SOUTH EAST EUROPE ENERGY COMMUNITY - DEVELOPMENT OF ELECTRICITY INFRASTRUCTURE

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Abstract

This paper presents basic data about Southeast Europe power systems and open discussion about infrastructure development, supporting electricity market establishment. 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 establishment of common electricity market, named South East Europe Energy Community. All power sectors in the region are going through turbulent processes of restructuring, market opening and privatization at the same time. Security of supply should be observed more carefully then ever on all three levels: national, regional and European.

Keywords: Southeast Europe power systems, electricity market, security of supply

1. INTRODUCTION

The region of Southeast Europe (SEE) 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 establishment of common electricity market, named South East Europe Energy Community, 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, nine countries (Croatia, Bosnia and Herzegovina, Serbia, Montenegro, the Former Yugoslav Republic of Macedonia, Albania, Romania, Bulgaria and UNMIK on behalf of Kosovo) agreed to work on common energy market including electricity market.

Figure 1. The Energy Community in Southeast Europe [7]

The Energy Community Treaty was signed last year by all participating countries, and negotiations with Turkey are ongoing. 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 [7].

Preliminary organizational, legal and institutional steps in organizing Southeast Europe Energy Community 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 fully 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. Regional market opening actualized question of supply security under new conditions. Number of market subjects dramatically increased, responsibilities are decentralized and consumer requests are significantly increased. Accordingly, the main market design task comprises optimal solution of supply security problem under new conditions between subjects with contradictorily targets. All power sectors in the region are going through

turbulent processes of restructuring, market opening and privatization at the same time. Security of supply should be observed more carefully then ever on all three levels: national, regional and European.

This paper is organized into following topics: after introduction in Chapter 1, South East Europe power systems will be described in Chapter 2, Chapter 3 will discuss about electricity infrastructure adequacy concerning market activities, Chapter 4 will present some future infrastructure projects and capacity building which are planed by Power companies and Transmission System Operators, Chapter 5 will give some steady state and security analysis results and identify possible congested areas in the future, and paper will conclude with Chapter 6.

2. SEE POWER SYSTEMS

Power systems in the region were designed and constructed in different political, economical and technical circumstances. Bulgarian and Romanian system were relied on ex USSR, while Bosnian, Croatian, Serbian, Macedonian, Montenegrin and UNMIK system were designed within ex Yugoslavia. Albanian system was developed independently of others. Power systems in the region were operated in two electrically separated zones for last 15 years due to war destructions. 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 2). 400 kV and 220 kV networks are well meshed due to many interconnection lines. There are two 750 kV, twenty one 400 kV and sixteen 220 kV interconnection lines in the region today.

Different production facilities exist in the region (thermal, nuclear, hydro) [1]. 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 equalled (hydro versus thermal) in Croatia and Bosnia and Herzegovina. Other electricity sources, including renewables, haven't been developed yet, excluding significant amount of small hydro power plants in Romania. Some countries are dominantly electricity importers (Albania, Montenegro, Macedonia, Serbia, Croatia, UNMIK) while other countries are exporters (Bulgaria, Romania, Bosnia and Herzegovina). The region as a whole is dominantly electricity importer. Different trading and production companies perform market transactions in the region, Vattenfall, Entrade, Atel, Eft, among others. Electricity production price is generally lower than in Western Europe countries, mainly due to strong state price regulation inherited from socialism age. 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). Predicted regional peak load in 2010 is around 30 GW.

Figure 2. Southeast Europe power system

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 (97 % of electricity was produced in HPP in 2001) imports electricity and sometimes reduces consumption when hydrological conditions are unfavourable. 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. 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 (production in TPPs and HPPs is almost equal depending on annual hydrological conditions) Bosnia and Herzegovina mostly exports electricity. 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 (based mostly on thermo and nuclear production) in the region. Croatian longitudinal 400 kV network is 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, with greater installed capacity in HPPs) are connected mostly to 220 kV and 110 kV networks. Croatia mostly imports electricity due to economical reasons (expensive domestic thermal power plants). 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. 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 (TPPs produce around 70 % of overall production). Network 400 kV between Serbian capital Belgrade, HPP Djerdap and SS Nis represents basic part of transmission network of Serbia, 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. ELECTRICITY INFRASTRUCTURE ADEQUACY

SEE is a diverse region of about 60 million people. Average income per capita has a wide range going from US$ 590 in Moldova to US$ 5350 in Croatia [6]. Since the end of the Kosovo conflict in 1999, however, there has been considerable improvement. Civil unrest has been overcome and a political balance has been found that has allowed a return to economic growth and closer regional cooperation.

