South-East Europe transmission system planning project

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***Abstract*-- After political situation in South-East Europe calmed down, better cooperation conditions are initiated between countries in the region. Power sector is extremely important for development of every single country. Also, numerous organizational and structural changes make impact to bulk power systems all over the world. According to new issues, there is a need to make a better cooperation and interconnection between countries in the region. Regional Transmission System Planning Project is launched by USAID. This paper presents the activities performed within this project.**

***Index Terms*-- Power transmission planning, bulk power systems, interconnections.**

I. Introduction

South-East Europe Cooperative Initiative (SECI) was established in 1996 to improve economical cooperation between South-East European countries. Project group on "Development of Interconnection of Electric Power Systems of SECI Countries for Better Integration to European System" has identified five projects as regional priorities concerning rehabilitation of existing transmission lines and substations, feasibility and technical study of east-west corridor in the high voltage transmission systems of the South-East European countries including issues related to the interconnection of the region to the Turkish power grid, investigation of economic and technical advantages of the integrated operation of the interconnected Balkan Electric Power Systems, tele-information system for the connection of the dispatching centers of the power systems in the region, and study to define a revitalization methodology for high-voltage lines and transformer substations by identifying priority criteria.

First project, as the most important for the region, has the expected finalization by the end of 2003. Activities comprise rehabilitation of transformer stations 400/110 kV Ernestinovo in Croatia and 400/220/110 kV Mostar in Bosnia and Herzegovina, together with 400 kV lines that are out of operation, or currently in operation at lower voltage levels, due to destructions during the war in the 90-ies. After that the region will be re-connected to the UCTE.

Fulfilment of these activities represents the starting point for Regional Transmission System Planning (TSP) Project, sponsored by USAID, Energy and Infrastructure Bureau for Europe and Eurasia. Main goal of this project was to analyze the possibilities for competition under Regional Electric Market (REM), which is under creation by participating South-East European countries and European Commission. Project was led by the CMS, with following countries (companies) were involved: Albania (KESH), Bosnia and Herzegovina (ZEKC, EPBiH, EPRS, EPHZHB), Bulgaria (NEK), Croatia (HEP), Macedonia (ESM), Greece (PPC/HSTO), Hungary (MVM), Romania (Transelectrica), Turkey (TEAS), Yugoslavia/Serbia (EPC), Montenegro (EPCG). Regional coordinator was ESM. Two companies were also involved in the project, especially within the regional model construction and analysis: EKC (Electricity Coordinating Centre) Belgrade and EIHP (Energy Institute "Hrvoje Pozar") Zagreb.

As a part of the Project, PSS/E software was delivered to all participating countries. The trainings on Power Flow and Steady State Analysis, Optimum Power Flow and Dynamic Simulations were organized, conducted by Power Technologies Inc (PTI) and sponsored by USAID.

Three working groups were formed on following tasks; data conversion and model development, transmission project technical and financial reviews and post-project cooperation on transmission system planning. All activities were coordinated between these three groups, Technical Coordination Group (TCG) and Steering Committee (SC). Interconnection Study Task Group (ISTG) was formed with experts from EKC, EPBiH, NEK, ESM, and EIHP performing calculations and preparing the final report.

II. Regional Model Construction

The tasks were set as to convert data for each power system in the South-East Europe (SEE) into the PSS/E format, and to create the regional transmission system model planned to be used for SEE regional planning studies, and studies performed by the participating countries in SEE. Common regional transmission model (RTM) was based on the internal models prepared by the experts in the participating countries, which are joined together and tested by EKC.

Currently (end of 2002), the SEE countries have different status in the UCTE. Former Yugoslavian countries (Slovenia, Croatia, Bosnia and Herzegovina, Serbia, Montenegro and Macedonia) are UCTE members, but only Slovenia, Croatia and part of Bosnia and Herzegovina are operated synchronously with the UCTE. Other countries (Serbia, other part of Bosnia and Herzegovina, Montenegro and Macedonia) are synchronized with Albania, Romania, Bulgaria and Greece

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(2nd UCTE zone). Romania and Bulgaria are in advanced process of getting full UCTE membership, while Turkey submitted the application and started the procedure to join UCTE.

