, Bulgaria and Turkey) are connected to the European transmission grid (ENTSO-E). Romania and Bulgaria have excess power capacity and export to the rest of the European market. Turkey is a balanced country, but the price of power production in Turkey is relatively high that in most cases Turkey is importing cheaper electricity from other markets.

Countries in the North (Ukraine and Russia) have large export capabilities with the exception of Moldova, which is balanced. Prices that are lower than the prices in Europe or the Western region in this region represent an attractive "power source" for electricity export.

Countries in the South (Caucasus region of Georgia, Armenia, and Azerbaijan) currently have ambitious generation development plans. If these plans are implemented, this region would represent a significant "power source" for electricity export.

Taking these power balances into consideration, and the transmission network in the region, three major export routes can be identified.

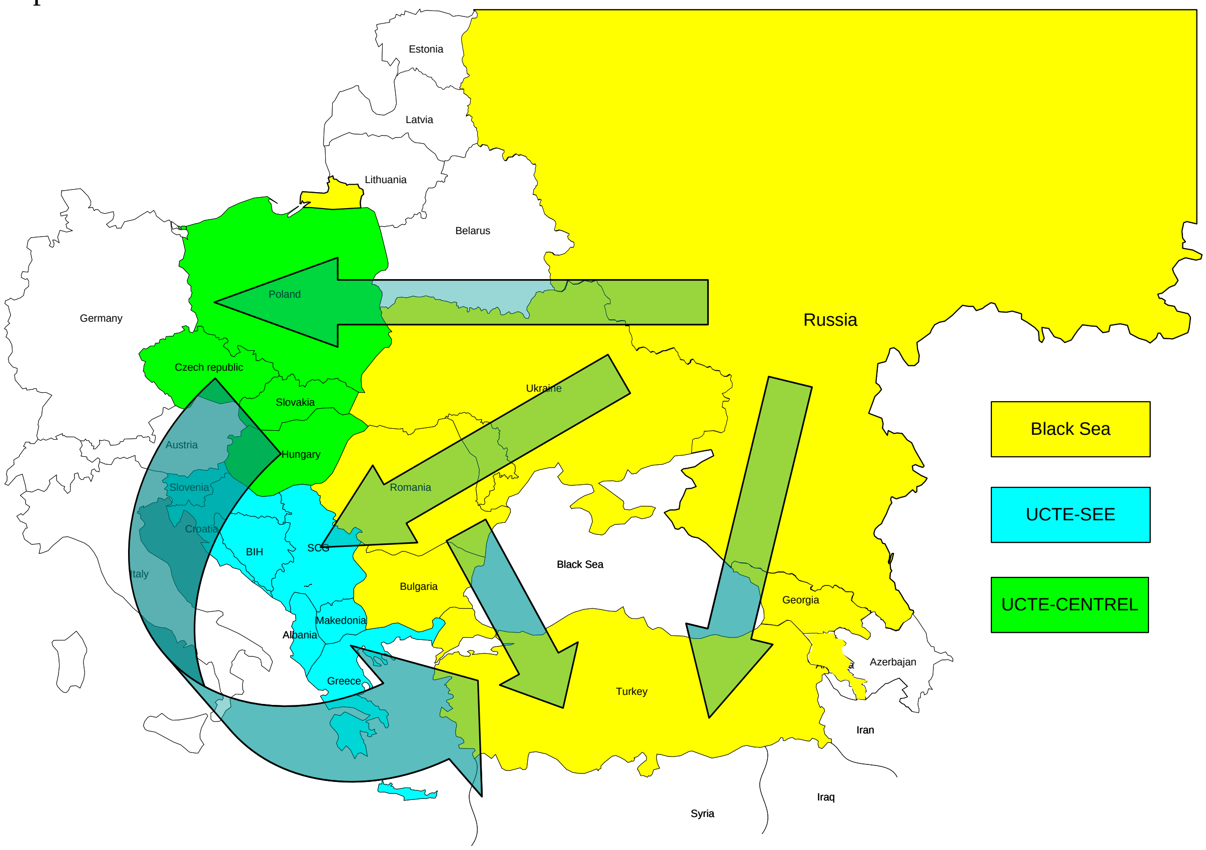


Figure 4.5 – Black Sea region realistic power exchange directions

1. North (From Ukraine, Russia to Southeast Europe or West Europe)
2. South (From Caucasus region to Turkey)
3. West (From Romania, Bulgaria to Turkey)

Network Capacities Evaluation

An important objective of the Phase II of this project is to better understand the import and export capacity of electric energy of the Black Sea Region. In this regard, an analysis of the transmission network Border Capacities and Composite Transfer Capacities was accomplished using the ENTSO-E methodology.

Border capacities are values that show trade possibilities between adjacent countries. These commonly used values are good indicators of export/import capability of one country/system to another. These capacity calculations reflect the present and assumed 2015 assumptions regarding synchronization in the region (see Figures 4.1 and 4.2).

Composite transfer capacities show electrical transfer capability of the transmission network and the ability of a system to drive large quantities of power throughout the region assuming that all countries are in synchronous operations. Analyses are usually performed along market realistic routes (expected exporters to expected importers of power) and give good information about limiting factors for driving power. Since all of the countries in the region are not in synchronous operations (see Figures 4.1 and 4.2), the composite transfer capacities presented in this report are only indicative of import and export opportunities.

Figure 4.6 of this report shows border capacity analyses results for the present network. It can be seen that border capacities are very limited on the borders between Russia, Georgia, Armenia and Turkey. In most cases, the limiting system components are interconnecting lines between these countries.

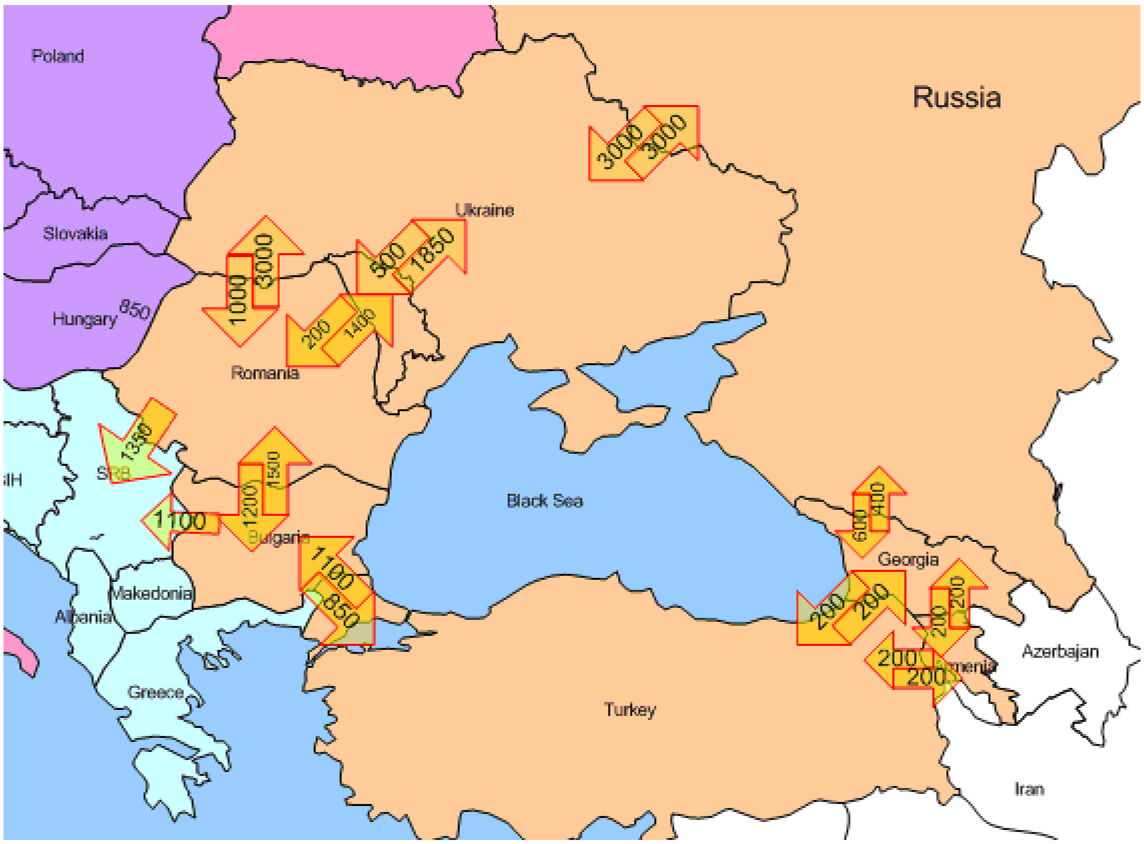


Figure 4.6 – Black Sea region – Border capacities present

Analyses of border capacities for 2015 (Figure 4.7), assuming expected level of transmission network development, shows a significant increase in border capacities. This increase is due to planned new interconnections between Georgia and Turkey (HVDC connection) and Georgia and Armenia (400 kV interconnection line Qsani-Hrazdan).

