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Southeast Europe Transmission Network Under Future Market Conditions

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Abstract: - This paper presents basic data about Southeast Europe transmission network and identifies potential congested areas under future market conditions taking into account predicted network middle-term development. Preliminary organizational, legal and institutional steps in organizing Southeast Europe Regional Electricity Market (SEE REM) have been performed. Regional power supply companies are in the process of unbundling and reorganization. New transmission system operator companies are established. Electricity market is expected to be introduced in next few years. Regional transmission network, consisted of several differently developed networks which have never been operated together before, will be subjected to different operating conditions. Several studies have been done recently in order to examine future operation of transmission network and to evaluate new interconnection lines construction candidates.

Key-Words: - Southeast Europe, transmission network, congestions, market conditions, network development, new interconnection lines

1 Introduction

The region of Southeast Europe has been passing through very intensive political and economical changes in last 15 years. Transition from state controlled economy to market conditions has been accelerated recently. One aspect of the transition is creation of common electricity market, named Southeast Europe Regional Electricity Market (SEE REM), encouraged by European Commission, USAID, World Bank and other political and financial organizations.

Recognizing that energy and electricity are critical to economic growth of the Region, seven countries (Albania, Bosnia and Herzegovina, Bulgaria, Croatia, the Former Yugoslav Republic of Macedonia - FYROM, Romania, Serbia and Montenegro, and UN Mission in Kosovo - UNMIK) agreed to work on common energy market including electricity market.

A region-wide uniform and well established institutional framework for electricity trading is expected to expand the region's generation-mix, diversify loads and fuel options and improve overall economic efficiency through improved utilization of existing resources and the introduction of competition. A well functioning regional electricity market, one in which investors operate under consistent market rules with appropriate regulatory oversight, will attract investments, supply, demand, and transmission projects. Under the agreement, participating countries are required to adopt the key principles of the EU Electricity Directive, including:

- Unbundling vertically integrated utilities.
- Creating national transmission system operators and independent regulatory authorities.
- Developing a system of Regulated Third Party Access to the transmission network based on published tariffs, applicable to all eligible customers and applied objectively without discrimination between system users.
- Progressive opening of the national markets and the development of transparent trading and market monitoring requirements [1].

Some countries like Romania have already performed required changes and made significant steps forward market opening, while some countries are in the process of unbundling and transmission system operators and regulatory agencies establishment. Legal prerequisites were accepted almost everywhere.

Future transmission system operation under market conditions has been studied through several projects in last few years. Under Southeast Europe Cooperation Initiative (SECI), regional transmission planning project was initiated in 2000 [2]. Members from all transmission system departments, future TSO's, were included in regional transmission system PSS/E (PTI Siemens) model creation. Models for 2005 and 2010, suitable for steady-state and dynamic analysis, were created and used in the studies. Under REBIS project (Regional Balkan

Infrastructure Study), GIS study (Generation Investment Study) was delivered. As a part of the study transmission network was analyzed from generators market engagement prospective [3].

This paper is organized into following topics: each Southeast Europe country power system and transmission network are described in Chapter 2, transmission network development and interconnection lines candidates are described in Chapter 3, Chapter 4 gives the results of steady-state analysis under predicted market conditions, in Chapter 5 possible congested areas are identified and paper concludes with Chapter 6.

2 Power systems basic data

Power systems in the region were operated in two electrically separated zones for last 15 years due to war destructions. Two main 400/x kV transformer stations, Ernestinovo in Croatia and Mostar in Bosnia and Herzegovina, were destroyed and third connection to UCTE, line 400 kV Sandorfalva (Hungary) – Subotica (Serbia) was out of operation because stability problems.

Croatia and part of Bosnia and Herzegovina were working synchronously with UCTE while other part of Bosnia and Herzegovina, Serbia and Montenegro, FYROM, Albania, Romania, Bulgaria and Greece were working synchronously isolated from UCTE. Re-connection of two UCTE zones was performed in October 2004 after SS Ernestinovo and SS Mostar reconstruction/reparation, so technical prerequisites for market competition were achieved.

Transmission network in the region (including Greece) operates under 750 kV, 400 kV, 220 kV, 150 kV and 110 kV voltage levels (Figure 1).

400 kV and 220 kV networks are well meshed due to many interconnection lines (Figure 2). There are two 750 kV, twenty one 400 kV and sixteen 220 kV interconnection lines in the region today.

Fig. 1 Southeast Europe transmission network

Different production facilities exist in the region (thermal, nuclear, hydro). Some countries produces electricity mostly from hydro sources (Albania, Montenegro), some produces electricity mostly from thermal units (Romania, Bulgaria, Serbia, FYR of Macedonia), while generation mix is quite equaled (hydro versus thermal) in Croatia and Bosnia and Herzegovina [4].

