Energy Technology and Governance Program:

Reliability Assessment of Southeast Europe Transmission Network

Phase I and II

Southeast Europe Cooperation Initiative Transmission System Planning Project (SECI)
Cooperative Agreement: AID-OAA-A-12-00036

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Prepared for:

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EXECUTIVE SUMMARY

INTRODUCTION

Southeast Europe Region

The region of SEE (without Turkey) consists of nine countries with different size and population, economic parameters and electricity consumption. GDP per capita ranges between 3500 USD and 24000 USD. These values present significantly different national economies that can not easily withstand all necessary changes in power sector such as market opening, real and market oriented tariffs, absence of state support to power companies etc. in the same timeframe. SEE average electricity consumption per capita is 3550 kWh. Annual electricity consumption ranges between 6 TWh in Albania to 53 TWh in Romania. Annual electricity consumption of the region is about 227 TWh, and individual peak loads (occur usually during cold winter months) vary between 0.7 GW and 7.5 GW. The synchronous SEE peak load is typically close to 30 GW. Different production facilities exist in the region (thermal, nuclear, hydro). Some countries produce electricity mostly from hydro sources (Albania, Montenegro), some produce electricity mostly from thermal units (Romania, Bulgaria, Serbia, Macedonia), while generation mix is quite equal (hydro versus thermal) in Croatia and Bosnia and Herzegovina. Other electricity sources, including renewables, are in the process of development, including significant amount of small hydro power plants in Romania and wind power plants in Bulgaria, Croatia and Romania. Some countries are dominantly electricity importers (Albania, Montenegro, Macedonia, Serbia, Croatia, Kosovo) 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 wholesale market transactions in the region. Electricity production price is generally lower than in Western Europe countries, mainly due to strong state price regulation inherited from socialism age. Transmission network in the region operates under 400 kV, 220 kV and 110 (150) kV voltage levels. Lines 400 kV and 220 kV are well meshed due to many interconnection lines. There are twenty one 400 kV and sixteen 220 kV interconnection lines in the region today, together with two 750 kV lines that have been operating under 400 kV.

Transmission network element ageing

Equipment and devices in an electric power network are deteriorating and aging during their lifetime. Each equipment part has its own lifetime cycle with expected operation in accordance to its declared characteristics without large number of outages and failures. The unavailability function or the number of failures on the units (elements, devices) of the transmission network is irregularly shaped and cannot be mathematically expressed. In reality it is bathtub-shaped, meaning that it is characterized by an increased number of failures (and thereby unavailability) in the initial period of unit usage after its commissioning, followed by a long span of normal use with a small and approximately constant number of failures, and, finally, a period of rapidly increasing number of failures occurring because of the age of the observed unit.

In a system having a greater number of old and deteriorated units with a higher level of unavailability, disrupted reliability begins to prevail and thereby reduced electricity supply security resulting in an increase in the operating costs of the power system as a whole.

The life expectancy of individual network units cannot be defined beforehand, so expected values are defined on the basis of the greatest possible number of units of the same type. Equipment lifetime end can be predicted relatively easily based on:

1) operational data,
2) visual monitoring and
3) laboratory tests.

With the approaching end of the life expectancy of equipment, the funds to be spent on its maintenance tend to rise significantly. The function of the number of failures, the unavailability or intensity of failures on electrical equipment is bathtub-shaped and cannot be mathematically formulated for each particular case.

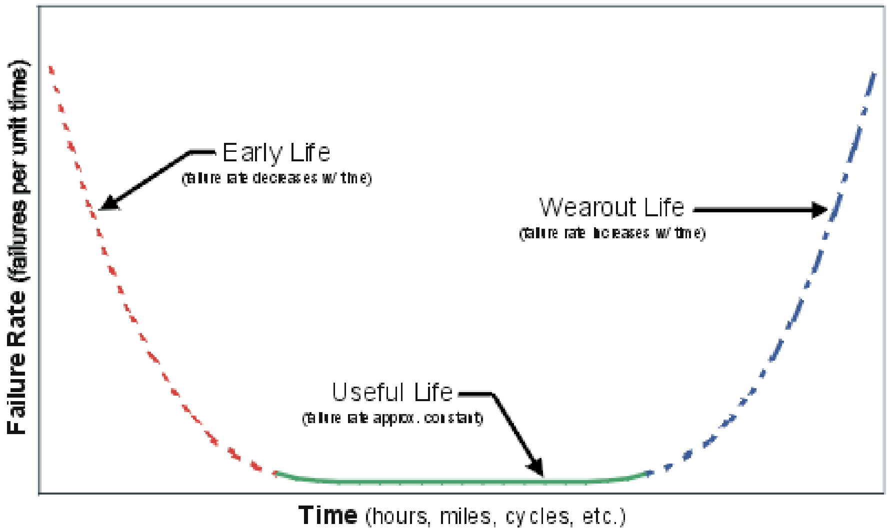


Figure 1 Bathtub curve

Scope of work

Even though there were significant transmission network reconstructions in South East Europe in the last decade, especially after war damages, it is of utmost importance to pay attention at the revitalization of existing network. Namely, most of the transmission network in the region was built during 60's and 70's, in the period of large electrification and industrialization. At that time annual demand growth was 7-8% in average, or in other words it was doubled in 10 years. Having in mind expected lifetime of the equipment, it is clear that all equipment installed in 60's and 70's is now at the end of the lifetime. Clearly, in SEE there are lot of transmission network equipment that need to be revitalized. It is expected that investments needed for network revitalization are several times higher than investments needed for the network reinforcements. It is very important for the future regional electricity market development to collect data on transmission network ageing and reliability, to compare revitalization criteria and to identify method of estimating the role and importance of revitalized units in the transmission network. It is also important to evaluate reliability indices which may lead to necessity of network reinforcements. Reliability assessment should be performed to identify network bottlenecks not only according to the N-1 criterion, but ones caused by multiple outages with relatively high probability.

EXPECTED LIFETIME OF TRANSMISSION OVERHEAD LINES AND CABLES

Expected lifetime of high voltage (≥110 kV) overhead lines and transformers is estimated as follows [3]:

- ACSR conductors of overhead lines have expected lifetime of 54 years (normal environment) with standard deviation of 14 years, and 46±15 years for not normal environment,
- towers have expected lifetime of 63 years with standard deviation of 21 years,
- transformers expected lifetime is 42±8 years.

Differences in assets lifetime are caused by different influential factors like climate conditions, corrosion, wind, ice, pollution, construction and design, etc.

Having in mind previous estimations on transmission equipment expected lifetime, one may conclude that equipment constructed before 1970 is today at risk because of their age. This is general observation and may be wrong observing individual transmission facilities and units because their condition may be much better or much worse independently of their age, due to operational history, thermal and mechanical stress under operation, environmental condition, maintenance and revitalization activities etc. This means that some transmission assets put in operation before 1970 may be in a good shape, while other assets put in operation after 1970 may be deteriorated and unreliable. Exact condition of specific transmission asset may be estimated according to its statistic reliability data and/or by laboratory tests and diagnostics activities.

In order to estimate a need and interest for SEE transmission system reliability analysis and to get deeper view into individual SEE TSO's concerns about network ageing, questionnaire was prepared and sent to all TSO's.

Observing average age of network assets (overhead lines and transformers) the worst situation appears to be in Romania and Bulgaria. In Romania average age of observed network elements exceed 40 years for all three transmission levels (400 kV – average age is around 45 years, 220 kV – average age is around 45 years, 110 kV – average age is more than 50 years). In Bulgaria lines 220 kV and 110 kV have average age of 45 and 50 years, respectively, while lines 400 kV and transformers have average age of 35 years that is below critical expected age. Transmission elements having high average age are in Bosnia and Herzegovina (220 kV, 110 kV elements), Croatia (220 kV, 110 kV), Montenegro (220 kV, 110 kV), Serbia (220 kV, 110 kV) and Slovenia (220 kV, 110 kV) also. Average age of network in Albania, Kosovo, Macedonia and Turkey is significantly below critical value. Observing SEE region, average age of 400 kV lines is 29 years, average age of 220 kV lines is 38 years and average age of 110 kV lines is 40 years. High-voltage transformers have an average age of 28 years.

Table 1 Average age of overhead lines and transformers in the SEE Transmission System

Country	**Average age (years)**			
	Overhead lines			Transformers
	400 kV	220 kV	110 kV	
Albania	10	25	35	15
Bosnia and Herzegovina	30	42	38	27
Bulgaria	35	45	50	35
Croatia	30	40	40	30
Kosovo	31	33	37	18
Macedonia	22	-	36	24
Montenegro	30	33	33	24
Romania	45	45	>50	40-45
Serbia	30	40	40	30
Slovenia	30	41	36	34
Turkey	22	26	-	-

Observing from regional perspective, lines 400 kV in the SEE, as the most important infrastructure for market transactions and regional electricity market functionality, are still not jeopardized by their age, except in Romania as one of the largest SEE countries and extremely important area for different transactions between Romanian market participants, and other traders/production companies primarily in Bulgaria, west Ukraine, Hungary, Serbia and further.

REGIONAL TRANSMISSION NETWORK

The most important voltage level for existing and future market transactions in the SEE region is 400 kV. Network 400 kV is generally well developed and meshed, connecting the SEE region with central Europe (Italy, Austria, Hungary), southern Europe (Greece), west Ukraine and Turkey, and thus allowing large electricity/power flows in different directions (north-east, east-west, etc.).

SEE region in general may cover its demand of electricity (power plants installed power is greater than peak load in the region), but due to different reasons like hydrological dependency, old technology in thermal power plants or high production costs, the region is mostly net electricity importer. Exporting countries are Bulgaria, Romania and Bosnia and Herzegovina, while importing countries are Croatia, Montenegro, Kosovo, Albania, Macedonia and sometimes Serbia. Large consumption and importers areas are Italy at the west, Turkey at the east and Greece at the south, and large production areas like west Ukraine at the north-east, Germany, Czech Republic and Poland at the north, surrounds the SEE region and expose its transmission infrastructure to significant load flows in different directions.

Short description of individual countries transmission systems and their topologies are given in the main part of the Report.

Almost each TSO in the region has defined its transmission development plan for a mid-term or long-term frame. Such plans usually comprise network reinforcements by new facilities construction, transmission facilities reconstruction and revitalization, as well as adoption of eventually other actions like voltage control sources installation.

Projects marked by ENTSO-E as pan-European significant projects in the SEE region are:

- Line 400 kV Krsko – Bericevo in Slovenia.
- Line 400 kV Cirkovce – Heviz/Zerjavinec between Slovenia and Hungary/Croatia.
- Line 2x400 kV Okroglo – Udine – Redipuglia between Slovenia and Italy.
- HVDC link 1000 MW Lastva – Villanova between Montenegro and Italy.
- Line 400 kV Višegrad – Pljevlja – Lastva in Bosnia and Herzegovina and Montenegro.
- Line 2x400 kV Pancevo – Resita between Serbia and Romania.
- Line 400 kV Tirana – Pristina between Albania and Kosovo.
- Line 400 kV Elbasan – Bitola between Albania and Macedonia.
- Line 400 kV Nis – Skopje between Serbia and Macedonia.
- Line 400 kV B. Luka – Lika between Bosnia and Herzegovina and Croatia.
- Line 2x400 kV Bajina Basta – Obrenovac in Serbia.
- Line 400 kV Bajina Basta – Visegrad/Pljevlja between Serbia, B&H and Montenegro.
- Line 400 kV Kosovo TPP – Skopje between Kosovo and Macedonia.
- Line 400 kV Mariza East 1 – N. Santa between Bulgaria and Greece.
- Large number of internal lines 400 kV in Slovenia, Croatia, Serbia, Romania, Bulgaria etc.

TRANSMISSION SYSTEM AGEING AND RELIABILITY INDICATORS

For the purpose of this study PSS/E software is used, activity “Reliability assessment”. Probabilistic reliability analysis by PSS/E is provided via an additional post-processing function to calculate probabilistic indices for local and system problems with given outage statistics for each contingency. PSS/E software is used as the common tool for transmission network analysis and planning in SEE and each TSO is equipped with this software. It was decided by SECI working group that SEE transmission model for winter high load regime 2012 will be used for reliability assessment. Additional reliability assessment was performed on the regional models for 2015 and 2020, also representing a winter peak load situation. Because of large number of network units (lines, transformers, generators) within the regional SEE transmission model it was decided that forced outages of 400 kV lines only will be observed in the reliability assessment. This is due to regional importance of 400 kV network that is major concern for study within SECI Regional transmission system planning project. Data for reliability assessment which were collected from each TSO comprises average annual number of forced outages for every line 400 kV within a grid under their jurisdiction and average annual duration of single forced outage. Three-year period was chosen for calculation of average number and duration of forced outages in order to decrease an influence of unintentional circumstances and deviations from normal situation. Observing total number of 400 kV lines per each country, average values of number of forced outages and single duration of forced outage for 400 kV lines, as well as average age of 400 kV lines referred to 2012, were calculated. Results are shown in the following table.

Table 2 Average number and single duration of 400 kV lines forced outages

Country	Average annual number of forced outages (400 kV lines)	Average duration of single line 400 kV forced outage (hours)	Average lines age (years)
Albania	4,0	2,5	28
Bosnia and Herzegovina	12,9	1,8	31
Bulgaria	0,4	1,6	27
Croatia	1,2	2,5	26
Kosovo	1,4	2,3	32
Macedonia	0,7	0,5	22
Montenegro	3,1	6,9	24
Romania	0,3*	14,3*	33
Serbia	0,9	2,0	32
Slovenia	0,3	1,6	32
Turkey	11,6	1,3	21
ALL (SEE+Slovenia+Turkey)	**3,4**	**3,4**	**28**

* According to the Reliability Normative

Average age of all 400 kV lines in the Southeast Europe including Slovenia and Turkey is 28 years. Average number of annual forced outages for all 400 kV lines is 3,4 while average duration of a single forced outage is 3,4 hours. This makes SEE transmission system quite reliable, with average annual unavailability of 400 kV lines due to forced outages of 0,10 % (one 400 kV line will be around 10 hours per year out of operation due to forced outages in average). Furthermore, one may conclude that critical contingences in the network 400 kV which may jeopardize overall system security or restrict market activities have very low probability. This means that consumers and market players in the SEE region will not suffer often from transmission system restrictions caused by accidental disturbances in the 400 kV transmission network, despite the age of 400 kV transmission system and its present condition. According to statistical data provided by SEE TSO's the best reliability parameters have lines 400 kV in Macedonia (average annual unavailability of 400 kV lines due to forced outages is 0,01 % or 0,6 hours/year) and the worst reliability parameters are noticed for Montenegro (average annual unavailability of 400 kV lines due to forced outages is 0,26 % or 22,8 hours/year). Above average, concerning unavailability of 400 kV lines in the SEE due to forced outages, are Albania, Bosnia and Herzegovina, Croatia, Kosovo, Montenegro and Turkey, with significant deviation for Bosnia and Herzegovina, Montenegro and Turkey. Bulgaria, Macedonia, Slovenia and Serbia experienced quite satisfactory reliability parameters in the past meaning that forced outages of 400 kV lines within their systems have very low probability. Situation concerning 400 kV lines reliability is still not clear in Romania due to missing input data. Romania provided typical data from the Reliability Normative, not measured ones, so Authors are still missing a clear view on the real situation there.

OPERATIONAL STATISTICS AND RELIABILITY INDICATORS

In order to estimate probabilistic indices for existing Southeast Europe transmission system common model representing third Wednesday in January 2012 was used. Model includes 400 kV and 220 kV national transmission networks with reduced number of busbars 150 kV and 110 kV. This means that reliability assessment is related to the networks 400 kV and 220 kV only, neglecting possible overloadings and out-of limit voltage situations which may happen in the network 110 kV and 150 kV. Multiple forced outages of 400 kV lines within jurisdiction of individual TSO's in the region will cause no problems in the network in general. Some problems, mainly with overvoltage situations, are probable in Turkey only. Albanian, Croatian, Macedonian, Montenegrin, Serbian, Kosovo and Slovenian network are not going to face any difficulties concerning 400 kV lines multiple forced outages during winter high load or peak load situations. Minor problems with undervoltages in Romania, overloadings in Bulgaria and loss of load in Bosnia and Herzegovina and Romania are possible, but probabilities of critical situations are extremely low. SEE transmission network overloadings under analyzed operational condition may be expected with probability of 0,62 % (54 hours per year). Loss of load directly connected to the network 400 kV may be expected with probability of 0,79 % (68,9 hours per year). Under-voltage problems are possible with probability of 0,1 % (9 hours per year). Problems in the regional transmission system during winter peak or high load in 2012, comprising under-voltage situations, branches overloading situations and loss of load due to 400 kV lines forced outages, are possible with probability of 1,71 % (150,2 hours per year). Possible branches overloading problems are detected in Bulgaria, Croatia, Macedonia, Romania, Turkey and Serbia. Bus voltage violation problems may appear in Bulgaria, Macedonia and Romania, but all with extremely low probability. Loss of load is possible in Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Romania, Turkey and Serbia.

Reliability assessment for winter peak load situation in 2015 shows that multiple forced outages of 400 kV lines within jurisdiction of individual TSO's in the region will cause no problems in the network in general. Some minor problems, mainly with branches overloading or loss of load situations are probable in Montenegro, Serbia, Kosovo and Turkey. Albanian, Bulgarian, Bosnian, Croatian, Macedonian, Romanian and Slovenian network are not going to face any difficulties concerning 400 kV lines multiple forced outages during winter high load or peak load situations. Transmission network overloadings under analyzed operational condition may be expected with probability of 0,2 %, (23,9 occurrences per year and 0,8 hours as average duration of single outage). Under-voltage situations are possible in Albania, Romania and Serbia including Kosovo but not probable (probability close to 0 %). Loss of load in the region may be expected with probability of 0,26 % (22,8 hours per year). Problems in the SEE regional transmission system during winter peak load in 2015, comprising under-voltage situations, branches overloading situations and loss of load due to 400 kV lines forced outages, are possible with probability of 0,44 % (38,4 hours per year, average number of failures is 40,6 and average duration of single failure is 0,9 hours). Possible branches overloading problems are detected in Bosnia and Herzegovina, Romania, Montenegro, Turkey and Serbia. Probability of branches overloading is low and close to 0 % for all critical branches. Loss of load is possible in Romania and Turkey. Several power plants may loose their own consumption and go out of operation due to 400 kV lines forced outages in Bosnia and Herzegovina and Serbia.

Reliability assessment for winter peak load situation in 2020 shows that multiple forced outages of 400 kV lines within jurisdiction of individual TSO's in the region will cause some minor problems, mainly with branches overloading or loss of load situations, which are probable in Bosnia and Herzegovina, Croatia, Serbia, Kosovo, Slovenia and Turkey. Probability of critical situations occurrence is extremely low. Albanian, Bulgarian, Macedonian and Romanian network are not going to face any difficulties concerning 400 kV lines multiple forced outages during winter high load or peak load situations. SEE Transmission system in 2020, as planed by national TSOs, may experience critical situations concerning under-voltage situations, branches overloading and loss of load situations caused by 400 kV lines forced outages during peak load situation with probability of 8,1 %. Number of critical situations is 194,67 occurrences/year and average duration of single failure is 3,6 hours. Under-voltage situations are detected during reliability analysis as possible in Albania, Bosnia and Herzegovina, Romania, Slovenia, Montenegro, Serbia and Kosovo. Probability of such critical situations is close to 0 % for all above mentioned countries except Slovenia where probability of under-voltage situations rise up to 1,03 %. Branches overloading may be expected with probability of 7,86 %. Number of critical situations related to transmission branches probability is 177,59 occurrences/year and average duration of single failure is 3,9 hours. Majority of branches overloading is related to transformers 400/x kV, 220/110 kV and lines 220 kV and 110 kV. Lines 400 kV are in general not jeopardized by 400 kV lines multiple forced outages. Loss of load during winter peak load in 2020 may be expected with probability 0,36 %, but it is mostly related to power plants own consumption disturbances and radial feeding of substations 110/x kV. One may conclude that SEE transmission system in 2020 could experience worsening of reliability indices comparing them with planned system in 2015 and existing transmission system, which is expected as a consequence of 400 kV lines ageing process.

CRITICAL PARTS OF SEE TRANSMISSION NETWORK ACCORDING TO RELIABILITY INDICATORS

By using existing transmission network model some limitations were noticed on Slovenian – Croatian border (line 220 kV Pehlin – Divaca that is jeopardized by the outage of Melina – Divaca line 400 kV) with probability of 0,41 %. Transformer 400/110 kV in Dobrudja substation in Bulgaria may be overloaded (related probability is 0,01 %). Transformers 400/150 kV in two substations in Turkey (PSS/E names AMBAR and AMBDG) may be at risk of being overloaded with probability of 0,2 %.

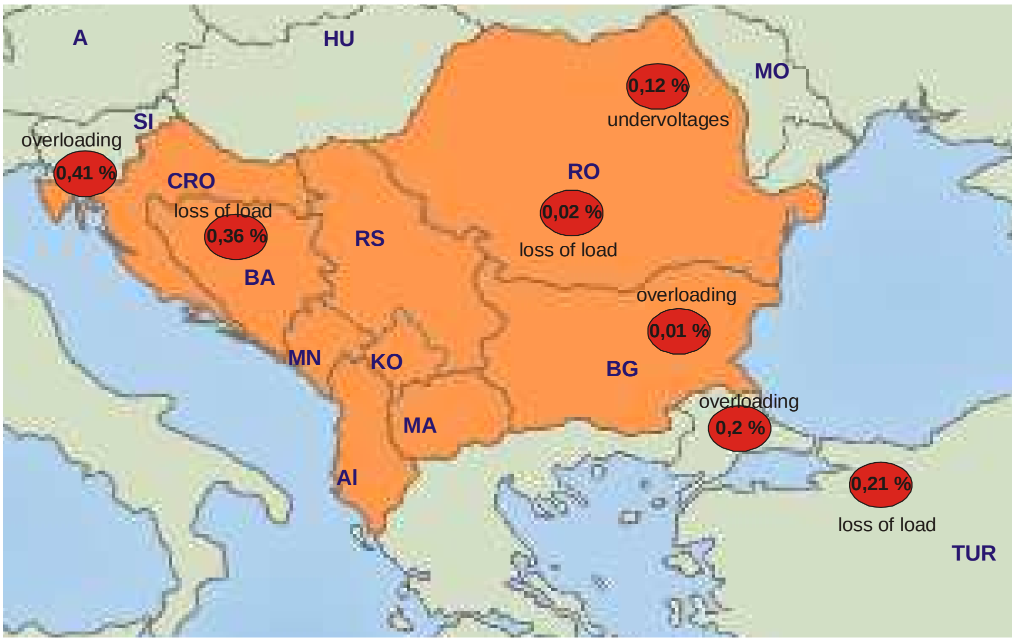


Figure 2 Critical areas in the SEE transmission system and probability of network overloadings, voltage problems and loss of load expectation (existing network topology - 2012)

Voltage violations for existing network topology may be expected in Romania at 400 kV and 220 kV voltage levels in the Suceava substations and at 400 kV and 110 kV voltage levels in the Roman Nord substation (probability of undervoltages is between 0,03 % and 0,1 %). Under-voltage problems are possible at 400 kV, 220 kV and 110 kV nodes in Bulgaria, and at 110 kV nodes in Macedonia, but with probability close to 0 %. Loss of load may be expected in Romania (range 20 MW – 30 MW, probability 0,02 %), Bosnia and Herzegovina (range 160 MW – 170 MW, probability 0,36 %) and Turkey (range 80 MW – 90 MW and range 210 MW – 220 MW with probability of 0,21 %). Loss of load may happen in Albania, Croatia, Bulgaria and Serbia but with probability close to 0 %.

Figure 3 Critical areas in the SEE transmission system and probability of network overloadings, voltage problems and loss of load expectation (short time frame future network topology - 2015)

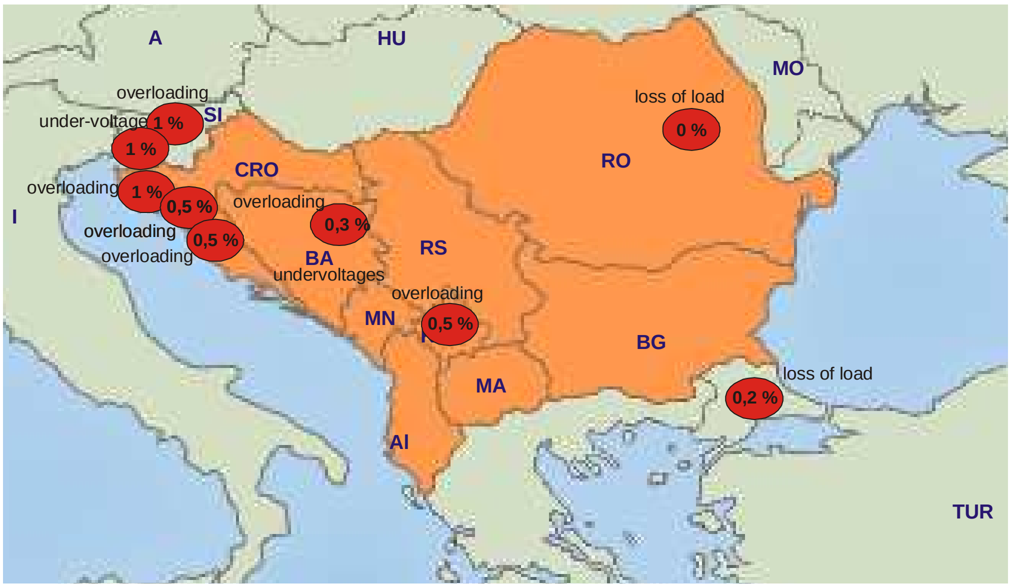


Figure 4 Critical areas in the SEE transmission system and probability of network overloadings, voltage problems and loss of load expectation (mid time frame future network topology - 2020)

Observing planned transmission network short time frame model (winter peak 2015) some limitations were noticed concerning the 110 kV line Tivat – Herceg Novi in Montenegro (probability of overloadings 0,16 %). Transmission branches overloading may happen in Bosnia and Herzegovina, Romania, Serbia and Turkey but with probability close to 0 %. Voltage violations for short time frame network topology may be expected in Albania, Romania, Serbia and Kosovo but with probability close to 0 %. Loss of load may be expected in Serbia (range 20 MW – 30 MW and range 30 MW – 40 MW, probability 0,05 %), and Turkey (range 230 MW – 240 MW, probability of 0,21 %). Majority of loss of load is related to power plants self consumption, with radial connection to the network 400 kV.

For 2020 limitations were noticed concerning 220 and 110 kV tie lines between Croatia and Slovenia (Pehlin – Divaca, Matulji – I. Bistrica, Buje – Koper), 220 kV tie line between Croatia and Bosnia (CCGT Sisak – Prijedor 2), transformer 400/110 kV in the Ugljevik SS (Bosnia and

Herzegovina), lines 220 kV and 110 kV around Senj and Brinje in Croatia, lines 110 kV in Lika area and along northern coastline of Croatia, 220 kV line in Kosovo (small impedance line in TPP Kosovo B substation). Voltage violations for short time frame network topology may be expected only in Slovenia concerning generators in TETO. Loss of load may be expected in Serbia (range 20 MW – 30 MW and range 30 MW – 40 MW, probability 0,15 %), and Turkey (range 290 MW – 300 MW, probability of 0,21 %). Loss of load possible problems were detected for certain number of 110 kV nodes in Romania, but with probability close to 0 %.

EVALUATION AND PRIORITIZATION OF INVESTMENTS IN NETWORK REINFORCEMENT AND/OR NETWORK REVITALIZATION ACCORDING TO RELIABILITY INDICATORS

Since network reinforcements are subject of more detailed analysis which deal with many possible system conditions, reliability analysis conducted in this study are not sufficient to determine necessary transmission network reinforcements, but some suggestions may be given:

- network 400 kV in the SEE region shows high level of availability and critical situations which occur as a consequence of 400 kV lines outages have very low probability,
- significant investments in 400 kV network development are not visible since network 400 kV in the SEE region is generally well meshed and highly available,
- construction of new lines 400 kV will be probably motivated by new power plants construction and market transactions in the future,
- motivation for new 400 kV interconnection lines construction should be based primarily on market and economic rationalization.

In order to keep high level of 400 kV lines availability transmission system operators will have to continuously conduct appropriate maintenance and revitalization activities. It may be expected that older lines 400 kV will be the most important candidates for revitalization activities in the future, concerning this voltage level (significant revitalization activities will be directed to the networks 220 kV, 150 kV-110 kV). Suggestions on 400 kV lines revitalization activities prioritization which are given in this Report are based on the following criteria:

1. lines 400 kV age;
2. lines 400 kV average unavailability in the past;
3. expected improvement of SEE transmission system reliability indices after line revitalization;

It should be stressed out that this is very simplified procedure because decision about revitalization activities is strongly dependent on different factors, like actual (monitored) condition of specific line 400 kV, regulatory requests, connection of new power plants at this line, fulfillment of technical requirements, maintenance and revitalization costs, etc. This means that prioritization lists which are determined according to previously mentioned criteria, and given in this Report are only indicative.

Usage of the first criterion gives revitalization list shown in Table 6.1. One may notice that the oldest lines 400 kV in the Southeast Europe are located mainly in Romania.

Usage of the second criterion gives revitalization list shown in Table 6.2. The worst unavailability data in the past were noticed for lines 400 kV Hamitabad – Maritsa East 3 between Turkey and Bulgaria and Konjsko – Velebit in Croatia. Lines 400 kV in Romania are included in the list but their unavailability data were not measured and values from Reliability Normative were used (real unavailability for lines 400 kV in Romania was unknown to the authors). Relatively large unavailability of these lines could be a consequence of lines length or unfavorable weather conditions across line route, not necessary a consequence of their age. More accurate estimation of revitalization priorities according to this criterion should be based on causes of outages for each considered line.

Usage of the third criterion gives revitalization list shown in Table 6.3. One may notice that probabilities of network limits violations are almost the same no matter of number of forced outages for individual lines 400 kV. Difference in probability for the first line in the prioritization list and the last one is only 0,11 % which means that revitalization of the first line, resulting in smaller number of outages for this line will decrease probability of system problems occurrence for 0,11 % only (9,7 hours per year), comparing it with the last line on the list.

CONCLUSIONS

The main task of this Study Report was to collect data on the SEE transmission network age and availability, and to give basic overview of statistical data in different countries. Furthermore, these data were used for transmission network reliability assessment related to present, short and mid term future network topology. Only forced outages of 400 kV lines have been taken into observation for two reasons: 1) it is the most critical set of reliability input data for market transactions, 2) if huge number of all transmission lines and transformers in the region were taken into account, the results would be blurry with no impact on the study result quality.

Based on questionnaire distributed among 12 SEE TSO's (including Turkey and Slovenia) and observing average age of network assets (overhead lines and transformers) the worst situation appears to be in Romania and Bulgaria. In Romania average age of observed network elements exceed 40 years for all three transmission levels. Transmission elements having high average age are in Bosnia and Herzegovina (220 kV, 110 kV elements), Croatia (220 kV, 110 kV), Montenegro (220 kV, 110 kV), Serbia (220 kV, 110 kV) and Slovenia (220 kV, 110 kV) also. Average age of network in Albania, Kosovo, Macedonia and Turkey is significantly below critical value. Average age of all 400 kV lines in the Southeast Europe including Slovenia and Turkey is 28 years. Average number of annual forced outages for all 400 kV lines is 3,4 while average duration of a single forced outage is 3,4 hours. This makes SEE transmission system quite reliable, with average annual unavailability of 400 kV lines due to forced outages of 0,1 % (one 400 kV line will be around ten hours per year out of operation due to forced outages in average). Furthermore, one may conclude that critical contingences which may jeopardize system security or restrict market activities have very low probability. This means that consumers and market players in the SEE region will not suffer often from transmission system restrictions caused by accidental disturbances in the 400 kV transmission network, despite the age of 400 kV transmission system and its present condition.