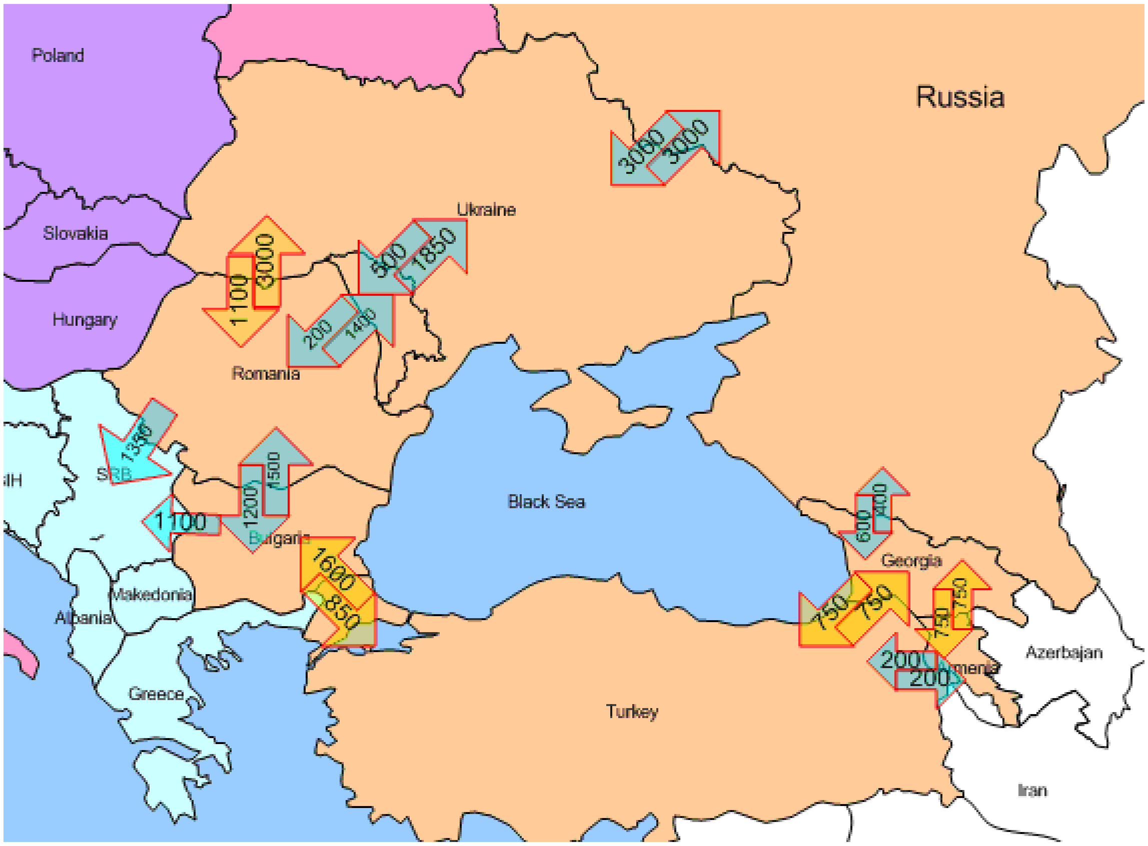


Figure 4.7 – Black Sea region – Border capacities 2015

In some cases, the real limiting element of border capacity is not the network, but is the production capacities (Moldova border capacities for example). If production is excessively increased or decreased, internal network security breaches can occur. This is what is limiting border capacity in the case of Moldova to Romania and Ukraine; not the network. The calculated Composite Transit scenarios from Russia to SEE identify network capacity in the most market realistic scenario. In almost all cases in the Caucasus region, limiting elements are interconnection lines (static security), and in some cases, dynamic stability reduces this figure even more.

Composite transfer capacities analyses (Figure 4.8) is performed along identified power exchange routes (Figure 4.5) that assumes the entire area is in synchronous operation. These composite transfer capacities are indicative of the potential that exists in the region to import and export but are not achievable since our 2015 and 2020 assumptions regarding synchronization do not include one synchronous zone. However, these calculations do begin the conversation on where strategic interconnections might be proposed in island mode or by HVDC methods.

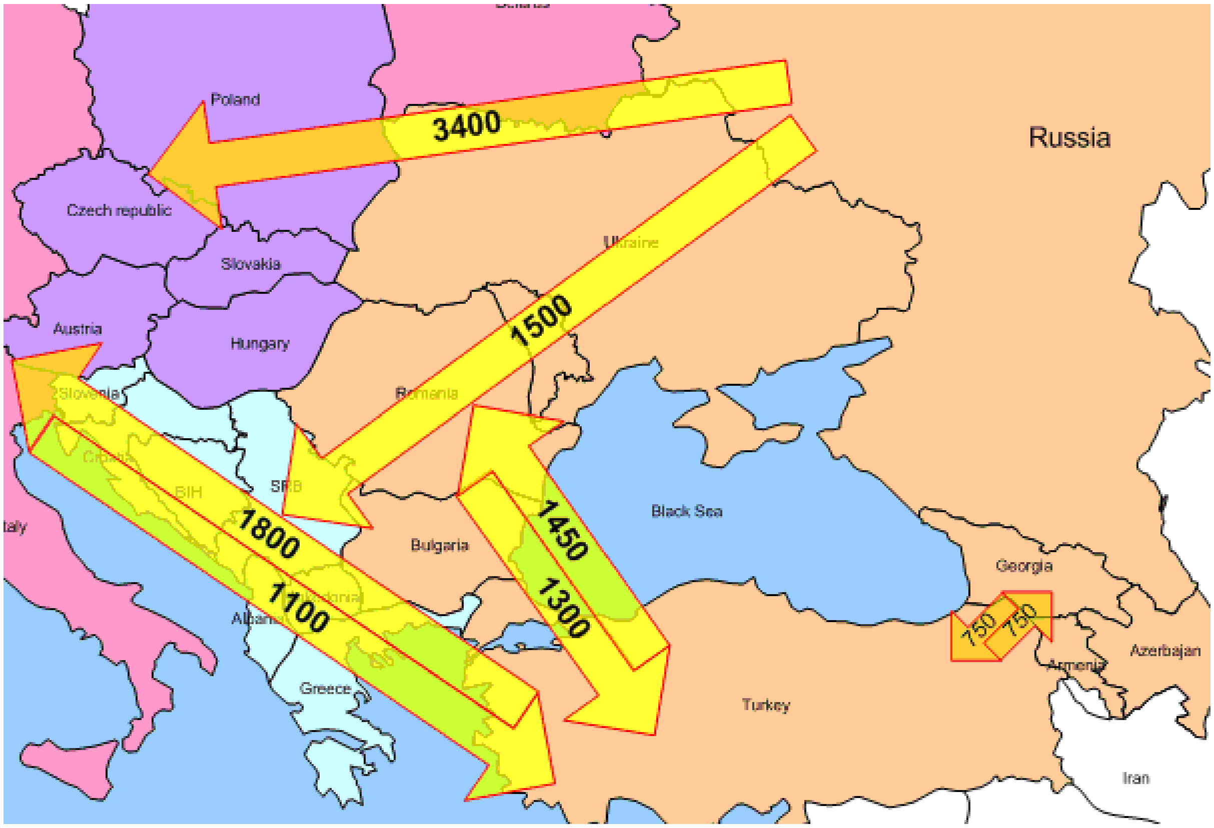


Figure 4.8 – *Black Sea region – Composite transfer capacities 2015*

In the north corridor (from Ukraine and Russia to Europe) the calculated static security limit is 3,400MW. The limiting factor for driving power from Russia and Ukraine to SEE is border capacity between Ukraine and Hungary. The Moldovan network does not influence this since most of the power is driven from Russia over Ukraine and Romania to SEE.

In scenarios to Turkey and vice versa, limiting factor are interconnections between Turkey and Bulgaria and Greece for static security. This value is reduced further when dynamic stability is taken into consideration. Implementation of Power System Stabilizers in some of Turkey's power plants should increase system stability and increase border and composite transfer capabilities to static values (*Figure 4*.8).

Dynamic Analyses

One major conclusion from these regional studies is that dynamic stability is the major concern in the region and system stability is a major limiting factor for system operation and high electricity exchange. In other words, links between interconnected systems are weak and stability reserve in the interconnected systems is low. Therefore, all transfer capacities values calculated through described methods (static security evaluation) need to be verified through dynamic analyses and system stability evaluation. It is expected that values for transfer capacities calculated taking into account system stability are much lower than those gained through static security evaluation alone.

Georgia-Armenia border: Presently, there is only one 220 kV line between Georgia and Armenia (Gardabani(GE)-Alaverdi(AM) with thermal limit 270MVA) that limits the border capacity to 200MW. There is a plan to build a new 400 kV line (Qsani(GE)-Hrazdan(AM) with thermal capacity 1330MVA) that would bring the total thermal capacity to 1600MVA. However, this capacity is limited to 1200MW as determined by static security analyses.

Dynamic analyses (Figure 4.9) decreases this value even further to 750MW due to a short circuit on Sipan line in duration 0.55s (critical clearing time). The first graph shows the power flow in the case of a major fault and the second graph shows the rotor angle of major generation units in the analyzed region. What can be seen from this data is that inter area system oscillation exists, but when it is dumped, the system is stable. For fault duration longer than 0.55s, some of the generators in the observed system would lose synchronism and the system would lose stability.

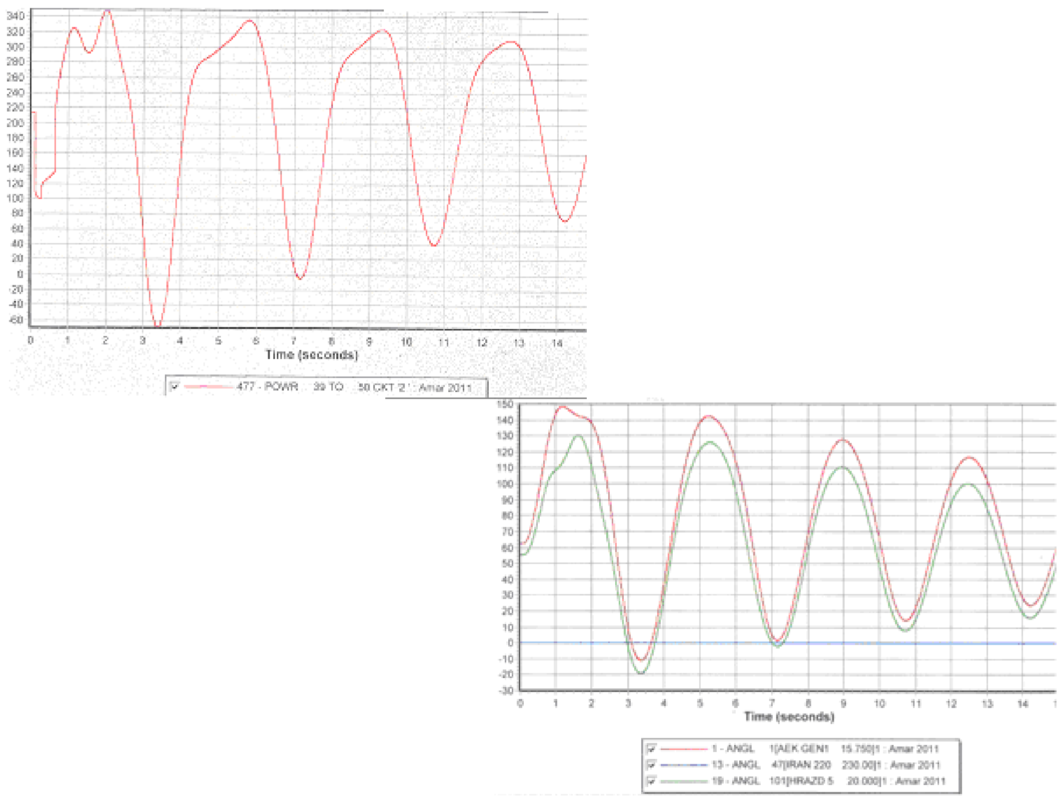


Figure 4.9 – Black Sea region – Dynamic analyses results for Qsani(GE)-Hrazdan(AM) line

Georgia-Turkey border: At this time there is only one 220 kV line between Georgia and Turkey (Batumi(GE)-Hopa(TR) with thermal limit 300MVA) that limits the border capacity to 200MW. There is a plan to build a new 400 kV line (Akhalchike(GE)-Borcka(TR) and HVDC back to back system) in Akhalchike with capacity of 600MW. This brings the total thermal capacity to 900MVA, but in reality static security analyses limits this value to 750MW (600MW over HVDC and 150MW over existing Batumi-Hopa line in island operation).