For the SEE region as a whole economic growth has been close to an annual value of 5 percent since 2000. Today average GDP/capita in the region is more than 7 times lower than EU-15 average. The following table presents characteristic country and power system specifics that prove large mutual differences in the region.

Table 1. GDP and Electricity Intensity in the Region

2003 Data / Country	GDP per Capita [US$]*	Demand per Capita [kWh]**
Albania	1740	1.66
Bulgaria	2130	5.44
Bosnia and Herzegovina	1852	2.19
Croatia	5350	3.33
FYR Macedonia	1710	3.61
Moldova	590	0.76
Serbia-Montenegro	1910	4.33
Romania	2310	2.30
UNMIK	750	1.98

* World Bank 2003
** Energy Regulatory Regional Association ERRA 2004

Table 2. Peak Load and Consumption in the Region

2003 Data / Country	Peak Load* [MW]	Demand** [TWh]
Albania	1254	5.7
Bulgaria	6468	36.5
Bosnia -Herzegovina* **	1800	8.8
Croatia* **	2760	15.5
FYR Macedonia	1417	7.2
Moldova* **	1200	4.2
Serbia	6067	34.4
Montenegro	668	4.4
Romania	7542	49.4
UNMIK	590	3.9

* Annual Report Southeastern European Power Utilities 2003, EKC
** National Energy Reports – 2003

GDP per capita in the region differs for 9 times (Croatia/Moldova) between the countries. Excluding Moldova this share drops to 3 times (Croatia/Albania). These values present significantly different national economies that can (not) easily withstand all necessary changes in power sector such as market opening, real tariffs, absence of state support to power companies etc. in the same timeframe. This is obvious disadvantage of unified steps to regional electricity market. Differences in electricity consumption per capita are not so significant. Peak loads are within wide range due to different country areas.

3.1 Installed Capacities and Generation

The region is characterized by 18711 MW of installed hydro generation capacities, 29086 MW of thermal and 4753 MW of installed nuclear capacities which gives total amount of 52550 MW. Country's share in total regional installed thermal capacity is dominantly defined by each power system size. Thermal power plants in the region are dominantly based on old technologies with high generation prices. If we include constant growth of primary energy source prices (fuel, gas, coal), the role of hydro production is supposed to be even more important.

Table 3. Installed Generation Capacities in SEE Region

Country	HPP [MW]	NPP [MW]	TPP [MW]
Albania	1445	0	119
Bulgaria	2863	3760	6566
Bosnia and Herzegovina	2390	0	1912
Croatia	2063	338	1589
FYR Macedonia	440	0	943
Moldova*	60	0	970
Serbia	2831	0	5524
Montenegro	649	0	210
Romania	5970	655	9775
UNMIK	0	35	1478
TOTAL	18711	4753	29086
Peak Load = 52550 MW			

Source: Annual Report SEE Power Utilities 2003, EKC, Austrian Energy Agency

Table 4. Power Generation in SEE Region

Country	HPP [TWh]	NPP [TWh]	TPP [TWh]
Albania	4.7	0	0.08
Bulgaria	3.3	17.3	22.0
Bosnia and Herzegovina	6.3	0	3.8
Croatia	4.9	1.6*	8.3
FYR Macedonia	1.3	0	4.9
Moldova	0.1	0	3.3
Serbia	9.2	0	24.3
Montenegro	1.5	0	1.1
Romania	13.0	4.6	33.9
UNMIK	0.08	0	2.0
TOTAL	30.08	4.6	77.8
Grand Total = 112.5 TWh			

* half of NPP Krško

Source: Annual Report SEE Power Utilities 2003, EKC, Moldova Energy Overview, World Bank Report

3.2 Transmission System

Several projects on the regional transmission system have been realized recently [4]. The studies have shown that the regional electric transmission system in 2005 fully interconnected to UCTE with and without Turkey and without any of the 12 proposed new interconnection candidate lines. is robust and capable of serving projected 2005 demands plus all long term contracted exchanges plus an additional 600 – 1500 MW bulk power exchange (depending on the exchange scenario).