Reliability assessment of individual countries in the Southeast Europe transmission grid, as well as regional SEE transmission grid, was performed using PSS/E (version 33) and outage statistic data provided by individual TSO's. Reliability assessment was performed for existing network configuration, short time frame expected configuration (year 2015) and mid time frame expected configuration (year 2020), during winter high load or peak load conditions. Reliability assessment for all three analyzed time frames proves high reliability of SEE transmission system, but also shows that more serious problems with 400 kV lines ageing may be visible in 2020.

In order to keep high level of 400 kV lines availability transmission system operators will have to continuously conduct appropriate maintenance and revitalization activities. It is expected that significant revitalization activities will be directed to the networks 220 kV and 110 kV (150 kV) in the near and mid future, and in the network 400 kV in the mid and long term time frame.

1 INTRODUCTION

1.1 Regional Electricity Market

The region of Southeast Europe (SEE) has been passing through very intensive political and economic changes in the last 20 years. Transition from state controlled to market oriented economies has been going on in that time period. One aspect of the transition is an effort for establishment of common regulatory framework, named the Energy Community, encouraged by the 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, Macedonia, Albania, Romania, Bulgaria and Kosovo) agreed to work on common energy market including electricity market. Ukraine and Moldova joined latter.

Figure 1.1 The Energy Community in the SEE [1]

The Energy Community Treaty was signed in 2005 by all participating countries. 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 framework with appropriate regulatory oversight, should attract investments, supply, demand, and transmission projects. Under the Treaty, participating countries are required to adopt the key principles of the EU Electricity Directive, especially to unbundle vertically integrated utilities, to create national Transmission System Operators and independent Regulatory Authorities, to develop 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, to progressively open the national markets and to develop transparent trading and market monitoring systems.

Organizational, legal and institutional steps in organizing the Energy Community were performed. Regional power supply companies were in the process of unbundling and reorganization. New Transmission System Operator companies are established. Electricity market is expected to be fully introduced in a next few years (up to 2015). Regional transmission network will be subjected to different operating conditions. Regional market opening actualized questions of security of supply and quality of services under new conditions. Number of market subjects dramatically increased, responsibilities are decentralized and consumer requests are significantly increased. Accordingly, one of the main market design tasks 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.

1.2 Southeast Europe Region

The region of SEE (without Turkey) consists of nine countries with different size and population, economic parameters and electricity consumption (Figure 1.2 and 1.3). GDP per capita ranges between 3500 USD and 24000 USD, as shown on the following Figure for last 11 years. GDP per capita is here defined as gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are given in current US dollars.

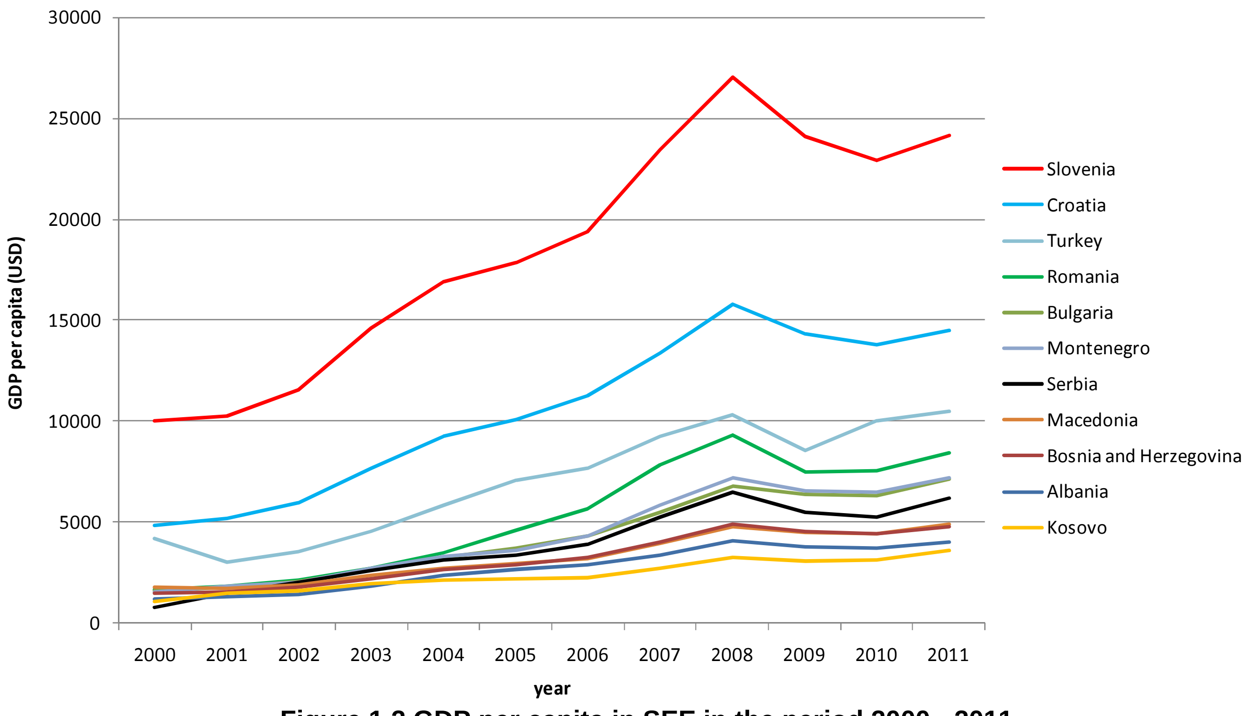


Figure 1.2 GDP per capita in SEE in the period 2000 - 2011

(Source: The World Bank)

These values present significantly different national economies that can not easily withstand all necessary changes in power sector such as market opening, real and market oriented tariffs, absence of state support to power companies etc. in the same timeframe. SEE average electricity consumption per capita is 3550 kWh. Annual electricity consumption ranges between 5 TWh in Albania to 53 TWh in Romania. Annual electricity consumption of the region is about 227 TWh, and individual peak loads (occur usually during cold winter months) vary between 0.7 GW and 7.5 GW. The synchronous SEE peak load is typically close to 30 GW.

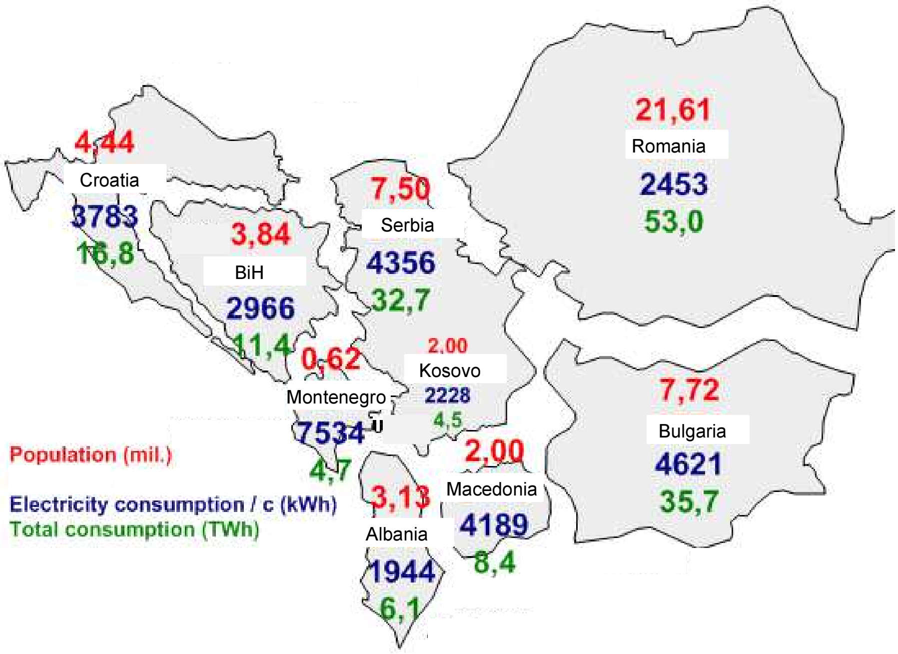


Figure 1.3 Basic data of the SEE countries

Figure 1.4 presents installed interconnection capacities, production capacities and peak loads in the SEE and surrounding countries. Different production facilities exist in the region (thermal, nuclear, hydro). Some countries produce electricity mostly from hydro sources (Albania, Montenegro), some produce electricity mostly from thermal units (Romania, Bulgaria, Serbia, Macedonia), while generation mix is quite equal (hydro versus thermal) in Croatia and Bosnia and Herzegovina. Other electricity sources, including renewables, are in the process of development, including significant amount of small hydro power plants in Romania and wind power plants in Bulgaria, Croatia and Romania. Some countries are dominantly electricity importers (Albania, Montenegro, Macedonia, Serbia, Croatia, Kosovo) 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.

Transmission network in the region operates under 400 kV, 220 kV and 110 kV voltage levels. Lines 400 kV and 220 kV are well meshed due to many interconnection lines. There are twenty one 400 kV and sixteen 220 kV interconnection lines in the region today, together with two 750 kV lines that have been operating under 400 kV. Modern transmission equipment and facilities based on energy electronic devices (HVDC, PST, SVC etc.) have still not been introduced to the Region significantly. Network age and current condition of the highest voltage network are discussed in detail in this Report.

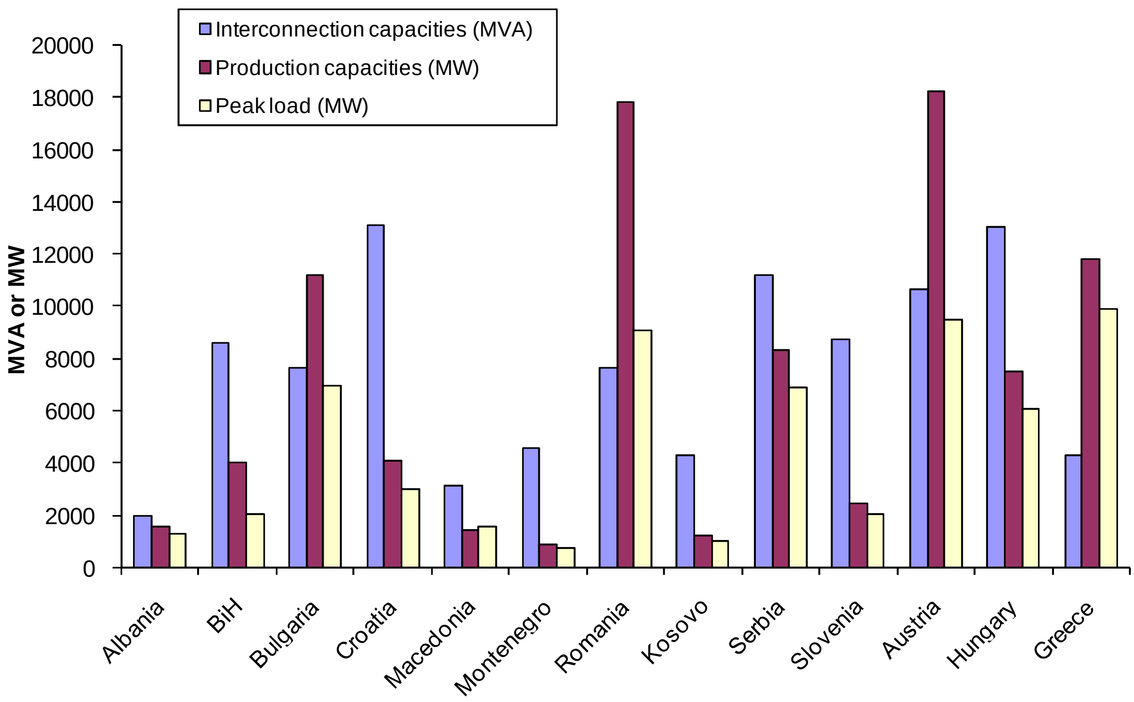


Figure 1.4 Installed interconnection capacities, production capacities and peak loads in the SEE countries

1.3 SECI Transmission System planning project – activities and studies

SECI Transmission System Planning Project started in 2001, comprising Transmission System Operators from eleven Southeast European countries (Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Kosovo, Macedonia, Montenegro, Romania, Serbia, Slovenia and Turkey). SECI (Southeast Europe Cooperation Initiative) was organized prior to that, and defined several projects which may improve regional cooperation between SEE countries, including one that deals with power transmission infrastructure issues.

Looking for the possibilities for realization of the projects from the SECI common interest list and in correlation with the other regional initiatives, the Regional Transmission Planning Project was identified and initiated with the main sponsorship of USAID. One of the goals of this project was to evaluate the regional benefits of the proposed new investments in the power interconnections in the region, but latter project spread over variety of other transmission issues.

Within this project, SEE TSO's were equipped and trained to use PSS/E software, that become a common tool for transmission system analysis and planning. Regional transmission system steady-state, short circuit and dynamic models in PSS/E format for 2005, 2010, 2015 and 2020 time-frames were constructed with participation of all TSO's in the Region, including neighboring countries like Turkey, Hungary, Italia and Greece. Models were made to reflect expected situation in the SEE transmission system for three basic operational regimes: peak load (winter maximum load), summer maximum load and summer minimum load. These models were used for different analyses by the Project group and individual TSO's. Following studies were prepared by SECI Transmission System Planning Project using regional PSS/E models:

SECI Regional Electricity Interconnection Study was prepared in order to evaluate regional transmission system capacities and prioritize planned interconnected lines. Analyses comprised load flow calculations and N-1 security criterion for different scenarios of power system exchanges in the region. 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 demands plus all long term contracted exchanges plus an additional 600 – 1500 MW bulk power exchange.

Generation Investment Study observed different option for power production development in the Southeast Europe and proposed the most beneficial ones. Appendix 12 of this Study, named PSS/E analyses and results, prepared within SECI project, performed feasibility analysis from transmission network point of view for different scenarios of power production development. Analyses were base on load flow and N-1 calculations.

Transmission Network Investment Criteria study elaborates the problem of transmission investments in an open market environment defining the most relevant uncertainties in the SEE region, reviews past experience in transmission network planning, analyzes transmission planning criteria which have been used by different SEE TSOs, reviews national grid codes and a draft version of the regional grid code, suggests transmission investment criteria from a regional perspective and proposes a methodology for project prioritization.

Conclusions and recommendations from previous study were used to make an *update for Generation Investment Study* that analyzed new options for power production development in SEE. Load flows and N-1 security analyses were calculated again.

Uncertainties in the South East European Transmission Network and Evaluation of Risk For Future Infrastructure Investments analyzed the impact of different uncertainties in the future (generation production plan, hydrological conditions, generators bids, load prediction, regional power balance) on the regional transmission network development and evaluation of new interconnection lines. Load flow steady-state analyses and N-1 criterion were performed.

Preparation for Large Scale Wind Integration in SEE Power System raised the question of regional transmission system to support plans for large scale wind power plants integration. Some network bottlenecks were identified by load flow and N-1 calculations, but in general it was concluded that transmission network is well developed and could accept wind farms which are planned. Significant savings may be expected concerning necessary power and frequency reserve if regional ancillary services market becomes functional.

All studies which have been prepared by SECI Transmission System Planning Project were based on steady-state load flow calculation and N-1 analyses which are in accordance with relevant grid codes in all SEE countries. All analyses were deterministic ones, performed without taking into account probabilities of different events. This study goes one step further, observing probabilities of different events from regional perspective, and evaluating reliability indicators for SEE existing transmission system.

1.4 Terms of Reference for Reliability Assessment of SEE Transmission Network

Outages in the transmission network

The most frequently used indicator of the reliability of a transmission network is its availability and unavailability respectively. Unavailability is defined as a time interval within the observed period of time (usually one year) when a network or one of its units is out of operation. Disruption is defined as a spontaneous event within the observed network when a forced disconnection occurs on at least one circuit breaker, or a forced outage of at least one unit of the transmission line. A disruption starts with a failure, an event where a unit passes from a correct into a faulty state. An outage is defined as an event where a unit forcibly passes from an operable into an inoperable state. A forced outage is the out-of-operation condition of the observed unit resulting from sudden outage or forced disconnection, not planned or done intentional. In terms of the causes there are two groups of forced outages:

1) forced outage caused by internal reason – outage due to own faultiness,
2) forced outage caused by external reason – outage due to a protective action or disconnection.

If the observed unit is in the state of forced outage due to its own faultiness, it is a case of an internal reason. A functional unit may be in the state of forced outage if out of operation due to a protective action or disconnection, so this is a case of a forced outage for an external reason. A forced outage can be permanent, temporary or transient. A permanent forced outage is one caused by a defective component or element of the unit, after which the unit resumes operation once the defect has been corrected. A temporary forced outage is one where the unit resumes operation after its disconnection without repair or replacement of one of its components. A transient forced outage is one where the unit resumes operation after its disconnection and successful automatic re-closure. It is obvious that the age of the unit will influence only the extent of permanent forced outages, whereas the temporary and transient forced outages will occur aside from the age of the observed unit.

Transmission network element ageing

Equipment and devices in an electric power network are deteriorating and aging during their lifetime. Each equipment part has its own lifetime cycle with expected operation in accordance to its declared characteristics without large number of outages and failures. The unavailability function or the number of failures on the units (elements, devices) of the transmission network is irregularly shaped and cannot be mathematically expressed. In reality it is bathtub-shaped, meaning that it is characterized by an increased number of failures (and thereby unavailability) in the initial period of unit usage after its commissioning, followed by a long span of normal use with a small and approximately constant number of failures, and, finally, a period of rapidly increasing number of failures occurring because of the age of the observed unit.

In a system having a greater number of old and deteriorated units with a higher level of unavailability, disrupted reliability begins to prevail and thereby reduced electricity supply security resulting in an increase in the operating costs of the power system as a whole.

The life expectancy of individual network units cannot be defined beforehand, so expected values are defined on the basis of the greatest possible number of units of the same type. Equipment lifetime end can be predicted relatively easily based on:

4) operational data,
5) visual monitoring and
6) laboratory tests.

Unfortunately, usually there are no sufficient input data for these criteria. That's why the specific group (type) of network units is statistically observed so as to define the approximate life expectancy of given unit (electrical and construction parts of the lines, cables, transformers, fields, other equipment in substations, protection systems, telecommunications, control systems..).

Amongst the observed failures on electrical equipment (devices, network units) two basic types of failures by their cause can be distinguished:

1) random failures – mostly caused by external influences and
2) age-related failures – caused by changed equipment characteristics after a long use.

In addition to these two types of failures there are failures caused by poor construction, coming to the fore largely in the initial stage of equipment use. Furthermore, failures on electrical equipment can be divided by the place of their cause into external and internal ones, and by their reparability into reparable and unrepairable ones. With the ageing of equipment there is an increasing number of defects and thereby an increasing number of outages, failures and unavailability of network units.

With the approaching end of the life expectancy of equipment, the funds to be spent on its maintenance tend to rise significantly. The function of the number of failures, the unavailability or intensity of failures on electrical equipment is bathtub-shaped and cannot be mathematically formulated for each particular case.

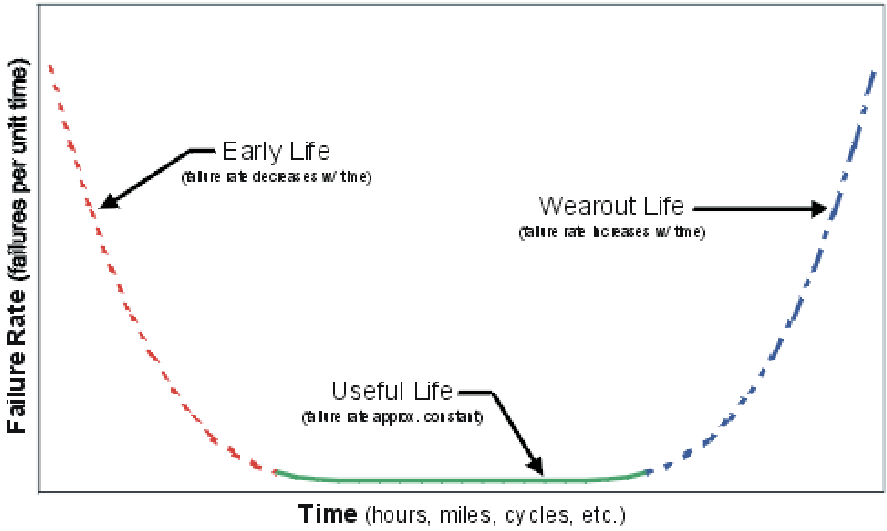


Figure 1.5 Bathtub curve

Within the failure intensity function three areas of the use of electrical equipment can be distinguished:

1) red line – represents the period of initial use, where after commissioning a certain number of failures occur. These failures are largely caused by structural and design errors during equipment manufacture. The failure intensity function is descending ($d\lambda(t)/dt)<0$, because all defects are corrected under the manufacturer's warranty,

2) green line – represents the period of normal use, where the failure intensity is approximately constant and failures are largely caused by external influences and are of random nature. The failure intensity function is approximately constant $d\lambda(t)/dt \approx 0$,

3) blue line – represents the period of deteriorated condition, where the failure intensity rapidly grows until reaching a point where operation is no longer possible. The failure intensity function is ascending $d\lambda(t)/dt > 0$. In that area the dominant failures are caused by the age of equipment and significantly exceed the failures caused by random factors.

End of green line in Figure 1 represents the time of normal use of electrical equipment, and can be approximately attributed to life expectancy. After that point the period of equipment use can be prolonged with reduced reliability/availability of units and increased spending on maintenance and repair. The point in time, or the limited period of time when the period of normal use passes into the period of deteriorated condition, differs from equipment to equipment in the network, depending on a variety of other internal and external factors, and cannot be predicted with any fair amount of certainty. The revitalization of equipment or each particular network unit would be ideal to carry out in the moment of green line ending or immediately thereafter, whereby the finances and the period of using the network unit would be optimized.

The time of transition from the period of normal use to the period of deteriorated condition for each particular equipment/network unit depends on a number of factors, such as operation conditions (loads, voltages, short-circuits, number of switching operations, etc.), external influences (weather, environment, exposure to atmospheric pollution, etc.), exposure to mechanical stress and thermal stress.

There is a number of indications that the observed equipment has reached the end of normal use or life expectancy, such as: greater unavailability, increased number of failures, higher maintenance costs or the end of using the same type of equipment in network. Apart from the end of the lifetime of certain network units as a result of age, permanently discontinued operation and replacement of individual units can also be caused by other reasons of strategic, economic or technical nature.

The assessments of the life expectancy of the electrical components of overhead lines in accessible literature vary between 40 and 60 years. Some transmission line components (insulators, parts of suspension and couplings, some conductor sections and protective wire) are partially replaced during the exploitation of the transmission line. In the relevant literature it is estimated the average value of an ACSR conductor at 54 years with a deviation of ±14 years, and of steel towers at 63 years ± 21 years. A distinction is made between the lines in a normal environment and those in an excessively polluted environment where the life expectancy of electrical components is 46 years ± 15 years. Life expectancy of transmission line towers varies between 50 and 70 years, and between 35 years and 50 years for conductors, insulators, suspension and couplings.

According to experiences gained so far in the operation of high-voltage cables and available technical data, the life expectancy of oil cables is around 50 years. For assessing the favorable replacement timing, this value can be corrected in dependence on the cable load (present and expected), recorded operation events and conditions under which the cable is laid. The life expectancy of other types is assessed in conjunction with the manufacturers.

Life expectancy of oil cables is 52 years with a deviation of ±20 years. It is only a comprehensive analysis of operation events and their diagnosis that can provide accurate information about the real condition of power transformers, based on which a decision on revitalization can be made. Due to the high cost of investment in large power transformers, their replacement is determined by age, in other words, they remain in operation as long as technically possible. The economic reasons for their replacement, such as reduction of losses within the transformers, are virtually never a motivation strong enough to undertake replacement. Major repair works on old transformers are, due to high costs of such repairs, virtually never practiced either. Important factors influencing the characteristics of transformers are humidity and oxygen. Increased humidity content in oil reduces their breakdown strength. Humidity can also impair the solid (paper) insulation of transformer windings, as can oxygen and heat. Generally, the main influence on the ageing of transformers is exerted by humidity, heat and oxygen, which depends above all on operation conditions to which a transformer has been exposed during its use. The life expectancy of large power transformers, judging by available estimates, varies between 42 and 50 years, provided that it is regularly serviced and spared from major defects that would leave a permanent damage.

Transmission network planning criterion

Transmission network in SEE is planned according to deterministic N-1 criterion. Each TSO in the region uses this planning criterion. N-1 analysis doesn’t take into account probability that some network branch is going to be disconnected. It doesn’t take into account probability of multiple outages in the network. Old or deteriorated network elements will probably go out of operation more frequently than newer network elements. That’s a reason why usage of N-1 criterion gives us very limited knowledge about studied transmission network and investments which are planned may be insufficient.

Reliability analysis and reliability criterion could provide us with more detailed information important to decide about network reinforcements. According to reliability assessment transmission planner may decide to revitalize existing transmission line instead to build a new one. He may also decide to invest in new line in order to avoid damage caused by multiple contingences in the network. This could be very important especially in the SEE because network equipment is generally old with significant share of deteriorated equipment.

Scope of work

Even though there were significant transmission network reconstructions in South East Europe in the last decade, especially after war damages, it is of utmost importance to pay attention at the revitalization of existing network. Namely, most of the transmission network in the region was built during 60's and 70's, in the period of large electrification and industrialization. At that time annual demand growth was 7-8% in average, or in other words it was doubled in 10 years.

Having in mind expected lifetime of the equipment given above, it is clear that all equipment installed in 60's and 70's is now at the end of the lifetime. Clearly, in SEE there are lot of transmission network equipment that need to be revitalized. It is expected that investments needed for network revitalization are several times higher than investments needed for the network reinforcements. SECI TSP development studies evaluated regional importance of new interconnection candidates and identified which most critical bottlenecks in the region could be expected in old internal networks rather than at the interconnections. Accordingly, it is very important for the future regional electricity market development to collect data on transmission network ageing and reliability, to compare revitalization criteria and to identify method of estimating the role and importance of revitalized units in the transmission network.

It is also important to evaluate reliability indices which may lead to necessity of network reinforcements. Reliability assessment should be performed to identify network bottlenecks not only according to the N-1 criterion, but ones caused by multiple outages with relatively high probability.

Provisionally, the study should cover the following chapters:

1. Introduction

2. Expected lifetime of transmission overhead lines and cables
   2.1. European and global experience
   2.2. Regional specifics

3. Regional transmission network
   3.1. Current status
   3.2. Expected development till 2020

4. Transmission system ageing and reliability indicators
   4.1. Reliability indicators definition
   4.2. 400 kV network elements
   4.3. 220 kV network elements
   4.4. 110 kV network elements
   4.5. Operational statistics and reliability indicators

5. Critical parts of SEE Transmission network according to reliability indicators

6. Evaluation and prioritization of investments in network reinforcement and/or network revitalization according to reliability indicators

7. Conclusions

1.5 Quality of Service Issues

Although the main topics of this report are network ageing and reliability indicators in the transmission system of SEE, this chapter gives basic description of quality of service from transmission network point of view which is of great importance for network users, TSOs and Regulatory Authorities. Availability of transmission lines and network age are very important factors which determines the most important quality of transmission service indicators. Energy not supplied from a transmission network will be reduced if network availability is satisfactory, and network availability will be higher if transmission assets are not old and well maintained.

Several reports prepared by Council of European Energy Regulators and Energy Community were used and described here [13, 14].

In the context of performing DSO and TSO activity, the quality of supply can be assessed on the basis of the following quality dimensions:

- the continuity of supply,
- the voltage quality, and
- the commercial quality.

For transmission networks performance the continuity of supply is the most important quality indicator. Continuity of supply concerns interruptions in electricity supply. Basic indicators referring to the continuity of supply at transmission voltage level are ENS (Energy Not Supplied or unsupplied energy) and AIT (Average Interruption Time or average duration of interruptions).

Unsupplied energy is the energy that would have been supplied from the system if there was no interruption of power supply. ENS is calculated as follows:

$$ENS = \sum_k P_k \cdot D_k \ \ [MWh],$$

where P_k is the power, at which the power supply was interrupted, expressed in MW, and D_k time interval, during which the power supply was interrupted, expressed in hours, for the interruption k.

Average duration of interruptions in the transmission network represents the cumulative duration of power supply interruptions per user in one year. AIT is calculated as follows:

$$AIT = \frac{60 \cdot \sum_i ENS_i}{P_T} \ \ [min\ per\ user],$$

where ENS_i is the amount of unsupplied energy in the *i-th* interruption, in MWh, and P_T the average power of the system, in MW, which is obtained as the electrical energy transmitted in the reporting period, in MWh, divided by the duration of this period, in hours.

Power supply interruption is a state of the network when the voltage at the customer connection point is lower than 5% of the declared voltage. Monitoring procedures of power supply interruptions are based on the distinctions between different types of interruptions:

- planned or unplanned interruptions with regard to their predictability,
- long and short interruptions with regard to their duration,
- external, *Force Majeure* or internal interruptions with regard to their cause, and
- originating from generation, transmission system or distribution system (either high voltage, medium voltage or low voltage).

Planned power supply interruption is the one where customers are informed in advance on the planned works in the distribution or transmission network. The impact of planned interruptions can be reduced by appropriate measures applied at the customer’s side. Unplanned power supply interruption is the one caused by permanent or transient fault, usually induced by an external event, equipment failure or disruption. Unplanned power supply interruptions are unpredictable, largely random events.

Power supply interruptions are by their cause regarded as either:

- external causes, that have been caused by "third parties", without direct liability by the observed service provider,
- *Force Majeure*, as the events, which the system operator was unable to control or prevent, with environmental parameters outside the boundaries determined by the state of the art and given in the design conditions, or
- internal causes.

Internal causes in general are all those causes of power supply interruptions that neither fall under external causes nor under the *Force Majeure*. Specifically, internal causes are: maintenance (inspection, audit, refurbishment, restoration/reconstruction), new construction, backup power supply, switching to normal operating condition, the safety switch off, poor installation, insufficient maintenance, incorrect switching manipulation, accidental contact, malfunction of protection, overload, overvoltage, the material (manufacture, wear), aging, reverse effects, unknown cause and other internal causes. Among the internal causes are also included atmospheric and natural causes other than *Force Majeure*, for example. atmospheric effects of heat, cold, fog, dew, condensation, rain (moisture), salt, dirt, corrosion and other atmospheric causes.

The origin of the power supply interruption is in one of the following four parts of the power system:

1. generation and transmission system, consisting of generating facilities with connections to the network operated by TSO, and the transmission network operated by TSO with a nominal voltage above 110 kV
2. high voltage (HV) network with a nominal voltage of 110 kV, operated by TSO or DSO,
3. medium voltage (MV) distribution network with voltage levels between, but excluding, 1 kV and 110 kV, operated by DSO, and
4. low voltage (LV) distribution network with voltage levels up to and including 1 kV, operated by DSO.

Although origin of a majority of power supply interruptions is in distribution (medium and low voltage) network, occasionally there are large disturbances in a transmission system that affect more consumers and result with large energy not delivered. This is the reason why transmission system should be well planned and designed in order to minimize such unwanted consequences during emergency situations.

1.6 European Legislation Concerning Quality of Service Issues

In October 2011 the Ministerial Council of the Energy Community decided (Decision D/2011/02/MC-EnC of the Ministerial Council of the Energy Community on the implementation of Directive 2009/72/EC, Directive 2009/73/EC, Regulation (EC) No 714/2009 and Regulation (EC) No 715/2009 and amending Articles 11 and 59 of the Energy Community Treaty, 9th Ministerial Council Meeting, Chisinau, Moldova, 6 October 2011), among other, to implement Directive 2009/72/EC instead of Directive 2003/54/EC and amend Article 11 of the Energy Community Treaty which defines the Energy Community *acquis communautaire* in energy. Consequently, each Contracting Party to the Energy Community shall bring into force the laws, regulations and administrative provisions necessary to comply with the Directive 2009/72/EC from the Third Package by 1 January 2015.