Dynamic analyses (*Figure 4*.9) confirmed this capacity to be 750MW. This analyses assumes the worst case concerning stability that is parallel operation of Azerbaijan, Armenia and Georgia on one side and

Turkey on other with 600 MW export from Azerbaijan to Turkey, meaning that the interconnections from Georgia to Russia and Azerbaijan to Russia, and from Turkey to Bulgaria and Greece are out of operation. The analyzed fault is the tripping of the HVDC connection after a three phase short circuit in Achalchike substation. In this case, we have a 600 MW surplus in the Georgia-Armenia-Azerbaijan region, and a 600 MW deficit in Turkey. The first graph in Figure 4.10 shows the frequency behavior in these two parts of the system. A 600 MW surplus causes frequency to rise and stabilize after 60s. In Turkey, as a consequence of the power deficit, the frequency drops and stabilizes after 30s. The next two diagrams show the response of generators in Georgia-Armenia-Azerbaijan and then in Turkey. The generation in Georgia-Armenia-Azerbaijan area is gradually reduced to correct power imbalance. On the other hand, in Turkey the remaining generation increases production to “cover” power imbalance. In conclusion, the system is stable under this fault condition, and the 750 MW border capacity is confirmed.

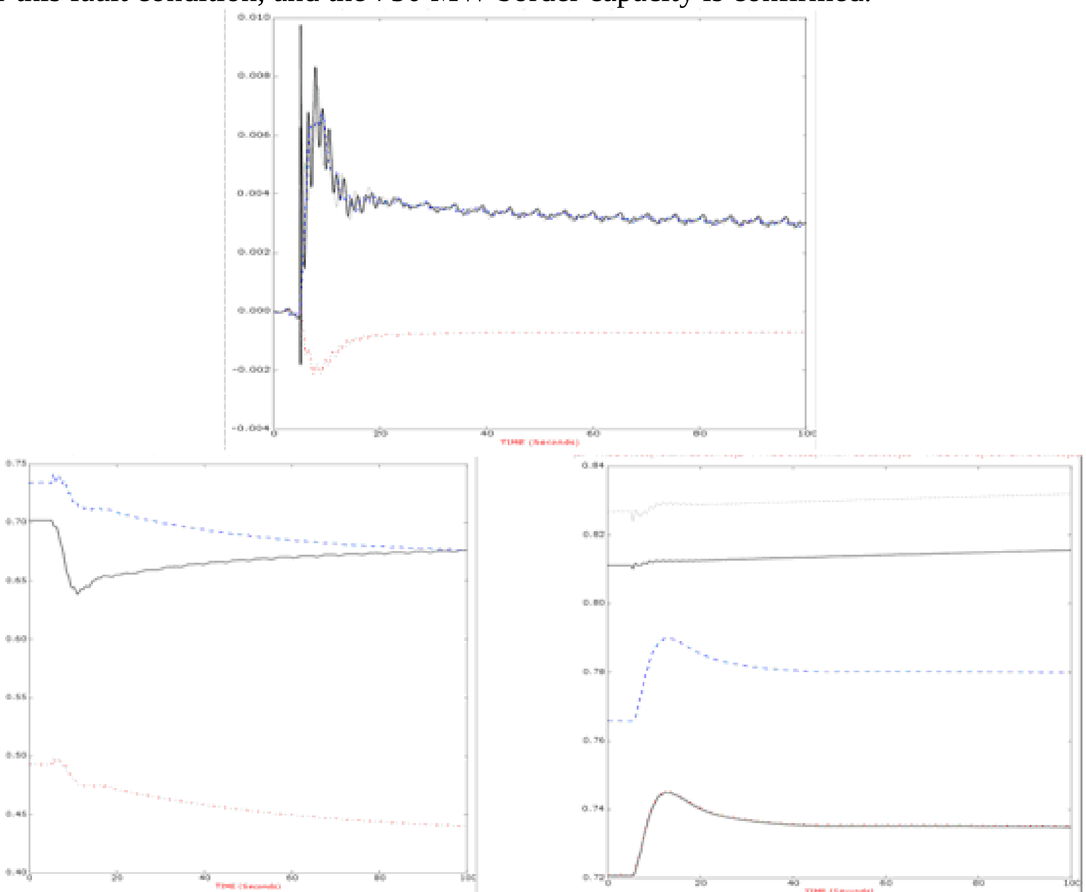


Figure 4.10 – Black Sea region – Dynamic analyses results for HVDC Akhalchike-Borcka

BSTP Phase II Conclusions and Next Steps

The following conclusions and next steps are based on the analysis, findings and results presented throughout this report.

Conclusions

2015 and 2020 Model Status

As previously stated in this report, national and regional models using 2015 and 2020 data were built and tested under static load flow and dynamic stability conditions. The project team has a high degree of confidence in the 2015 model data due to a high level of certainty that lines, generation and loads included in this model are a good estimate of conditions that will exist in 2015. However, this level of certainty does not extend to the 2020 model for two important reasons:

- In the current world economic situation, it is difficult to accept the very optimistic forecast of new system expansions and load growth presented in the 2020 models. Many of the 2020 assumptions were developed before the world economic contraction occurred and, for many of the participants, this was a first look at the 2020 planning horizon.
- The impact of renewable energy supplies in the Black Sea Region by 2020 has not been adequately quantified in the 2020 models. The growth of renewable forms of generation in one location, that could supplement new conventional generation in another, makes this issue of great importance in the process of finalizing the 2020 regional models.

For these reasons, the project team has concluded that only 2015 study results should be reported in these project findings.

Present Synchronous Operations

The Black Sea project participants presently operate with three synchronous zones;

- the ENTSO-E countries of Romania and Bulgaria operating synchronously with Europe
- the IPS/UPS countries of Russia, Ukraine, Moldova, Georgia, Armenia and Azerbaijan
- and Turkey

However, Turkey is very close to becoming part of the ENTSO-E system and the Ukraine and Moldova have initiated plans to become part of ENTSO-E in the future. Therefore, by the 2015 planning year, three high probability possibilities for the region are:

- 2 synchronous zones consisting of ENTSO-E (including Turkey) and IPS/UPS including Ukraine and Moldova.
- 3 synchronous zones consisting of ENTSO-E (including Turkey), Ukraine and Moldova (in an ENTSO-E testing mode) and IPS/UPS.
- 2 synchronous zones consisting of an ENTSO-E that includes Turkey, Ukraine and Moldova and the IPS/UPS.

The 2015 study results presented in this report have assumed that two synchronous zones will exist in that year and will consist of ENTSO-E (Romania, Bulgaria and Turkey) and the IPS/UPS (Russia, Ukraine, Moldova, Georgia, Armenia and Azerbaijan)

Regional Power Balance

Figure 4.3 of this report shows the 2015 winter peak power balance for each country participant as well as the total regional balance. This chart concludes that Russia, Ukraine, Romania, Bulgaria and Armenia have excess power in the winter peak that can be exported. Moldova and Georgia are balanced with no export or import and Turkey has a winter peak deficit. In total, the region has significant potential to export power outside of the Black Sea Region. Figure 4.4 of this report shows the 2015 summer peak power balance for each country participant as well as the total regional balance. This chart show that Net Interchange quantities are similar to the Winter Peak data except that Georgia also shows excess power and the total available power for export is higher than at the winter peak.

Power Balances for the Black Sea Region in 2015 (winter and summer peaks) reveal that the region has 4,015MW of export capacity on winter peak and 4,400MW on summer peak. This surplus capacity in the Black Sea Region represents a significant export opportunity considering projected future energy needs of central and southeastern Europe. The regional transmission planning models developed in this phase of the project are exactly the right tools to determine where this power can go and the capacity of those routes to facilitate the exchange.

National Border Capacities

Border capacities are values that show trade possibilities between adjacent countries. These commonly used values are good indicators of export/import capability of one country/system to another. These capacity calculations reflect the present and assumed 2015 assumptions regarding synchronization in the region (see Figures 4.1 and 4.2).

Figure 4.7 presents an analysis of border capacities for 2015 assuming expected level of transmission network development. This figure shows a significant increase in border capacities between Georgia and Turkey and between Armenia and Georgia. This increase is due to planned new interconnections between Georgia and Turkey (HVDC connection) and Georgia and Armenia (400 kV interconnection line Qsani-Hrazdan).

Regional Composite Transfer Capacities

Composite transfer capacities show electrical transfer capability of the transmission network and the ability of a system to drive large quantities of power throughout the region assuming that all countries are in synchronous operations. Analyses are usually performed along market realistic routes (expected exporters to expected importers of power) and give good information about limiting factors for driving power. Since all of the countries in the region are not in synchronous operations (see Present Synchronous Operations section above), the composite transfer capacities presented in this report are only indicative of import and export opportunities.