As a result of the war activities in ex-Yugoslavia, very important points in the high voltage network in the region were damaged and have been out of operation for many years. These points are:

(1) Mostar substation 400/220/110 kV with connected lines that caused the interruption of the Adriatic line and,

(2) Ernestinovo substation 400/110 kV with connected lines that caused interruption of the northern ex-Yugoslavian power corridor.

As a consequence, the southeast UCTE island was separated from the main European interconnecting grid. In the meantime, UCTE members from the southeast island (Greece, Macedonia, Serbia, Montenegro and part of B&H) were interconnected and work in parallel synchronous operation mode with Bulgaria, Romania and Albania. Turkey is connected with Bulgaria with one 400 kV line in an island mode operation.

The separated UCTE zones will be reconnected through repaired substations Mostar and Ernestinovo (400 kV Adriatic line and northern Croatia/Serbia corridor), existing interconnecting line Subotica (Yug) – Sandorfalva (Hun) and optionally interconnection of Romania with CENTREL through Burshtin Island (Ukr).

The influence of connection of the huge power system of Turkey on regional power flows and its various effects have been considered and compared, especially taking into account the option that Turkey could be very strongly interconnected with the new line to Greece. UCTE interconnection was modeled with adequate equivalents at the border region of Hungary and Slovenia.

Regional model was created with following assumptions:

- Target year is 2005.
- All SEE countries work synchronously with UCTE (re-connection of 2nd UCTE zone is expected till target year).
- Two base sub scenarios are defined depending whether Turkey works synchronously with the UCTE or not.
- Winter and summer peak conditions are included.
- In the Base Case all countries are balanced including long term electricity exchange contracts.
- The existing and the new interconnections confirmed to be in operation until 2005, approved by TCG, are implemented in the base scenarios (Figure 1).
- Model is intended to be used for steady state analysis.

The regional model deals mostly with 400 kV, 220 kV and 150 kV network. Four base case models were created: winter with Turkey, winter without Turkey, summer with Turkey and summer without Turkey. Table 1 shows the size of the "winter with Turkey" model.

III. REGIONAL TRANSMISSION SYSTEM PLANNING STUDY

The study was performed in order to test the regional transmission system under REM conditions. It was the project goal to see how the system, as it is predicted to exist in 2005, would react to winter and summer peak loads as base cases and then how it would react to the added bulk power transits predicted to occur under REM conditions. Starting scheduled exchanges are shown in table 2.

Eight scenarios for winter peak and two scenarios for summer peak 2005 were observed within the study. To model these transits injection nodes tables were created and approved by the TCG.

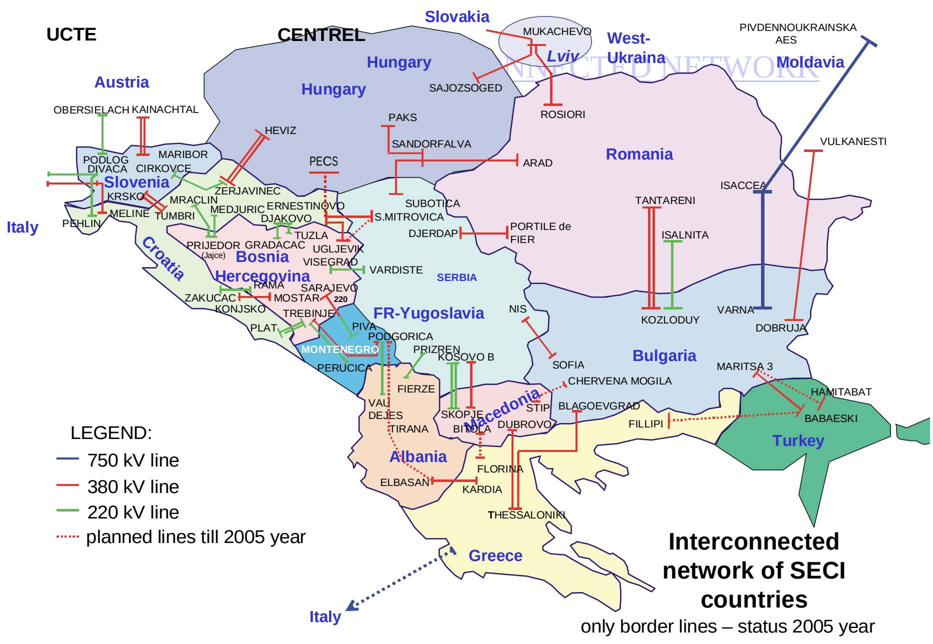

Fig. 1. Interconnected network of SECI countries (2005

In addition, the study goals included a detailed look at twelve proposed interconnections between countries to see which of them, if any, would provide the most regional benefit in terms of increasing maximum exchanges, reducing system losses and improving system security.