Directive 2009/72/EC mentions the quality as a term:

- Preamble (45) – in the context of universal service

  *Member States should ensure that household customers and, where Member States deem it appropriate, small enterprises, enjoy the right to be supplied with electricity of **a specified quality** at clearly comparable, transparent and reasonable prices.*

- Preamble (51) – in the context of strengthening consumer interests

  *Consumer interests should be at the heart of this Directive and **quality of service** should be a central responsibility of electricity undertakings. Existing rights of consumers need to be strengthened and guaranteed, and should include greater transparency. Consumer protection should ensure that all consumers in the wider remit of the Community benefit from a competitive market. Consumer rights should be enforced by Member States or, where a Member State has so provided, the regulatory authorities.*

- Preamble (61) – in the context of provision of information by regulatory authorities

  *Regulatory authorities should also provide information on the market to permit the Commission to exercise its role of observing and monitoring the internal market in electricity and its short, medium and long-term evolution, including aspects such as generation capacity, different sources of electricity generation, transmission and distribution infrastructure, **quality of service**, cross-border trade, congestion management, investments, wholesale and consumer prices, market liquidity and environmental and efficiency improvements.*

- Article 3 paragraph 2 – in the context of public service obligation

  *Having full regard to the relevant provisions of the Treaty, in particular Article 86 thereof, Member States may impose on undertakings operating in the electricity sector, in the general economic interest, public service obligations which may relate to security, including security of supply, regularity, **quality and price of supplies** and environmental protection, including energy efficiency, energy from renewable sources and climate protection. Such obligations shall be clearly defined, transparent, non-discriminatory, verifiable and shall guarantee equality of access for electricity undertakings of the Community to national consumers.*

- Article 3 paragraph 3 – in the context of universal service

  *Member States shall ensure that all household customers, and, where Member States deem it appropriate, small enterprises (namely enterprises with fewer than 50 occupied persons and an annual turnover or balance sheet not exceeding EUR 10 million), enjoy universal service, that is the right to be supplied with electricity of **a specified quality** within their territory at reasonable, easily and clearly comparable, transparent and non-discriminatory prices. To ensure the provision of universal service, Member States may appoint a supplier of last resort. Member States shall impose on distribution companies an obligation to connect customers to their network under terms, conditions and tariffs set in accordance with the procedure laid down in Article 37(6).*

- Article 4 – in the context of monitoring of security of supply

  *Member States shall ensure the monitoring of security of supply issues. Where Member States consider it appropriate, they may delegate that task to the regulatory authorities referred to in Article 35. Such monitoring shall, in particular, cover the balance of supply and demand on the national market, the level of expected future demand and envisaged additional capacity being planned or under construction, and **the quality and level of maintenance of the networks**, as well as measures to cover peak demand*

and to deal with shortfalls of one or more suppliers. The competent authorities shall publish every two years, by 31 July, a report outlining the findings resulting from the monitoring of those issues, as well as any measures taken or envisaged to address them and shall forward that report to the Commission forthwith.

- Article 37 paragraph 1 indent h – in the context of regulatory monitoring

The regulatory authority shall have the following duties:

h) *monitoring compliance with and reviewing the past performance of network security and reliability rules and setting or approving standards and requirements for **quality of service and supply** or contributing thereto together with other competent authorities;*

- Annex I – in the context of measures on consumer protection

… the measures referred to in Article 3 are to ensure that customers:

(a) *have a right to a contract with their electricity service provider that specifies*

- *the services provided, **the service quality levels offered**, as well as the time for the initial connection,*
- *any compensation and the refund arrangements which apply if **contracted service quality levels** are not met, including inaccurate and delayed billing.*

These provisions of Directive 2009/72/EC shall be transposed into national legislation of the Contracting Parties in a satisfactory manner.

2 EXPECTED LIFETIME OF TRANSMISSION OVERHEAD LINES AND CABLES

2.1 European and Global Experience

Transmission assets ageing process has significant impact on system operation and planning. Unreliable and older assets may jeopardize system reliability and security, while increasing transmission system operational costs [2]. Important issue for Transmission System Operators (TSOs) is to choose an optimal moment for assets revitalization or replacement, in order to ensure satisfactory level of system reliability and security. At the same time, overall revitalization or replacement costs should be reduced and optimized.

The problem of transmission assets revitalization has been recognized recently because of the large number of old transmission facilities worldwide [3]. Research activities related to this topic are usually connected with asset management, impact of old assets on power system reliability, diagnostic methods and assets expected lifetime estimations. There is no well defined and published methodology for transmission assets revitalization that will take into consideration assets condition and their importance within a power system.

Transmission assets expected lifetime is usually estimated observing a history of the same group of assets. In order to make satisfactory statistical estimation this group should be large enough. Number of assets failures is theoretically described with the well known bath-tube (Figure 1.4), but specific shape of this curve for each asset can not be determined in advance. Although impendency to a specific asset lifetime may be predicted using operational data and different field and laboratory tests, large groups of specific assets are usually observed, and approximate values for expected lifetime are defined for overhead lines, cables, transformers, bays, protection devices, telecommunication network, control systems etc.

Expected lifetime of high voltage (≥110 kV) overhead lines and transformers is estimated as follows [3]:

- ACSR conductors of overhead lines have expected lifetime of 54 years (normal environment) with standard deviation of 14 years, and 46±15 years for not normal environment,
- towers have expected lifetime of 63 years with standard deviation of 21 years,
- transformers expected lifetime is 42±8 years.

Differences in assets lifetime are caused by different influential factors like climate conditions, corrosion, wind, ice, pollution, construction and design, etc.

Expected lifetime of high-voltage cables could not be simply predicted due to:

- underground and submarine cables were constructed after overhead lines, so there are no accurate data about their last and ageing,
- due to technical reasons, cables are not revitalized or renewed, but completely replaced by new ones,
- accidental cables failures and damages are hardly predictable and should be removed immediately.

Table 2.1 Overhead lines expected lifetime [3]

Type	Voltage (kV)	Estimated average lifetime (years)	Standard deviation (years)	Differences due to
ACSR conductors Normal circumstances Unfavorable circumstances	 ≥110 ≥110	 54 46	 14 15	Climate conditions, environment, corrosion, greasiness, extension, mechanical fatigue, isolation deconstruction, wind, ice, pollution, quality of material, high temperature due to loadings, construction
Towers (steel)	≥110	63	21	Climate conditions, environment, corrosion, maintenance, poor galvanization, substructure failures, quality of concrete, connections steel/concrete

Cables loadings and their thermal stress have much greater influence on their condition and expected lifetime, then on overhead lines. The same is valid for stresses under unpredicted contingences and failures like short-circuit. Cable isolation is sensitive on ageing process, so its dielectric capabilities could be worsened. Major impact on a cable expected lifetime comes from environmental conditions across its laying route (ground, sea), type of laying and its construction. Some existing data give expected lifetime of oil cables up to 50 years.

It should be mentioned that some other research papers give different estimations of transmission lines and transformers lifetimes. It is clearly that experiences are different and dependent on specific circumstances. Generally, it may be said that lines and transformers older than 40 years may be considered as old.

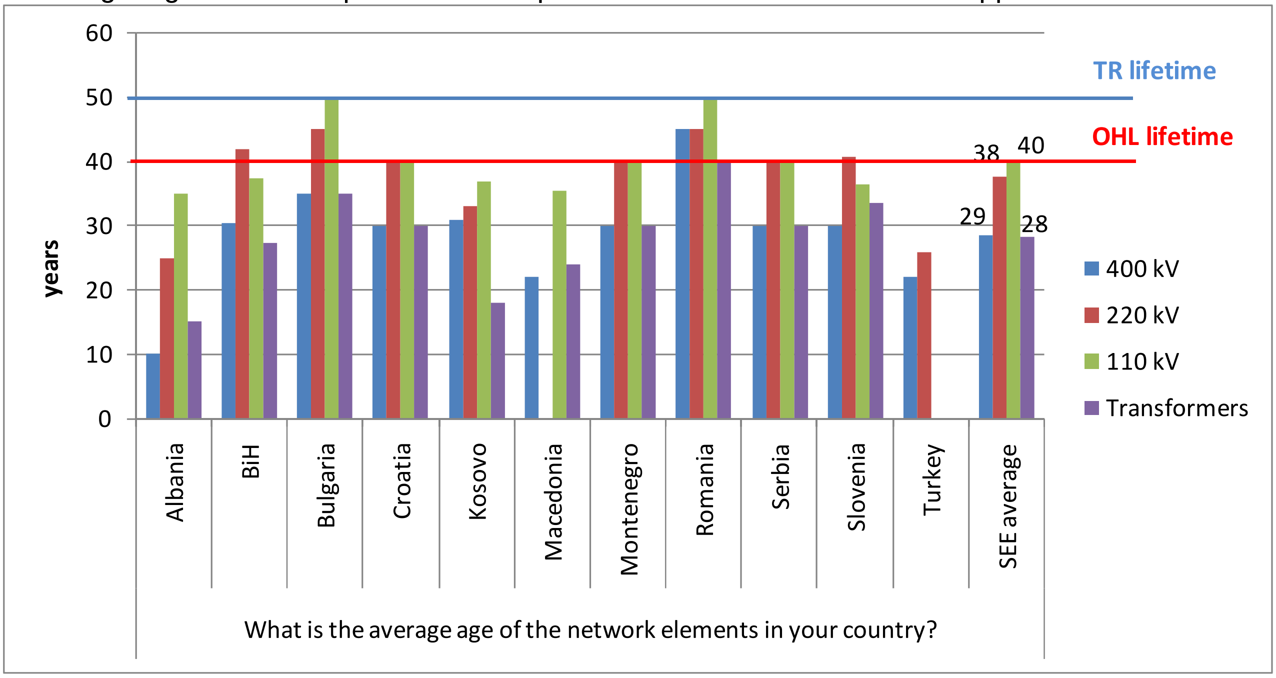
According to literature [3] other transmission equipment which operate above 110 kV voltage have expected lifetime as follows:

- circuit breakers
    - pneumatic 41±6 years
    - oil 41±6 years
    - SF_6 42±6 years
- breakers 42±8 years,
- current measuring transformers 39±7 years,
- voltage measuring transformers 39±7 years,
- electromechanical protection 32±9 years.

Having in mind previous estimations on transmission equipment expected lifetime, one may conclude that equipment constructed before 1970 is today at risk because of their age. This is general observation and may be wrong observing individual transmission facilities and units because their condition may be much better or much worse independently of their age, due to operational history, thermal and mechanical stress under operation, environmental condition, maintenance and revitalization activities etc. This means that some transmission assets put in operation before 1970 may be in a good shape, while other assets put in operation after 1970 may be deteriorated and unreliable. Exact condition of specific transmission asset may be estimated according to its statistic reliability data and/or by laboratory tests and diagnostics activities.

2.2 Regional Specifics

In order to estimate a need and interest for SEE Transmission system reliability analysis and to get deeper view into individual SEE TSO's concerns about network ageing, questionnaire was prepared and sent to all TSO's. All responses were received and answers were grouped into following diagrams. All responses to the questionnaire are included in the Appendix 1.



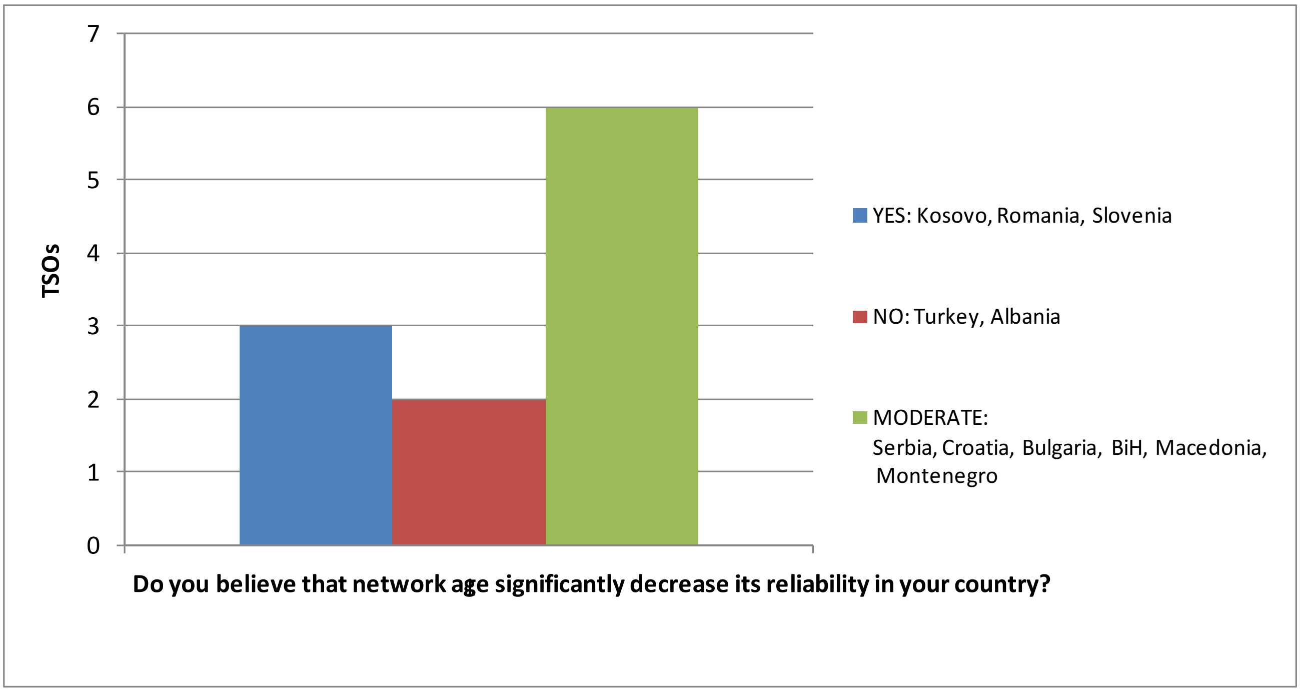
Observing average age of network assets (overhead lines and transformers) the worst situation appears in Romania and Bulgaria. In Romania average age of observed network elements exceed 40 years for all three transmission levels (400 kV – average age is around 45 years, 220 kV – average age is around 45 years, 110 kV – average age is more than 50 years). Network 110 kV belongs to Distribution System Operator in Romania. Romanian TSO representative stated that many transmission transformers were replaced in the recent past or will be replaced in the near future. In Bulgaria lines 220 kV and 110 kV have average age of 45 and 50 years, respectively, while lines 400 kV and transformers have average age of 35 years that is below critical expected age. Transmission elements having high average age are in Bosnia and Herzegovina (220 kV, 110 kV elements), Croatia (220 kV, 110 kV), Montenegro (220 kV, 110 kV), Serbia (220 kV, 110 kV) and Slovenia (220 kV, 110 kV) also. Average age of network in Albania, Kosovo, Macedonia and Turkey is significantly below critical value. Observing SEE region, average age of 400 kV lines is 29 years, average age of 220 kV lines is 38 years and average age of 110 kV lines is 40 years. High-voltage transformers have an average age of 28 years.

Observing from regional perspective, lines 400 kV in the SEE, as the most important infrastructure for market transactions and regional electricity market functionality, are still not jeopardized by their age, except in Romania as one of the largest SEE countries and extremely important area for different transactions between Romanian market participants, and other traders/production companies primarily in Bulgaria, west Ukraine, Hungary, Serbia and further.

Observing expected 400 kV overhead lines lifetime (42 years) next ten-year period may be "calm" in other countries except Romania, but individual older lines 400 kV in some countries may be at risk of high failure rates (number of outages).

Table 2.2 Average age of overhead lines and transformers in the SEE Transmission System

Country	Average age (years)			
	Overhead lines			Transformers
	400 kV	220 kV	110 kV	
Albania	10	25	35	15
Bosnia and Herzegovina	30	42	38	27
Bulgaria	35	45	50	35
Croatia	30	40	40	30
Kosovo	31	33	37	18
Macedonia	22	-	36	24
Montenegro	30	33	33	24
Romania	45	45	>50	40-45
Serbia	30	40	40	30
Slovenia	30	41	36	34
Turkey	22	26	-	-



Several TSO's believe that network age significantly decreases transmission system reliability in Kosovo, Romania and Slovenia. The majority of TSO's responded that this influence is moderate (Serbia, Croatia, Bulgaria, Bosnia and Herzegovina, Macedonia, Montenegro) and two TSO's in Albania and Turkey don't consider network age as a problem. These responses are in accordance with average network age in countries under their jurisdiction.

All SEE TSO's collect and analyze transmission reliability data, some of them less than five years (Bulgaria), some of them from 5 to 10 years (Bosnia and Herzegovina, Kosovo, Macedonia) and the others for more than 10 years.

Based on the answers about time period for which TSO's could provide statistic reliability data it was chosen than 3-years average will be applied in the SEE Reliability assessment study.

Criteria for network reconstruction and revitalization which are applied in different TSO's are shown in the following table. Almost all TSO's have network element ageing as one criterion for reconstruction or revitalization (except Albania). Many TSO's decide about revitalization activities due to network element present condition (except Albania and Bulgaria). Some TSO's major concern is supply interruption and some of them take care of network element reliability. Specific network element importance within the system is revitalization criterion in Romania, while security of supply is criterion in Slovenia.

Transmission network revitalization plan is influential to transmission system planning studies and their integral part in Turkey, Kosovo, Serbia, Croatia, Bosnia and Herzegovina, Montenegro, Slovenia, Romania and Bulgaria, while TSO in Macedonia (MEPSO) practices separate definition of revitalization and reinforcements plans, but with some impact on the planning studies.

Table 2.3 Criteria for network reconstruction and revitalization

Country	Criteria				
	Supply interruption	Network element ageing	Network element reliability	Present condition of network element	Other
Albania			+		
Bosnia and Herzegovina	+	+		+	
Bulgaria	+	+	+		
Croatia		+		+	
Kosovo		+	+	+	
Macedonia	+	+		+	
Montenegro	+	+		+	
Romania		+	+	+	+*
Serbia		+		+	
Slovenia	+	+	+	+	+**
Turkey	+	+		+	

* importance of the network element
** security of supply

Table 2.4 The most specific problems with network reliability in SEE transmission network

Country	Problem				
	Network ageing	Extreme climate conditions	Lack of maintenance	Lack of regulatory framework	Other
Albania		+			
Bosnia and Herzegovina	+				
Bulgaria	+				
Croatia	+	+			
Kosovo	+				
Macedonia	+	+			
Montenegro	+	+			
Romania	+				
Serbia	+				
Slovenia				+	+*
Turkey	+	+			

* complex legislation which require numbers of revisions, allowances, permits and approvals

Transmission network reliability studies are not common practice in SEE TSO's, but some of them have experience of that. Romanian TSO (TRANSELECTRICA) prepares every two years a Study for calculation of reliability indices for network developing plan – NDP (the results of the study are included in the NDP) and commercial relations.

The most specific problems related to and having some influence to the network reliability are network ageing and somewhere extreme climate conditions. Slovenia miss regulatory framework and has very complex administrative and environmental barriers to be more active in transmission network reinforcements and revitalizations.

2.3 Methodology for transmission units short-term unavailability estimation

Reliability of a network and its units (facilities, assets), and unavailability (q) as the most important reliability parameter, is dependent on the number of failures and their removal time. Failure type and its magnitude have a large impact on network reliability also. Outages and related unavailability may be divided according to a failure duration (short and long duration), and a cause of fault (forced and planned outages). We may distinguish two types of forced outages (q_f) according to their cause:

1) forced outages caused by internal failure, and
2) forced outages caused by external failure.

Forced outage may also be permanent or temporary. Permanent forced outage is caused by at least one component failure and unit may be put in operation only when the failure is removed. Temporary forced outage is the outage when a unit may be put in operation without repairing or replacing any component of a unit. Planned outage (q_p) is caused by intentional action so it may be controlled or scheduled. We may also distinguish two types of planned outages according to their cause:

1) planned outage caused by internal reason (scheduled activity on a specific unit), and
2) planned outage caused by external reason (scheduled activity on other unit).

A network unit age has certain influence on both types of outages (forced and planned) but only those with internal reasons (forced and planned outages with external reason occur no matter of a network unit age). External reasons for outages happen with the same probability to new and older transmission units. Number of forced outages caused by internal failures is increasing with a unit ageing, but also the number of planned outages caused by internal reasons because of activities on unit maintenance, faults removal, diagnostics, etc.

Estimation of future network units unavailability described below is based on data about network units forced and planned outages and their division according to the causes of failures (internal, external), having in mind that transmission unit reliability behaves according to the bath-tube curve. Transmission units and components outages may be treated as accidental events that are related to some probability function. Statistical group of network units may be defined, and following types of their outages (and related unavailability) are observed:

- permanent forced outages caused by an internal failure ($q_{f,in-per}$),
- temporary forced outages caused by an internal failure ($q_{f,in-temp}$),
- forced outages caused by an external failure ($q_{f,ext}$),
- planned outages caused by an internal reason ($q_{p,in}$),
- planned outages caused by an external reason ($q_{p,ext}$).

Transmission unit unavailability is the sum of all previously defined outages duration divided by the number of hours per year (1).

$$q = q_f + q_p = (q_{f,in-per} + q_{f,in-temp} + q_{f,ext}) + (q_{p,in} + q_{p,ext}) \tag{1}$$

Each outage type and related portion of unavailability may be described with a probability function $P(x)$, with continuous distribution based on some well-known theoretical probability distribution functions like normal distribution or Weibull distribution [4]. Parameters of these probability distribution functions like mean value and standard deviation may be determined from historical data that each TSO collects and usually publishes. Normal probability distribution is defined by these two parameters, and Weibull scale and shape parameters may be determined from mean value and standard deviation also [5].

Estimation of future network units unavailability could be made separately for units younger than 40 years and for units older than 40 years (this value may be differently defined if TSO estimates that younger units condition is not satisfactory).

For network units younger than 40 years it is estimated that future unavailability will be constant and equal to the mean value calculated over past 5-years or 10-years period.

$$q_f = \frac{1}{N} \cdot \sum_{n=1}^{N} q_{f,n} \qquad (2)$$

$$q_p = \frac{1}{N} \cdot \sum_{n=1}^{N} q_{p,n} \qquad (3)$$

Further division between different types of outages (internal, external reason) is not necessary to be performed for younger network units (<40 years) because network unit age is not influential for such failures.

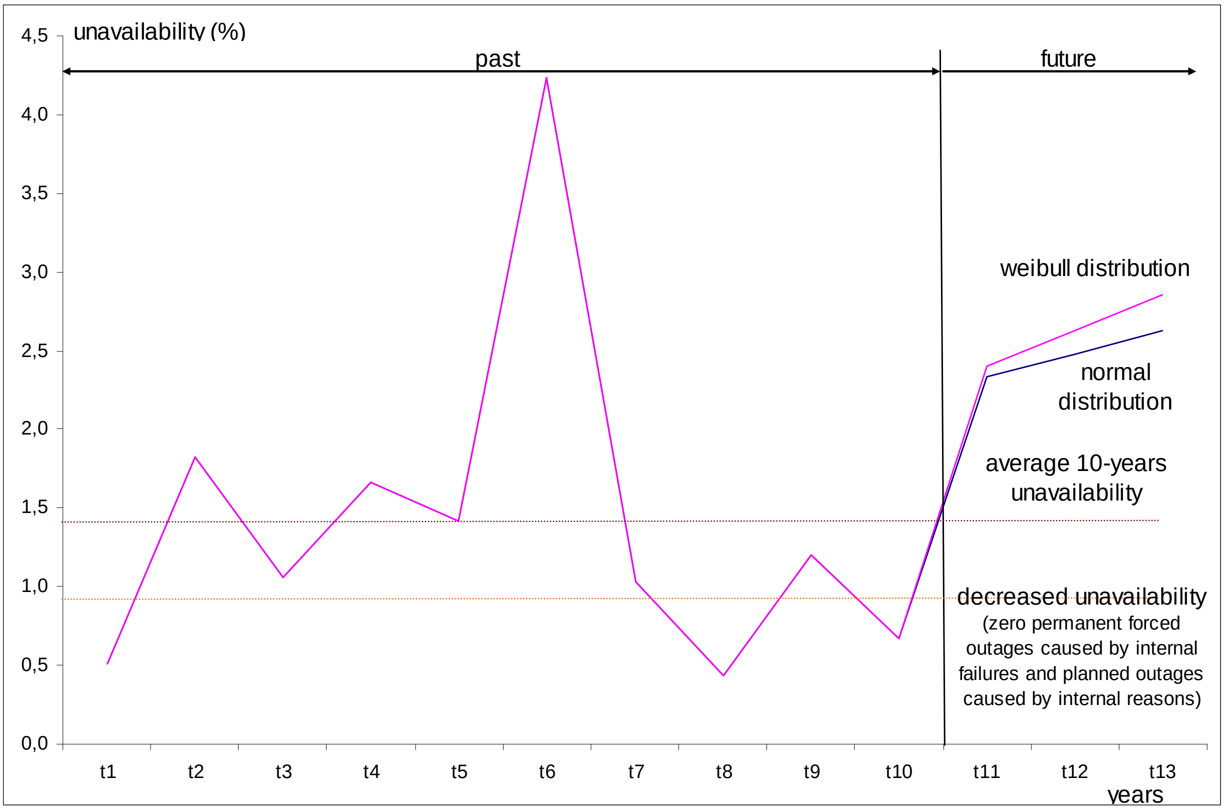


Figure 2.1 Example of a network unit (line, transformer) unavailability estimation

For the network units older than 40 years the following assumptions could be made:

- destruction of any network unit will not happen inside the observed future short-time period ($q <$ 100 %),

- network unit age has an impact on permanent forced outages caused by internal failures and planned outages caused by internal reasons only,
- temporary forced outages caused by internal failures, and forced and planned outages caused by external failures (reasons) are not dependent on a network unit age,
- unavailability portion because of the permanent forced outages caused by internal failures and unavailability portion because of the planned outages caused by internal reasons are described with probability distribution functions (normal or Weibull) separately,
- mean values and standard deviations for past 5-years or 10-years statistical data define parameters of probability distribution functions for each type of unavailability,
- future unavailability portion because of the permanent forced outages caused by internal failures and future unavailability portion because of the planned outages caused by internal reasons is determined using inverse probability distribution functions with the assumption that probability $P(x)$ is set to 0.95,
- unavailability portion because of the temporary forced outages caused by internal failures, and unavailability portions because of the forced and planned outages caused by external failures (reasons) are equal to the mean values for each unavailability portion group calculated over past 5-years or 10-years historical period.

Example of a network unit (line, transformer) future unavailability prediction, using two different probability distribution functions, is shown in the previous figure. Described procedure for future unavailability estimation is accurate enough only for short-time domain (up to 3 years).

The procedure gives increasing values of future unavailability (that is expected for older units), but it can not predict if some units will be permanently destroyed during observed time domain. Nevertheless, this simple procedure described above may be applied for the purpose of short-term future reliability analyses.

3 REGIONAL TRANSMISSION NETWORK

3.1 Current status

General description of the SEE region and SEE power system is given in Chapter 1. This Chapter gives more detailed description of SEE countries transmission systems with basic data about production capacities, electricity consumption, power balance and other relevant information.

The most important voltage level for existing and future market transactions in the SEE region is 400 kV. Network 400 kV is generally well developed and meshed, connecting the SEE region with central Europe (Italy, Austria, Hungary), southern Europe (Greece), west Ukraine and Turkey, and thus allowing large electricity/power flows in different directions (north-east, east-west, etc.).

SEE region in general may cover its demand of electricity (power plants installed power is greater than peak load in the region), but due to different reasons like hydrological dependency, old technology in thermal power plants or high production costs, the region is mostly net electricity importer. Exporting countries are Bulgaria, Romania and Bosnia and Herzegovina, while importing countries are Croatia, Montenegro, Kosovo, Albania, Macedonia and sometimes Serbia. Large consumption and importers areas are Italy at the west, Turkey at the east and Greece at the south, and large production areas like west Ukraine at the north-east, Germany, Czech republic and Poland at the north, surrounds the SEE region and expose its transmission infrastructure to significant load flows in different directions.

Indicative Net Transfer Capacities (NTC) for winter season 2010/2011 calculated by national TSO's and published by ENTSO-E are shown at the following figure. They show different possibilities for power trading across borders and possible limitations somewhere for market transactions which could be expected in the future.

Figure 3.1 SEE high voltage transmission grid

(Source ENTSO-E)

Figure 3.2 Indicative NTC values for winter 2010/2011 *(Source: ENTSO-E)*

3.1.1 Albania

Albania is situated in southern part of the SEE region, close to Montenegro, Kosovo, Macedonia and Greece. It has around 2,8 millions of inhabitants, with electricity consumption of 7,3 TWh.

Albanian Power Corporation KESH is the public owned company, obliged for electricity production and wholesale power supply. Electricity consumption consists of hydro power plants with total installed capacity of 1432 MW, situated in Drin, Mat and Bistrica river cascades. Four medium hydro power plants were separated from KESH with an intention to be privatized. Average hydro production in Albania is around 4,2 TWh covering 65 % of total electricity needs. Vlora thermal power plant (oil-fired) with installed capacity of 97 MW was commissioned in 2009. Several small diesel thermal power plants also exist.

Table 3.1 Albania – Basic power system data

Parameter	Value
Population 2011 (millions)	2,83
Area (km^2)	28.748
GDB/capita 2010 (USD)*	3.677
Electricity consumption 2011 (TWh)	7,342
Electricity generation 2011 (TWh)	4,158
Electricity import/export (TWh)**	-3,262
Installed capacity 2011 (MW)	1.659
Peak demand 2011 (MW)	1.400

* http://data.worldbank.org/indicator/NY.GDP.PCAP.CD
** (-) import, (+) export

The Albanian electricity market is based on a Power Sector Law which came into force on May 23 2003 (amended in June 2008), with the aim to restructure the Albanian Power Sector. The regulatory framework attempts to promote competition in electrical energy production and supply. Transmission System Operator OST was established, under regulation of Regulatory Authority ERE. Distribution System Operator was unbundled and privatized in 2009 by CEZ. A New Market Model (AMM) was adopted in March 2008 and technical rules were prepared by the Regulator, with the assistance of the Donor Community. The AMM stipulates that KESH Generation will provide ancillary services to the TSO and offer its remaining electricity to the Wholesale Public Supplier at a regulated tariff [6]. All consumers in Albania have the right to be eligible consumers from January 2010.

Albanian transmission system, operated by OST, have more than 2500 km of lines 400 kV (120,2 km), 220 kV (1128 kV), 150 kV (34,4 km) and 110 kV (1216,2 km). Transformations 400/x kV (220 kV, 110 kV) have installed capacity of 750 MVA (Elbasan 2, Zemblak), while transformations 220/110 kV have installed capacity of 2.126 MVA (Fierze, Koman, Vau Dejes, Burrel, Tirana, Sharre, Rrashbull, Elbasan 1, Fieri, Babice).

Albania is interconnected with Greece (400 kV line Zamblak - Kardia), Kosovo (Fierza-Prizren line 220 kV) and Montenegro (Elbasan – Tirana line 400 kV and Vau Dejes-Podgorica line 220 kV), with two 400 kV and two 220 kV lines supporting electricity imports up to 3,3 TWh.