The European Council agreed on a target for the level of interconnection between EU Member States corresponding to 10% of installed generation capacity in each Member State in order to improve security of supply and facilitate competition. Generally, this request is satisfied in South East Europe. Currently the system limitations aren't on interconnections. but in internal networks [4,5]. Since there were no this kind of study coordination in the past there is a need for further tight cooperation between power experts from region especially in the field of the power transit margins. Planned interconnections observed as single elements in the network do not increase transit margins significantly. In other words, transmission system is capable of supporting market opening in the region, while generation capacities data and new investment plans give us a basis for exchange possibilities within the region as well as between East and West.

3.3 Electricity Prices

While speaking of future common electricity market it is interesting to analyze existing electricity prices in region as shown in Figure 3 [9]. Average residential electricity prices in the region in 2004 (including Turkey) vary between 3.8 USc/kWh (Bulgaria) and 9 USc/kWh (Romania) with average value of 6.4 USc/kWh.

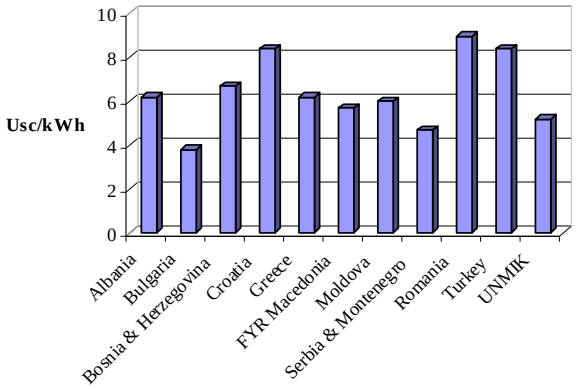

Figure 3. Average residential electricity price in 2004

Obvious significant differences in existing electricity prices present good basis for market development. Consequently, organized electricity market will support higher level of electricity exchange in the region.

3.4 Security of Supply Issues

Control of critical energy infrastructures is in turn highly dependent on the security and reliability of the monitoring and controlling interconnection infrastructures. To deal with this uncertainty, network operators adopt rules to ensure that the network has enough capacity so that the grid can be operated safely in a variety of extreme circumstances. In this sense there is no experience in SEE Europe. Rules and standards in data exchange, procedure adoption as well as adequate software platforms are to be taken and adopted from EU experience. Expert education can significantly influence supply security on electricity market in the region. Big effort has to be done to prepare staff for completely new working environment that consists of network performance standards and balancing supply and demand. Importance of this issue is proven by European

Commission [6]. Apart from network operation standards and supply and demand balance, the most important aspect for supply security level is the construction of new lines. Since transmission system is regulated monopoly network reinforcements should be strictly and clearly defined. The network must not be limiting factor to market activities. At the same time, the consumers must not pay additional price for network overinvestment.

4. INFRASTRUCTURE PROJECTS

4.1 Production projects

Regional production companies plan to construct significant amount of new capacities in mid-term time horizon. Albanian power supply company KESH plans to rehabilitate and upgrade existing HPP on the Drin river and TPPs at Fieri and Ballshi, and to construct new hydro and thermal capacities (HPP Bratila, many small HPPs, TPP Vlora) [8]. Bosnian power supply companies (Elektroprivreda BiH, Elektroprivreda HZ H-B, Elektroprivreda RS) plan to rehabilitate existing thermal facilities and to construct significant number of small hydro power plans. 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). Bulgaria intends to build new lignite-fired TPP 600 MW, HPP Tzankov Kamak 80 MW and to increase the share of combined cycle gas turbines (CCGT) till 2020 [2]. Croatia plan to construct several new mid-scale HPPs, and two TPPs based on CCGT technology with rated power of 250 MW each, located inside existing thermal production facilities (Sisak and Osijek). Serbia and UNMIK plan to construct new coal fired power plants which will use domestic coal, while Montenegro plan to construct new TPPs at Pljevlja and Berane locations and several hydro power plants mostly on the Morača river.

New power plants candidates are valuated with respect to common regional market point of view and construction plan is suggested in [3]. According to that study, following production projects have regional significance: NPP Cernavoda 2 (Romania), TPP Kolubara 1 (Serbia), TPP Kosovo (UNMIK) till 2010, and NPP Cernavoda 3 (Romania), TPP Kolubara 2 (Serbia), TPP Kosovo 2, TPP Kosovo 3, TPP Kosovo 4 (UNMIK), CCGT 2x300 MW and CCGT 500 MW (Croatia) from 2010 to 2015.

4.2 Transmission projects

Regional TSOs 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 Figure 4 [4]. Interconnection lines candidates were valuated in [4] from regional prospective point of view.