TABLE I
SIZE OF THE REGIONAL "WINTER WITH TURKEY" MODEL

Element	Total
Buses	1720
Plants	300
Machines	473
Switched shunts	8
Loads	890
Branches	2595
Transformers (2 winding)	552
DC lines	0
FACTS devices	0

These 12 proposed interconnections are summarized as follows:

1. 203 km of 400kV OHL from Podgorica (Montenegro, Yug) to Elbasan (Albania)
2. 75 km of 400kV OHL from Sremska Mitrovica (Serbia, Yug) to Ugljevik (B&H)
3. 156 km of 400kV OHL from Nis (Serbia, Yug) to Skopje 5 (Macedonia)
4. 80 km of 400kV OHL from Sombor (Serbia, Yug) to Pecs (Hungary)
5. 71 km of 220kV OHL (second circuit) from Prizren (Serbia, Yug) to Fierze (Albania)
6. 230 km of 400kV OHL from Banja Luka (B&H) to Tumbri (Croatia)
7. 85 km of 400kV (double circuit) OHL from Ernestinovo (Croatia) to Pecs (Hungary)
8. 92 km of 400kV Overhead Line from Bekescaba (Hungary) to Oradea (Romania)
9. 160 km of 400kV OHL from Heviz (Hungary) to Cirkovce (Slovenia)
10. 200 km of 400kV OHL from Skopje (Macedonia) to Tirana (Albania)
11. 150 km of 400kV OHL from Chervena Mogila (Bulgaria) to Stip (Macedonia)
12. 257 km of 400 kV OHL from Maritza East 3 (Bulgaria) to Phillipi (Greece)

The study looked at the regional system Base Case for 2005 with only projected 2005 winter and summer peak loads plus long term contracted exchanges, but without any incremental transits and any of the 12 proposed new interconnections installed. Then, the region was modeled by adding each of the 12 proposed new interconnections, one at a time, subjecting it to each of 8 bulk power transit scenarios for winter peak and 2 for summer peak conditions. Data for each scenario was collected to measure the impact of each proposed new line on power flows, losses and the lines ability to increase maximum exchanges (transits) across the region using (n-1) security criteria. Economical criteria were not considered in this project phase.

For examined scheduled power exchanges some limitations within internal networks were determined. Due to these limitations, exchange programs were not possible according to (n-1) criteria. To solve this, decrease of scheduled bulk power transfers is applied by using a 100 MW step. As a result, maximum possible transfers according to security criteria were calculated as shown in table 2. Maximum power exchanges were decreased in scenarios 1 (600 MW), 2 (700 MW), 3 (1000 MW), 4 (700 MW), 5 (1000 MW) and 7 (1000 MW) for winter regime and scenarios 1 (600 MW) and 5 (1200 MW) for summer regime. Starting scheduled exchange of 1500 MW was achieved only in scenarios 6 and 8 for winter peak.

TABLE II
BULK POWER EXCHANGE SCENARIOS

Winter peak			
From	To	Scheduled exchange (MW)	Maximum exchange (MW)
1.UCTE	TUR	1500	600
2.TUR, GR	UCTE	1500	700
3.UCTE	BUL, GR, ALB	1200	1000
4.ROM, BUL, GR	UCTE	1500	700
5.CENTR,Burstin Isl.,ROM	TUR,GR	1500	1000
6.TUR,BUG	CENTR	1500	1500
7.CENTR,Burstin Isl.	BUL,GR, ALB	1200	1000
8.ROM,BUL,GR	CENTR	1500	1500
Summer peak			
1.UCTE	TUR	1500	600
5.CENTR,Bur,ROM	TUR,GR	1500	1200

Because of the limitations in certain internal networks, each new candidate line has a low impact on increase of maximum exchanges. Some lines improve power exchanges in scenarios 3 and 7 for 100 MW only. Limiting internal lines and transformers are located in Turkey (OHL 380 kV Habipler – Unimrdg) and Yugoslavia (transformer 400/220 kV Sremska Mitrovica and OHL 220 kV Pljevlja – Mojkovac). There is also one existing interconnection line that limits power exchanges (scenarios 1 and 4 for winter and scenario 1 for summer regime) and that is OHL 400 kV Redipuglia (ITA) – Divaca (SLO).