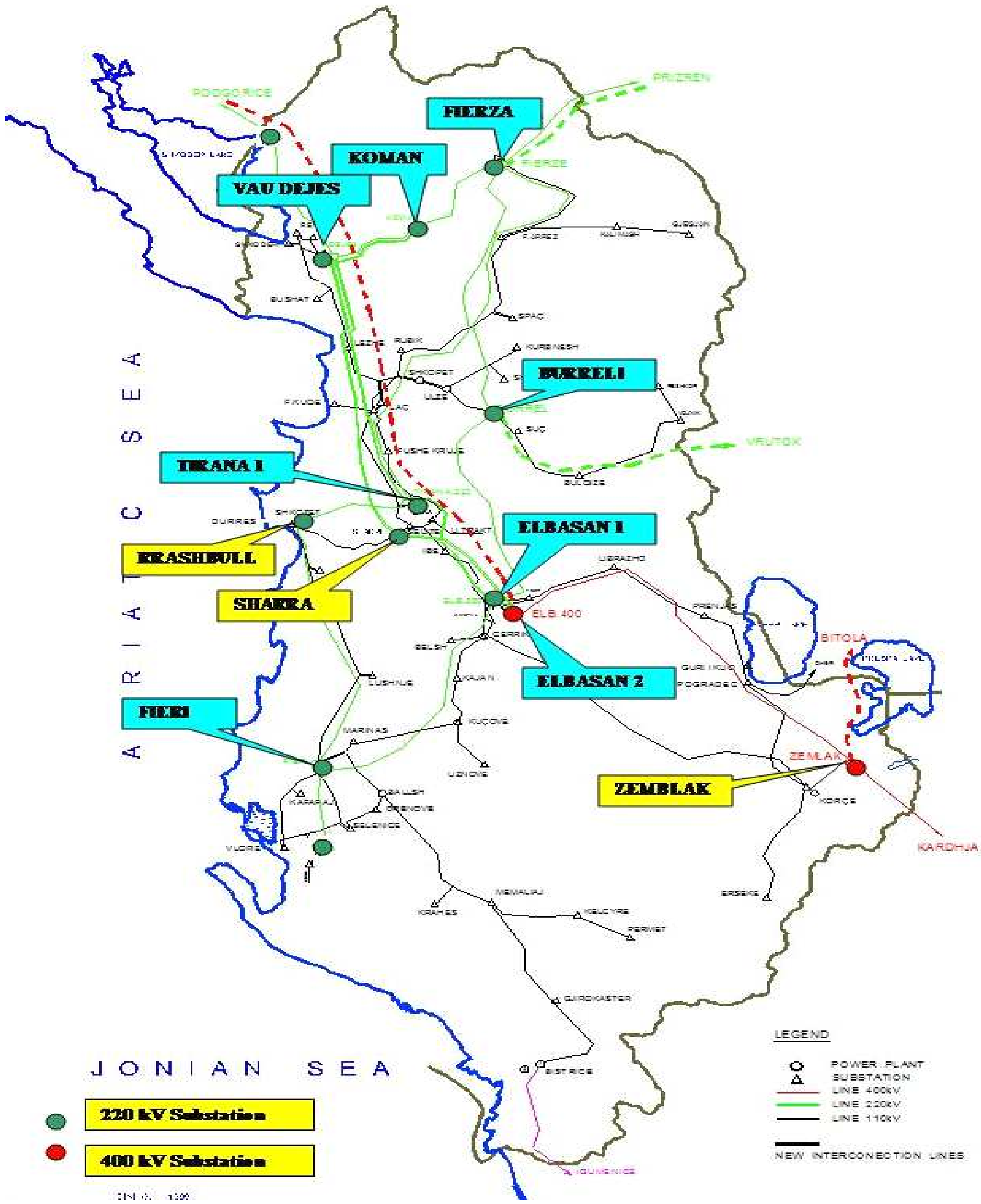


Figure 3.3 Transmission system of Albania

(Source OST)

* line 400 kV Elbasan 2 – Tirana 2 – Podgorica in operation (since November 2010)

3.1.2 Bosnia and Herzegovina

Bosnia and Herzegovina is situated in central part of the SEE region, surrounded by Croatia, Serbia and Montenegro. It has around 3,8 millions of inhabitants, with electricity consumption of around 12,2 TWh.

Table 3.2 Bosnia and Herzegovina – Basic power system data

Parameter	Value
Population 2011 (millions)	3,84
Area (km^2)	51.197
GDB/capita 2010 (USD)*	4.409
Electricity consumption 2011 (TWh)	12,204
Electricity generation 2011 (TWh)	13,695
Electricity import/export (TWh)**	1,491
Installed capacity 2011 (MW)	3.536,2
Peak demand 2011 (MW)	2.150

* http://data.worldbank.org/indicator/NY.GDP.PCAP.CD
** (-) import, (+) export

Figure 3.4 Transmission system of Bosnia and Herzegovina

(Source NOS BIH)

There are three production companies in BiH (EP BiH, EP RS, EP HZHB) supplying tariff consumers and eligible consumers and operating distribution network as well. Electricity is produced by thermal and hydro power plants, with usual share of 60 % in TPPs and 40 % in HPPs. Bosnia and Herzegovina exports electricity at the wholesale market in an annual amount up to 3,7 TWh.

Electricity transmission is organized through three companies, Elektroprijenos BiH owns and operates transmission assets, NOS BiH is responsible for system control while Regulatory Authority DERK regulates transmission business.

Transmission network consists of lines 400 kV (865 km), 220 kV (1525 km) and 110 kV (3919 km), together with 9 transformer stations 400/x kV, 8 transformers stations 220/110 kV and 127 transformer stations 110/x kV. Installed capacity in SS 400/x kV is 4900 MVA, in SS 220/110 kV 2100 MVA, while installed capacity in SS 110/x kV is 5204 MVA. There are four interconnection lines 400 kV with the neighbouring countries, in the direction of Croatia (two lines), Serbia (one line) and Montenegro (one line), ten interconnection lines 220 kV (seven to Croatia, one to Serbia and two to Montenegro), and 22 interconnection lines 110 kV (mostly to Croatia).

Bosnia and Herzegovina is electricity exporter, mainly because of large domestic lignite reserves in Tuzla, Kakanj, Ugljevik and Gacko regions. Annual export vary due to market prices and hydrological situation, ranging from 0,6 TWh to 3,7 GWh observing time period 2002 – 2011.

3.1.3 Bulgaria

Bulgaria is situated in eastern part of the SEE region, surrounded by Romania, Serbia, Macedonia, Greece and Turkey. It has around 7,6 millions of inhabitants, with electricity consumption of around 38 TWh, which makes Bulgaria one of the highest electricity consumption countries in Southeast Europe.

Generation capacities in Bulgaria consist of thermal, nuclear and hydro power plants with total installed capacity of 12668 MW. Significant wind resources have been developed, and in the process of development. Electricity is produced usually by thermal power plants (53 %), nuclear power plants (34 %), hydro power plants (9 %) and other renewable sources (4 %).

Table 3.3 Bulgaria – Basic power system data

Parameter	Value
Population 2011 (millions)	7,56
Area (km^2)	110.910
GDB/capita 2010 (USD)*	6.333
Electricity consumption 2010 (TWh)	37,506
Electricity generation 2011 (TWh)	44,76
Electricity import/export (TWh)**	10,5
Installed capacity 2011 (MW)	10.522
Peak demand 2011 (MW)	6.897

* http://data.worldbank.org/indicator/NY.GDP.PCAP.CD
** (-) import, (+) export

There are 82 generation licenses issued in Bulgaria, four regional distribution/supply licenses and 102 electricity trading licenses issued by the State Energy and Water Regulatory Commission. There is one Transmission Company, named NEK, which still owns hydro power plants but has to separate them this year.

In 2010 the electricity transmitted through the transmission grid of the country totally amounted to 41,57 mln MWh. In 2010 there were 2451 km of lines 400 kV, 2805 km of lines 220 kV and 9957 km of lines 110 kV. There are 32 HV/HV substations with total transformer capacity of 15.888 MVA and 257 HV/MV substations with total transformer capacity of 15.243 MVA, together with one 400 kV and one 110 kV switching substation.

Bulgaria is very well connected with neighboring transmission systems by nine lines 400 kV and four lines 110 kV. Connection with Romania is established by Kozloduy NPP – Tintareni double circuit line 400 kV, Varna – Isaccea and Dobrudza – Isaccea single circuit lines 400 kV, connection with Serbia is established with 400 kV line Sofia West – Nis and two lines 110 kV, connection with Macedonia is established by Cervena Mogila – Stip line 400 kV and two lines 110 kV, while connection with Greece and Turkey is established by one line 400 kV (Blagoevgrad – Thessaloniki) to Greece and two to Turkey (Maritza East 3 TPP – Babaeski and Maritza East 3 TPP – Hamitabat GPP). Bulgarian electricity export in 2010 was mainly conducted through Bulgarian-Greek border (2,5 TWh, 49 % of total annual export), Bulgarian-Serbian border (1,6 TWh, 30 % of total annual export) and Bulgarian-Macedonian border (0,85 TWh, 17 % of total annual export).

Figure 3.5 Transmission system of Bulgaria

(Source NEK)

3.1.4 Croatia

Croatia is situated in western part of the SEE region, surrounded by Slovenia, Italy, Hungary, Serbia, Bosnia and Herzegovina and Montenegro. It has around 4,3 millions of inhabitants, with electricity consumption of around 18 TWh.

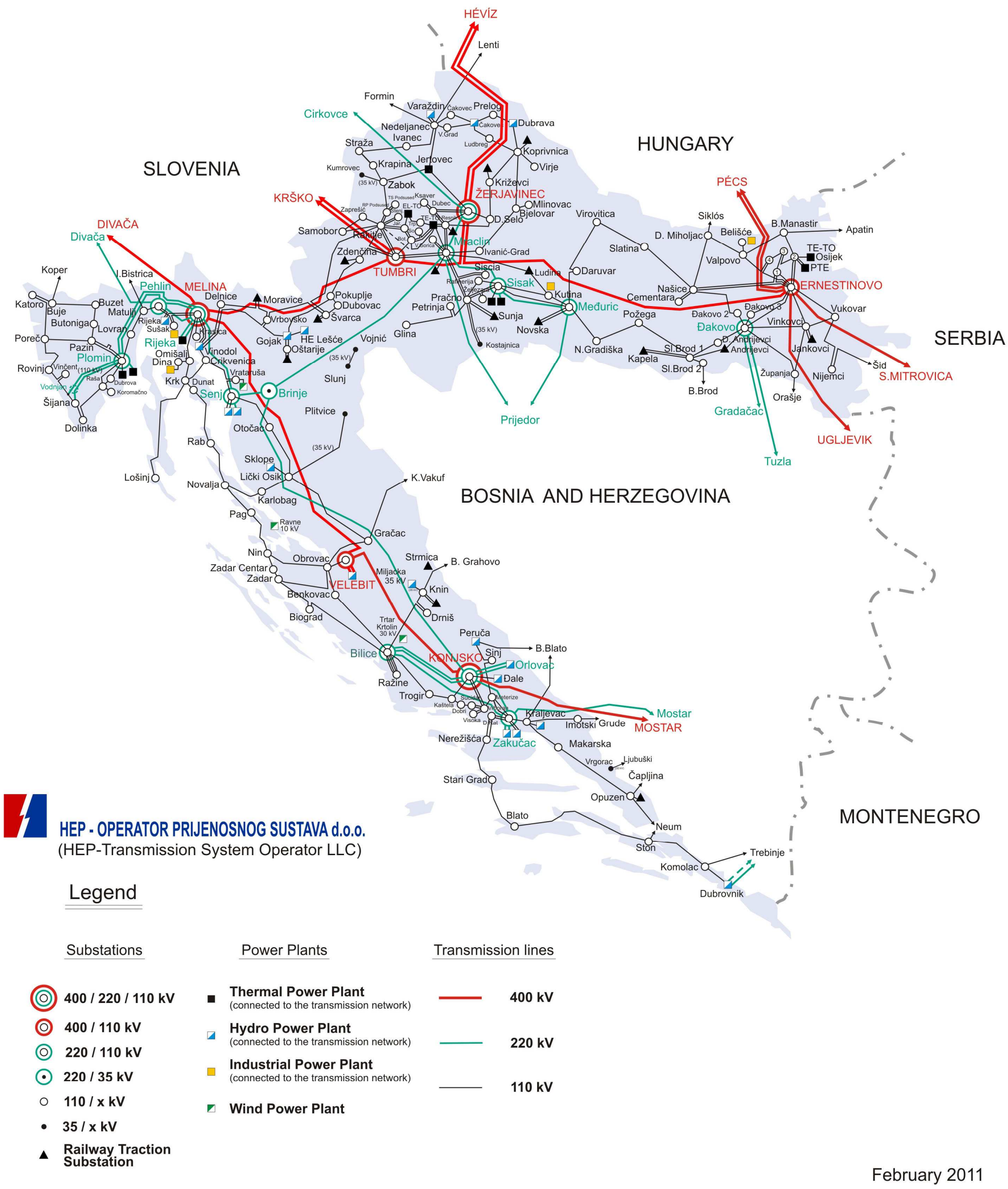


Figure 3.6 Transmission system of Croatia

(Source HEP OPS)

Croatian production facilities comprise thermal, hydro and wind power plants. Thermal and hydro sources are ownership of HEP, while wind power plants are private companies. Due to large variations in annual hydro production and high production costs from several domestic thermal power plants, Croatia is one of the highest electricity importers in the SEE region. Electricity is imported from Slovenia where Croatian power supply company HEP owns half of Krsko NPP, and from the wholesale market. Annual electricity imports are usually higher than 4,5 TWh, including electricity produced by Krsko NPP.

Table 3.4 Croatia – Basic power system data

Parameter	Value
Population 2011 (millions)	4,29
Area (km^2)	56.594
GDB/capita 2010 (USD)*	13.774
Electricity consumption 2011 (TWh)	17,703
Electricity generation 2011 (TWh)	10,00
Electricity import/export (TWh)**	-7,7
Installed capacity 2011 (MW)	4.268
Peak demand 2011 (MW)	2.970

* http://data.worldbank.org/indicator/NY.GDP.PCAP.CD
** (-) import, (+) export

Transmission System Operator named HEP OPS is organized within the HEP Group, but unbundled and regulated by the Regulatory Authority HERA. Transmission network consists of lines 400 kV, 220 kV and 110 kV of total length of 7437 km. There are five substations 400/x kV with installed capacity of 4100 MVA, six SS 220/x kV with installed capacity of 2120 MVA, and 118 substations 110/x kV with installed capacity of 4900 MVA.

Croatian transmission network is very well connected with Slovenian, Hungarian, Bosnian and Serbian transmission networks with seven 400 kV lines (two lines 400 kV to Hungary are double-circuit lines, while other interconnection lines are single-circuits), nine lines 220 kV and numerous 110 kV lines. This makes Croatian transmission network highly important path for electricity transits especially from east-west and north-west direction toward Italy.

3.1.5 Kosovo

Kosovo is situated in central part of the SEE region, surrounded by Albania, Serbia, Montenegro and Macedonia. It has around 1,8 millions of inhabitants, with electricity consumption of around 5,5 TWh.

Table 3.5 Kosovo – Basic power system data

Parameter	Value
Population 2011 (millions)	1,8
Area (km^2)	10.887
GDB/capita 2010 (USD)*	3.059
Electricity consumption 2010 (TWh)	5,506
Electricity generation 2010 (TWh)	5,037
Electricity import/export (TWh)**	-0,466
Installed capacity 2010 (MW)	1.171***
Peak demand 2011 (MW)	1.158

* http://data.worldbank.org/indicator/NY.GDP.PCAP.CD
** (-) import, (+) export
*** net capacity

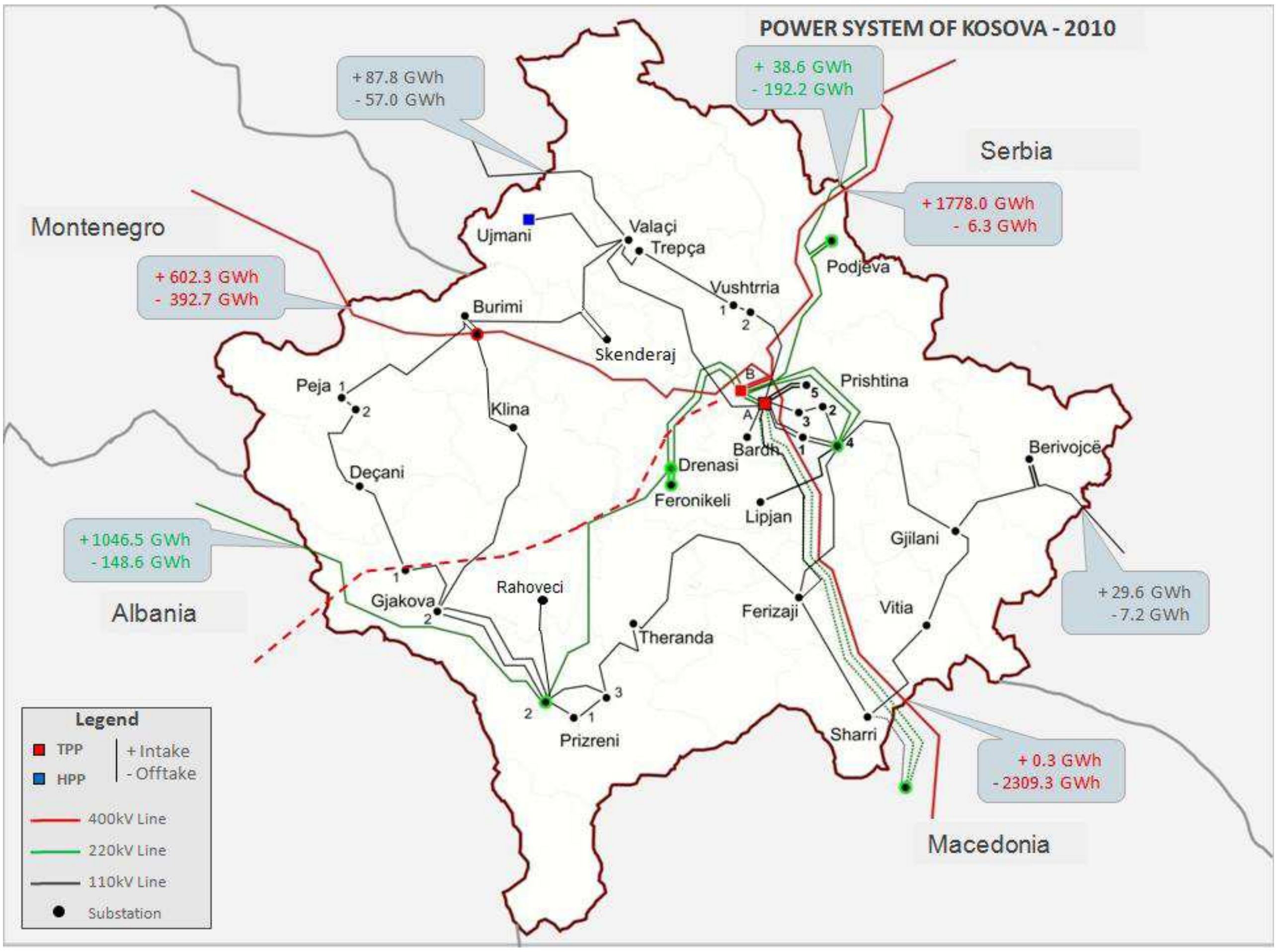


Figure 3.7 Transmission system of Kosovo

(Source ERO)

The Transmission System and Market Operator (KOSTT) and Distribution System Operator (KEK) hold licenses for the operation, maintenance and security of electricity supply in Kosova. ERO (Energy Regulatory Office) has also licensed Public Supplier (KEK), which is responsible for supplying electricity to customers in the entire territory of Kosovo.

Two thermal power plants, TPP Kosova A and TPP Kosova B, which use lignite as fuel, make over 97% of the total electricity production in Kosovo. Power production company named KEK owns production facilities. Hydro Power Plant Ujmani (35 MW), managed by the public enterprise Iber-Lepenci, and four small hydro power plants, which were given to private investors in concession, are operating. Due to large thermal base production and demand variability, Kosovo misses variable energy and appropriate power system ancillary services, which makes power system control hard to conduct [9].

The interconnection of the Kosovo transmission network with the region is mainly carried out through 400 kV voltage level lines (two of them, towards Serbia and Montenegro). Kosovo is also interconnected with neighboring countries through 220 kV and 110 kV lines (Albania, Serbia, Macedonia). Lack of investment for a long time in the transmission and distribution network has caused congestions and insufficient supply in many parts of the network. In recent years, investments have been made which have greatly improved the operation of the power system.

3.1.6 Macedonia

Macedonia is situated in south-eastern part of the SEE region, surrounded by Kosovo, Serbia, Bulgaria, Greece and Albania. It has around 2,1 millions of inhabitants, with electricity consumption of around 7,6 TWh.

Table 3.6 Macedonia – Basic power system data

Parameter	Value
Population 2011 (millions)	2,06
Area (km^2)	25.333
GDB/capita 2010 (USD)*	4.461
Electricity consumption 2011 (TWh)	7,616
Electricity generation 2011 (TWh)	6,288
Electricity import/export (TWh)**	-2,749
Installed capacity 2011 (MW)	1.896
Peak demand 2010 (MW)	1.642

* http://data.worldbank.org/indicator/NY.GDP.PCAP.CD
** (-) import, (+) export

Figure 3.8 Transmission system of Macedonia

(Source MEPSO)

The former national power utility Elektrostopanstvo na Makedonija (ESM) has been split in separate companies for generation and distribution: AD ESM is the distribution company which also owns 11 mini and small hydro power plants with a total capacity of 31 MW, ELEM is the largest generation company, TEC Negotino is a one-plant generation company and MEPSO is the owner of high voltage transmission grid.

Macedonian production facilities comprise thermal power plants (1010 MW of installed capacity), hydro power plants (566,8 MW), small hydro power plants (30,9 MW), CHP (287 MW_e) and PV (1,31 MW). The largest production facility is the lignite-fired Bitola complex with 3 units of 225 MW each and net production of about 1,434 GWh per unit. Peak demand is met by hydropower, which includes pumped storage, run of river and small hydroelectric plants.

Macedonia is net importer of electricity due to variable hydrological situations and old technology in existing thermal power plants. Macedonian transmission network with lines 400 kV, 220 kV and 110 kV is interconnected with Serbian, Bulgarian and Greek power systems on 400 kV voltage level, so lines 400 kV are exposed to significant transits from Bulgaria-Greece, Serbia-Greece and Bulgaria – Serbia electricity transits.

3.1.7 Montenegro

Montenegro is situated in southern part of SEE region, surrounded by Bosnia and Herzegovina, Kosovo, Serbia, Albania and Croatia. It has around 0,65 millions of inhabitants, with electricity consumption of around 3,7 TWh.

Table 3.7 Montenegro – Basic power system data

Parameter	Value
Population 2011 (millions)	0,645
Area (km^2)	13.812
GDB/capita 2010 (USD)*	6.505
Electricity consumption 2011 (TWh)	3,720
Electricity generation 2011 (TWh)	2,679
Electricity import/export (TWh)**	-1,050
Installed capacity 2011 (MW)	827
Peak demand 2009 (MW)	703

* http://data.worldbank.org/indicator/NY.GDP.PCAP.CD
** (-) import, (+) export

Former vertically integrated company EPCG was separated and founded a completely independent Transmission Company CGES. CGES was issued two licenses: The license for transmission network, the license for TSO. The Italian company TERNA owns around 22% of the CGES shares.

Power production and supply company has three power plants (one thermal and two hydro) with total installed capacity of 827 MW that is not enough to cover domestic electricity demand, so electricity has to be imported from the market (usually around 1 TWh/year). One HPP (Piva HPP) is operated by Serbian power production and supply company (EPS) due to mutually signed agreement (Serbia provide base power to Montenegro, while EPS uses Piva HPP to cover peak demand). Montenegro has one large electricity consumer, Aluminum factory KAP that consumes one third of overall electricity demand in Montenegro.

Transmission network 400 kV, 220 kV and 110 kV is vulnerable because of its structure (parallel operation of 400 kV and 220 kV lines, large imports, significant power transits etc), while network 110 kV is under-designed in some areas (like coastal part).

Montenegro is interconnected to Kosovo (one line 400 kV), Bosnia and Herzegovina (one line 400 kV, two lines 220 kV), Albania (one line 400 kV, one line 220 kV) and Serbia (two lines 220 kV). Montenegrin network stands between important transit path of electricity from Bulgaria and Serbia to Albania.

Figure 3.9 Transmission system of Montenegro

(Source CGES)

3.1.8 Romania

Romania is situated in eastern part of the SEE region, surrounded by Ukraine, Hungary, Serbia, Bulgaria and Moldova. It has around 21,4 millions of inhabitants, with electricity consumption of around 57 TWh.

Table 3.8 Romania – Basic power system data

Parameter	Value
Population 2011 (millions)	21.4
Area (km^2)	237.500
GDB/capita 2010 (USD)*	7.539
Electricity consumption 2011 (TWh)	55,64
Electricity generation 2011 (TWh)	60,39
Electricity import/export (TWh)**	1,9
Installed capacity 2011 (MW)	9.328
Peak demand 2011 (MW)	8.876

* http://data.worldbank.org/indicator/NY.GDP.PCAP.CD
** (-) import, (+) export

Annual production and consumption places Romania as the biggest SEE country and important part for transmission regional system and market activities in the region.

Electricity production is organized in three state owned companies, Termoelectrica, Nuclearelectrica and Hydroelectrica. There are two nuclear reactors, Cernavoda 1 and 2, with installed capacity of 1310 MW, generating 20 % of domestic electricity demand. The most important primary source in thermal power plants is coal (40 % of produced electricity), while hydro power plants generate around 26 % of total generation.

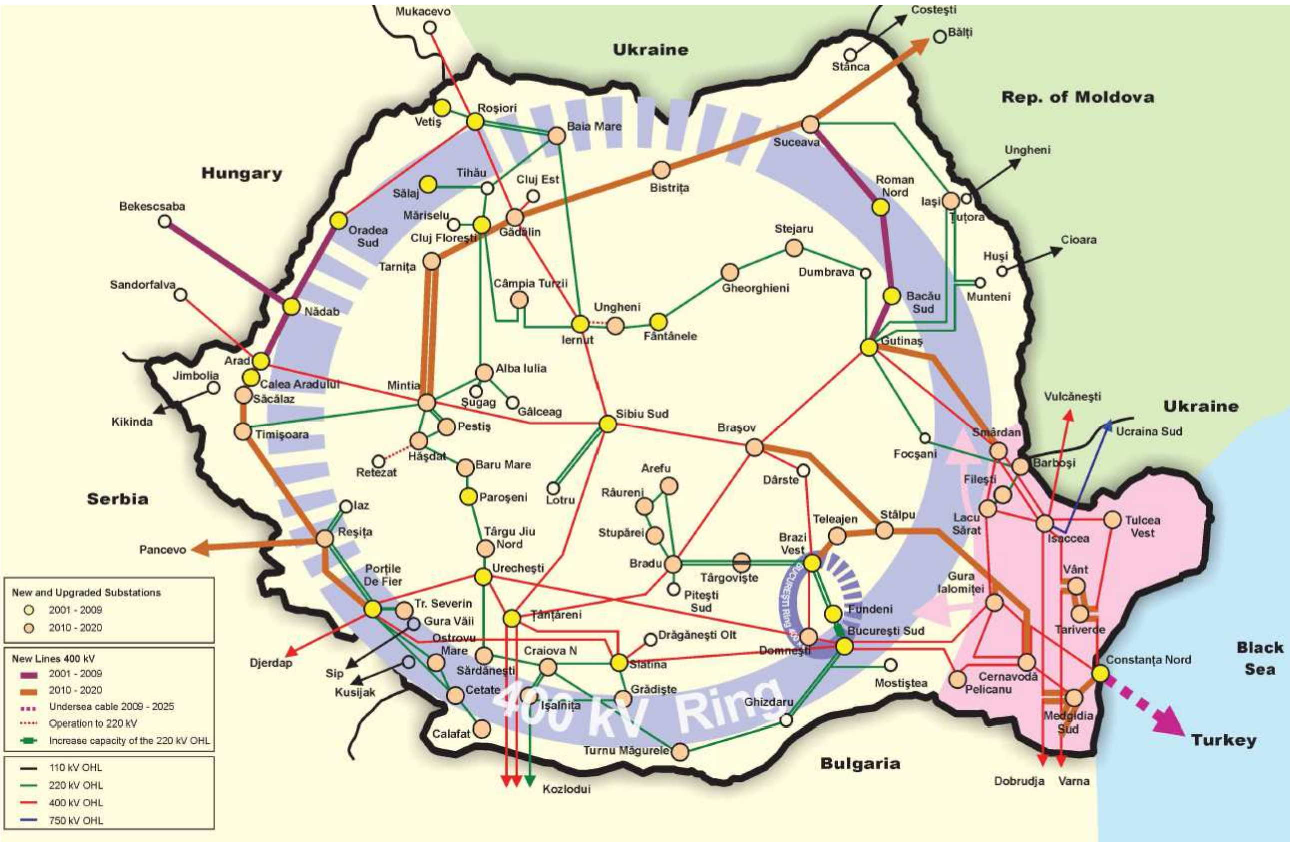


Figure 3.10 Transmission system of Romania

(Source Transelectrica)

Transelectrica is the Romanian Transmission and System Operator (TSO) which plays a key role in the Romanian electricity market. Transelectrica, through its subsidiary OPCOM, also operates the electricity trading market. Energy regulatory authority ANRE regulates electricity, heat and natural gas. The main components of the wholesale electricity market are a bilateral contracts market, a voluntary power exchange (day-ahead market- DAM) and a balancing market.

The amount of installations managed by Transelectrica SA consists of 79 substations (one 750 kV substation, 36 substations at 400 kV, 42 substations at 220 kV) and 8931.6 km of overhead power lines (154.6 km at 750 kV, 4703.7 km at 400 kV, 4035.2 km at 220 kV and 38 km at 110 kV). Installed capacity in substations managed by Transelectrica is 37,565 MVA (218 main transformer units).

Romania is interconnected with neighboring countries by eight 400 kV lines (one double-circuit line and two single-circuit line to Bulgaria, two lines to Hungary, one line to Moldova, Ukraine and Serbia) and one 220 kV line to Bulgaria. Romania is moderate electricity exporter nowadays (exports around 3 TWh/year), but with ambitious plan to increase its export in the near future.

3.1.9 Serbia

Serbia is situated in central part of SEE region, surrounded by Romania, Croatia, Hungary, Macedonia, Bosnia and Herzegovina, Kosovo (Serbia doesn't recognize Kosovo as independent state, considers its future status to be a subject of negotiations) and Montenegro. It has around 7,3 millions of inhabitants, with electricity consumption of around 34 TWh.

Table 3.9 Serbia – Basic power system data

Parameter	Value
Population 2011 (millions)	7.3
Area (km^2)	77.474
GDB/capita 2010 (USD)*	5.270
Electricity consumption 2010 (TWh)	34,073
Electricity generation 2010 (TWh)	35,855
Electricity import/export (TWh)**	0,297
Installed capacity 2011 (MW)	7.124
Peak demand 2011 (MW)	6.372

* http://data.worldbank.org/indicator/NY.GDP.PCAP.CD
** (-) import, (+) export

Power production and supply company, EPS, owns six thermal power plants with installed net capacity of 3936 MW, three combined heat and electricity production power plants with installed net capacity of 353 MW, and 12 hydro power plants of installed capacity of 2835 MW. Coal-fired power plants use domestic lignite. Serbia is self balanced country, or small electricity importer or exporter.

Transmission system operator EMS owns 8.989 km of 400 kV, 220 kV and 110 kV lines. Network 400 kV is 1494 km long. There are 17 SS 400/x kV, 17 substations 220/x kV and 61 substations 110/x kV.