Taking the power balances identified in this phase of the project into consideration, and considering the transmission network in the region, three major export routes are identified in Figure 4.5:

- North (From Ukraine, Russia to Southeast Europe or West Europe)
- South (From Caucasus region to Turkey)
- West (From Romania, Bulgaria to Turkey)

Figure 4.8 presents a set of indicative values for these export routes and identifies maximum transfer capacities assuming synchronization in the region. The analysis done in this regard has revealed that more work is needed to determine strategic locations for HVDC or island mode connections between existing and projected synchronous zones.

Border Capacities and Dynamic Modeling

This phase of the BSTP project has determined that Load Flow Analysis and Static Stability studies do not always determine the lowest border capacities. This is especially true in the Georgia-Armenia-Azerbaijan region where dynamic stability analysis is necessary to find the actual lowest limits. This is an important finding of the project that must be recognized by the transmission planning specialists in these countries. Since national and regional dynamic models have been built and dynamic modeling training has been accomplished, it should now become a standard practice to check static results using dynamic stability analysis.

Custom Dynamic Model Development

The PSS/E software dynamic model library includes many types of generation equipment models as described in Chapter 4 of this report. However, this library does not include the needed models for certain Russian built generating equipment. Custom models were constructed by the project team in order to accurately simulate this equipment in the dynamic models. These custom built models, and the procedure used to develop them, will be very useful to transmission planning experts as they continue to refine the national and regional models.

Technical Results vs. Economic Results

This report shows important findings regarding the amount of power available in the region for export and the ability of the transmission systems to move that power in 2015. It is apparent that the region now has the technical expertise to carry out national and regional electric transmission capacity studies. However, it is also apparent that no analyses have been presented regarding the economics of power exchanges. Some interest in this subject was generated at a workshop on financial and economic analysis of transmission projects held in Kiev on July 7 and 8 of 2009. This workshop was designed as an introduction to the subject and was attended by Black Sea participants as well as SECI participants. The basics of financial and economic analysis were presented in the context of evaluating competing transmission projects. However, the same techniques can be applied to the economics of imports and exports using the information presented in this report (see next steps for a further discussion).

Next Steps

Integrating Renewable Energy into National and Regional Network Models

As previously stated in this report, national and regional models using 2015 and 2020 data were built and tested under static load flow and dynamic stability conditions making the BSTP consistent with the Southeast Europe Coordination Initiative (SECI) Transmission Planning Project. As discussed in the Conclusions section of this report, the data contained in the 2020 models for new generation is based on the official development plans of the respective national ministries or transmission system operators (TSOs) but may be overstated due to current and forecasted economic conditions. In addition, it does not yet reflect the recent interest in renewable energy that has been expressed by project developers throughout the region.

Armenia and Georgia have ambitious plans to develop wind, hydro and solar energy. Romania and Bulgaria have received over 5,000 MW of applications from project developers for new wind energy stations, and Turkey is reviewing applications for wind energy projects that would more than double its current capacity. However, wind energy in particular poses technical challenges to the safe, secure and reliable operation of the high voltage network due to its intermittent nature and the geographical concentration of resources in relatively small wind corridors. Experience in North America and Europe indicates these challenges can be overcome with improved forecasting, flexible operation of the network, smart grid technologies and markets that incentivize the ancillary services necessary to compensate for the intermittency of wind power.

Transmission planners in the Black Sea region lack experience and knowledge of the methods and technologies used to smooth production patterns of wind energy. It is recommended that a next step for the BSTP should be to improve the capacity of transmission planners to incorporate reasonable wind energy estimates into the network models for 2020.

Reviewing and Refining the 2020 National and Regional Models

As has been stated in the Conclusions section of this report, the project team has a high degree of confidence in the 2015 model data due to a high level of certainty that lines, generation and loads included in this model are a good estimate of conditions that will exist in 2015. However, this level of certainty does not extend to the 2020 model because renewable energy sources are not adequately modeled (see "Integrating Renewable Energy into National and Regional Network Models" discussed above) and because estimates of growth in lines, conventional generation and loads are thought to be inconsistent with current world economic forecasts.

It is recommended that a next step for the BSTP should be to revisit national modeling data estimates for 2020, taking into account current economic forecasts for the region and the estimates of renewable generation (with emphasis on wind) including the amount of such generation and its location. It is probable that the amount and location of wind generation will significantly alter the need for other sources of generation and will change the required system network configuration.

Additional Synchronous Scenarios

As has been stated in the Conclusions section of this report, this BSTP final report data and results have been determined using the 2015 model and assumes that two synchronous zones will exist in that year and will consist of ENTSO-E (Romania, Bulgaria and Turkey) and the IPS/UPS (Russia, Ukraine, Moldova, Georgia, Armenia and Azerbaijan). It is recommended that two other scenarios be investigated for 2015:

- 3 synchronous zones consisting of ENTSO-E (including Turkey), Ukraine and Moldova (in an ENTSO-E testing mode) and IPS/UPS.
- 2 synchronous zones consisting of ENTSO-E that includes Turkey, Ukraine and Moldova and the IPS/UPS.

It is also recommended that, once the 2020 model is updated as described above, the 2020 regional model be used to examine two possible scenarios:

- 2 synchronous zones consisting of ENTSO-E that includes Turkey, Ukraine and Moldova and the IPS/UPS.
- 2 synchronous zones consisting of ENTSO-E (including Turkey) and IPS/UPS (including Ukraine & Moldova).

Strategic Interconnections Between Synchronous Zones

This report has demonstrated that the region has excess power in the winter and summer and the Composite Transfer Capacity analysis has indicated that, if the region was one synchronous zone, the transmission system has substantial capacity to move that excess. Since the region will not be one synchronous system in our planning years of 2015 and 2020, it is recommended that further study be conducted to determine strategic locations for HVDC or island mode connections between synchronous zones. This approach has already begun in the HVDC proposal between Georgia and Turkey.

Economic and Financial Analysis of Power Exchanges

Phase II of the BSTP revealed that surplus capacity in the Black Sea Region represents a significant export opportunity considering projected future energy needs of central and southeastern Europe. It is recommended that the working group evaluate the projected costs (current and planned) of generation (by fuel) to optimize electricity generation in the region. In this regard, the working groups can begin to evaluate import-export options using modern economic and financial analysis techniques that have already been introduced into the project. This information can be coupled with more accurate demand projections within the region and in Southeast Europe through cooperation with the USAID Strategic Planning Project. This type of analysis has the potential to reveal the likely trading scenarios within the region and between the regions. The revised 2020 network models (as described above) can be used to provide a more accurate picture of the capability of the network, both in parallel operation with ENTSO-E and using HVDC connections depending on the synchronous scenario chosen, to identify network investment requirements necessary to support the most likely trade and exchange scenarios.

Training/Capacity Building to Support Renewable Energy and Energy Security Initiatives

To support the initiatives on integrating renewable energy and exporting Black Sea surplus capacity for Southeast Europe, training on the following subjects will be provided to improve the capacity of the TSOs:

- Modeling Wind Turbine
- Use and Application of Smart Grid Technologies to Integrate Wind and Other Renewables
- Advanced Economic and Financial Analysis of Transmission Planning Projects
- GT Max or other Software used to Estimate Productions Costs for Modeling Most Likely Trade Scenarios

Regional Grid Code Benchmarking Study

As TSOs in the region express greater interest in mutual trade and exchange and long-term parallel operation with ENTSO-E, it will be essential that they develop and adopt harmonized rules for operating the network through a common grid code. The project will prepare a benchmarking study to examine the contents of each country’s grid code as a first step toward the eventual development of a regional grid code.

APPENDIX A: Planned Network Reinforcement Table

TYPE	SUBSTATION1		SUBSTATION2		VOLTAGE LEVEL	number of circuits /units	CAPACITY		MATERIAL OR TRANSFORMER TYPE	CROSS SECTION	LENGTH			DATE OF COMMISSION	STATUS	COMMENT
								limited			BR1	BR2	TOTAL			
					kV/kV		A or MVA	A or MVA		mm2	km	km	km			
1	2	3	2	3	4	5	6	7	8	9	10	11	12	13	14	15
								ARMENIA								
SS	AM	Hrazdan TPP			400/220	2	2x500	2x500						2015	Under negotiation	
OHL	AM	Hrazdan TPP	IR	Tavriz	400	2	2x1800	2x1900	ACSR	2x(2x500)	332	100	432	2015	Under negotiation	
OHL	AM	Shinuhayr	AM	Ararat 2	220	1	1100	1400	ACSR	2x300	90	80	170	2014	Under negotiation	
OHL	AM	Hrazdan TPP	GE	Ksani	400	1	1100	1400	ACSR	2x300	90	80	170	2014	Under negotiation	
SS	AM	Agarak 2			220/110	1	63		OTC					2015	Under negotiation	
OHL	AM	Agarak 2	AM	Agarak 1	110	1			ACSR					2014	Under negotiation	
SS	AM	Noravan			400/220	2	2x200							2015	Under negotiation	
OHL	AM	Noravan	AM	Hrazdan TPP	400	2	1445		ACSR	2x300				2015	Under negotiation	
OHL	AM	NPP Medzamor	AM	Hrazdan TPP	400	2	1445		ACSR	2x300				2015	Under negotiation	
								BULGARIA								
OHL	BG	M.East	GR	Nea Santa	400	1	1700	-	ACSR	3x400	-	-	-	2015	Project	
OHL	BG	Zlatitsa	BG	Plovdiv	400	1	1700	-	ACSR	3x400	-	-	75	2010	Commissioning	
OHL	BG	M.East1	BG	Plovdiv	400	1	1700	-	ACSR	3x400	-	-	93	2013	Project	
OHL	BG	M.East1	BG	M.East3	400	1	1700	-	ACSR	3x400	-	-	13	2010	Construction	
OHL	BG	M.East1	BG	Burgas	400	1	1700	-	ACSR	3x400	-	-	135	2017	Project	
OHL	BG	HPP Aleko	BG	Plovdiv	220	1	720	-	ACSR	500	-	-	2x40=80	2015	Project	
OHL	BG	Karnobat	BG	Dobrudja	220	1	360	-	ACSR	500	-	-	90	2017	Project	
OHL	BG	Dobrich	BG	Majak	110	1	180	-	ACSR	500	-	-	140	2012	Project	
OHL	BG	Kavarna	BG	Varna	110	2	360	-	ACSR	500	-	-	2x90=180	2013	Project	
Substation	BG	Krushari			400/100									2020	Project	
Substation	BG	Vidno			400/100									2020	Project	
OHL	BG	Krushari	BG	Vidno	400	2	2x1700	-	ACSR	3x400	-	-	2x115=230	2020	Project	
								GEORGIA								
SS	GE	Qsani			500/400	1	3X267		LTC					2009	Feasibility study	
OHL	GE	Qsani	AM	TPP Hrazdan	400	1	1100	1400	ACSR	2x300	80	90	170	2009	Feasibility study	
OHL	GE	Mukharani	AZ	AZ TPP	330	1							283			
SS	GE	Akhaltske			500/400	1										
BB	GE	Akhaltske			400	1										
OHL	GE	Akhaltske		Marneuli	500	1										
OHL	GE	Marneuli		Gardabani	500	1										
OHL	GE	Akhaltske		Menji	500	1										
OHL	GE	Menji		Kudoni	500	1										
OHL	GE	Akhaltske		Zestaponi	500	1							71			
OHL	GE	Akhaltske	TR	Borcka	400	1							130			
OHL	GE	Gardabani	AR	Atarbeksan	330	1										
OHL	GE	Enguri	RU	Centralna(Sochi)	500	1							450			