Some countries are dominantly electricity importers (Albania, Montenegro, Macedonia, Serbia, Croatia) while other countries are exporters (Bulgaria, Romania, Bosnia and Herzegovina).

Annual electricity consumption ranges between 5.5 TWh in Albania to 50 TWh in Romania. Peak loads occur during cold winter months and range between 1250 MW (Albania) and 7500 MW (Romania).

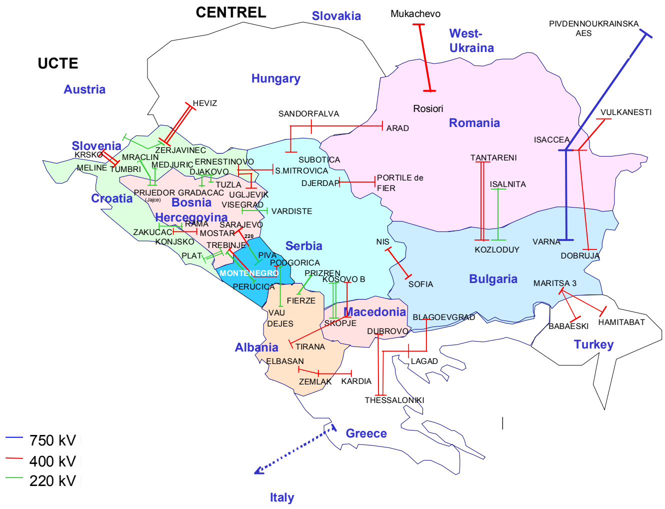

Fig. 2 Southeast Europe interconnection lines (2005)

2.1 Albania

Albanian transmission network is the least developed network in the region. There is only one 400 kV line (interconnection to Greece), 220 kV network is meshed only in middle and northern part, and 110 kV lines are mostly radial. Two 220 kV interconnections with Montenegro and UNMIK are in operation. Albania, as dominantly hydro production country, imports electricity and sometimes reduces consumption. Albanian power supply company KESH plans to develop 400 kV network across the country in mid-term period and construct new 400 kV interconnections to Montenegro and UNMIK.

2.2 Bosnia and Herzegovina

Bosnian 400 kV network has longitudinal structure and it is connected to Croatia, Serbia (line under construction) and Montenegro. There are also several radial 400 kV lines feeding larger consumption areas or connecting larger power plants. The majority of power plants are connected to 220 kV network. Due to large thermal and hydro production facilities Bosnia and Herzegovina mostly exports electricity.

2.3 Bulgaria

Bulgarian transmission network consists of 400 kV and 220 kV loops across the country, where most power plants are connected to. Bulgaria is interconnected to Romania (two lines 400 kV), Serbia (one 400 kV line), Greece (one 400 kV line) and Turkey (one 400 kV line). Bulgarian TSO plan to construct new interconnections to FYROM, Greece and Turkey, and to support the largest electricity exports in the region.

2.4 Croatia

Longitudinal 400 kV network across the country are connected to Serbia, Hungary, Slovenia and Bosnia and Herzegovina. There are also many 220 kV interconnection lines to Bosnia and Herzegovina and Slovenia. Power plants (hydro and thermal) are connected mostly to 220 kV and 110 kV networks. Croatia mostly imports electricity due to economical reasons (expensive domestic power plants).

2.5 FYR of Macedonia

Macedonian 400 kV network is meshed across the country and connected to UNMIK and Greece (line to Bulgaria is under construction), while 220 kV network exists only in North-West part of the country. Macedonian thermal resources represent around 2/3 of installed capacity. The rest is installed in hydro power plants.

2.6 Romania

Romanian transmission network operates on 750 kV, 400 kV and 220 kV voltage levels. The core is 400 kV network that is meshed in central and southern part, with radial lines to western and northern part. Interconnections 400 kV to Ukraine, Hungary, Serbia and Bulgaria are in operation, and new one to Hungary is planned. Thermal and hydro power plants are mostly connected to 220 kV network.

2.7 Serbia and Montenegro (with UNMIK)

Network 400 kV between Serbian capital Belgrade, HPP Djerdap and SS Nis represents basic part of transmission network, with radial lines to UNMIK, Bulgaria, Romania, Hungary and Croatia. Large power plants are connected to 400 kV network. Line 400 kV to UNMIK extends further to Montenegro and Bosnia and Herzegovina. While Serbia covers their consumption mostly with coal fired power plants, Montenegro is dominantly hydro production country.