Serbia is interconnected with neighboring power systems of Hungary (one line 400 kV), Croatia (one line 400 kV), Bosnia and Herzegovina (one line 400 kV, one line 220 kV), Montenegro (two lines 220 kV), Kosovo (one line 400 kV and one line 220 kV), Bulgaria (one line 400 kV) and

Romania (one line 400 kV). These lines, together with well-meshed internal 400 kV network, make Serbia very important country for electricity transits from east-west and north-south directions.

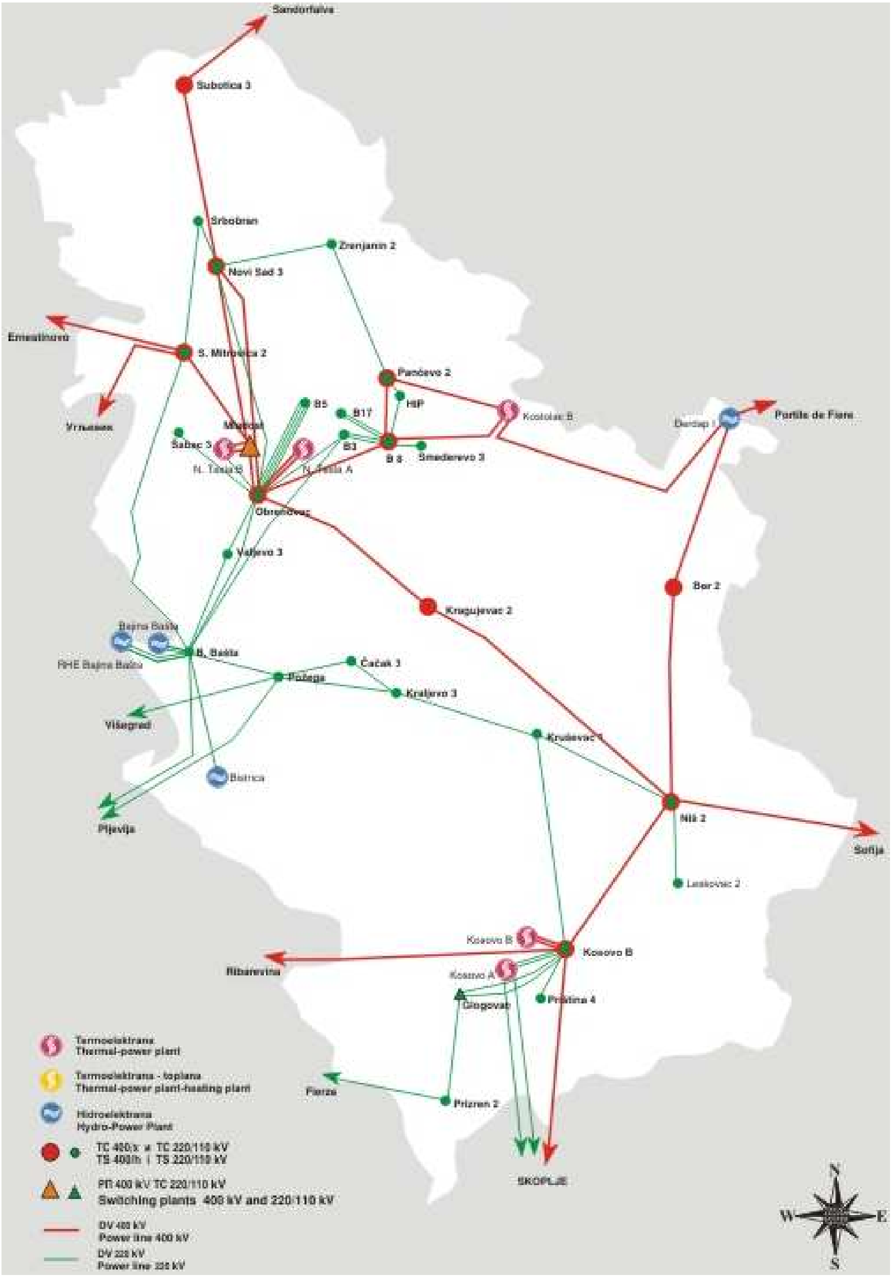


Figure 3.11 Transmission system of Serbia

(Source EMS)

3.1.10 Slovenia

Slovenia is situated in north-western part of the SEE region, surrounded by Italy, Hungary, Austria and Croatia. It has around 2,1 millions of inhabitants, with electricity consumption of around 12,1 TWh.

Table 3.10 Slovenia – Basic power system data

Parameter	Value
Population 2011 (millions)	2.05
Area (km^2)	20.273
GDB/capita 2010 (USD)*	22.893
Electricity consumption 2011 (TWh)	12,088
Electricity generation 2010 (TWh)**	14,526
Electricity import/export (TWh)**	0,267
Installed capacity 2011 (MW)	3.282
Peak demand 2010 (MW)	1.940

* http://data.worldbank.org/indicator/NY.GDP.PCAP.CD
** 100 % of Krsko NPP included (50 % belongs to Slovenia)
** (-) import, (+) export

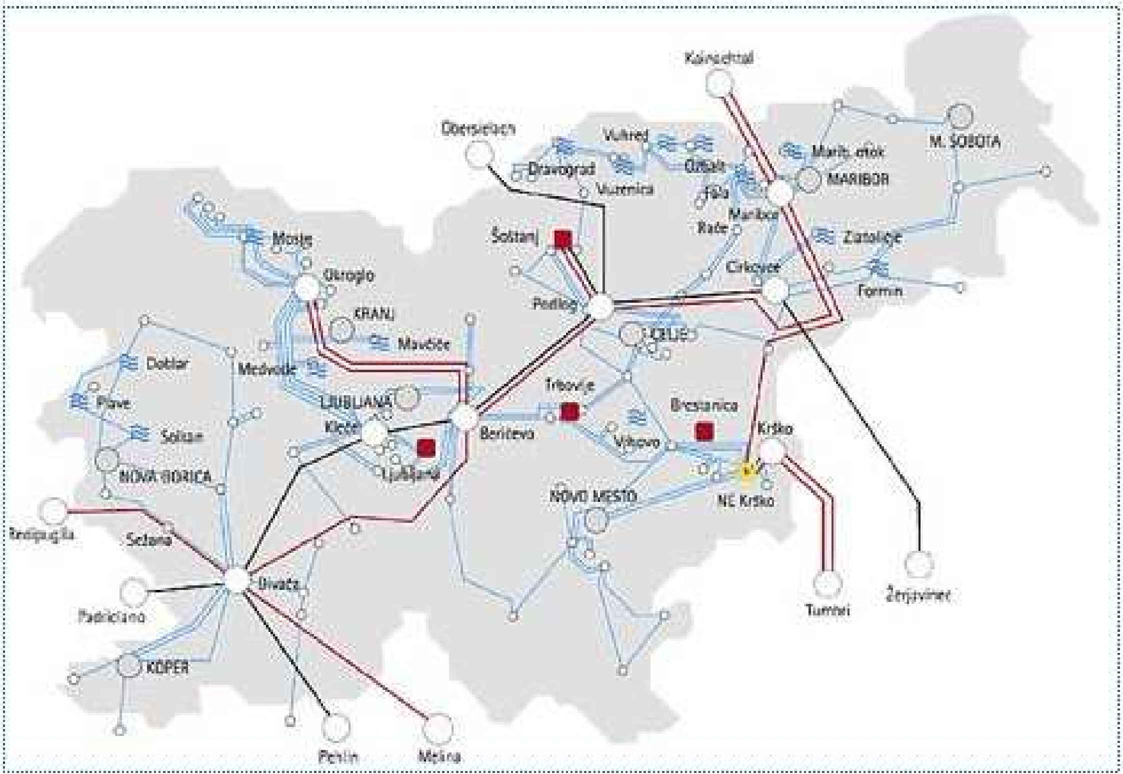


Figure 3.12 Transmission system of Slovenia

(Source ELES)

Electricity in Slovenia is produced from Krsko NPP that covers around 40 % of domestic demand, hydro power plants (Drava, Sava and Soca rivers) and several thermal power plants (Sostanj, Trbovlje, Ljubljana, Brestanica). Larger consumers are ironworks (Store, Ravne, Jesenice), industrial facilities (Ruse) and aluminum plant (Kidricevo).

Slovenian transmission system operator ELES owns facilities on three different voltage levels: 400 kV, 220 kV and 110 kV. Transmission network is used for the transmission of electricity from larger power plants, as well as the nuclear power plant, to the distribution networks and operators and immediate customers on the high-voltage network. Slovenia's transmission network is also used for the transmission of electricity between the electric power systems of neighboring countries, especially towards Italy (from the direction of Austria and Croatia). Large power flows to Italy in the past decreased security of supply in Slovenia and caused large transmission losses, so ELES commissioned phase shift transformer 2x600 MVA, 400 kV, in the Divaca substation.

Slovenian transmission network encompasses 1736 km of 110 kV transmission lines and 8 pertaining transformers, 328 km of 220 kV transmission lines and 10 pertaining transformers and 508 km of 400 kV transmission lines and 9 pertaining transformers. The combined system length of all transmission lines is 2.572 km and the aggregate power of all transformers is 4,768 MVA [10].

Slovenian transmission network is connected with the networks in three neighboring states. One 220 kV transmission line and two 400 kV lines link Slovenia with Austria; one 400 kV and one 220 kV lines link it with Italy, whereas three 400 kV, two 220 kV and three 110 kV transmission lines traverse the Croatian border. Currently, there is no power connection between Slovenia and Hungary.

3.1.11 Turkey

Turkey is large country and huge electricity consumption area placed at the east edge of the SEE Europe. It is bigger than the SEE region, with almost 75 millions of inhabitants, with electricity consumption of around 228 TWh.

Table 3.11 Turkey – Basic power system data

Parameter	Value
Population 2011 (millions)	74.7
Area (km^2)	783.562
GDB/capita 2010 (USD)*	10.094
Electricity consumption 2011 (TWh)	228
Electricity generation 2011 (TWh)	229,3
Electricity import/export (TWh)**	0,914
Installed capacity 2011 (MW)	53.235
Peak demand 2010 (MW)	33.392

* http://data.worldbank.org/indicator/NY.GDP.PCAP.CD
** (-) import, (+) export

Electricity in Turkey is produced from thermal power plants (64 % of total installed capacity and 74 % of total generation in 2011), hydro power plants and other renewable resources like wind and PV (36 % of total installed capacity and 26 % of total generation in 2011). Turkey is still able to cover its demand, but different values of electricity exports/imports are possible with the SEE region after Turkey joined ENTSO-E organization.

Electricity consumption and load growth rate in Turkey are extremely high, so new generation facilities and transmission infrastructures have to be constructed constantly.

Turkish transmission network operates under 400 kV, 220 kV, 154 kV and 66 kV voltage levels. It has 15.830 km of lines 400 kV and 78 substations 400/x kV, 85 km of lines 220 kV and two substations 220/x kV, as well as 32.513 km of lines 154 kV and 520 substations 154/x kV. Turkish transmission network also have 220 km of 400 kV and 154 km cables.

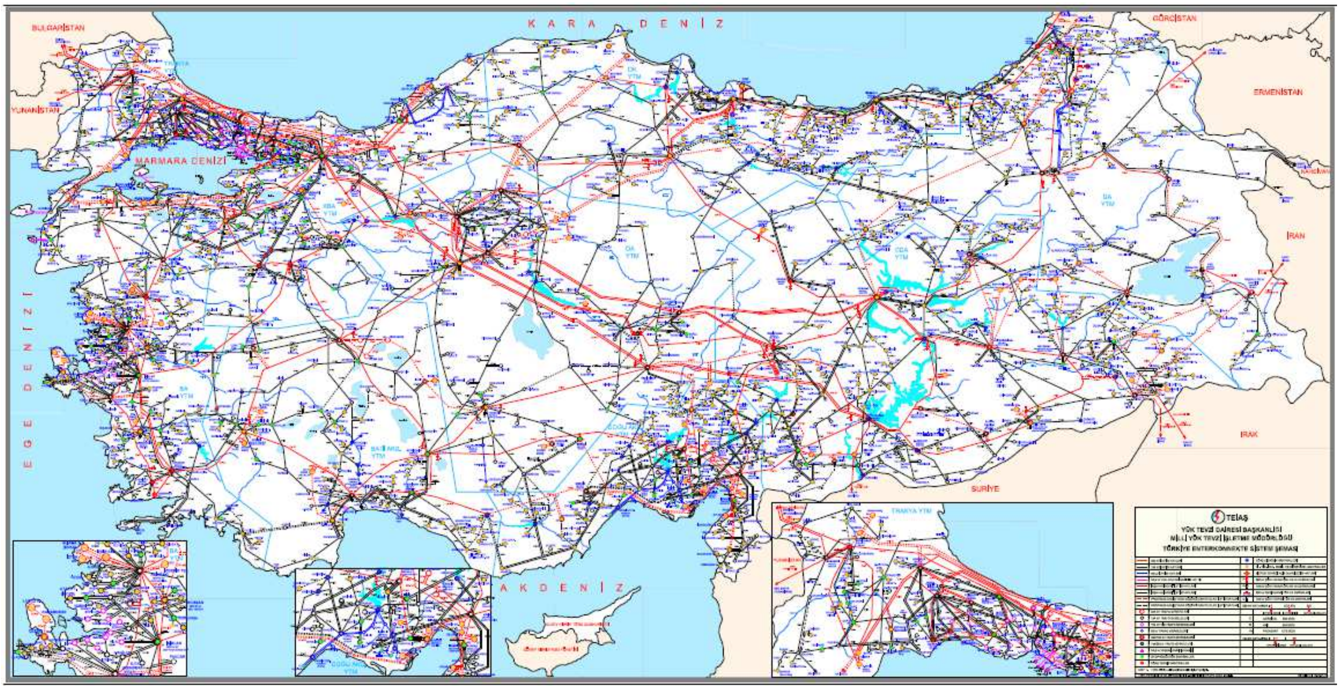


Figure 3.13 Transmission system of Turkey

(Source TEIAS)

Turkey is interconnected with the SEE and ENTSO-E countries (Bulgaria with two 400 kV lines and Greece by one 400 kV line), as well with Syria, Iraq, Iran, Armenia and Georgia. Turkey is currently limited to export up to 300 MW to the SEE region (Bulgaria, Greece) and import up to 400 MW from the SEE region (during the third phase of trial run synchronous operation with ENTSO-E), but plans to increase these imports/exports up to 1200 MW in the near future (beginning from 2013).

3.2 Expected development till 2020

Almost each TSO in the region has defined its transmission development plan for a mid-term or long-term frame. Such plans usually comprise network reinforcements by new facilities construction, transmission facilities reconstruction and revitalization, as well as adoption of eventually other actions like voltage control sources installation.

SEE TSO’s are actively included into ENTSO-E who prepares European 10 Years Network Development Plan - TYNDP (draft report for 2012 has been issued recently). Some projects in the SEE region are also included in this plan as pan-European significant projects.

Following figure presents key network reinforcement drivers according to the EU policy goals (security of supply, RES integration, internal market integration). One may notice that the most important grid investment drivers in SEE are RES integration (wind power plants in Croatia, Serbia, Romania and Bulgaria) and new conventional generation (Serbia, Romania). Demand growth is key network driver for grid reinforcements in eastern Bulgaria.

According to ENTSO-E, much larger East to West and South flows in South-Eastern Europe are expected in the future than the present transfer capability of the grid allows for. This is probably due to expected construction of 1000 MW HVDC link between Montenegro and Italy, intended to be used for large power transits from Romania and Bulgaria toward Italy.

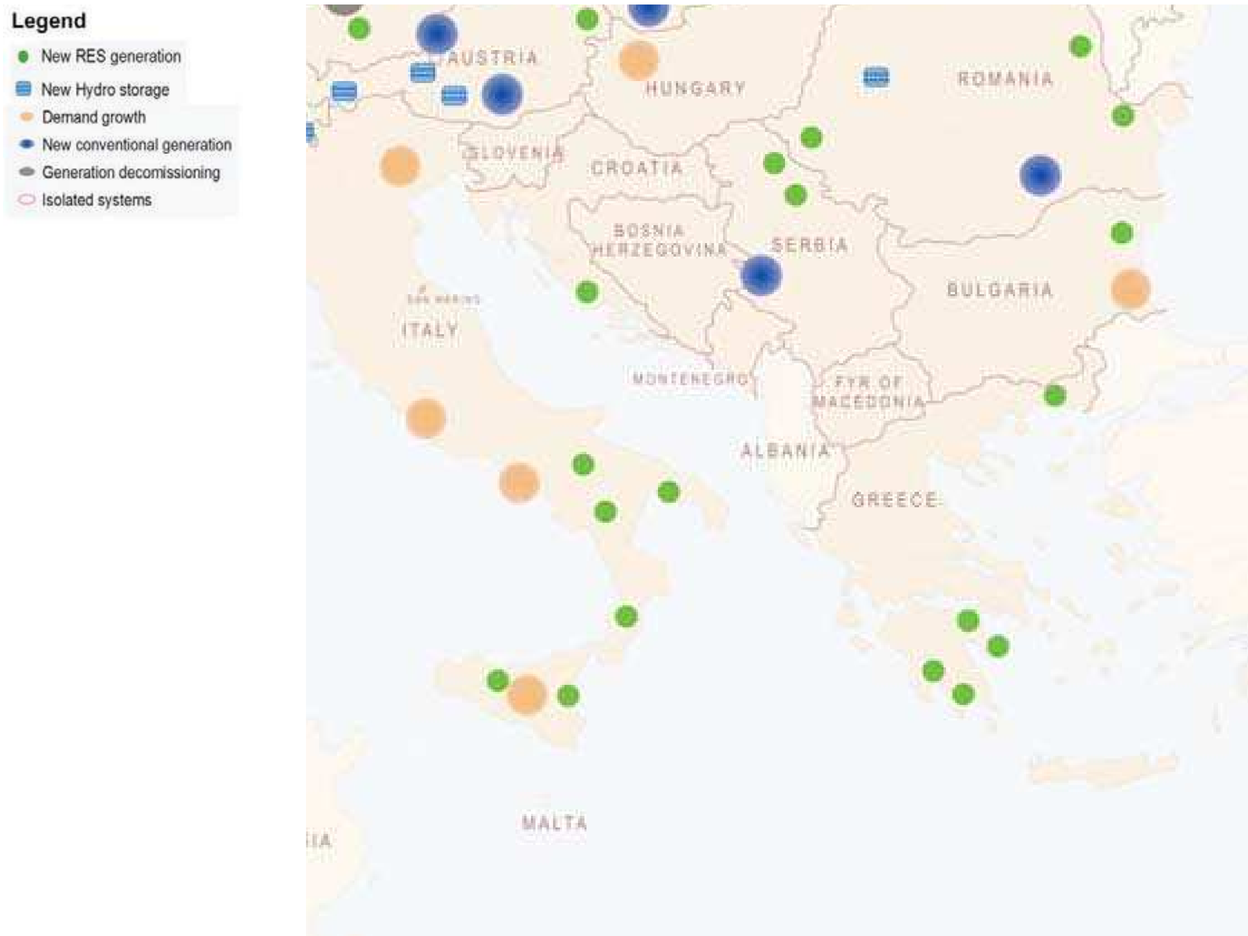


Figure 3.14 Grid development drivers in SEE

(Source ENTSO-E, TYNDP)

Projects marked by ETSO-E as pan-European significant projects in the SEE region are:

- Line 400 kV Krsko – Bericevo in Slovenia.
- Line 400 kV Cirkovce – Heviz/Zerjavinec between Slovenia and Hungary/Croatia.
- Line 2x400 kV Okroglo – Udine – Redipuglia between Slovenia and Italy.
- HVDC link 1000 MW Lastva – Villanova between Montenegro and Italy.
- Line 400 kV Višegrad – Pljevlja – Lastva in Bosnia and Herzegovina and Montenegro.
- Line 2x400 kV Pancevo – Resita between Serbia and Romania.
- Line 400 kV Tirana – Pristina between Albania and Kosovo.
- Line 400 kV Elbasan – Bitola between Albania and Macedonia.
- Line 400 kV Nis – Skopje between Serbia and Macedonia.
- Line 400 kV B. Luka – Lika between Bosnia and Herzegovina and Croatia.
- Line 2x400 kV Bajina Basta – Obrenovac in Serbia.
- Line 400 kV Bajina Basta – Visegrad/Pljevlja between Serbia, B&H and Montenegro.
- Line 400 kV Kosovo TPP – Skopje between Kosovo and Macedonia.
- Line 400 kV Mariza East 1 – N. Santa between Bulgaria and Greece.
- Large number of internal lines 400 kV in Slovenia, Croatia, Serbia, Romania, Bulgaria etc.

4 TRANSMISSION SYSTEM AGEING AND RELIABILITY INDICATORS

4.1 Reliability Indicators Definition

For a purpose of this study PSS/E software is used, activity “Reliability assessment”. A reason for using PSS/E software is because it is common tool for transmission network analysis and planning in SEE and each TSO is equipped with this software. Regional planning models of SEE transmission grid have been regularly created by SECI working group for three different operational regimes:

- winter peak load situation
- summer peak load situation
- summer off-peak load situation.

Regional transmission models for 2005, 2010, 2015 and 2020 were created so far, including planned investments in electricity generation and demand forecast with new transmission infrastructure as are seen by individual TSOs in the region. These models are extremely robust and many planned investment are included so it was decided that actual SEE transmission system model will be used for reliability assessment in order to achieve more accurate results which will be applicable for different purposes (estimation of influence of aged equipment, identification of weak grid areas, base for revitalization activities in the future etc.).

It was decided by SECI working group that SEE transmission model for winter peak regime 2012 will be used for reliability assessment. Additional reliability assessment was performed on the regional model for 2015, winter peak load situation. In order to model an actual situation in the network date January 18, 2012 at 10:30 am was chosen, and each TSO provided a snapshot of a grid under its jurisdiction. Winter peak situation (actually winter high load situation) was chosen because it represents the toughest situation for SEE transmission network according to previous experience (majority of countries achieve peak load during cold winter months). That means that reliability assessment of SEE transmission network was performed in this study for actual winter high load situation, but is applicable for majority of possible annual operating conditions which are easer to withstand from transmission point of view.

During winter high loads transmission lines and transformers are usually in operation, without maintenance activities which would cause intentional or planned outages of some lines and/or transformers due to maintenance activities. This is the reason why forced outages were observed only in this reliability assessment, neglecting planned outages which are not expected during winter conditions.

Summer regimes may sometimes be also critical for network operation, especially because load is rising during summer thanks to air conditioning installations and some network infrastructure could be unavailable due to maintenance activities. Increased number of outages (forced and planned) may deteriorate reliability indicators for this operational regime, so reliability assessment of SEE transmission grid during summer high loads may be further step in determination of overall reliability performance of the grid.

The application of probabilistic methods may provide new and different perspectives for transmission planners and operators, focusing on the frequency and duration of system problems, and for customers focusing on the impact of unreliability on load curtailments. Typically probabilistic reliability assessment is applied to [12]:

- Calculation of reliability indices;

- Weak points analysis, i.e. components most affected by outages;
- Comparisons between different operating conditions, network structure as well as planning alternatives;
- Analysis of effectiveness of corrective actions.

Reliability indices may be defined as deterministic ones and probabilistic ones. Deterministic reliability indices don't take into account probability of contingences (like transmission equipment outages) thus withholding important information to transmission analysts or planners. Probabilistic reliability analysis is provided via an additional post-processing function to calculate probabilistic indices for local and system problems with given outage statistics for each contingency.

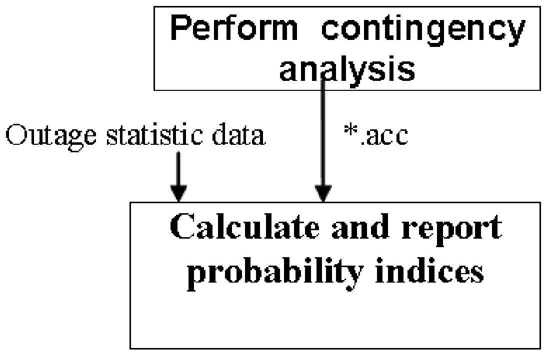


Figure 4.1 Process of Probabilistic Reliability Assessment [12]

The results are referred to as "probabilistic indices". They are composite probabilities of problems given in terms of frequency and duration indices, and determined by probabilities of transitions from 'success' operating conditions to 'failure' operating conditions. Generally, outage statistics are given in terms of frequencies and duration to reflect the probability that a transmission element will be forced out-of-service, and to calculate transition probabilities [12].

Because of large number of network units (lines, transformers, generators) within the regional SEE transmission model it was decided that forced outages of 400 kV lines only will be observed in the reliability assessment. This is due to regional importance of 400 kV network that is major concern for study within SECI Regional transmission system planning project. Transformers 400/x kV and 220/x kV, and lines 220 kV, 154 kV and 110 kV have local importance mostly, and have moderate or small contribution on performance of the regional transmission grid. Nevertheless, it was left to each TSO to estimate which voltage levels and network units will be analyzed within this study and to deliver appropriate data.

Data for reliability assessment which were collected from each TSO comprises average annual number of forced outages for every line 400 kV within a grid under their jurisdiction and average annual duration of single forced outage. Three-year period was chosen for calculation of average number and duration of forced outages in order to decrease an influence of unintentional circumstances and deviations from normal situation. Longer time period for average values was not used because some TSO's have started to statistically follow outages data recently.

It was also chosen that individual data for every single 400 kV line will be used, in order to avoid generalization and inaccuracy of generic data (line average number of outages for all 400 kV lines in one TSO area).

Two sets of data were collected in order to create Outage Statistic Data File:

- f - frequency of single line 400 kV forced outage,

- d - duration of single line 400 kV forced outage.

Following reliability indices were observed:

1. deterministic reliability indices

• system problem summary;
• branch flow overloading;
• bus voltage violations;
• contingency summary;

2. probabilistic reliability indices

• system problem probabilistic indices;
• branch flow overloading probabilistic indices;
• bus voltage violation probabilistic indices;
• contingency summary with probabilistic indices;

System and bus load curtailment probabilistic indices were not calculated because of unknown load curtailment schemes in the SEE TSO's areas of jurisdiction.

System reliability indices summary report under post-contingency output mode consists of frequency, average duration and probability for each type of problems. Impact indices of overloads and bus voltage violations with respect to voltage limits are also given. For each type of problems, the number of contingencies causing the problem, the worst violation as well as the contingency causing the worst violation is reported.

Branch flow overload probabilistic indices for each circuit and for the study subsystem comprise the sum of frequency, average duration and probability of all contingencies resulting in a circuit overload. The system overload impact index is equal to the sum of overload impact indices of all circuits.

4.2 400 kV Network Elements

Data related to individual 400 kV lines number of forced outages per year and average single duration of forced outages per year were collected from all SEE TSO's for three-year time period 2008-2010 or 2009-2011. Collected data are included in the Appendix.

Observing total number of 400 kV lines per each country, average values of number of forced outages and single duration of forced outage for 400 kV lines, as well as average age of 400 kV lines referred to 2012, were calculated. Results are shown in the following table (Table 4.1).

Table 4.1 Average number and single duration of 400 kV lines forced outages

Country	Average number of forced outages (400 kV lines)	Average duration of single line 400 kV forced outage (hours)	Average lines age (years)
Albania	4,0	2,5	28
Bosnia and Herzegovina	12,9	1,8	31
Bulgaria	0,4	1,6	27
Croatia	1,2	2,5	26
Kosovo	1,4	2,3	32
Macedonia	0,7	0,5	22
Montenegro	3,1	6,9	24
Romania	0,3*	14,3*	33
Serbia	0,9	2,0	32
Slovenia	0,3	1,6	32
Turkey	11,6	1,3	21
ALL (SEE+Slovenia+Turkey)	**3,4**	**3,4**	**28**

* According to the Reliability Normative

Albanian peak load for 2012 was predicted to be 1420 MW. Albanian TSO (OST) plans that import of 450 MW will be necessary to cover the peak load. Average number and duration of 400 kV lines forced outages were given for time period from 2008 to 2010. Data comprise only two 400 kV lines (Elbasan 2 – Zemlak and Zemlak – Kardia) since lines 400 kV Elbasan 2 – Tirana 2 and Tirana 2 – Podgorica were put in operation after observed time period. Average number of forced outages for two observed 400 kV lines was 4 outages/year, while average duration of single forced outage was 2,5 hours. Average age of Albanian 400 kV lines is 15 years, with two lines of 28 years and two lines of 2 years.

Peak load in 2012 for Bosnia and Herzegovina was predicted to be 2260 MW. Bosnian TSO (NOS BiH) planed that maximum theoretical export of 1209 MW could be achieved during the peak load situation (power plants installed capacities - peak load - primary reserve - secondary reserve - tertiary reserve). Average number and duration of 400 kV lines forced outages were given for time period from 2008 to 2010. Age of 400 kV lines in Bosnia and Herzegovina vary between 6 years (Ugljevik – Sremska Mitrovica) and 36 years (Mostar – Konjsko and Ugljevik – Tuzla). Average age of 400 kV lines is 31 years. Average number of 400 kV lines forced outages per year vary between 5 (Ugljevik – Tuzla) and 29 (Gacko – Trebinje), which is extremely high value. Average duration of single line 400 kV forced outage vary between 0,26 (Trebinje – Podgorica) and 4,14 (Ugljevik – Ernestinovo). Average number of forced outages of all 400 kV lines is 12,9 outages/year, while average duration of single forced outage for all 400 kV lines in Bosnia and Herzegovina is 1,8 h/single forced outage-year. Lines 400 kV in Bosnia and Herzegovina show decreased level of availability comparing them with other SEE countries, especially interconnection line 400 kV Ugljevik – Ernestinovo (unavailability due to forced outages was 0,47 %). Majority of lines 400 kV were constructed in mid 70-ties. High unavailability due to forced outages may suggest that 400 kV network ageing could jeopardize system performance in Bosnia and Herzegovina. The oldest lines have 36 years in operation, but due to war damages in the near past some lines 400 kV were rehabilitated ten years ago.