MOLDOVA																
OHL	MD	Balti	UA	Dnestrovsca HPP	330	1	1670	-			88	32	120	2020		
OHL	MD	Balti	MD	Straseni	330	1	1380	-			102.8		102.8	2020		
OHL	MD	Straseni	MD	Chisinau	330	1	1380	-			36.4	-	36.4	2020		
OHL	MD	Balti	MD	Ribnita	330	1	1380	-			82.5	-	82.5	2020		
OHL	MD	Straseni		Ribnita	330	1	1380	-			75	-	75	2020		
SS	MD	Balti			400/330	1	630	-	IPC					2015		
OHL	MD	Balti	RO	Suceava	400	1	1750	-			55	-		2015		
OHL	MD	Ungheni	RO	Iasi	400	2	1750	-			10	-		2020		
OHL	MD	Ungheni	MD	Balti	400	1	1750	-			86.1	-		2020		
OHL	MD	Ungheni	MD	Straseni	400	1	1750	-			113.9	-		2020		
ROMANIA																
SS	RO	Portile de Fier II			220/110	2	2*200		2 windings					2008	completed	
OHL	RO	Portile de Fier II	RO	Cetate	220	1	875		Ol-Al	450			80	2008	completed	
OHL	RO	Portile de Fier II	RO	Portile de Fier I	220	1	875		Ol-Al	450			71	2008	completed	
CSS	RO	Nadab		-	400										completed	
OHL	RO	Oradea	RO	Nadab	400	1	1997		Ol-Al	3x300			75		completed	
OHL	RO	Arad	RO	Nadab	400	1	1997		Ol-Al	3x300			35		completed	
OHL	RO	Nadab	HU	Bekescsaba Border	400	1	1750		Ol-Al	3x300			23	2008	completed	
OHL	HU	Bekescsaba Border	HU	Bekescsaba	400	1	1750		Ol-Al	2x500			37	2010	completed	
SS	RO	Resita			400/220	1	400		2 windings					2014		
SS	RO	Resita			400/110	1	250		2 windings					2014		
OHL	RO	Portile de Fier I	RO	Resita	400	1	1997		Ol-Al	3x300			117	2014		new 400kV OHL
SS	RO	Timisoara			400/220	1	400		2 windings					2014		
OHL	RO	Timisoara	RO	Resita	400	1	1997		Ol-Al	3x300			73	2014		upgrade from 220 kV
OHL	RO	Timisoara	RO	Arad	400	1	1997		Ol-Al	3x300			55	2014		upgrade from 220 kV
OHL	RO	Timisoara	RS	Pancevo	400	1	1750		Ol-Al	3x300			100	2014		
SS	RO	Suceava			400/110	2	250		2 windings					2010		
OHL	RO	Suceava	MD	Balti	400	1	1750		Ol-Al	3x300	40	55	95	2019		
SS	RO	Bacau			400/220	1	400		2 windings					2014		
SS	RO	Roman			400/220	1	400		2 windings					2014		
OHL	RO	Suceava	RO	Roman	400	1	1700		Ol-Al	3x300			100	2014		upgrade from 220 kV
OHL	RO	Roman	RO	Bacau	400	1	1700		Ol-Al	3x300			58.8	2014		upgrade from 220 kV
OHL	RO	Bacau	RO	Gutinas	400	1	1700		Ol-Al	3x300			55.3	2014		upgrade from 220 kV
SS	RO	Bistrica			400/110	1	250		2 windings					2020		
OHL	RO	Suceava	RO	Bistrica	400	1	1700		Ol-Al	3x300				2020		upgrade from 220 kV
OHL	RO	Gadalin	RO	Bistrica	400	1	1700		Ol-Al	3x300				2020		upgrade from 220 kV
SS	RO	Vant			400/110	2	250		2 windings					2014		
OHL	RO	Isaccea	RO	Vant	400	1	1800		Ol-Al	3x300				2014	Constr.	to line Isaccea-Dobrudja

OHL	RO	Medgidia	RO	Vant	400	1	1800		Ol-Al	3x300				2014	Construction	to line Isaccea-Dobrudja
OHL	BG	Dobrudja	RO	Medgidia	400	1	1800		Ol-Al	3x300				2012	Construction	to line Isaccea-Dobrudja
SS	RO	Tariverde			400/110	2	250		2 windings					2011	Construction	
OHL	RO	Tulcea west	RO	Tariverde	400	1	1800		Ol-Al	3x300				2011	Construction	to line Tulcea-Constanta
OHL	RO	Constanta	RO	Tariverde	400	1	1800		Ol-Al	3x300				2011	Construction	to line Tulcea-Constanta
OHL	RO	Isaccea	RO	Medgidia	400	1	1800		Ol-Al	3x300				2014		to line Isaccea-Varna
OHL	BG	Varna	RO	Medgidia	400	1	1800		Ol-Al	3x300				2014		to line Isaccea-Varna
OHL	RO	Constanta	RO	Medgidia	400	1	1800		Ol-Al	3x300			21	2014		new 400kV OHL
DC	RO	Constanta			400		600 MW							2020		DC Converter station
SK	RO	Constanta	TR	Pasakoy	400	1	600 MW				200	200	400	2020		
SS	RO	Iasi			400/220									2020		
OHL	RO	Iasi	MD	Chisinau	400	1	1750		Ol-Al	3x300				2020		
RUSSIA																
OHL	RU	Centralna(Sochi)	GE	Enguri	500									2015		450 km, single circuit
SS	RU	Rostov			500/220									2011		-
OHL	RU	Rostov		Sahti 30	500									2011		single circuit
OHL	RU	Rostov		Frolovska	500									2011		single circuit
OHL	RU	Rostov		R20	220									2011		single circuit
SS	RU	Krimskaya II			500/220									2015		-
OHL	RU	Krimskaya II		Tihoreck	500									2015		single circuit
SS	RU	Senaya			220									2015		-
OHL	RU	Krimskaya II		Senaya	220									2015		single circuit
OHL	RU	Krimskaya II		Slavyansk	220									2015		single circuit
OHL	RU	Slavyansk		Senaya	220									2015		single circuit
SS	RU	Nevinomysk			500/220									2010		-
OHL	RU	Nevinomysk		Volgodonska	500									2010		single circuit
SS	RU	Mozdok			500/220									2012		-
OHL	RU	Nevinomysk		Mozdok	500									2012		single circuit
SS	RU	Alagir			330/110									2015		-
OHL	RU	Nalcik		Alagir	330									2015		single circuit
OHL	RU	V2		Alagir	330									2015		single circuit

SS	RU	Kizljar			330/110									2015		on 330 kV Budenovsk-Chirjurt
SS	RU	Grozniy			330/110									2015		on 330 kV V2-Chirjurt
SS	RU	Artem			330/110									2010		on 330 kV Mahachkala-Chirjurt
OHL	RU	Mozdok		Artem	330									2010		single circuit
OHL	RU	HPP Irganskaya		Artem	330									2010		single circuit
OHL	RU	Derbent		Artem	330									2010		single circuit
OHL	RU	Derbent	AZ	Apsheron	330									2010		single circuit
									TURKEY							
OHL	TR	Hpp oymapinar		Hpp ermenek	400	1			ACSR	3bx1272					Construction	
OHL	TR	Mersin		Hpp ermenek	400	1			ACSR	3bx1272					Construction	
SS	TR	Mersin			400/150		2x250								Construction	
DC	TR	Alibeykoy			400		600 mw								Idea	Dc converter station
SC	TR	Alibeykoy	Ro	Constanta	400	1	600 mw				200	200	400		Idea	Dc cable
OHL	TR	Gercuz-ilisu		Cizre-sinir	400	2			ACSR	3bx954	30	100	130		Planning	Planning
OHL	TR	Agri		Van	400	1			ACSR	3bx1272					Planning	
OHL	TR	Batman-siirt		Van	400	1			ACSR	3bx1272	65	205	270		Planning	
OHL	TR	Van		Baskale	400	1			ACSR	3bx954					Planning	
OHL	TR	Hpp boyabat		Hpp altinkaya	400	1			ACSR	3bx1272					Planning	
OHL	TR	Seydisehir		Varsak	400	1			ACSR	3bx1272			130		Constr	
OHL	TR	Temelli		Afyon2	400	1			ACSR	3bx1272					Construction	
OHL	TR	Afyon2		Denizli	400	1			ACSR	3bx1272			180		Construction	
OHL	TR	Bursa ngccpp		Bursa san	400	2			ACSR	3bx954					Planning	
OHL	TR	Icdas		Bursa san	400	1			ACSR	3bx954					Planning	
OHL	TR	Soma		Manisa	400	1			ACSR	3bx1272			50		Construction	
OHL	TR	Ozluce		Diyarbakir	400	1			ACSR	3bx1272			100		Construction	
SS	TR	Konya			400/150		150								Construction	Capacity add
SS	TR	Adana			400/150		250								Construction	
SS	TR	Eskisehir			400/150		2x250								Construction	
SS	TR	Catalca			400/150		2x250								Planning	
SS	TR	Kucukbakkalkoy gis			400/150		2x250								Construction	
SS	TR	Kucukbakkalkoy gis			400/33		2x125								Construction	
C	TR	Umraniye		Kucukbakkalkoy	400					2000mm2			6.3		Construction	
SS	TR	Van			400/150		2x250								Planning	
SS	TR	Uzundere			400/33		125								Planning	
SS	TR	Yenibosna gis			400/150		2x250								Construction	
SS	TR	Yenibosna gis			400/33		2x125								Construction	
C	TR	Yenibosna gis		Davutpasa	400					2000mm2			6.98		Construction	
SS	TR	Afyon2			400/150		2x250								Construction	Capacity add
SS	TR	Viransehir			400/150		250+150								Construction	
SS	TR	Diyarbakir			400/33		125								Construction	
SS	TR	Usak			400/150		250								Planning	