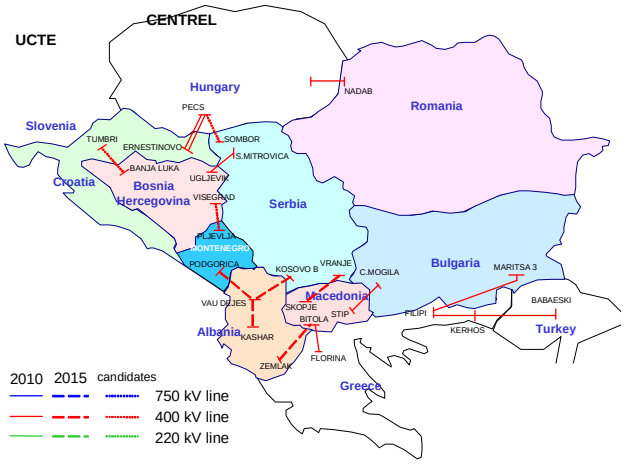

Figure 4. Southeast Europe candidate interconnection lines

All TSOs intends to rehabilitate some parts of existing transmission networks and to construct new lines and transformer stations, or to increase installed capacities of existing ones. Albania plans to construct 400 kV network across the country, Romanian TSO plans to close the loop between SS Arad, SS Oradea and SS Rosiori, while Serbia plans to strengthen 220 kV network around Belgrade. All countries plan to construct new 110 kV lines. Significant investments in telecommunication networks and dispatching facilities will also be needed.

5. SECURITY ANALYSIS AND PREDICTION OF POSSIBLY CONGESTED AREAS

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 [5]. 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 5 and 6) observing both analyzed time horizons. 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.

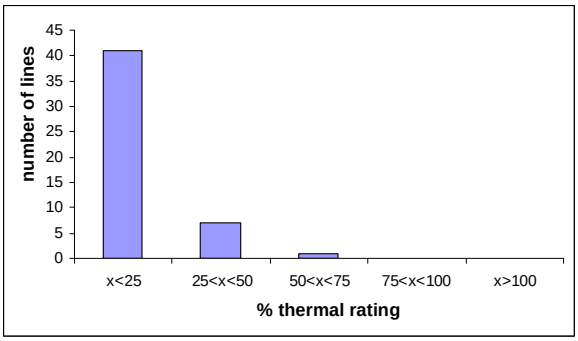

Figure 5. Interconnection lines loading (% $I_{thermal}$) for average hydrology in 2010

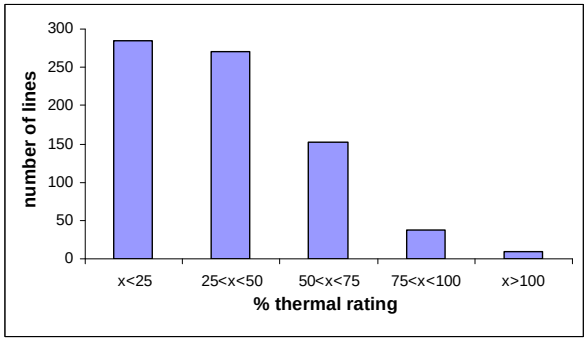

Figure 6. Internal 400 kV and 220 kV branches loading (% $I_{thermal}$ or S_r) for wet hydrology in 2015

Observing (n-1) security criterion under generators market engagement one may notice that congestions might appear in Romanian, Serbian and Albanian internal networks. 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. 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 [5] 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 faced with new challenges related to power sector. Through establishment of the Energy Community, consisted of nine countries, electricity market has been introduced. It is expected that market opening in power sector will attract investors, increase possible production possibilities, diversify fuels, and improve economy of member states. Vertically integrated power supply companies in the region have been going through the process of unbundling, restructuring, and privatization. New production companies, transmission system operators, supply companies and traders appeared. Regulatory authorities were established everywhere. First privatization acquisitions were performed (Bulgarian and Romanian distribution companies). Present electricity infrastructure is not fully designed to serve market activities properly. Some investments in transmission systems internally, as well in interconnection lines, telecommunication network and dispatching systems will be necessary to support competition and expected market activities. First calculations of stead-state load flows and security analysis show that SEE transmission network will not fully allow generators market engagement. Potential congestions may appear in Romanian, Albanian and Serbian transmission systems. After completion of several interconnection projects which are in the process of construction right now, SEE countries will be satisfactory mutually connected.

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