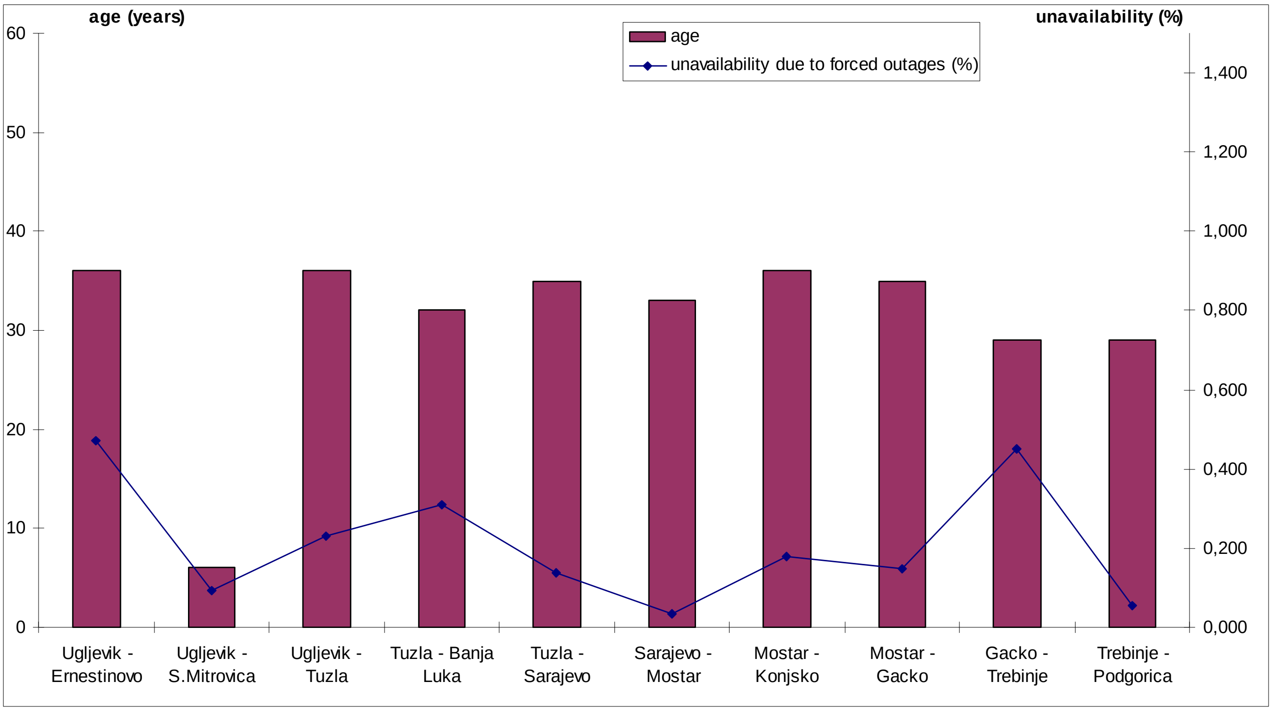


Figure 4.2 Age of 400 kV lines in Bosnia and Herzegovina and average 3-years unavailability due to forced outages

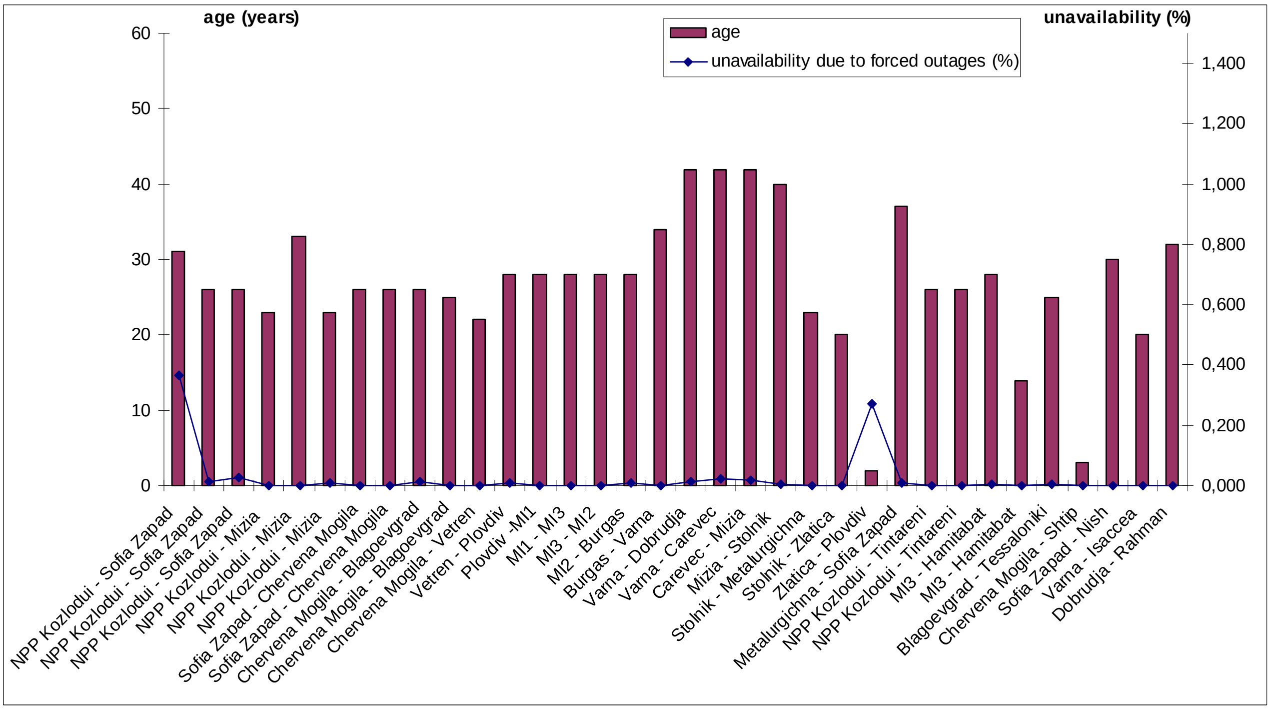


Figure 4.3 Age of 400 kV lines in Bulgaria and average 3-years unavailability due to forced outages

Bulgarian peak load for 2012 was predicted to be 7450 MW. Bulgarian TSO plans that export of 1000 MW will be achieved during the peak load situation. Average number and duration of 400 kV lines forced outages were given for time period from April 2010 to April 2012. Age of 400 kV lines in Bulgaria vary between 2 years (Zlatica – Plovdiv) and 42 years (Varna – Dobrudja, Varna – Carevec, Carevec – Mizia). Average age of 400 kV lines is 27 years. Average number of 400 kV lines forced outages per year vary between 0 (Plovdiv - MI1, MI1 - MI3, MI3 - MI2, Stolnik – Metalurgichna, Stolnik – Zlatica, NPP Kozlodui – Tintareni, MI3 – Hamitabat, Chervena Mogila –

Shtip, Sofia Zapad – Nish, Varna – Isaccea, Dobrudja – Rahman) and 2,5 (NPP Kozlodui - Sofia Zapad), while average duration of single line 400 kV forced outage vary between 0 and 15,7 (Zlatica – Plovdiv). Average number of forced outages of all 400 kV lines is 0,4 outages/year, while average duration of single forced outage for all 400 kV lines in Bulgaria is 1,6 h/single forced outage-year. Lines 400 kV in Bulgaria show high level of availability, even older lines, and this fact point out that 400 kV network ageing is still not critical for system performance (average unavailability of 400 kV lines in Bulgaria is 0,02 %). Following figure presents age of 400 kV lines in Bulgaria and their unavailability due to forced outages only (unavailability due to planned outages is not included). One may notice that the youngest line (Zlatica – Plovdiv, 2 years old) has the highest value of unavailability due to forced outages (0,27 %). On the other hand, older lines like Varna – Dobrudja, Varna – Carevec and Carevec – Mizia have significantly lower values of unavailability due to forced outages ranging from 0,01 % to 0,03 %.

Croatian peak load for 2012 was predicted to be 3291 MW. Croatian TSO plans that import of 950 MW will be achieved during the peak load situation. Average number and duration of 400 kV lines forced outages were given for time period from January 2008 to January 2010. Age of 400 kV lines in Croatia vary between 2 years (Ernestinovo – Pecs) and 37 years (Konjsko – Velebit). Average age of 400 kV lines is 26 years. Average number of 400 kV lines forced outages per year vary between 0 (Ernestinovo – S. Mitrovica, Zerjavinec – Heviz 1, Tumbri – Zerjavinec, Tumbri – Krsko) and 4,7 (Melina – Velebit), while average duration of single line 400 kV forced outage vary between 0 and 19,5 hours (Melina – Velebit). Average number of forced outages of all 400 kV lines is 1,2 outages/year, while average duration of single forced outage for all 400 kV lines in Croatia is 2,5 h/single forced outage-year. Lines 400 kV in Croatia show high level of availability, even older lines, and this fact point out that 400 kV network ageing is still not critical for system performance (average unavailability of 400 kV lines in Croatia is 0,1 %). Line 400 kV Melina – Velebit that is 33 years old shows increased level of unavailability comparing it with other 400 kV lines, but reason for that is not its age but long length (180 km) and unfavorable climate conditions across the line route (strong winters, wind, ice).

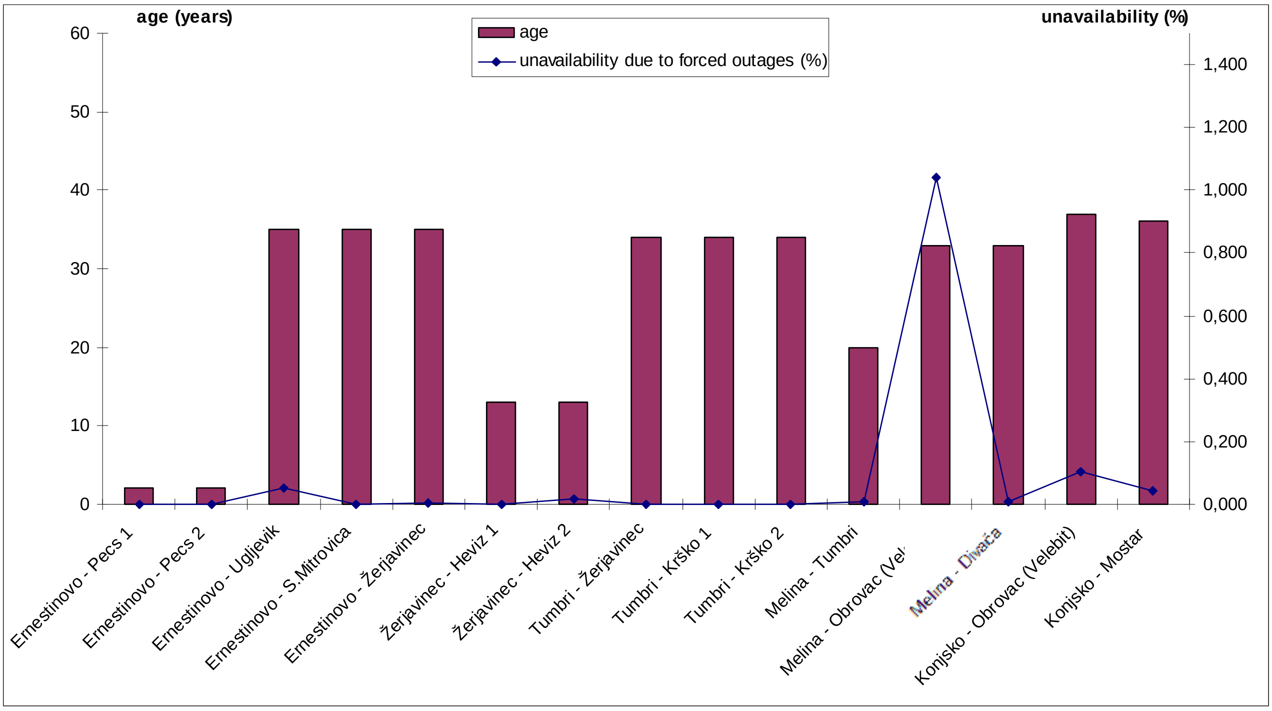


Figure 4.4 Age of 400 kV lines in Croatia and average 3-years unavailability due to forced outages

KOSTT predicts that Kosovo peak load for 2012 will achieve 1138 MW, and import of 266 MW will be necessary to cover it. Average number and duration of 400 kV lines annual forced outages were given for time period from 2008 to 2011. Lines 400 kV at Kosovo are 32 years old in average, ranging from 29 years to 35 years. Reliability parameters are satisfactory, with average number of annual forced outages of 1,4 and 2,3 hours in average of single forced outage duration. Line 400 kV Ribarevina – Peja 3 stands slightly above average with 5 forced outages per year and 10,2 hours of single forced outage duration. It seems that 400 kV network age doesn't have any influence on transmission system reliability, having in mind that average 400 kV lines unavailability due to forced outages is 0,12 % only.

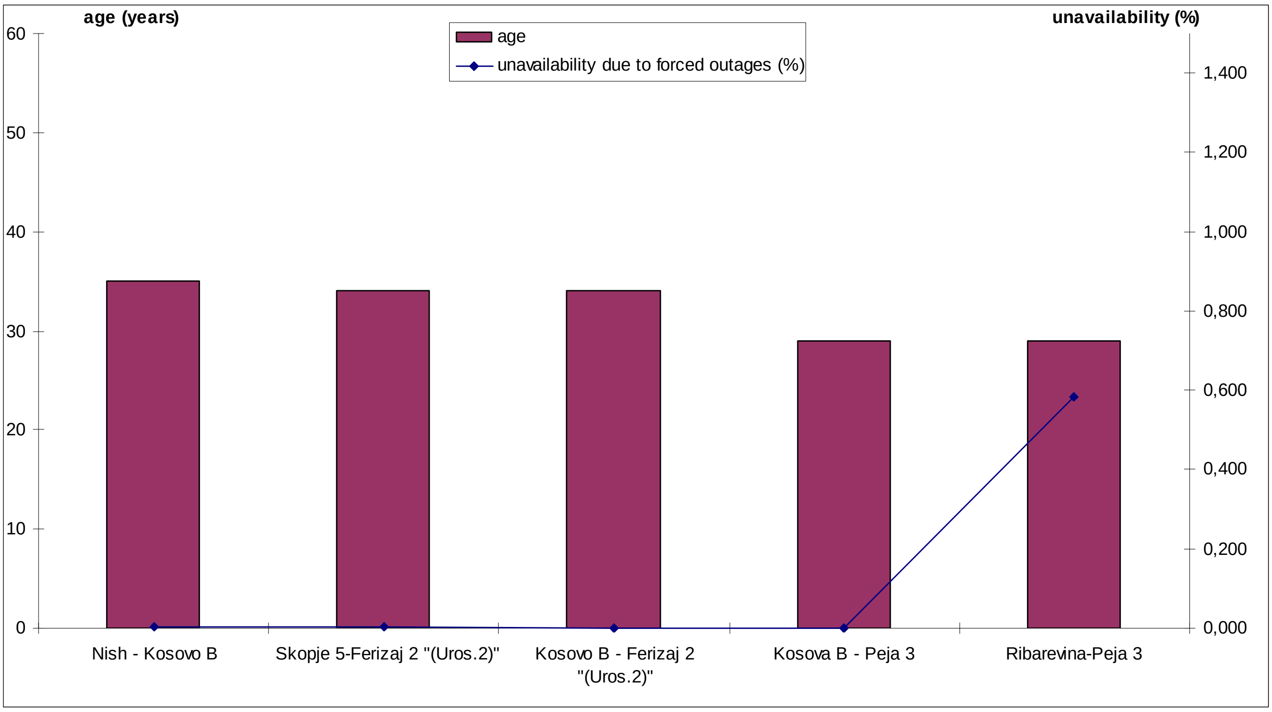


Figure 4.5 Age of 400 kV lines in Kosovo and average 4-years unavailability due to forced outages

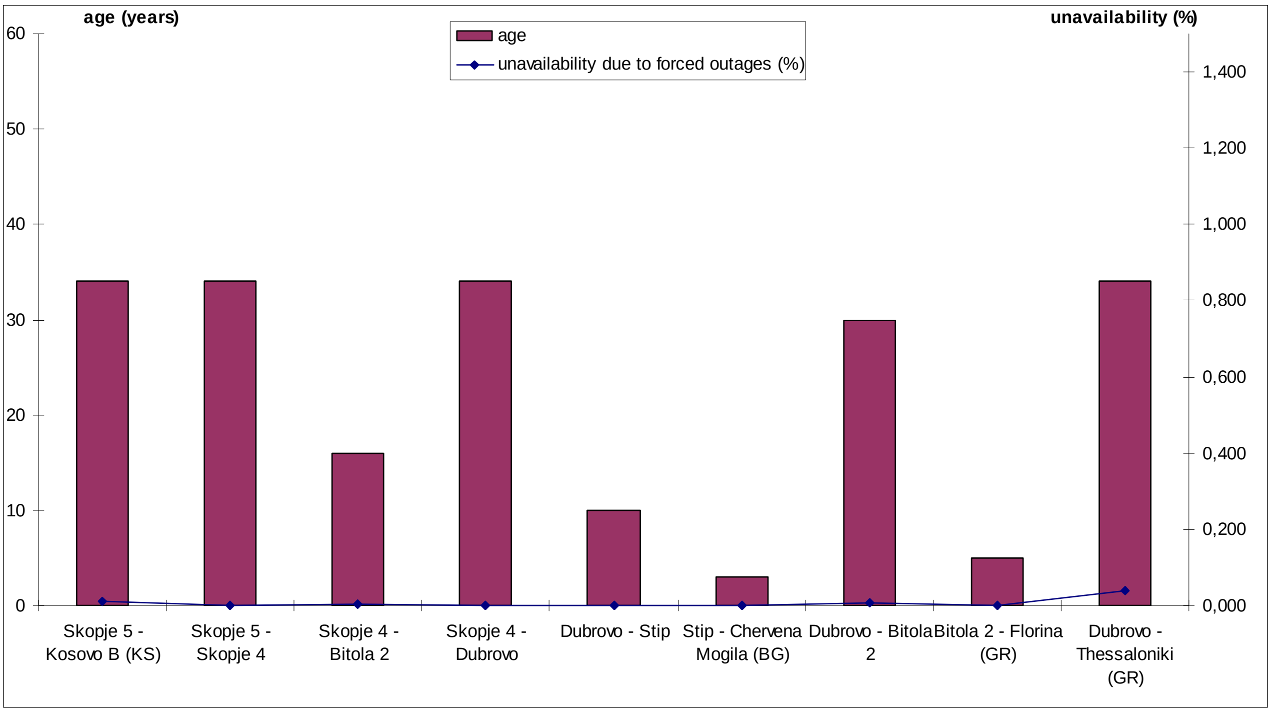


Figure 4.6 Age of 400 kV lines in Macedonia and average 3-years unavailability due to forced outages

MEPSO, Macedonian TSO, predicts peak load in 2012 to be 1363 MW with necessary import of 531 MW during peak load hour. Statistical reliability data for Macedonia refers to the time period 2008 – 2010. Lines 400 kV in Macedonia are between 3 years and 34 years old, with average age of 22 years. Average number of 400 kV lines forced outages for observed time period was 0,7 (values are within range of 0,33 and 1,5). Average duration of 400 kV lines forced outages was 0,5 hours, ranging between 0,05 hours and 2,24 hours. Lines 400 kV have very high reliability (average of 0,01 % due to forced outages only) which means that 400 kV network age still doesn't jeopardize system performance.

Statistical reliability data for Montenegro refers to the time period 2008 – 2010. Lines 400 kV in Montenegro are between 2 years and 30 years old, with average age of 24 years. Average number of 400 kV lines forced outages for observed time period was 3,1 (values are within range of 2 and 4). Average duration of 400 kV lines forced outages was 6,9 hours, ranging between 0,59 hours and 19,53 hours. Lines 400 kV have moderately high reliability (average of 0,26 % due to forced outages only) which means that 400 kV network age still doesn't jeopardize system performance. It should be stressed that 400 kV lines in Montenegro are very often subjected to strong tunderstorms.

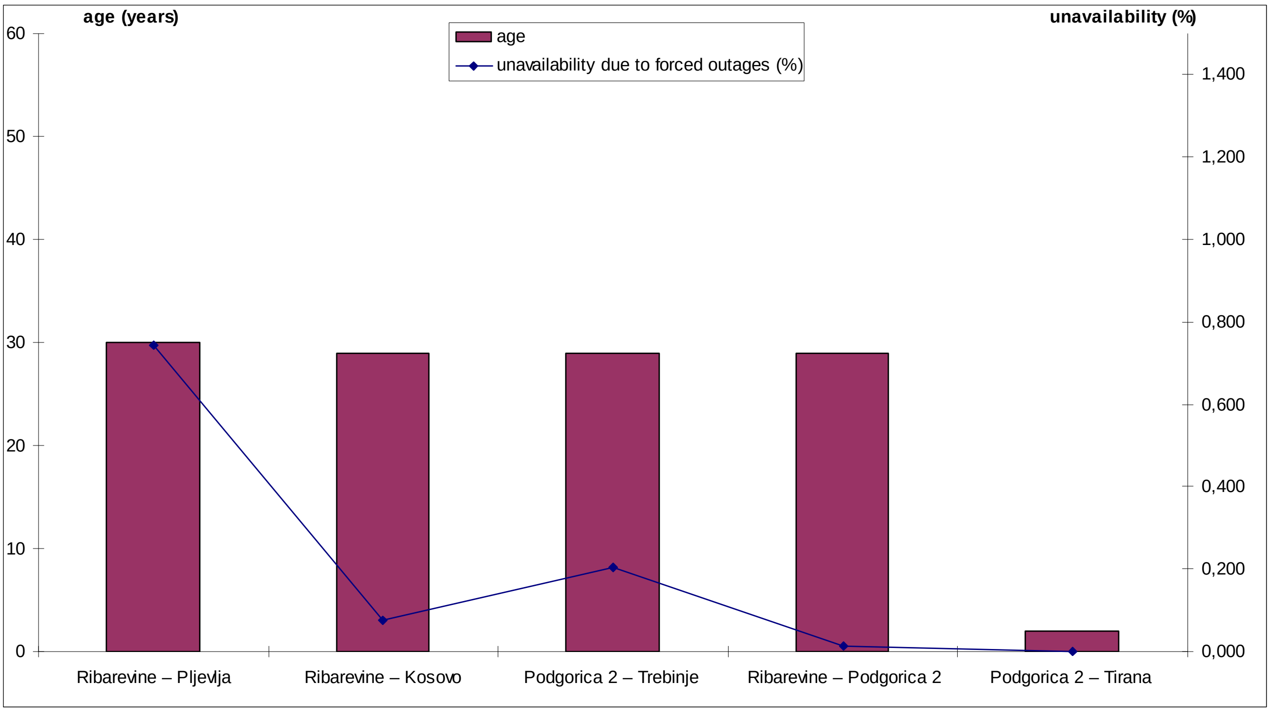


Figure 4.7 Age of 400 kV lines in Montenegro and average 3-years unavailability due to forced outages

Romanian TSO, Transelectrica, predicts that peak load in 2012 will reach 9901 MW, and Romanian power plants will export 800 MW during that hour. Romanian transmission lines reliability data were not provided for this Report, but instead of statistical data Transelectrica provided data from Romanian Reliability Normative which has to be reached concerning average number and duration of 400 kV and 220 kV lines forced outages. For lines 400 kV average duration of single forced outage must be lower than 14 hours, while average duration for single line 220 kV outage must be lower than 10 hours. Annual number of forced outages for lines 400 kV should be kept within 0,002 (Portile De Fier – Djerdap) to 1,04 (Tantareni – Sibiu) with average value of 0,3. Average lines 400 kV age is 33 years with 16 lines olden than 40 years. It is unknown does Transelectrica manage to keep reliability data according to the Reliability Normative.

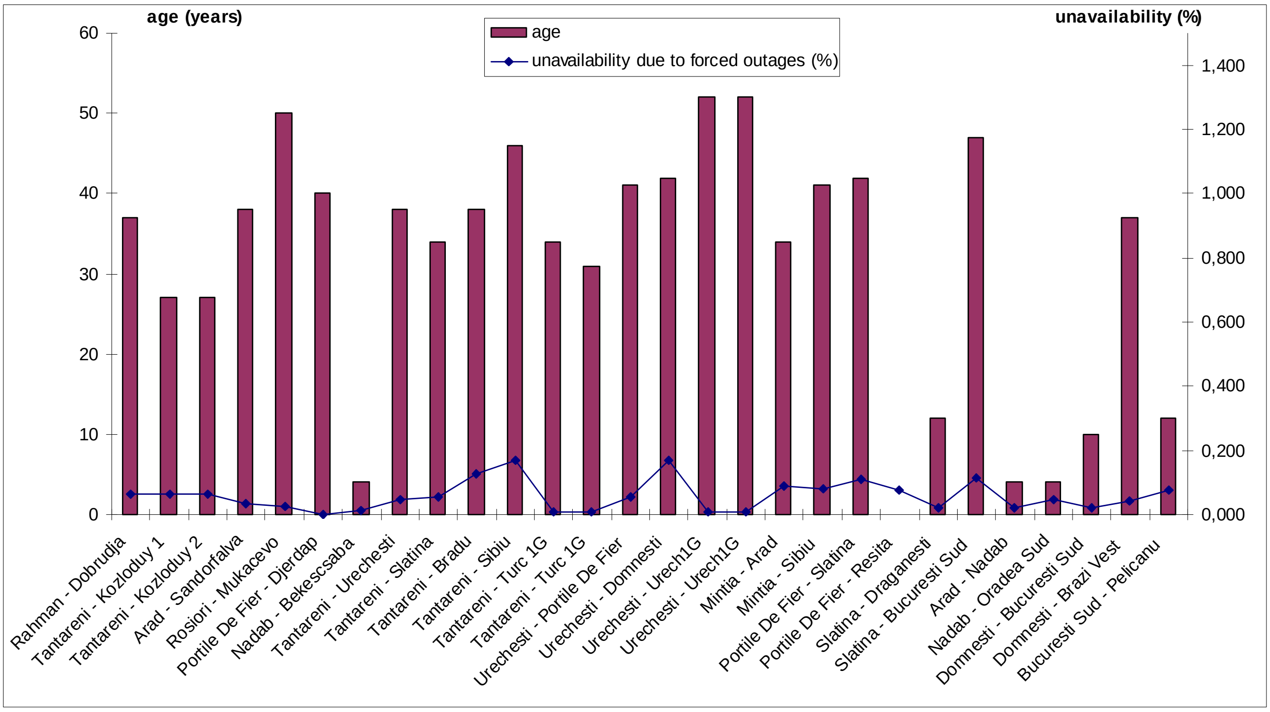


Figure 4.8 Age of 400 kV lines in Romania and allowed unavailability according to the Reliability Normative (part 1)

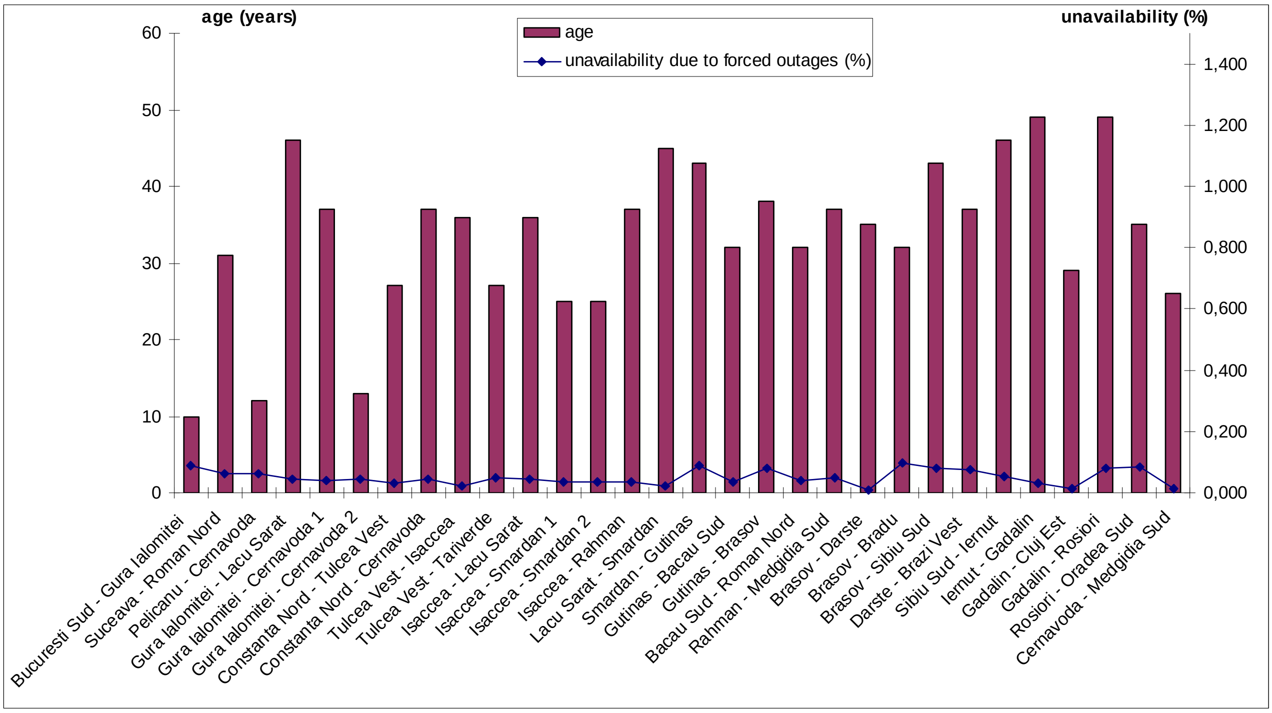


Figure 4.9 Age of 400 kV lines in Romania and allowed unavailability according to the Reliability Normative (part 2)

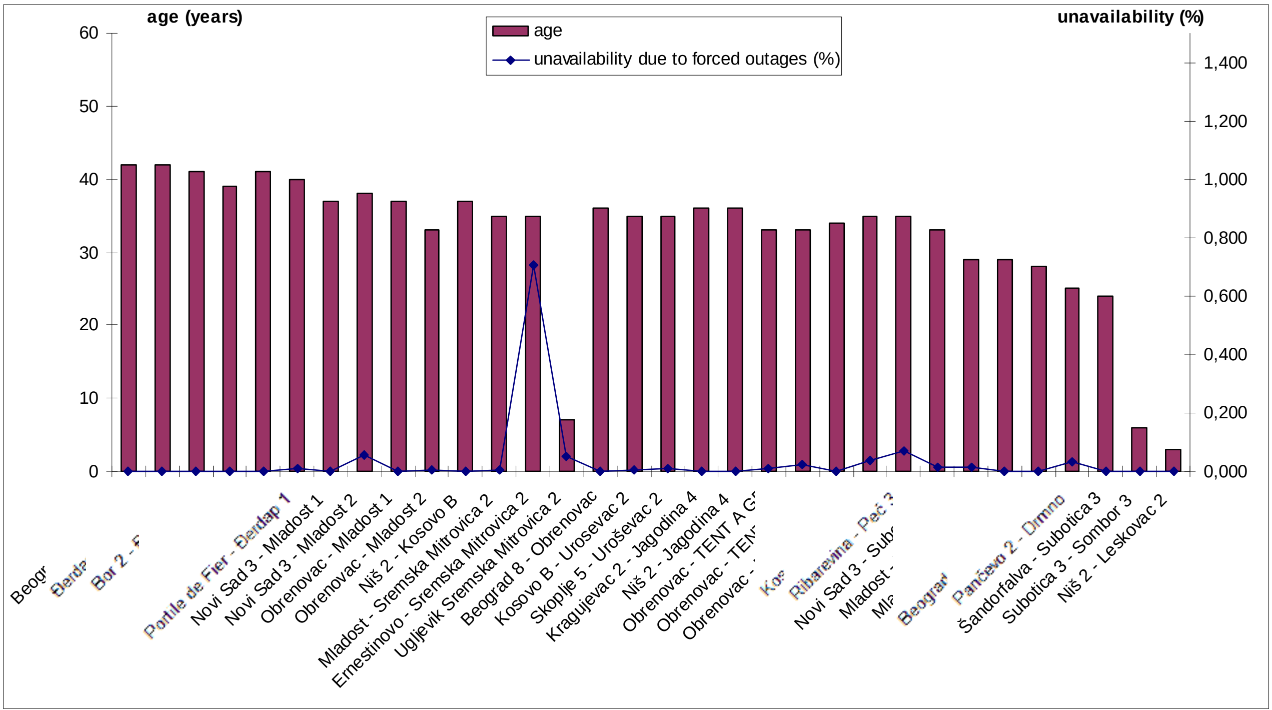


Figure 4.10 Age of 400 kV lines in Serbia and average 3-years unavailability due to forced outages

Serbian peak load in 2012 will reach value of 7450 MW and import of 400 MW is predicted to be necessary to cover the highest annual load. Average age of lines 400 kV in Serbia is 32 years, but Serbian transmission network has four lines older than 40 years. Average annual number of forced outages, observing 3-years time period 2008-2010, is 0,9 outages per line 400 kV. Average annual duration of single forced outage for 400 kV lines is 2 hours. Lines 400 kV unavailability due to forced outages is still at the high level (average is 0,03 %) but one line stands out with its reliability data (Ernestinovo – S. Mitrovica 2, average unavailability due to forced outages is 0,7 %).