UKRAINE																
OHL	UA	Novoodeska	UA	Artsyz	330	1	1670 A	-	ACSR	400*2	140	0	140	2012	project	
OHL	UA	Adgalyk	UA	Usatovo	330	1	1670 A	-	ACSR	400*2	124	0	124	2010	Construction	second line
OHL	UA	Zarya	UA	Mirna	330	1	1380 A	-	ACSR	300*2	14	0	14	2010	Construction	second line
SS	UA	Simferopol			330	1			SVC					2011	project	SVC
OHL	UA	Simferopol	UA	Sevastopol	330	1	1670 A	-	ACSR	400*2	70	0	70	2010	finished	upgrade from 220kV to 330 kV
OHL	UA	Dgankoj	UA	Melitopol–Simferopol	330	1	1380 A	-	ACSR	400*2	16	0	16	2008	finished	Connectors of Dgankoj SS to OHL Melitopol–Simferopol
OHL	UA	Zapadnokrymskaya	UA	Sevastopol	330	1	1670 A	-	ACSR	400*2				2014	Idea	
OHL	UA	Zapadnokrymskaya	UA	Kahovska	330	1	1670 A	-	ACSR	400*2				2015	Idea	
SS	UA	Kyivska			750/330	1	1000 MVA	-	PST	-	-	-	-	2009	finished	I stage
OHL	UA	Pivnichnoukrainska	UA	Kyivska	750	1	4000 A	-	ACSR	400*5	292	0	292	2015	Idea	
OHL	UA	Rivnenska NPP	UA	Kyivska	750	1	4000 A	-	ACSR	400*5	370	0	370	2012	Construction	
OHL	UA	Zahidnoukrainska	UA	Bogorodchani	330	1	1670 A	-	ACSR	400*2	111	0	111	2013	project	
OHL	UA	NPP Rivne	BY	Mikashevichi	330	1	1670 A	-	ACSR	400*2				2015	Idea	
SS	UA	Novodonbaska			500/220			-		-	-	-	-	2015	feasibility	Reconstruction 500 кV SS “Novodonbasskaya" with construction 2 OHL 500 кV, AT 500/220 кV and 5 OHL 220 кV
SS	UA	Primorska			750/330	1	1000 MVA	-	PST	-	-	-	-	2015	feasibility	
OHL	UA	Pivdenoukrainskaya	RO	Isaccea	750	1	4000 A	-	ACSR	400*5	406	3	409	2015	Feasibility study	Restoration. Voltage level to be defined
OHL	UA	Dnistrovska PSHPP	UA	Bar	330	1	1670 A	-	ACSR	400*2	95	0	95	2010	Construction	
OHL	UA	Dnistrovska PSHPP	UA		750	1	4000 A	-	ACSR	400*5				2015	project	To existing line Zapadnoukrainskaya – Vinnitsa
OHL	UA	K.Podolska (Chernovcy)	UA	Ternopil	330	1	1670 A	-	ACSR	400*2	150	0	150	2015	Feasibility study	
OHL	UA	Lutsk Pivnichna	UA	Ternopil	330	1	1670 A	-	ACSR	400*2	180	0	180	2011	project	
OHL	UA	HPP Dnistrovska	MD	Balti	330	1	1670 A	-	ACSR	400*2	120	0	120	2015	Idea	second line
SS	UA	Kahovska			750/330	2	1000 MVA	-	PST	-	-	-	-	2012	project	
OHL	UA	Zaporizka NPP	UA	Kahovska	750	1	4000 A	-	ACSR	400*5	190	0	190	2012	project	
SS	UA	Zaporizka NPP			750/330	1	1000 MVA	-	PST	-	-	-	-	2017	Idea	second transformer
SS	UA	Dnieprovska			750/330	1	1000 MVA	-	PST	-	-	-	-	2016	finished	third transformer
OHL	UA	Novoodeska	UA	Artsyz	330	1	1670 A	-	ACSR	400*2	140	0	140	2012	project	
OHL	UA	Adgalyk	UA	Usatovo	330	1	1670 A	-	ACSR	400*2	124	0	124	2010	Construction	second line
OHL	UA	Zarya	UA	Mirna	330	1	1380 A	-	ACSR	300*2	14	0	14	2010	Construction	second line
SS	UA	Simferopol			330	1			SVC					2011	project	SVC

APPENDIX B: Planned New Generation Units Table

TYPE	SUBSTATION1		VOLTAGE LEVEL		CAPACITY		DATE OF COMMISSIONING	STATUS	COMMENT
			kV	kV	MW	MVA	year		
1	2	3	4	5	6	7	8	9	10
ARMENIA									
CCHP	AM	Yerevan TPP new unit	18	110	208	240	2009	Tendering	
TPP	AM	Hrarzdan TPP unit 5	15.75	220	440	510	2009	Partly Constructed	
NPP	AM	NPP Medzamor	24	400	2x500	2x588	2017		
HPP	AM	Shnoch			75	85	2017		
HPP	AM	Megri			140	165	2017		
HPP	AM	Loriberd			60	71	2017		
SHPP	AM				140	189	2010		
WPP	AM				200	220	2012		
BULGARIA									
NPP	BG	Belene	24	400	2x1000	2x1111	2017,2018	Project	
CCGT	BG	TPP Varna New unit 1	19	220	280	336	2016	Project	
CCGT	BG	TPP Varna New unit 2	19	220	280	336	2016	Project	
CCGT	BG	TPP Varna New unit 3	19	110	312	336	2016	Project	
TPP	BG	TPP Galabovo, U1	20	400	335	436	2010	Commissioning	
TPP	BG	TPP Galabovo, U2	20	400	335	436	2011	Commissioning	
TPP	BG	TPP Maritsa East4	?	400	700	?	2018	Project	
HPP	BG	HPP Cankov Kamak, U1	10.5	110	40	50	2010	Commissioning	
HPP	BG	HPP Cankov Kamak, U2	10.5	110	40	50	2011	Commissioning	
HPP	BG	HPP Gorna Arda	?	110	174	?	2018	Project	
TPP	BG	TPP Ruse	13.8	110	100	137.5	2014	Project	
HPP	BG	HPP Nikopol	?	110	440	?	2020, 2021	Project	
HPP	BG	HPP Silistra	?	110	130	?	2020, 2021	Project	
WPP	BG	Wind PP	?	110	1519	?	2015	Project	
CHPP	BG	GPP Haskovo	11	110	256	284	2012, 2013	Project	
CHPP	BG	GPP Mramor	11.5	110	250	312	2012, 2013	Project	
MOLDOVA									
CCHP	MD	KSPP-2	15.75	110	from 240 to 440		2020	Reconstruction and extension of existing plant	CCHP
TPP	MD	Chisinau	22	400	350		2020		TPP
ROMANIA									
CCHP	RO	Brazi	20	400	2x305	4x288	2010	Construction	
CCHP	RO	Brazi	20	220	315	4x288	2010	Construction	
TPP	RO	Galati	24	400	800		2014	Construction	
TPP	RO	Braila	24	400	880		2016	Construction	
NPP	RO	Cernavoda	24	400	2x720	2x800	2016	Construction	
HPP	RO	Tarnita	15.75	400	4x256	4x288	2016	Project	

RUSSIA									
NPP	RU	Leningrad2	24	500	2x1150	2x1278	2010	Construction	old plant decommissioned
NPP	RU	Leningrad2	24	750	2x1150	2x1278	2011	Construction	old units decommissioned
NPP	RU	Novovoronez	24	500	2x1150	2x1278	2015	Construction	
NPP	RU	Kostromska	24	500	2x1150	2x1278	2020	Construction	
NPP	RU	Nizhegorodskaya	24	500	2x1150	2x1278	2020	Construction	
NPP	RU	Kaliningrad	24	500	2x1150	2x1278	2015	Construction	
NPP	RU	Kola2	24	500	1150	1278	2015	Construction	
NPP	RU	Seversk	24	500	2x1150	2x1278	2020	Construction	
HPP	RU	Boguchanskaya		330	3000		2020		Krasnoyarsk area
HPP	RU	Evenky		330	1000		2020		Krasnoyarsk area
HPP	RU	Motiginskaya		330	757		2020		Krasnoyarsk area
PHPP	RU	Leningrad		330	4x390		2015		Sankt-Petersburg area
PHPP	RU	Zagorsk-2		330	2x420		2015		Moscow region
PHPP	RU	Zelenchuk		330	1x140		2015		Karachay-Cherkessia
HPP	RU	Zaramagskaya		330			2010		
HPP	RU	Cherkeskaya II		330			2010		
NPP	RU	Volgodonskaya	24	500	1000	1111	2010	Construction	unit 2
CCGT	RU	Stavropol	15.75	500	2x400	2x440	2012	Planning	
CCGT	RU	Nevinnomyssk	15.75	500	410	450	2010	Construction	
CCHP	RU	Sochi	10.5	110	80	90	2010	Construction	
CCHP	RU	Tuapce	15.75	110	150	170	2011	Construction	
CCHP	RU	Tuapce	15.75	110	180	200	2012	Construction	
CCHP	RU	Adler	15.75	110	2x180	2x200	2012	Construction	
CCHP	RU	Olimpic	15.75	110	2x180	2x200	2012	Construction	
TURKEY									
HPP	TR	Ermenek		400	320		2010	Construction	
HPP	TR	Obruk		400	4x50		2010	Construction	
HPP	TR	Borçka		400	300		2010	Finished	
HPP	TR	Deriner		400	670		2010	Construction	
TPP	TR	Teren		400	2X600		2015	Planned	Coal fired TPP
HPP	TR	Tireb		400	300		2015	Planned	Equivalent of lots of HPPs in the river basin, most of them run of river type
HPP	TR	Kalkandere		400	3X200		2015	Planned	Equivalent of lots of HPPs in the river basin, most of them run of river type
HPP	TR	Yusufeli		400	4x135		2015	Planned	Equivalent of lots of HPPs in the river basin, most of them run of river type
CCGT	TR	Tbandrma		400	1000		2015	Planned	NGCCPP(Private company)
CCGT	TR	Ambarli		400	2X270		2015	Planned	NGCCPP. Extension of existing Ambarlı NGCCPP
CCGT	TR	Aksa antalia		400	1000		2015	Planned	NGCCPP(Private company)
TPP	TR	Sugozu		400	700		2015	Planned	Coal fired. Extension of existing Sugozu TPP