3 Transmission network development

3.1 Predicted peak load growth

Achieved and predicted peak loads in the region are shown in Table 1.

Data for 2003 present achieved not simultaneous peak loads, while data for 2010 and 2015 presents predicted share of each country in regional peak load. According to [3] regional peak load in 2010 and 2015 are assumed on 30 GW and 33 GW respectively, referring to the base case load growth scenario.

Tab.1 Peak loads in the region

Country	P_{max} (MW)		
	2003	2010	2015
Albania	1254	1338	1614
Bosnia and Herzegovina	1854	2077	2410
Bulgaria	6717	6193	6688
Croatia	2673	3217	3752
FYROM	1317	1229	1438
Romania	7542	7797	9056
Serbia and Montenegro*	6564** + 732***	7799	8193

* including UNMIK
** Serbia
*** Montenegro

3.2 Power plants construction plans

Regional production companies plan to construct significant amount of new capacities in mid-term time horizon. The majority of activities in Romania and Bulgaria are oriented to existing thermal power plants revitalization, although they plan to construct new nuclear capacities also (NPP Cernavoda 2 and 3 in Romania, NPP Belene in Bulgaria). Serbia and UNMIK plan to construct new coal fired power plants which will use domestic coal, while Bosnia and Herzegovina and Montenegro plan to construct new hydro power plants only. Croatian power production company plan to construct several new combined cycle gas turbine power plants. Albanian plan is to construct one smaller thermal power plant.

New power plants candidates are valuated with respect to common regional market point of view and construction plan is suggested in [3].

3.3 Interconnection lines construction plans

Regional TSO's plan to construct significant amount of interconnecting transmission capacities. Those candidate lines, which have different status according to construction works (idea, project, financing, construction) are shown in Table 2 and Figure 3 [2].

Interconnection lines candidates were valuated in [2] from regional prospective point of view. Study has shown that the regional electric transmission system as predicted to exist in the year 2005, fully interconnected to UCTE and without any of the proposed interconnections, is robust and capable of serving projected 2005 demands plus all long term contracted exchanges plus an additional 600 – 1500 MW bulk power exchange.

Similar investigations are currently going on observing year 2010.

Tab. 2 New regional interconnection lines candidates

Interconnection	Lenght (km)	Status*	In operation
Ugljevik (B&H) - S. Mitrovica (SER)	79	1	2005/06
V.Dejes (ALB) – Podgorica (MN)	145	2	2006/07
M.Istok (BUL) – Filipi (GRE)	243	2	2007/08
C.Mogila (BUL) – Stip (FYROM)	150	2	2006/07
Ernestinovo (CRO) – Pecs (HU)	85	2	2007/08
Bekescaba (HUN) – Nadab (ROM)	118	2	2008
Florina (GRE) – Bitola (FYROM)	38	2	2006/07
Filipi (GRE) – Babaeski (TUR)	100	2	2007/08
Zemlak (ALB) – Bitola (FYROM)	85	3	2010/15
V.Dejes (ALB) - Kosovo B (UNMIK)	215	3	2010/15
Nis (SER) – Skopje (FYROM)	192	3	2010/15
Tumbri (CRO) - B.Luka (B&H)	~200	3	2010/15
Sombor (SER) – Pecs (HUN)	~80	3	2010/15
Višegrad (B&H) – Pljevlja (MON)	~60	3	2010/15

* 1 - construction
2 - preparation for construction
3 - idea

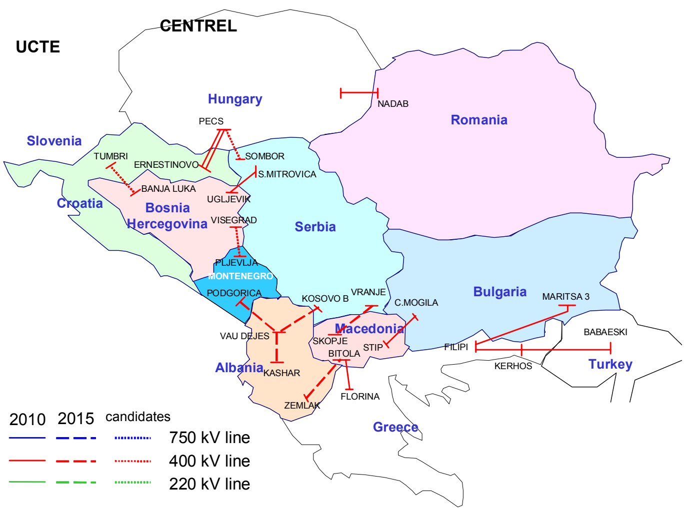

Fig. 3 Southeast Europe candidate interconnection lines

3.4 Internal networks development

Some southeast European countries plan to strengthen internal 400 kV networks. Albania plans to construct 400 kV network across the country, Romanian TSO plan to close the loop between SS Arad, SS Oradea and SS

Rosiori, while Serbia plans to strengthen 220 kV network around Belgrade.