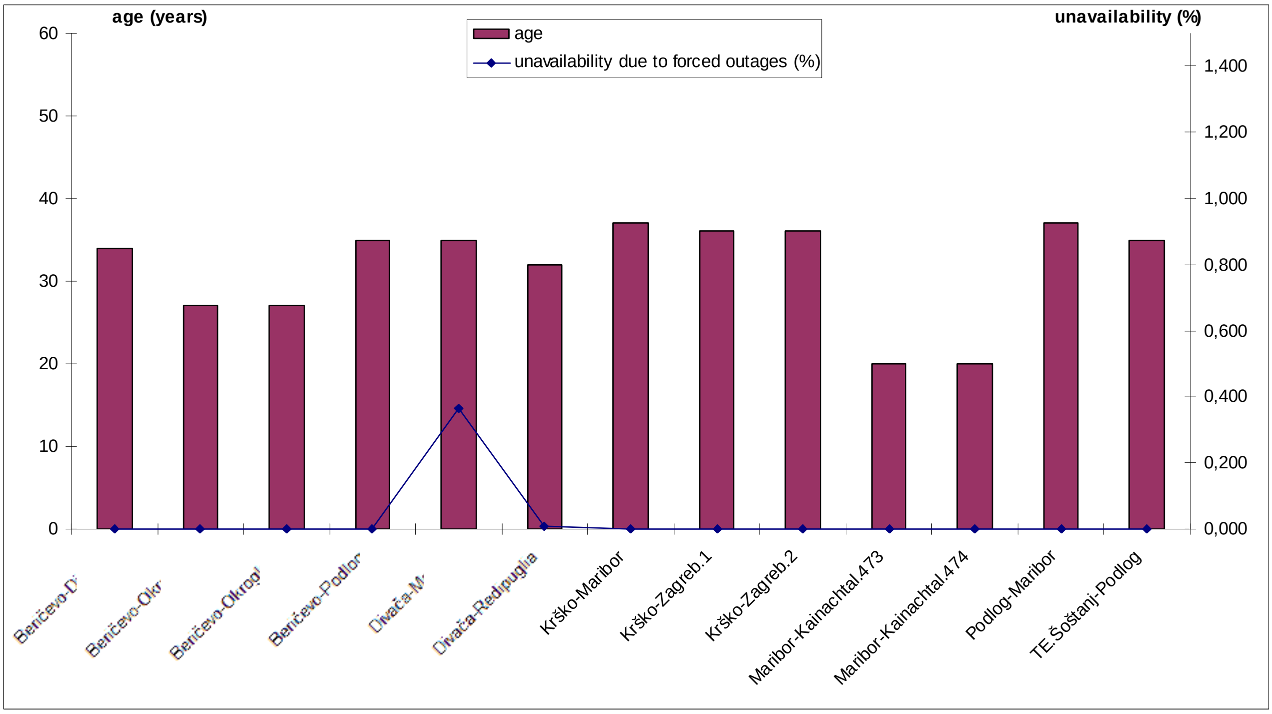


Figure 4.11 Age of 400 kV lines in Slovenia and average 3-years unavailability due to forced outages

Slovenian TSO (ELES) predicts peak load in Slovenia for 2012 to be 2028 MW, with possible export of 198 MW outside Slovenia. Slovenian lines 400 kV are 32 years old in average but reliability parameters are still satisfying (average unavailability due to 400 kV lines forced outages in time period 2009 – 2011 is 0,03 %, average annual number of forced outages is 0,3 while average duration of single forced outage is 1,6 hours).

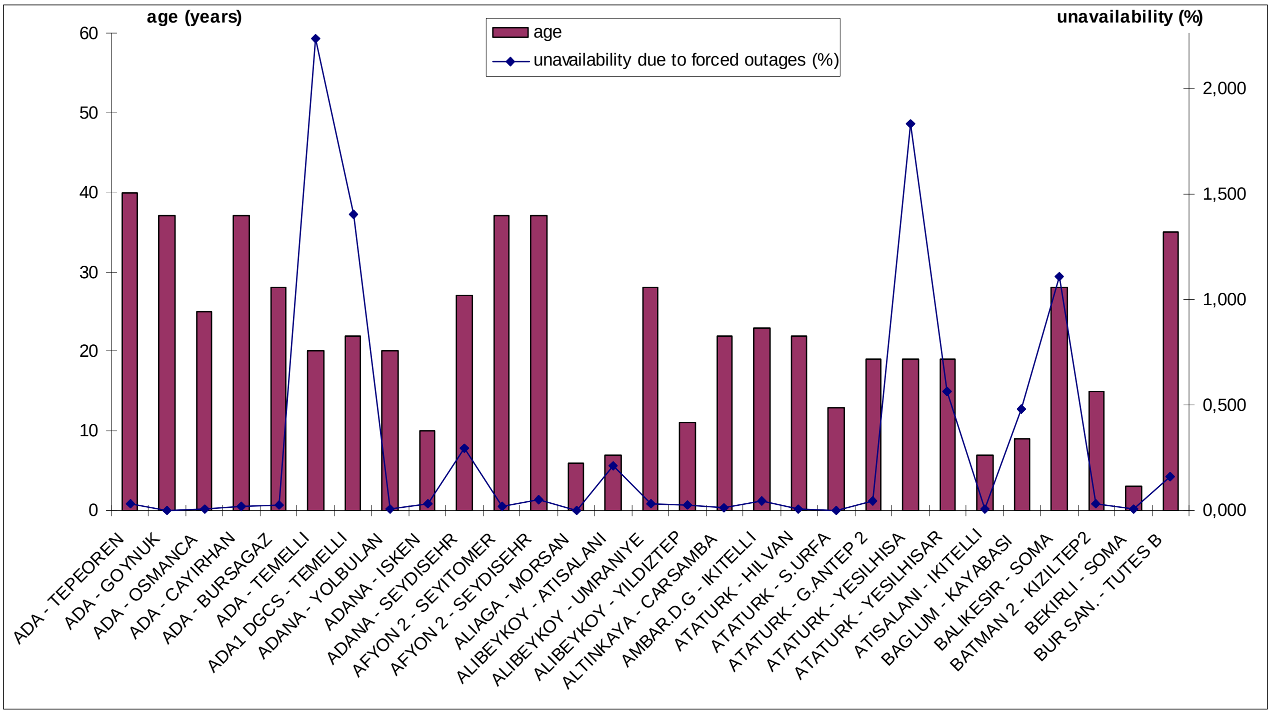


Figure 4.12 Age of 400 kV lines in Turkey and average 3-years unavailability due to forced outages (part 1)

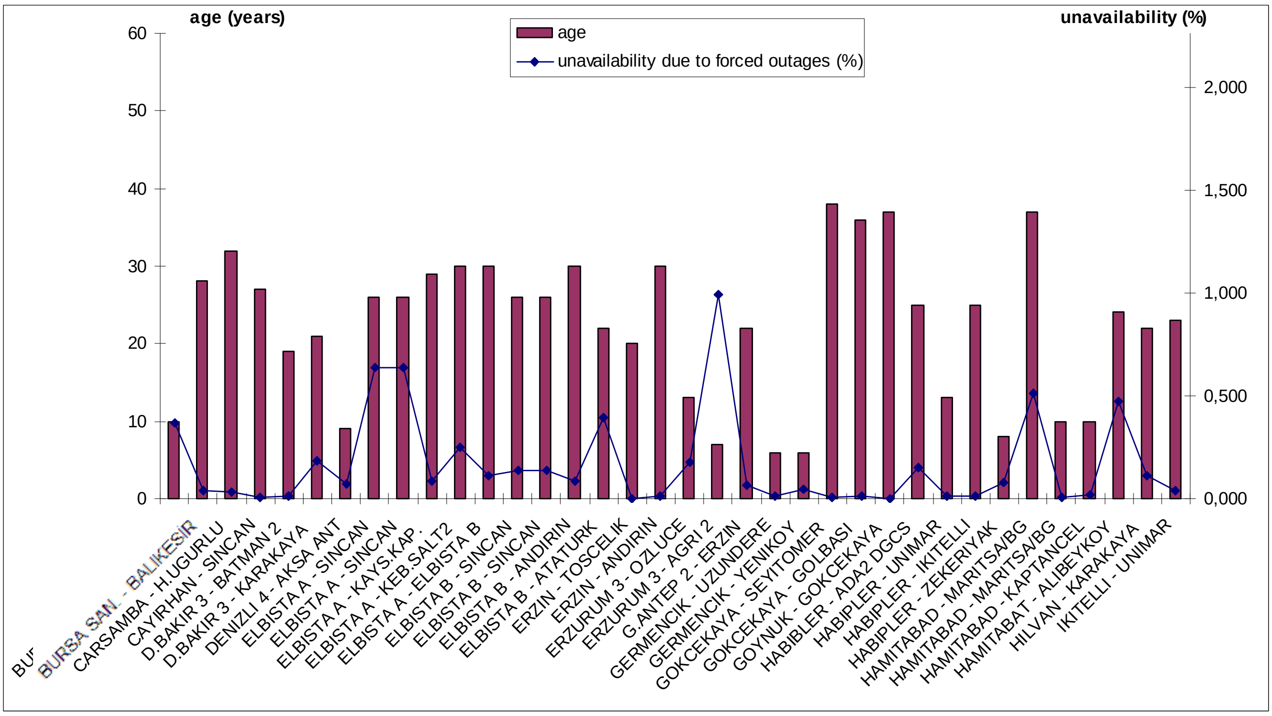


Figure 4.13 Age of 400 kV lines in Turkey and average 3-years unavailability due to forced outages (part 2)

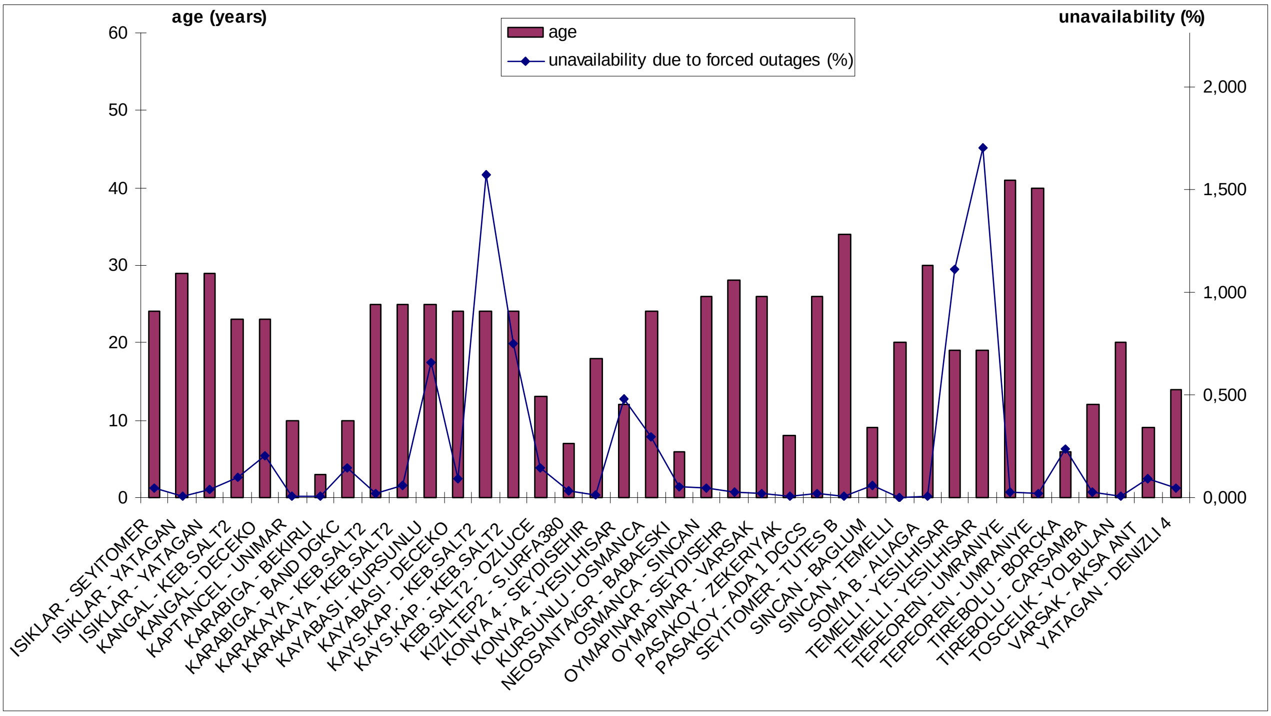


Figure 4.14 Age of 400 kV lines in Turkey and average 3-years unavailability due to forced outages (part 3)

Turkish reliability data for time period 2009 – 2011 shows that average annual number of forced outages was 11,6 while average duration of single forced outage is 1,3 hours. Lines 400 kV in Turkey are 21 years old in average, and only one line 400 kV is 40 years old. Average unavailability of 400 kV lines due to forced outages are quite high (0,22 %), with several lines which have extremely high unavailability (> 2% hours per year). Peak load for Turkey in 2012 is predicted to be 37841 MW with necessary import of 350 MW.

Average age of all 400 kV lines in the Southeast Europe including Slovenia and Turkey is 28 years. Average number of annual forced outages for all 400 kV lines is 3,4 while average duration of a single forced outage is 3,4 hours. This makes SEE transmission system quite reliable, with average annual unavailability of 400 kV lines due to forced outages of 0,10 % (one 400 kV line will be around ten hours per year out of operation due to forced outage in average). Furthermore, one may conclude that critical contingences in the network 400 kV which may jeopardize overall system security or restrict market activities have very low probability. This means that consumers and market players in the SEE region will not suffer often from transmission system restrictions caused by accidental disturbances in the 400 kV transmission network, despite the age of 400 kV transmission system and its present condition.

According to statistical data provided by SEE TSO’s the best reliability parameters have lines 400 kV in Macedonia (average annual unavailability of 400 kV lines due to forced outages is 0,01 % or 0,6 hours/year) and the worst reliability parameters are noticed for Montenegro (average annual unavailability of 400 kV lines due to forced outages is 0,26 % or 22,8 hours/year). Above average, concerning unavailability of 400 kV lines in the SEE due to forced outages, are Albania, Bosnia and Herzegovina, Croatia, Kosovo, Montenegro and Turkey, with significant deviation only for Bosnia and Herzegovina, Montenegro and Turkey. Bulgaria, Macedonia, Slovenia and Serbia experienced quite satisfactory reliability parameters in the past meaning that forced outages of 400 kV lines within their systems have very low probability. Situation concerning 400 kV lines reliability is still not clear in Romania due to missing data. Romania provided typical data from the Reliability Normative, not measured ones, so Authors are still missing a clear view on the real situation there.

4.3 220 kV Network Elements

Data for 220 kV lines were only provided by Albanian TSO because network 220 kV makes the main part of Albanian transmission network. Observing the SEE region it is estimated that network 220 kV is having moderate impact on regional grid performance (market transactions, security of supply), but it is very important concerning security of supply for local areas.

Average lifetime of lines 220 kV in Albania is 30 years. Average number of annual forced outages for 220 kV lines in Albania is 5,9 while average duration of single forced outage is 2 hours. These data are comparable with lines 400 kV. Average unavailability due to forced outages in Albania for network 220 kV is 0,13 %. Older lines 220 kV in Albania in general have higher unavailability (like Tirana 1 – Elbassan 1, Burrel – Elbassan 1, V.Deja – Tirana 1 etc).

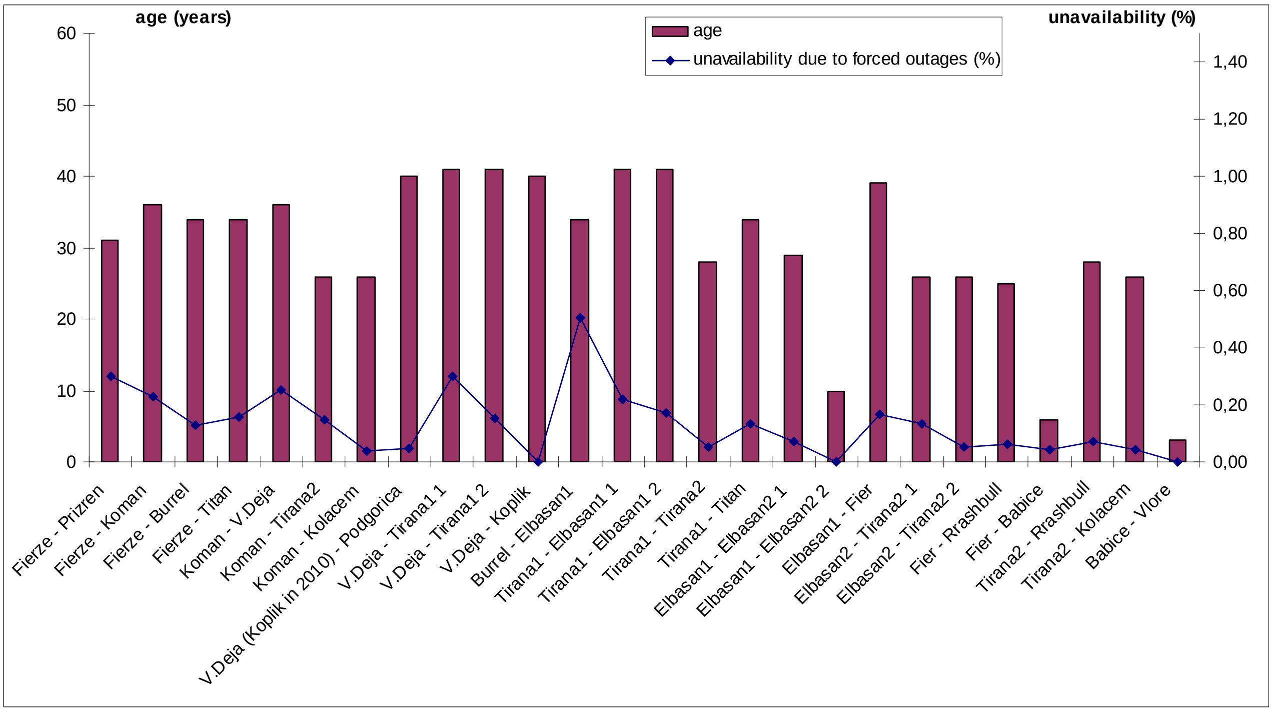


Figure 4.15 Age of 220 kV lines in Albania and average 3-years unavailability due to forced outages

4.4 110 kV Network Elements

Data for 154 kV and 110 kV lines were not provided by any TSO in the region. Network 110 kV or 150 kV has local significance to individual TSO's but doesn't contribute to the overall system performance in the region.

4.5 Operational Statistics and Reliability Indicators

Reliability assessment of individual countries in the Southeast Europe transmission grid, as well as regional SEE transmission grid, was performed using PSS/E (version 33) and outage statistic data provided by individual TSO's. Reliability assessment was performed for existing network configuration, short and mid time-frame expected configuration (years 2015 and 2020).

Reliability assessment is based on the winter peak load situation, and only multiple forced outages of 400 kV lines were observed since planned outages are not usual during critical (peak load) system conditions. Monitored network elements were lines and transformers 400 kV, 220 kV and 110 kV.

Model representing existing SEE transmission grid is based on a real situation that happened on January 18, 2012 at 10:30 am. All TSO's collected data representing their system and sent them to the ENTSO-E. The same data was collected by SECI working group latter on.

Model representing short-term future SEE transmission grid was made by SECI working group and the latest version was used (SECI WINTER MAX 2015_SEE_ver 47). This model was slightly corrected because phase shifting transformers in Divaca (Slovenia) and Padriciano (Italy) were added to the model.

Model representing mid-term future SEE transmission grid was made by SECI working group and the latest version was also used (SECI WINTER MAX 2020_SEE_ver 35). This model was also slightly corrected because phase shifting transformers in Divaca (Slovenia) and Padriciano (Italy) were added to the model.

All probabilistic indices were calculated with respect to individual and multiple forced outages of 400 kV lines during observed operational conditions. Post contingency mode was used during reliability assessment because tripping scenarios and corrective measures for individual contingencies were not known to the authors of this report.

4.5.1 Existing SEE transmission network (2012)

In order to estimate probabilistic indices for existing Southeast Europe transmission system common model representing third Wednesday in January 2012 was used. Basic load flow data are presented in the following figure (Figure 4.16). Model includes 400 kV and 220 kV national transmission networks with reduced number of busbars 150 kV and 110 kV. This means that reliability assessment is related to the networks 400 kV and 220 kV only, neglecting possible overloadings and out-of limit voltage situations which may happen in the network 110 kV and 150 kV.

There were several lines loading violations in the base case scenario, located in Bulgaria and Slovenia.

Outage statistic data were determined using average number of forced outages per year and average duration of single forced outage which had been collected from each TSO. Only lines 400 kV are included in analysis, which means that only lines 400 kV multiple forced outages under analyzed operational condition are observed.

There are several 400 kV lines in different countries which exceeded their expected lifetime of 40 years until today. Three of them are in Bulgaria, sixteen in Romania, four in Serbia and just one in Turkey. It may be expected that some of these lines will be the most important candidates for revitalization activities in the near future.

Analyzing contingences and probabilistic indices for each SEE country, and monitoring only branches under jurisdiction of national TSO's, reliability assessments give the following results.

There are few critical situations during analyzed operation regime In Albania. Reliability assessment for Albania shows that loss of load under analyzed operational conditions may be expected with very low probability (lower than 0,05 %) - Figure 4.17. This means that under analyzed situation loss of any 400 kV line or combination of 400 kV lines in Albania will not jeopardize Albanian transmission system security.

PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS(R)E FRI, SEP 14 2012 10:16
AREA TOTALS
IN MW/MVAR

X-- AREA --X	FROM GENE-RATION	FROM IND GENERATN	TO IND MOTORS	TO LOAD	TO BUS SHUNT	TO GNE BUS DEVICES	TO LINE SHUNT	FROM CHARGING	TO LOSSES	-NET INTERCHANGE- TO TIE LINES	TO TIES + LOADS	DESIRED NET INT
3	672.1	0.0	0.0	1058.0	0.0	0.0	0.5	0.0	13.6	-400.0	-400.0	-400.0
AL	239.6	0.0	0.0	473.0	0.0	0.0	2.9	312.8	92.9	-16.3	-16.3	
4	1926.2	0.0	0.0	1583.8	0.0	0.0	0.0	0.0	14.4	328.0	328.0	328.0
BA	400.5	0.0	0.0	718.2	0.0	0.0	0.0	745.0	108.4	318.9	318.9	
5	5112.7	0.0	0.0	4585.4	0.0	0.0	2.7	0.0	74.8	449.8	449.8	450.0
BG	715.0	0.0	0.0	1558.7	0.0	0.0	23.1	1905.2	852.9	185.5	185.5	
7	664.9	0.0	0.0	1358.5	0.0	0.0	0.0	0.0	21.5	-715.1	-715.1	-715.0
HR	-25.6	0.0	0.0	289.0	0.0	0.0	2.2	890.1	219.5	353.7	353.7	
9	601.5	0.0	0.0	570.1	0.0	0.0	0.0	0.0	11.4	20.0	20.0	20.0
ME	-6.0	0.0	0.0	194.1	0.0	0.0	0.0	277.7	97.0	-19.5	-19.5	
10	1002.6	0.0	0.0	1423.2	0.0	0.0	0.0	0.0	29.4	-450.0	-450.0	-450.0
MK	30.6	0.0	0.0	466.0	0.0	0.0	0.0	337.9	182.7	-280.2	-280.2	
11	8683.0	0.0	0.0	7950.4	0.0	0.0	10.9	0.0	121.6	600.1	600.1	600.0
RO	-13.7	0.0	0.0	1994.5	0.0	0.0	101.7	3243.0	1211.4	-78.4	-78.4	
12	1159.3	0.0	0.0	1125.0	0.0	0.0	0.3	0.0	34.1	-0.0	-0.0	0.0
SI	-61.7	0.0	0.0	297.1	0.0	0.0	2.6	342.1	606.4	-625.8	-625.8	
13	19697.1	0.0	0.0	19163.4	0.0	0.0	0.0	0.0	233.8	299.9	299.9	300.0
TR	-6490.4	0.0	0.0	1898.4	0.0	0.0	0.0	10591.7	2523.6	-320.7	-320.7	
16	4765.7	0.0	0.0	5208.1	0.0	0.0	0.3	0.0	67.3	-509.9	-509.9	-510.0
RS	1029.4	0.0	0.0	1979.4	0.0	0.0	2.5	1200.7	684.7	-436.3	-436.3	
COLUMN	44285.2	0.0	0.0	44025.9	0.0	0.0	14.7	0.0	621.8	-377.2	-377.2	-377.0
TOTALS	-4182.4	0.0	0.0	9868.4	0.0	0.0	135.1	19846.1	6579.4	-919.1	-919.1	

Figure 4.16 Load flow base case – winter high load 2012

Reliability assessment for Bosnia and Herzegovina (Figure 4.18) shows that loss of load under analyzed operational conditions may be expected with probability of 0,32 % (27,6 hours per year, these kind of results given by the Reliability assessment is just theoretical because only one, probably the worse operation condition is analyzed, 1 hour among 8760 hours per year). This loss of load refers to radial 400 kV line feeding SS 400/110 kV Banja Luka 6. In real situation loss of load will be avoided because of well developed network 110 kV in the area of Banja Luka, which is not included in the model for 2012. Transmission network 400 kV and 220 kV overloadings or undervoltage situations in Bosnia and Herzegovina are not probable during analyzed operational conditions.

Transmission lines overloadings may be expected in Bulgaria, with probability of 0,79 % (69,5 hours per year) - Figure 4.19. Frequency of critical failures is 13 occurrences per year and average duration of single failure is 5,3 hours. Some undervoltage problems and loss of load were detected also, but with very low probability (lower than 0,05 %).

Reliability assessment for Croatia (Figure 4.20) shows that branch overloadings under analyzed operational conditions may be expected with probability of 0,1 % (0,7 hours per year). Loss of load probability is very low (0,1 h/y). Unacceptable voltage deviations were not detected at the model for analyzed operational condition. These results prove that Croatian 400 kV network is quite reliable.

There are few critical situations during analyzed operation regime in Macedonia but with very low probability. Very rare undervoltage situations may be expected (Figure 4.21).
There are no critical situations during analyzed operation regime in Montenegro so probabilistic indices could not be calculated.

Undervoltage situations may be expected in Romania with probability of 0,1 % (8,5 hours/year). Loss of load may happen with probability of 0,02 % (1,4 hours per year) - Figure 4.22. Average annual number of critical failures is 0,73 and average duration of single failure is 13,7 hours.

These results are only indicative since statistical data from the Reliability Normative was used in the analysis, not the measured ones. This means that if Transelectrica manages to keep prescribed level of 400 kV lines outages, Romanian transmission network are going to be quite reliable.

There are several critical situations during analyzed operation regime in Serbia and Kosovo concerning undervoltages, overloads and loss of load situations but with very low probability - Figure 4.23.

In the Slovenian network some non-converging situations were detected at the model with probability of 0,7 h/year. Phase shifting transformers in the Divaca substations were overloaded at the model without any branch outages, but since power flows through these transformers may be controlled this modeling problem was neglected.

Turkish network may expect some overvoltages during analyzed system conditions with probability of 8,17 % (715,5 hours per year) and overloadings in the network with probability of 0,17 % (15,1 hours per year). Loss of load could be expected with probability of 0,34 %.

Individual SEE transmission systems reliability indices are summarized in Table 4.2 and Figure 4.31. Multiple forced outages of 400 kV lines within jurisdiction of individual TSO's in the region will cause no problems in the network in general. Some problems, mainly with overvoltage situations, are probable in Turkey only. Albanian, Croatian, Macedonian, Montenegrin, Serbian and Kosovo, and Slovenian network are not going to face any difficulties concerning 400 kV lines multiple forced outages during winter high load or peak load situations. Minor problems with undervoltages in Romania, overloadings in Bulgaria and loss of load in Bosnia and Herzegovina and Romania are possible, but probabilities of critical situations are extremely low.

Figure 4.26 - Figure 4.30 presents reliability indices for the Southeast Europe region, observing it as a single power system and electricity market. Combination of simultaneous multiple forced outages of 400 kV lines across the region were observed. Due to large number of possible lines outages combination, calculation was limited to simultaneous forced outage of two lines 400 kV in the Region. Probabilistic indices refer to the third Wednesday at 10:30 AM in January 2012. All transmission lines and transformers in the Southeast Europe region including Slovenia and Turkey were monitored during contingences, but only 400 kV and 220 kV network branches were included in the model that was used (additional congestions may be expected in the network 150 kV and 110 kV).

The following probabilistic indices were observed:

- System Reliability Indices Summary (Figure 4.26)
- System Load Curtailment Probabilistic Indices (Figure 4.27)
- Bus Load Curtailment Probability Indices (Figure 4.28)
- Branch Flow Overloading Probability Indices (Figure 4.29)
- Bus Voltage Violation Probability Indices (Figure 4.30)

Transmission network overloadings under analyzed operational condition may be expected with probability of 0,62 % (54 hours per year). Loss of load directly connected to the network 400 kV may be expected with probability of 0,79 % (68,9 hours per year). Under-voltage problems are possible with probability of 0,1 % (9 hours per year).

Problems in the regional transmission system during winter peak or high load in 2012, comprising under-voltage situations, branches overloading situations and loss of load due to 400 kV lines forced outages, are possible with probability of 1,71 % (150,2 hours per year).

Possible branches overloading problems are detected in Bulgaria, Croatia, Macedonia, Romania, Turkey and Serbia. The most critical branches overloading situations may appear in Turkey (transformers 400/150 kV TAMBAR11-TAMBDG31, busbar name in the PSS/E model), lines 150 kV around bus TAMBDG31, probability of overloading is 0,2 %). Branch overloading probability is moderate for 220 kV line Pehlin – Divaca (Croatia-Slovenia tie line, probability of overloading is 0,41 %). Probabilities of other branches overloading is extremely low (close to 0 %).

Bus voltage violation problems may appear in Bulgaria, Macedonia and Romania, but all with extremely low probability (close to 0 %).