CCGT	TR	Denizli		400	1000		2015	Planned	NGCCPP(Private company)
HPP	TR	Boyabat		400	3X180		2015	Planned	HPP(Private company)
TPP	TR	Galata		400	2X135		2015	Planned	TPP (oil fired)
CCGT	TR	Makina		400	2X300		2015	Planned	NGCCPP(Private company)
HPP	TR	Alkumru		400	3X80		2015	Planned	HPP(Private company)
CCGT	TR	Rasa		400	80		2015	Planned	NGCCPP(Private company)
TPP	TR	Silopites		150	135		2015	Planned	TPP (oil fired)
HPP	TR	Incir		150	122		2015	Planned	HPP(Private company)
HPP	TR	Akdam		400	300		2015	Planned	Equivalent of lots of HPPs in the river basin, most of them run of river type
CCGT	TR	Egemer		400	6X300		2015	Planned	NGCCPP+ Coal fired(Private company)
WPP	TR	Geli		400	300		2015	Planned	Equivalent of lots of WPPs in the region
WPP	TR	Can		400	300		2015	Planned	Equivalent of lots of WPPs in the region
TPP	TR	Basat		400	2X150		2015	Planned	Coal fired TPP
TPP	TR	Orta		400	2X150		2015	Planned	Coal fired TPP
TPP	TR	Atlas		400	600		2015	Planned	Coal fired TPP
TPP	TR	Karasu		400	2X600		2015	Planned	Coal fired TPP
HPP	TR	Ilisu		400	6x200		2015	Planned	
NPP	TR	Akkuyu bay		400	5x1100		2020	Planned	
UKRAINE									
PSHPP	UA	Dnistrovska	15.75	330	360/390	420	2009	in operation	unit 1
PSHPP	UA	Dnistrovska	15.75	330	360/390	420	2012	Construction	unit 2
PSHPP	UA	Dnistrovska	15.75	330	360/390	420	2015	Construction	unit 3
PSHPP	UA	Dnistrovska	15.75	330	4x360/4x390	420	2015-2020	Construction	units 4-7
CCHP	UA	Kyivska 6	20	330	300	353	2015	Construction	unit 3
PSHPP	UA	Tashlykska	15.75	330	2x151/2x233	307	2008	in operation	units 1 and 2
PSHPP	UA	Tashlykska	15.75	330	2x151/2x233	307	2015	Construction	units 3 and 4
NPP	UA	Khmelinskaya	24	750	2x1000		2016-2020	PLANNED	
TPP	UA	Dobrotvirska	15.75	220	3x225		2020	PLANNED	
PSHPP	UA	Kanev	15.75	330	4x250/4x260	4x263/4x273	2030	PLANNED	

APPENDIX C: Survey of Planning Criteria and Principles Among BSRTSO's

BLACK SEA REGIONAL TRANSMISSION PLANNING PROJECT

A Survey of Planning Criteria and Principles Among the Black Sea Region Transmission System Operators

Prepared by:
Turkish Electricity Transmission Company (TEIAS)

February 4, 2010
Ankara, Turkey

Introduction

This report is a survey of the network planning criteria used by the Black Sea Transmission System Operators (TSO's). The survey was conducted as a component of Phase II of Black Sea Regional Transmission Planning Project, which was established by USAID to foster regional cooperation in transmission planning and analysis. Impetus for the Project results from a desire among the Transmission System Operators (TSOs) in the region to identify investments necessary to improve system security and to take advantage of the potential for east-west electricity trade with neighboring markets in Southeast Europe and the ENTSO-E system.

Though integrated at the borders, the Black Sea electrical network is an amalgamation of two electric power systems, each employing distinct planning software, methodologies and operational criteria. Until recently, communication between the TSOs of the Black Sea region has been quite limited, restricted primarily to daily operational matters with little focus on longer term planning issues related to system expansion, security and the facilitation of trade and exchange.

There is a growing desire for long term integration of the TSOs operating in the region in terms of harmonizing the legal regulatory framework, grid codes, increased trade and exchange of electricity and, ultimately, synchronous operation. This survey is an initial step in this direction designed to identify similarities and differences in the criteria the Black Sea TSOs apply when preparing expansion plans for their high voltage networks. The eight Black Sea Region (BSR) Transmission System Operators participating in Phase II of the BSTP and this survey are: Armenia, Bulgaria, Georgia, Moldova, Romania, Russia, Turkey and Ukraine.

In preparing this survey, The Turkish Electricity Transmission Company (TEIAS) acted as the lead to develop a survey instrument and in collecting and analyzing the responses. Three topical areas were reviewed: the role and interaction between TSOs and regulators in the planning process; technical criteria employed by the TSO in the planning process; and economic and financial criteria used to evaluate potential projects (Table-1).

TSO and Regulatory Responsibilities

The survey revealed that the role of regulators in the transmission network planning and approval process varies within the region. All Black Sea TSOs are responsible for developing transmission network plans. The development plans must be approved by their respective national regulatory authorities, with the exception of Moldova and Russia. Also with the exception of Russia, transmission planning criteria is published within national grid codes, which are approved by the regulatory authorities.

Technical Criteria

The questionnaire revealed that (n-1) criteria is applied uniformly throughout the region. However, Armenia is the only TSO in the Black Sea that evaluates the probability of a (n-1) occurrence. The (n-1) technical criterion, as practiced throughout the Black Sea Region requires planners to design the system to withstand the loss of a single line, transformer or generator, such that the following do not occur:

- thermal overloading of branches,
- voltage declination below permitted range,
- loss of stability,
- loss of load,
- interruption of power transits, and
- disturbance spreading over power system;

Bulgaria and Romania employ (n-2) criteria for grid connection of nuclear power plants, and Turkey uses (n-2) for generation plants equal to or greater than 1500 MW.

Some TSO's employ additional technical criteria and the development of their system plans is also influenced by national development objectives. Russia seeks to minimize reserve factors and eliminate self-oscillations when planning network additions. Georgia reported that it orients its plans to emphasize development of the significant untapped hydropower power resources in its mountainous regions.

Armenia seeks to optimize its national power flow and electricity balances through efficient exchange with neighboring countries. Like Armenia, Turkey, Russia and Georgia also evaluate the potential for transferring power across borders in their planning processes. Romania does the same and is the only Black Sea TSO to report that it employs the ENTSO-E methodology for calculating net transfer capacity at its borders.

There is a divergence in the way TSO's apply thermal ratings in different operating conditions. Georgia, Romania, Russia, and Turkey each apply different thermal ratings for winter and summer operation. Bulgaria, Armenia, Moldova, and Ukraine do not differentiate thermal ratings on a seasonal basis. However, Bulgaria, Moldova, Russia, Turkey and Ukraine also apply different thermal ratings to normal and emergency operating conditions, whereas Armenia, Georgia, and Romania do not.

The TSO's are consistent in their use of a one and five year time lines for the planning process. All TSO's performed the following analyses in their planning processes:

- load flow,
- security,
- short circuit calculations,
- system stability.

In addition, Armenia, Bulgaria, Moldova, Turkey, and Ukraine use optimal power flow analysis. Georgia and Romania are the only TSO's that employ reliability analysis, and Russia is the only Black Sea TSO to report that it conducts static/dynamic analysis in post-emergency conditions.

Finally, nearly all TSOs taking uncertainties into account during transmission planning use a multi-scenario analyses approach for modeling (Table-2). They reported the following as the most critical uncertainties in the planning process.

- new power plants size and location,
- generators engagement,
- load prediction,
- country power balance.

Economic and Financing Criteria

The use of economic and financial planning criteria varies widely among the Black Sea TSOs. All TSO's reported that they employ basic economic and financial analysis, though it is clear from the survey responses technical criteria are of greater importance than economic and financial criteria are not. The following table lists the different analyses used by TSOs for economic and financial evaluation of transmission projects in the planning process.

Country	Economic and Financial Evaluations Performed in the Planning Process
Armenia	Internal Rate of Return, and Net Present Value
Georgia	Building Costs and the Effect of New Elements on Reducing Power Losses
Romania	NPV, IRR, Benefit to Cost Ratio, and the Payback Period
Russia	Selection of Lower Cost Option with Equal Technical Efficiency
Ukraine	Capital Costs of Construction of Power Transmission Networks

Bulgaria reported that it conducted economic and financial analysis but did not specify which analyses it performs. TSOs in Moldova and Turkey reported that they do not routinely perform economic and financial analyses during the planning process.