All countries in the region also plan to build new transformer stations 400/220 kV, 400/110 kV and 220/110 kV or to raise installed capacity of existing ones.

4 Steady-state analysis

Steady-state analysis and security (n-1) analysis of regional transmission network operation, as predicted to exist in 2010 and 2015, under market conditions with generators economically engaged on regional level, were performed in [3]. Several scenarios dependent on hydrological conditions (normal, dry and wet hydrology), load growth rate (referent, extra high rate) and system balance (balanced region, import from UCTE and Ukraine) were analyzed. GTMax software (Argonne NL) was used for market simulations and generators engagement while PSS/E (Siemens PTI) was used for transmission network analyses.

Load flows through transmission network, including new interconnection lines which are under construction or preparation right now, shows that lines and transformers will be loaded under permitted ratings in year 2010 if all branches are in operation. Some transformers (Romania, Albania) and 220 kV lines (Serbia) are overloaded in fully available network 2015. For both time horizons there will be some overloaded 110 kV lines in each southeast European country but mostly in Serbia.

The majority of interconnection lines and internal 400 kV and 220 kV branches are loaded less than 50 % of their thermal ratings (Figures 4 and 5) observing both analyzed time horizons.

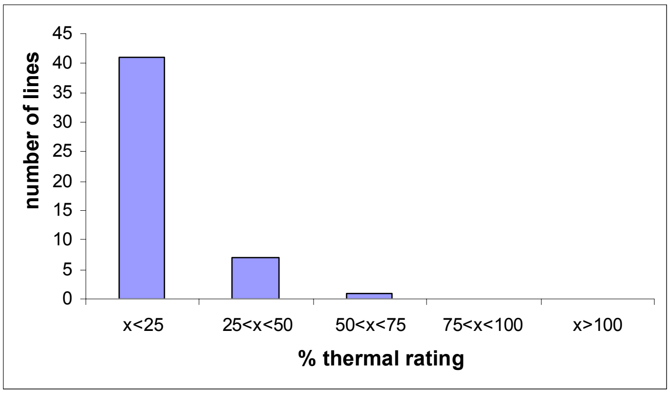

Fig. 4 Interconnection lines loading (% $I_{thermal}$) for average hydrology in 2010

Voltage profile during peak load conditions in the network is considered as satisfactory in 2010, while voltage stability problems may appear in Albania and southern Serbia in 2015. Construction of interconnection lines between Serbia and Macedonia, and Albania and UNMIK has positive impact on voltage stability but these lines can not be justified only due to their positive impact on voltage stability, especially because more sophisticated usage of existing and new compensating devices has not been analysed yet.

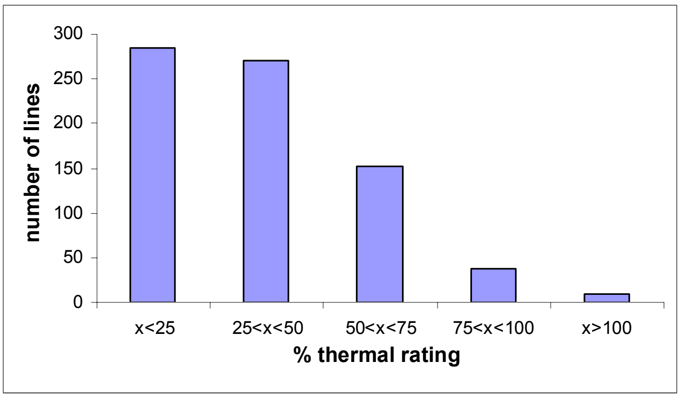

Fig. 5 Internal 400 kV and 220 kV branches loading (% $I_{thermal}$ or S_r) for wet hydrology in 2015

5 Congestions

Observing (n-1) security criterion under generators market engagement one may notice that congestions might appear in Romanian, Serbian and Albanian internal networks (Figures 6-8). Other areas are not congested in examined scenarios. Interconnection lines are not congested and all insecure operating conditions appear due to bottlenecks in internal networks.

Not simultaneous losses of 400/220 kV transformers in Romania (Mintia, Bucuresti Sud), 400/110 kV transformers in Romania and Serbia (Brasov, Dirste, Nis), some 400 kV lines in Romania and 220 kV lines in Serbia and Albania, may lead to insecure operation in 2010. The majority of insecure states may be solved by re-dispatching actions or network sectioning.