The Hungarian power system is modeled by MVM experts. Since 120 kV network is not MVM's property, the Hungarian power system has been modeled by using equivalents. Thus, some transit limitations occurred in Hungarian system in winter exchange scenarios 2, 4, 6 and 8. However, due to a lack of clear understanding of these limitations, they were not taken into account in this study.

Power losses in each power system of South-East Europe were also determined for each power exchange scenario. Losses were calculated with and without each new candidate line. In general, new candidate line influence on total regional active power losses is very limited (less than 1%). But, active power losses in some systems in the region are significantly reduced with a new line in comparison with power losses without a new line. Those systems are neighboring systems connected by new candidate line. Loss reduction in these cases varies from 1% to 22% of active power losses. In some cases active power losses reduction is very high. The most significant is for the line Ernestinovo (Cro) – Pecs (Hun) in scenario 8 where active power losses in Croatian system are 22% lower than without line, and at the same time loss reduction in Hungarian system is 11%, even though total regional power losses are not significantly reduced (0.9%). In some cases, power losses are reduced or increased in the neighboring systems that are not connected with a new line. The most significant one is the case of the line Heviz (Hun) – Cirkovce (Slo), when power losses in Croatian system are decreased for 16.5% for summer scenario 1. The new line 400kV Podgorica (Yug) – Tirana (Alb) – Elbasan (Alb) has a big influence on active power losses in Albania, Yugoslavia and Macedonia, for two reasons:

1. Upgrade of part of Albanian network on 400 kV level (causes slight decrease of losses in Albanian transmission system up to 3.6%);
2. The line represents an alternative path for energy transfer from East to West, parallel to path over power systems of Serbia and Macedonia.

IV. STUDY CONCLUSIONS AND RECOMMENDATIONS

This study has shown that the regional electric transmission system, as predicted to exist in the year 2005, fully interconnected to UCTE, with and without Turkey and without any of the 12 proposed interconnections, is robust and capable of serving projected 2005 demand plus all long term contracted exchanges plus an additional 600 – 1500 MW bulk power exchange (depending on the Scenario). The system limitations are currently posed by four system elements mentioned in section 3, but it is probable that other internal limiting conditions would be found if these four are removed.

It has been shown that three of the twelve proposed interconnecting lines (1, 4 and 7) do offer some increased system performance in terms of power flows and loss reduction but offer no significant increases in maximum exchanges due to other internal limitations. Considering that the three projects range in price from 20million to 50million euros, it is concluded that they could not be cost justified on power flows and loss reduction issues alone.

It was recommended that the study team continue to work on the regional model and perform additional studies as follows:

- Confirm the four limiting elements with the operating experts from Turkey, Slovenia, Italy, Montenegro (Yug) and Serbia (Yug) and develop needed operation or construction plans to remedy these limitations.
- Perform additional studies to see if more internal limitations occur after the four known restrictions are remedied or if one or more of the 12 proposed new interconnections surfaces as a best candidate.
- Work with the appropriate experts from involved countries (Hungary, Albania, Romania and Serbia) in order to clear up the ignored restrictions in order to assure quality of obtained results.

V. CONCLUSION

The regional transmission network planning project was introduced under the sponsorship of the USAID using infrastructure of SECI initiative. Regional power system model was created in PSS/E format. The main task of the project was to test the regional transmission system under REM conditions and to evaluate new interconnecting lines in the region. Different bulk power exchange scenarios were defined, examined and analyzed. Some limitations in internal networks of Turkey and Serbia were detected. Maximum transit for each scenario was calculated according to (n-1) security criteria. Due to internal limitations, candidate interconnecting lines have no significant impact on maximum exchanges increasing. Study has shown that the regional electric transmission system as predicted to exist in the year 2005 is robust and capable of serving projected 2005 demands plus all long term contracted exchanges plus an additional 600 – 1500 MW of bulk power exchange. Evaluation of the new interconnecting lines should be continued, especially from the economical point of view.

VI. ACKNOWLEDGMENT

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VIII. BIOGRAPHIES

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