In addition to economic and financial criteria of specific projects in question, TSOs reported they also calculate other economic benefits to their companies, consumers and national economies associated with new transmission projects. Georgia calculates benefits from co-locating transmission lines with its high voltage lines. Armenia and Romania reported that their calculations include the effects of new lines on reducing congestion and increasing transmission service revenue. Likewise, Russia calculates the effect of proposed lines on reducing re-dispatching costs.

Only three TSOs reported that they calculate the effect of reducing the cost of unserved load when considering development of new transmission lines. The TSO's that perform this calculation report the following values:

- Bulgaria- more than 3 Euro/kWh for unserved load
- Ukraine - less than 1 Euro/kWh for unserved load
- Romania- between 1 and 10 Euro/kWh for unserved load

All the TSO's report financing their investments through transmission fees, loans, and internal sources. In addition to traditional sources, Georgia, Romania, Russia, and Turkey report that they also receive funds from private investors.

Summary and Conclusion

Overall, the survey revealed that national transmission networks are planned based primarily on technical considerations and economic rationalization of new investments. All Black Sea TSOs employ the (n-1) security criteria. The TSO's utilize the deterministic approach in which probabilities of different event occurrences such as network failures, generator dispatch, branches availability etc. are not taken into consideration.

Most seek to optimize the use of interconnections with neighboring countries and include analysis of cross border transfer in their planning processes. Standard load flow, security, short circuit and system reliability calculations are used commonly across the regions. The survey revealed differences in how the TSOs treat thermal ratings both on a seasonal basis and in normal and emergency operating conditions.

It is clear that to the extent economic and financial criteria are used, they are used only to evaluate financial return on investments in new lines on a national basis. Market oriented transmission investments and investments that may have value from a regional perspective, either to improve security or promote trade, are not employed.

As market oriented trading grows in the region, Black Sea TSOs will face greater uncertainties in the planning process. The most important uncertainties identified by the TSO's are: generation investment plans, including the size, location and date of commissioning; generator bidding behavior in the future, hydrological conditions, branches and generators future availability, load growth, and regional power balance. The survey revealed that today, when these uncertainties are examined they are taken into account using multi-scenario analysis.

The results of the survey identify the consistencies and the gaps in transmission system planning among the Black Sea TSOs. It is essential to consider the results of the study, in order to synchronize the planning principles to better identify goals and objectives of the project. The survey reveals significant commonalities found throughout the planning processes, which provide a basis for enhanced collaboration on a regional basis. This may include agreement on common planning collection; establishment of common planning scenarios; further development of network models for necessary analyses (load flow, dynamic, short-circuit, probabilistic models), performance of analyses, and comparison of candidate projects on both technical and economic bases.

Table-1 Transmission System Planning Criteria among the Black Sea Region TSO's

Transmission System Planning Criteria	Armenia	Bulgaria	Georgia	Moldova	Romania	Russia	Turkey	Ukraine
Responsibility for Transmission System Planning	TSO/ISO	TSO	TSO/Ministry	TSO	TSO	Others (Grid Comp. and System Operator are separated, there is no TSO.	TSO	TSO
Network Investment Plan Types*	LT	ST/MD/LT	ST/MT	ST/MT	MT/LT	NO	ST/MT	ST/MD/LT
Approval from Regulatory Authority	YES	YES	YES	YES	YES	NO	YES	YES
Financing of Transmission Investments	Trans.Fee/loans/ internal sources	Trans.Fee/ loans	loans / private	Trans.Fee/ loans/internal sources	Trans.Fee/ loans/ private	Trans.Fee/loans/ internal sources / private	Trans.Fee/loans/ internal sources / private	Trans.Fee/loans/ internal sources
Documents related with the planning criteria	YES Other Documents	YES Grid Code/ Other Documents	YES Other Documents	YES/Grid Code	YES/Grid Code	NO	YES Grid Code/ Other Documents	YES Grid Code is under development/ Other Documents

Usage of (n-1) criteria	YES	YES	YES	YES	YES	YES	YES	YES
Different Thermal Ratings for Winter and Summer Regime	NO	NO	YES	NO	YES	YES	YES	NO
Different Thermal Ratings for Normal and Emergency Operation	NO	YES	NO	YES	NO	YES	YES	YES
Valuation of the Probability of (n-1) events	YES	NO	NO	NO	NO	NO	NO	NO
Other Technical Criteria	YES (power and electricity balances, power flow)	NO	YES (Realization of HP Resources of High Mountain Areas)	NO	NO	YES (minimal reserve factors and no self-oscillations within the accepted operation regimes)	NO	NO
Analyses during planning process **	LF-SA/OPF/ SC/ SS	LF-SA/OPF/SC/SS	LF-SA/ SC/ SS/ RA	LF-SA/OPF/SC/SS	LF-SA/ SC/ SS/ RA	LF-SA/ SC/ SS/ others (static and dynamic analysis for post-emergency conditions)	LF-SA/ OPF/ SC/ SS	LF-SA/OPF/SC/ SS

Application of Economical Criteria	YES (Capital investment, IRR, NPV)	YES	YES (building costs and power losses)	NO	YES (net present value, benefit to cost ratio, internal rate of return, payback period)	YES (lower cost option with equal tech. efficiency)	NO	YES (capital investments into construction of power transmission networks)
Value of undelivered energy (loss of load) costs per kWh	?	more than 3 euro/kWh	?	?	between 1 and 10 euro/kWh	?	?	less than 1 euro/kwh
Additional Planning Criteria for interconnection lines	NO	NO	YES/ Power Transfer	NO	YES/ ITC and NTC Maximization	YES/ possibility of cross-border trade	YES/ possibility of cross-border trade	NO
Taking into account uncertainties during planning process	NO	YES	YES	YES	YES	YES	YES	YES
Risk Analysis Techniques	YES	NO	NO	NO	NO	NO	NO	NO

Table-2 The most important uncertainties in Transmission System Planning among the Black Sea Region TSO's

Uncertainties	Armenia	Bulgaria	Georgia	Moldova	Romania	Russia	Turkey	Ukraine
New Power Plants Size & Location			√	√	√	√	√	
Generators engagement			√		√	√	√	√
Hydrological Conditions		√				√	√	
Existing Power Plants Decommissioning					√		√	√
Load Prediction		√	√	√	√	√	√	√
Branches Availability			√		√		√	
Regulatory and market issues							√	
Market Transactions							√	
Country Power Balance		√		√	√		√	√

QUESTIONNAIRE – Transmission Network Planning Criteria

1. Who is responsible for transmission network planning in your country?

☐ TSO/ISO
☐ Regulatory agency
☐ others

Additional comments:

2. Are you obliged to prepare transmission network investment plans by law?

☐ no
☐ yes, short-term plans
☐ yes, mid-term plans
☐ yes, long-term plans

Additional comments:

3. Is Regulatory Authority obliged to give its approval on transmission network development plans?

☐ no
☐ yes

Additional comments:

4. How transmission investments are financed in your country?

☐ through transmission fee
☐ by loans
☐ by internal TSO financial sources
☐ by private investors

Additional comments:

5. Do you have official document related to transmission network planning with defined planning criteria?

☐ no
☐ yes, grid code
☐ yes, other document(s)

Additional comments:

6. Do you use n-1 criterion for transmission network planning?

☐ no
☐ yes

Additional comments:

7. n-1 criterion is related to single loss of following assets?

☐ single-circuit lines
☐ double-circuit lines,
☐ transformers
☐ generators
☐ busbars
☐ others

Additional comments:

8. What events are not allowed to happen during n-1 operational conditions?

☐ thermal overloading of branches
☐ voltage declination below permitted range
☐ loss of stability
☐ loss of load
☐ interruption of power transits
☐ others

Additional comments:

9. Do you have different thermal ratings for lines and transformers during winter and summer period?

☐ no
☐ yes (if yes, please explain the difference)

Additional comments:

10. Do you have different thermal ratings for lines and transformers during normal and interrupted operational conditions (for example different I_{max} and $I_{max\ 20\ minutes}$?

☐ no
☐ yes (if yes, please explain the difference)

Additional comments:

11. What is permitted voltage range in your country in transmission networks?

12. Do you valuate the probability of n-1 events?

☐ no
☐ yes (if yes, please explain how do you valuate the difference)

Additional comments:

13. Do you have some other technical criteria defined for transmission network planning?

☐ no
☐ yes (if yes, please explain which one)

Additional comments:

14. What kind of analyses do you perform for transmission network planning?

☐ load-flow, security analysis
☐ optimum power flows
☐ probabilistic analysis
☐ short-circuit calculation
☐ stability simulations
☐ others (please, explain which ones)

Additional comments:

15. Do you apply economic criteria for transmission network planning?

☐ no
☐ yes (if yes, please explain which one)

Additional comments:

16. If you apply economic criteria for transmission network planning, what kind of benefits do you estimate?

☐ reduction of loss of load costs,
☐ reduction of losses costs,
☐ reduction of re-dispatching costs,
☐ reduction of congestion costs,
☐ benefit from telecommunication lines,
☐ others (please explain which ones)

Additional comments:

17. What's the value of undelivered energy (loss of load) costs per kWh in your country?

☐ less than 1 euro/kWh
☐ between 1 and 3 euro/kWh
☐ more than 3 euro/kWh,

<u>Please note the exact value of undelivered energy costs:</u>

18. Do you have some additional planning criteria for interconnection lines?

☐ no
☐ yes (please, explain which ones)

<u>Additional comments:</u>

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

☐ no
☐ yes, uncertainties in new power plants size and location
☐ yes, uncertainties in generators engagement
☐ yes, uncertainties in hydrological conditions
☐ yes, uncertainties in existing power plants decommissioning
☐ yes, uncertainties in load prediction
☐ yes, uncertainties in branches availability
☐ yes, uncertainties in regulatory and market issues
☐ yes, uncertainties in market transactions
☐ yes, uncertainties in country power balance
☐ yes, other uncertainties (please explain which ones)

<u>Additional comments:</u>

20. If you take into account uncertainties during transmission network planning what kind of approach do you use for modeling?

☐ multi-scenario analyses
☐ probabilistic calculations
☐ other methods (please explain which ones?)

<u>Additional comments:</u>

21. Do you estimate a risk of wrong transmission investments?
☐ no
☐ yes (if yes, please explain how)

<u>Additional comments:</u>