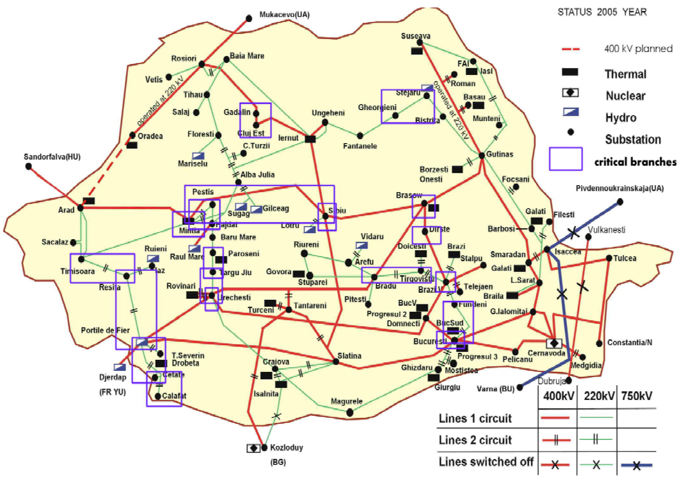

Fig. 6 Congested branches in Romania

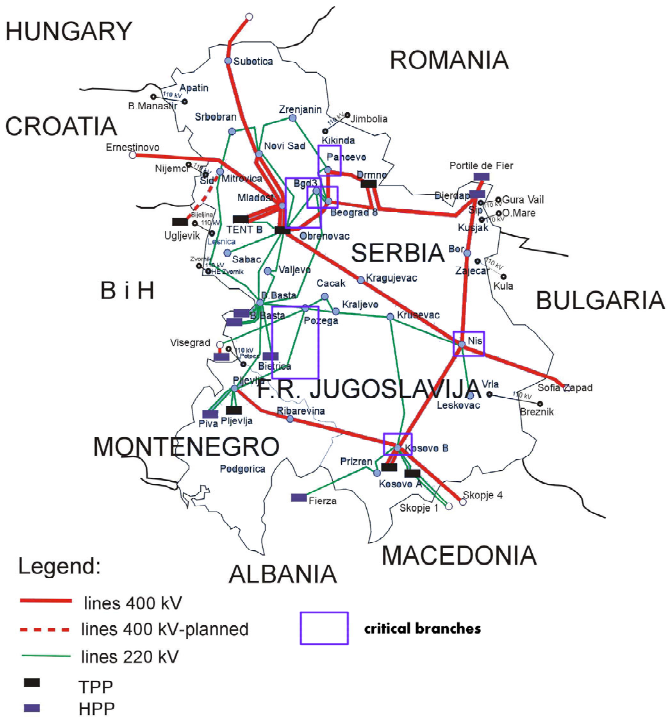

Fig. 7 Congested branches in Serbia

Fig. 8 Congested branches in Albania

Number of critical events and insecure operating conditions are significantly higher in 2015. Possible congestions are identified on internal branches again (interconnection lines are not congested).

It should be mentioned that transmission relief actions like generators re-dispatching or installation of FACTS devices were not analysed in [3] because interest was directed to the possibility of transmission network to support generators market engagement. This will probably be performed in the near future.

6 Conclusions

The southeast Europe region is organizing the electricity market in which seven countries will fully participate. Legal, organizational and institutional steps have already been done almost everywhere. Under the sponsorship of European Commission and USAID, countries are working on market design.

Regional transmission network consists of national networks which are developed under different political and economical environment. Reconnection of second UCTE zone to the main UCTE grid gives the basic technical prerequisite for market development. Southeast Europe transmission network operates on 750 kV, 400 kV, 220 kV, 150 kV and 110 kV voltage levels. Power systems are strongly interconnected through many 400 kV and 220 kV lines. Certain number of new interconnection lines is under construction or under preparation.

Several projects have been initiated recently to study technical aspect of regional transmission network operation in the future and to evaluate technical needs for new interconnection lines construction. PSS/E regional transmission system model for steady-state and dynamic analysis was made and used in those studies.

Calculations have shown that regional transmission network, as predicted to exist in 2005, 2010 and 2015 will be robust and capable to serve projected demand and to support generators market engagement. Insecure operational conditions are expected in some parts of Romanian, Serbian and Albanian network so additional network reinforcement activities will be necessary in order to minimize network congestions. Interconnection lines will not be congested according to studies. Voltage stability problems may appear in Albanian and southern Serbian networks. Generally, transmission network will be capable to support market activities.

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