Loss of load is possible in Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Romania, Turkey and Serbia.

```
                                                          FREQ. DURATION    PROB.     IMPACT NO. OF   WORST.
<--            F A I L U R E   C R I T E R I A        --> (OC/Y)  (HOURS)   (H/Y)              CONT.   VIOL.  <----- WORST CONTINGENCY ------>
LOSS OF LOAD (MW)                                        0.0086      0.7      0.0       0.28       1   48.000 1_3(AL-01:AL-06)
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL                          0.0086      0.7      0.0                  1
```

Figure 4.17 System Reliability Indices Summary for Albania – winter high load 2012

```
                                                          FREQ. DURATION    PROB.     IMPACT NO. OF   WORST.
<--            F A I L U R E   C R I T E R I A        --> (OC/Y)  (HOURS)   (H/Y)              CONT.   VIOL.  <----- WORST CONTINGENCY ------>
LOSS OF LOAD (MW)                                       20.7038      1.3     27.6    4651.52      47  168.700 1_1_3(BA-01:BA-02:BA-05)
NOT CONVERGE                                             0.0297      0.2      0.0                 12
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL                         20.7335      1.3     27.6                 59
```

Figure 4.18 System Reliability Indices Summary for Bosnia and Herzegovina – winter high load 2012

```
                                                          FREQ. DURATION    PROB.     IMPACT NO. OF   WORST.
<--            F A I L U R E   C R I T E R I A        --> (OC/Y)  (HOURS)   (H/Y)              CONT.   VIOL.  <----- WORST CONTINGENCY ------>
OVERLOAD (%)                                            13.0000      5.3     69.5       5.13      18  110.691 BG-42
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL                         13.0000      5.3     69.5                 18
```

Figure 4.19 System Reliability Indices Summary for Bulgaria – winter high load 2012

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                                                          FREQ. DURATION    PROB.     IMPACT NO. OF   WORST.
<--            F A I L U R E   C R I T E R I A        --> (OC/Y)  (HOURS)   (H/Y)              CONT.   VIOL.  <----- WORST CONTINGENCY ------>
OVERLOAD (%)                                             1.3095      0.5      0.7       0.00      13  110.391 11_2_1(HR-12:HR-14:HR-15)
LOSS OF LOAD (MW)                                        0.0396      2.4      0.1       7.64       6   78.900 1_11_1(HR-01:HR-13:HR-14)
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL                          1.3491      0.6      0.8                 18
```

Figure 4.20 System Reliability Indices Summary for Croatia – winter high load 2012

```
                                                          FREQ. DURATION    PROB.     IMPACT NO. OF   WORST.
<--            F A I L U R E   C R I T E R I A        --> (OC/Y)  (HOURS)   (H/Y)              CONT.   VIOL.  <----- WORST CONTINGENCY ------>
AREA 10 BUS WITH VOLTAGE < 0.900                         0.0008      0.3      0.0       0.00      28    0.871 1_1_4(MK-01:MK-02:MK-08)
OVERLOAD (%)                                             0.0000      0.1      0.0       0.00       9  111.011 2_1_6(MK-02:MK-03:MK-12)
NOT CONVERGE                                             0.0000      0.0      0.0                  2
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL                          0.0009      0.3      0.0                 35
```

Figure 4.21 System Reliability Indices Summary for Macedonia – winter high load 2012

<-- F A I L U R E C R I T E R I A -->	FREQ. (OC/Y)	DURATION (HOURS)	PROB. (H/Y)	IMPACT	NO. OF CONT.	WORST. VIOL.	<----- WORST CONTINGENCY ------>
AREA 11 BUS WITH VOLTAGE < 0.900	0.6208	13.8	8.5	0.53	1067	0.670	29_13_1(RO-36:RO-53:RO-54)
OVERLOAD (%)	0.0023	6.9	0.0	0.00	262	207.803	8_6_1(RO-11:RO-17:RO-18)
LOSS OF LOAD (MW)	0.1066	13.6	1.4	33.39	1376	218.900	33_1_19(RO-40:RO-43:RO-65)
NOT CONVERGE	0.0010	6.9	0.0		80		
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL	0.7306	13.7	10.0		2703		

Figure 4.22 System Reliability Indices Summary for Romania – winter high load 2012

<-- F A I L U R E C R I T E R I A -->	FREQ. (OC/Y)	DURATION (HOURS)	PROB. (H/Y)	IMPACT	NO. OF CONT.	WORST. VIOL.	<----- WORST CONTINGENCY ------>
AREA 16 BUS WITH VOLTAGE < 0.900	0.0000	0.1	0.0	0.00	38	0.705	1_9_5(RS-01:RS-14:RS-20)
OVERLOAD (%)	0.0000	0.1	0.0	0.00	20	114.897	12_15_1(RS-16:RS-38:RS-39)
LOSS OF LOAD (MW)	0.7609	0.1	0.1	14.31	821	532.100	3_14_3(RS-03:RS-22:RS-26)
NOT CONVERGE	0.0000	0.3	0.0		14		
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL	0.7610	0.1	0.1		893		

Figure 4.23 System Reliability Indices Summary for Serbia and Kosovo – winter high load 2012

Including system ties: Disable

<-- F A I L U R E C R I T E R I A -->	FREQ. (OC/Y)	DURATION (HOURS)	PROB. (H/Y)	IMPACT	NO. OF CONT.	WORST. VIOL.	<----- WORST CONTINGENCY ------>
NOT CONVERGE	1.0040	0.7	0.7		7		
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL	1.0040	0.7	0.7		7		

Figure 4.24 System Reliability Indices Summary for Slovenia – winter high load 2012

<-- F A I L U R E C R I T E R I A -->	FREQ. (OC/Y)	DURATION (HOURS)	PROB. (H/Y)	IMPACT	NO. OF CONT.	WORST. VIOL.	<----- WORST CONTINGENCY ------>
AREA 13 BUS WITH VOLTAGE > 1.100	539.4001	1.3	715.5	2028.43	47	1.359	TR-09
OVERLOAD (%)	11.6000	1.3	15.1	30.90	1	145.306	TR-25
LOSS OF LOAD (MW)	23.2000	1.3	30.2	4468.36	2	212.200	TR-39
NOT CONVERGE	11.6000	1.3	15.1		1		
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL	551.0001	1.3	730.6		48		

Figure 4.25 System Reliability Indices Summary for Turkey – winter high load 2012

Table 4.2 Individual SEE countries reliability indices (winter high load 2012)

Country	Voltage violations probability (%)	Branch overloads probability (%)	Loss of load probability (%)	TOTAL PROBABILITY (%)
Albania	0,00	0,00	0,00	0,00
Bosnia and Herzegovina	0,00	0,00	0,32	0,32
Bulgaria	0,00	0,79	0,00	0,79
Croatia	0,00	0,01	0,00	0,01
Macedonia	0,00	0,00	0,00	0,00
Montenegro	0,00	0,00	0,00	0,00
Romania	0,10	0,00	0,02	0,11
Serbia and Kosovo	0,00	0,00	0,00	0,00
Slovenia	0,00	0,00	0,00	0,00
Turkey	8,17	0,17	0,34	8,34

```
                                                                          FREQ. DURATION    PROB.     IMPACT NO. OF   WORST.
<--             F A I L U R E   C R I T E R I A              -->  (OC/Y)  (HOURS)   (H/Y)             CONT.   VIOL.  <----- WORST CONTINGENCY ------>
AREA 5 BUS WITH VOLTAGE < 0.900                                   0.0009      1.3      0.0       0.00       5    0.823 46_1(BG-35:BG-36)
AREA 10 BUS WITH VOLTAGE < 0.900                                  0.0008      0.3      0.0       0.00       4    0.894 68_4(MK-01:MK-07)
AREA 11 BUS WITH VOLTAGE < 0.900                                  0.8292     10.9      9.0       0.56     164    0.756 121_3(RO-51:RO-54)
OVERLOAD (%)                                                     19.4492      2.8     54.0      35.36     524  177.191 205_1(TR-27:TR-28)
LOSS OF LOAD (MW)                                                56.6067      1.2     68.9   10656.07    1024  380.900 9_208(BA-05:TR-39)
NOT CONVERGE                                                     16.0011      1.2     18.5                298
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL                                  92.6980      1.6    150.2               2000

CONTINGENCY LEGEND:
<----- CONTINGENCY LABEL ------> EVENTS
46_1(BG-35:BG-36)                OPEN BRANCH FROM BUS 253 [VCAREV11    400.00] TO BUS 306 [VVARNA11    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 253 [VCAREV11    400.00] TO BUS 278 [VMIZIA11    400.00] CKT 1
68_4(MK-01:MK-07)                OPEN BRANCH FROM BUS 80 [XTH_DU11    400.00] TO BUS 948 [YDUBRO1     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 940 [YBITOL1     400.00] TO BUS 948 [YDUBRO1     400.00] CKT 1
121_3(RO-51:RO-54)               OPEN BRANCH FROM BUS 1125 [RGUTI41     400.00] TO BUS 1203 [RSMIR411    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 1026 [RBACS41     400.00] TO BUS 1182 [RROMN41     400.00] CKT 1
205_1(TR-27:TR-28)               OPEN BRANCH FROM BUS 1298 [TBABES11    400.00] TO BUS 1376 [THAMIT11    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 1298 [TBABES11    400.00] TO BUS 1493 [TUNIMA11    400.00] CKT 1
9_208(BA-05:TR-39)               OPEN BRANCH FROM BUS 205 [WBLUKA1     400.00] TO BUS 236 [WTUZLA1     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 1402 [TKCKBK11    400.00] TO BUS 1491 [TUMRAN11    400.00] CKT 1
```

Figure 4.26 System Reliability Indices Summary for the SEE region – winter high load 2012

<-- LOAD CURTAILMENTS (MW) -->	FREQ. (OC/Y)	DURATION (HOUR)	PROB. (H/Y)	I.P. (MW/Y)	E.U.E. (MWH/Y)	NO. OF CONT.	<----- WORST CONTINGENCY ------:
0.0 -- 10.0	0.0002	7.0	0.0	0.00	0.00	1	113_3(RO-39:RO-44)
20.0 -- 30.0	0.2339	7.0	1.6	5.33	37.39	171	113_2(RO-39:RO-43)
30.0 -- 40.0	0.0399	0.7	0.0	1.21	0.79	1	199_8(TR-21:TR-29)
40.0 -- 50.0	0.0086	0.7	0.0	0.41	0.28	1	1_3(AL-01:AL-06)
70.0 -- 80.0	0.0395	2.4	0.1	3.12	7.63	1	64_1(HR-13:HR-14)
80.0 -- 90.0	14.7301	1.2	17.6	1231.43	1469.23	163	1_209(AL-01:TR-32)
90.0 -- 100.0	0.0002	0.5	0.0	0.02	0.01	2	69_95(MK-02:RS-44)
100.0-- 110.0	0.0420	0.7	0.0	4.21	2.85	2	97_113(RO-19:TR-32)
110.0-- 120.0	0.0006	7.0	0.0	0.08	0.53	1	106_3(RO-31:RO-35)
120.0-- 130.0	0.0052	0.9	0.0	0.67	0.60	2	79_86(ME-03:RS-45)
130.0-- 140.0	0.0001	0.3	0.0	0.01	0.00	1	49_1(BG-44:BG-45)
140.0-- 150.0	0.8848	0.1	0.1	129.03	16.20	330	1_162(AL-01:RS-41)
160.0-- 170.0	25.6606	1.2	31.7	4328.94	5344.56	172	1_8(AL-01:BA-05)
190.0-- 200.0	0.0035	1.2	0.0	0.67	0.83	1	9_88(BA-05:RO-19)
210.0-- 220.0	14.7301	1.2	17.6	3125.72	3729.32	163	1_216(AL-01:TR-39)
220.0-- 230.0	0.0014	0.1	0.0	0.33	0.04	2	163_47(RS-41:TR-32)
230.0-- 240.0	0.0020	1.2	0.0	0.48	0.57	1	97_120(RO-19:TR-39)
250.0-- 260.0	0.0702	0.7	0.0	17.71	11.73	1	9_201(BA-05:TR-32)
290.0-- 300.0	0.0399	0.6	0.0	11.81	7.68	2	210_7(TR-32:TR-39)
300.0-- 310.0	0.0399	0.7	0.0	12.26	7.97	1	198_6(TR-20:TR-26)
310.0-- 320.0	0.0025	0.1	0.0	0.80	0.09	2	9_154(BA-05:RS-41)
350.0-- 360.0	0.0014	0.1	0.0	0.51	0.06	2	163_54(RS-41:TR-39)
380.0-- 390.0	0.0702	0.7	0.0	26.73	17.70	1	9_208(BA-05:TR-39)
ENTIRE SYSTEM	56.6067	1.2	68.9	8901.45	10656.07	1024	

CONTINGENCY LEGEND:

<----- CONTINGENCY LABEL ------>	EVENTS
113_3(RO-39:RO-44)	OPEN BRANCH FROM BUS 1073 [RCONS411 400.00] TO BUS 1213 [RTARIV1 400.00] CKT 1
	OPEN BRANCH FROM BUS 1213 [RTARIV1 400.00] TO BUS 1231 [RTULC41 400.00] CKT 1
113_2(RO-39:RO-43)	OPEN BRANCH FROM BUS 1073 [RCONS411 400.00] TO BUS 1213 [RTARIV1 400.00] CKT 1
	OPEN BRANCH FROM BUS 1140 [RISAC41 400.00] TO BUS 1231 [RTULC41 400.00] CKT 1
199_8(TR-21:TR-29)	OPEN BRANCH FROM BUS 1275 [TALIBY11 400.00] TO BUS 1313 [TBEYKZ11 400.00] CKT 1
	OPEN BRANCH FROM BUS 1313 [TBEYKZ11 400.00] TO BUS 1446 [TPSKOY11 400.00] CKT 1
1_3(AL-01:AL-06)	OPEN BRANCH FROM BUS 55 [XZE_KA11 400.00] TO BUS 203 [AZEMLA1 400.00] CKT 1
	OPEN BRANCH FROM BUS 186 [AELBS21 400.00] TO BUS 203 [AZEMLA1 400.00] CKT 1
64_1(HR-13:HR-14)	OPEN BRANCH FROM BUS 843 [HKONJS1 400.00] TO BUS 855 [HVELEB1 400.00] CKT 1
	OPEN BRANCH FROM BUS 846 [HMELIN1 400.00] TO BUS 855 [HVELEB1 400.00] CKT 1
1_209(AL-01:TR-32)	OPEN BRANCH FROM BUS 55 [XZE_KA11 400.00] TO BUS 203 [AZEMLA1 400.00] CKT 1
	OPEN BRANCH FROM BUS 1352 [TEREGL11 400.00] TO BUS 1442 [TOSMNC11 400.00] CKT 1
69_95(MK-02:RS-44)	OPEN BRANCH FROM BUS 101 [XSK_UR11 400.00] TO BUS 989 [YSK 51 400.00] CKT 1
	OPEN BRANCH FROM BUS 2173 [JKOSB 11 400.00] TO BUS 2232 [JUROS211 400.00] CKT 1
97_113(RO-19:TR-32)	OPEN BRANCH FROM BUS 1185 [RROV5 15 400.00] TO BUS 1241 [RUREC41 400.00] CKT 1
	OPEN BRANCH FROM BUS 1352 [TEREGL11 400.00] TO BUS 1442 [TOSMNC11 400.00] CKT 1
106_3(RO-31:RO-35)	OPEN BRANCH FROM BUS 1051 [RBUCU41 400.00] TO BUS 1172 [RPELI41 400.00] CKT 1
	OPEN BRANCH FROM BUS 1060 [RCERN41 400.00] TO BUS 1172 [RPELI41 400.00] CKT 1
79_86(ME-03:RS-45)	OPEN BRANCH FROM BUS 100 [XRI_PE11 400.00] TO BUS 931 [ORPRIB1 400.00] CKT 0
	OPEN BRANCH FROM BUS 2173 [JKOSB 11 400.00] TO BUS 2196 [JPEC3 1 400.00] CKT 1E
49_1(BG-44:BG-45)	OPEN BRANCH FROM BUS 251 [VBURGA11 400.00] TO BUS 306 [VVARNA11 400.00] CKT 1
	OPEN BRANCH FROM BUS 251 [VBURGA11 400.00] TO BUS 300 [VTMI2411 400.00] CKT 1
1_162(AL-01:RS-41)	OPEN BRANCH FROM BUS 55 [XZE_KA11 400.00] TO BUS 203 [AZEMLA1 400.00] CKT 1
	OPEN BRANCH FROM BUS 2214 [JSOMB31 400.00] TO BUS 2216 [JSUBO311 400.00] CKT 1
1_8(AL-01:BA-05)	OPEN BRANCH FROM BUS 55 [XZE_KA11 400.00] TO BUS 203 [AZEMLA1 400.00] CKT 1
	OPEN BRANCH FROM BUS 205 [WBLUKA1 400.00] TO BUS 236 [WTUZLA1 400.00] CKT 1
9_88(BA-05:RO-19)	OPEN BRANCH FROM BUS 205 [WBLUKA1 400.00] TO BUS 236 [WTUZLA1 400.00] CKT 1
	OPEN BRANCH FROM BUS 1185 [RROV5 15 400.00] TO BUS 1241 [RUREC41 400.00] CKT 1
1_216(AL-01:TR-39)	OPEN BRANCH FROM BUS 55 [XZE_KA11 400.00] TO BUS 203 [AZEMLA1 400.00] CKT 1
	OPEN BRANCH FROM BUS 1402 [TKCKBK11 400.00] TO BUS 1491 [TUMRAN11 400.00] CKT 1
163_47(RS-41:TR-32)	OPEN BRANCH FROM BUS 2214 [JSOMB31 400.00] TO BUS 2216 [JSUBO311 400.00] CKT 1
	OPEN BRANCH FROM BUS 1352 [TEREGL11 400.00] TO BUS 1442 [TOSMNC11 400.00] CKT 1
97_120(RO-19:TR-39)	OPEN BRANCH FROM BUS 1185 [RROV5 15 400.00] TO BUS 1241 [RUREC41 400.00] CKT 1
	OPEN BRANCH FROM BUS 1402 [TKCKBK11 400.00] TO BUS 1491 [TUMRAN11 400.00] CKT 1
9_201(BA-05:TR-32)	OPEN BRANCH FROM BUS 205 [WBLUKA1 400.00] TO BUS 236 [WTUZLA1 400.00] CKT 1
	OPEN BRANCH FROM BUS 1352 [TEREGL11 400.00] TO BUS 1442 [TOSMNC11 400.00] CKT 1
210_7(TR-32:TR-39)	OPEN BRANCH FROM BUS 1352 [TEREGL11 400.00] TO BUS 1442 [TOSMNC11 400.00] CKT 1
	OPEN BRANCH FROM BUS 1402 [TKCKBK11 400.00] TO BUS 1491 [TUMRAN11 400.00] CKT 1
198_6(TR-20:TR-26)	OPEN BRANCH FROM BUS 1275 [TALIBY11 400.00] TO BUS 1292 [TATISA11 400.00] CKT 1
	OPEN BRANCH FROM BUS 1292 [TATISA11 400.00] TO BUS 1382 [TIKITL11 400.00] CKT 1
9_154(BA-05:RS-41)	OPEN BRANCH FROM BUS 205 [WBLUKA1 400.00] TO BUS 236 [WTUZLA1 400.00] CKT 1
	OPEN BRANCH FROM BUS 2214 [JSOMB31 400.00] TO BUS 2216 [JSUBO311 400.00] CKT 1
163_54(RS-41:TR-39)	OPEN BRANCH FROM BUS 2214 [JSOMB31 400.00] TO BUS 2216 [JSUBO311 400.00] CKT 1
	OPEN BRANCH FROM BUS 1402 [TKCKBK11 400.00] TO BUS 1491 [TUMRAN11 400.00] CKT 1
9_208(BA-05:TR-39)	OPEN BRANCH FROM BUS 205 [WBLUKA1 400.00] TO BUS 236 [WTUZLA1 400.00] CKT 1
	OPEN BRANCH FROM BUS 1402 [TKCKBK11 400.00] TO BUS 1491 [TUMRAN11 400.00] CKT 1

Figure 4.27 System Load Curtailment Probabilistic Indices for the SEE region – winter high load 2012

<BUS WITH LOAD CURTAILMENT (MW)>			LOAD (MW)	FREQ. (OC/Y)	DURATION (HOUR)	A.I.P. (MW/OC)	I. P. (MW/Y)	E.U.E. (MWH/Y)	B.I.P.	B.E.U.	NO. OF CONT.	<----- WORST CONTINGENCY ------>
ENTIRE SYSTEM			79471.1	56.6067	1.22	157.25	8901.45	10656.07	0.1120	0.1341	1024	
203	AZEMLA1	400.00	48.0	0.0086	0.67	48.00	0.41	0.28	0.0086	0.0058	1	1_3(AL-01:AL-06)
205	WBLUKA1	400.00	168.7	25.8069	1.23	168.70	4353.62	5361.02	25.8069	31.7784	175	1_8(AL-01:BA-05)
252	VBURGA51	110.00	135.0	0.0001	0.31	135.00	0.01	0.00	0.0001	0.0000	1	49_1(BG-44:BG-45)
855	HVELEB1	400.00	78.9	0.0395	2.45	78.90	3.12	7.63	0.0395	0.0967	1	64_1(HR-13:HR-14)
1172	RPELI41	400.00	117.9	0.0006	7.00	117.90	0.08	0.53	0.0006	0.0045	1	106_3(RO-31:RO-35)
1185	RROV5 15	400.00	22.8	0.2414	6.82	22.80	5.50	37.57	0.2414	1.6477	174	1_96(AL-01:RO-19)
1214	RTARIV5	110.00	3.7	0.0003	7.00	3.70	0.00	0.01	0.0003	0.0018	2	113_2(RO-39:RO-43)
1230	RTULC 5	110.00	24.0	0.0002	7.00	24.00	0.00	0.03	0.0002	0.0011	2	113_2(RO-39:RO-43)
1294	TATISA32	150.00	34.2	0.0399	0.65	34.20	1.37	0.89	0.0399	0.0260	1	198_6(TR-20:TR-26)
1313	TBEYKZ11	400.00	30.3	0.0399	0.65	30.30	1.21	0.79	0.0399	0.0260	1	199_8(TR-21:TR-29)
1352	TEREGL11	400.00	83.6	14.8436	1.19	83.60	1240.93	1475.50	14.8436	17.6496	168	1_209(AL-01:TR-32)
1401	TKCELK11	400.00	100.0	0.0399	0.65	100.00	3.99	2.60	0.0399	0.0260	1	214_2(TR-36:TR-38)
1402	TKCKBK11	400.00	212.2	14.8436	1.19	212.20	3149.82	3745.24	14.8436	17.6496	168	1_216(AL-01:TR-39)
1447	TSAGMA31	150.00	219.0	0.0399	0.65	219.00	8.75	5.69	0.0399	0.0260	1	198_6(TR-20:TR-26)
1482	TTOPKA32	150.00	53.9	0.0399	0.65	53.90	2.15	1.40	0.0399	0.0260	1	198_6(TR-20:TR-26)
2180	JLESK21	400.00	145.7	0.2962	0.10	145.70	43.15	4.28	0.2962	0.0294	170	1_150(AL-01:RS-22)
2196	JPEC3 1	400.00	129.1	0.0052	0.90	129.10	0.67	0.60	0.0052	0.0046	2	79_86(ME-03:RS-45)
2214	JSOMB31	400.00	145.9	0.5941	0.14	145.90	86.68	12.01	0.5941	0.0823	170	1_162(AL-01:RS-41)
2232	JUROS211	400.00	94.6	0.0002	0.48	94.60	0.02	0.01	0.0002	0.0001	2	69_95(MK-02:RS-44)

CONTINGENCY LEGEND:

<----- CONTINGENCY LABEL ------>	EVENTS
1_3(AL-01:AL-06)	OPEN BRANCH FROM BUS 55 [XZE_KA11 400.00] TO BUS 203 [AZEMLA1 400.00] CKT 1
	OPEN BRANCH FROM BUS 186 [AELBS21 400.00] TO BUS 203 [AZEMLA1 400.00] CKT 1
1_8(AL-01:BA-05)	OPEN BRANCH FROM BUS 55 [XZE_KA11 400.00] TO BUS 203 [AZEMLA1 400.00] CKT 1
	OPEN BRANCH FROM BUS 205 [WBLUKA1 400.00] TO BUS 236 [WTUZLA1 400.00] CKT 1
49_1(BG-44:BG-45)	OPEN BRANCH FROM BUS 251 [VBURGA11 400.00] TO BUS 306 [VVARNA11 400.00] CKT 1
	OPEN BRANCH FROM BUS 251 [VBURGA11 400.00] TO BUS 300 [VTMI2411 400.00] CKT 1
64_1(HR-13:HR-14)	OPEN BRANCH FROM BUS 843 [HKONJS1 400.00] TO BUS 855 [HVELEB1 400.00] CKT 1
	OPEN BRANCH FROM BUS 846 [HMELIN1 400.00] TO BUS 855 [HVELEB1 400.00] CKT 1
106_3(RO-31:RO-35)	OPEN BRANCH FROM BUS 1051 [RBUCU41 400.00] TO BUS 1172 [RPELI41 400.00] CKT 1
	OPEN BRANCH FROM BUS 1060 [RCERN41 400.00] TO BUS 1172 [RPELI41 400.00] CKT 1
1_96(AL-01:RO-19)	OPEN BRANCH FROM BUS 55 [XZE_KA11 400.00] TO BUS 203 [AZEMLA1 400.00] CKT 1
	OPEN BRANCH FROM BUS 1185 [RROV5 15 400.00] TO BUS 1241 [RUREC41 400.00] CKT 1
113_2(RO-39:RO-43)	OPEN BRANCH FROM BUS 1073 [RCONS411 400.00] TO BUS 1213 [RTARIV1 400.00] CKT 1
	OPEN BRANCH FROM BUS 1140 [RISAC41 400.00] TO BUS 1231 [RTULC41 400.00] CKT 1
198_6(TR-20:TR-26)	OPEN BRANCH FROM BUS 1275 [TALIBY11 400.00] TO BUS 1292 [TATISA11 400.00] CKT 1
	OPEN BRANCH FROM BUS 1292 [TATISA11 400.00] TO BUS 1382 [TIKITL11 400.00] CKT 1
199_8(TR-21:TR-29)	OPEN BRANCH FROM BUS 1275 [TALIBY11 400.00] TO BUS 1313 [TBEYKZ11 400.00] CKT 1
	OPEN BRANCH FROM BUS 1313 [TBEYKZ11 400.00] TO BUS 1446 [TPSKOY11 400.00] CKT 1
1_209(AL-01:TR-32)	OPEN BRANCH FROM BUS 55 [XZE_KA11 400.00] TO BUS 203 [AZEMLA1 400.00] CKT 1
	OPEN BRANCH FROM BUS 1352 [TEREGL11 400.00] TO BUS 1442 [TOSMNC11 400.00] CKT 1
214_2(TR-36:TR-38)	OPEN BRANCH FROM BUS 1376 [THAMIT11 400.00] TO BUS 1401 [TKCELK11 400.00] CKT 1
	OPEN BRANCH FROM BUS 1401 [TKCELK11 400.00] TO BUS 1493 [TUNIMA11 400.00] CKT 1
1_216(AL-01:TR-39)	OPEN BRANCH FROM BUS 55 [XZE_KA11 400.00] TO BUS 203 [AZEMLA1 400.00] CKT 1
	OPEN BRANCH FROM BUS 1402 [TKCKBK11 400.00] TO BUS 1491 [TUMRAN11 400.00] CKT 1
1_150(AL-01:RS-22)	OPEN BRANCH FROM BUS 55 [XZE_KA11 400.00] TO BUS 203 [AZEMLA1 400.00] CKT 1
	OPEN BRANCH FROM BUS 2180 [JLESK21 400.00] TO BUS 2183 [JNIS2 12 400.00] CKT 1
79_86(ME-03:RS-45)	OPEN BRANCH FROM BUS 100 [XRI_PE11 400.00] TO BUS 931 [ORPRIB1 400.00] CKT 0
	OPEN BRANCH FROM BUS 2173 [JKOSB 11 400.00] TO BUS 2196 [JPEC3 1 400.00] CKT 1E
1_162(AL-01:RS-41)	OPEN BRANCH FROM BUS 55 [XZE_KA11 400.00] TO BUS 203 [AZEMLA1 400.00] CKT 1
	OPEN BRANCH FROM BUS 2214 [JSOMB31 400.00] TO BUS 2216 [JSUBO311 400.00] CKT 1
69_95(MK-02:RS-44)	OPEN BRANCH FROM BUS 101 [XSK_UR11 400.00] TO BUS 989 [YSK 51 400.00] CKT 1
	OPEN BRANCH FROM BUS 2173 [JKOSB 11 400.00] TO BUS 2232 [JUROS211 400.00] CKT 1

Figure 4.28 Bus Load Curtailment Probability Indices for the SEE region – winter high load 2012

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<---------- O V E R L O A D E D   L I N E S --------->    FREQ. DURATION    PROB.   IMPACT MAX VIO. NO. OF
<------ F R O M --------> <-------- T O ---------->CKT    (OC/Y)   (HOUR)    (H/Y)    (PU)     (%)    CONT. <----- WORST CONTINGENCY ------>
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL                          19.4492      2.8     54.0    35.36     0.00    524
    85 XPE_DI21    220.00    850 HPEHLI2     220.00 1    3.8484      9.4     36.0     0.32   101.97    142 7_162(BA-03:SI-03)
   241 VALEKO21    220.00    286 VPLOVD21    220.00 1    0.0030      0.5      0.0     0.00   112.29      3 50_131(BG-45:TR-03)
   261 VDOBR151    110.00    263 VDOBRU11    400.00 1    1.3822      0.5      0.7     0.02   104.24    216 46_98(BG-35:RS-14)
   262 VDOBR221    220.00    270 VKARN221    220.00 1    0.0001      1.0      0.0     0.00   102.10      1 47_3(BG-36:BG-45)
   266 VGORIA21    220.00    267 VGORIA51    110.00 1    0.0003      1.5      0.0     0.00   144.07      2 46_1(BG-35:BG-36)
   846 HMELIN1     400.00    847 HMELIN2     220.00 1    0.0087      0.9      0.0     0.00   108.83      2 65_1(HR-14:HR-15)
   984 YSK  15     110.00    988 YSK  45     110.00 2    0.0000      0.1      0.0     0.00   103.50      1 76_88(MK-12:RS-44)
   984 YSK  15     110.00   1002 YTETO 5     110.00 1    0.0001      0.1      0.0     0.00   128.21      3 76_88(MK-12:RS-44)
   987 YSK  41     400.00    988 YSK  45     110.00 1    0.0000      0.1      0.0     0.00   102.03      1 76_88(MK-12:RS-44)
   987 YSK  41     400.00    988 YSK  45     110.00 2    0.0000      0.1      0.0     0.00   102.03      1 76_88(MK-12:RS-44)
  1041 RBRAS 52    110.00   1042 RBRAS41     400.00 1    0.0002      7.0      0.0     0.00   103.46      1 125_3(RO-56:RO-59)
  1045 RBRAZ221    220.00   1046 RBRAZ41     400.00 1    0.0013      7.0      0.0     0.00   104.50      1 91_37(RO-13:RO-59)
  1138 RIERN22     220.00   1139 RIERN41     400.00 1    0.0004      7.0      0.0     0.00   137.15      2 85_45(RO-05:RO-61)
  1151 RMEDG 52    110.00   1152 RMEDG41     400.00 1    0.0003      7.0      0.0     0.00   150.18      1 110_4(RO-36:RO-40)
  1151 RMEDG 52    110.00   1153 RMEDI 5     110.00 1    0.0003      7.0      0.0     0.00   101.79      1 110_4(RO-36:RO-40)
  1281 TAMBAR11    400.00   1282 TAMBDG31    150.00 1   14.0049      1.2     17.1     5.88   134.39    147 18_185(BG-01:TR-25)
  1281 TAMBAR11    400.00   1282 TAMBDG31    150.00 2   14.0049      1.2     17.1     5.88   134.39    147 18_185(BG-01:TR-25)
  1282 TAMBDG31    150.00   1284 TAMBDT31    150.00 1   14.0848      1.2     17.2     7.75   145.31    149 201_2(TR-23:TR-25)
  1284 TAMBDT31    150.00   1285 TAMBFO31    150.00 1   14.0848      1.2     17.2     7.74   145.24    149 80_123(ME-04:TR-25)
  1284 TAMBDT31    150.00   1285 TAMBFO31    150.00 2   14.0848      1.2     17.2     7.74   145.24    149 80_123(ME-04:TR-25)
  1297 TBABAE31    150.00   1377 THAMIT31    150.00 1    0.0799      0.7      0.1     0.02   177.19      2 205_1(TR-27:TR-28)
  1523 TZEKER11    400.00   1524 TZEKER31    150.00 1    0.0399      0.7      0.0     0.00   100.26      1 201_6(TR-23:TR-29)
  2155 JBGD3 22    220.00   2191 JOBREN21    220.00 1    0.0000      0.1      0.0     0.00   105.06      1 142_4(RS-11:RS-16)

CONTINGENCY LEGEND:
<----- CONTINGENCY LABEL ------> EVENTS
7_162(BA-03:SI-03)               OPEN BRANCH FROM BUS 64 [XTR_PG11    400.00] TO BUS 229 [WTREBI1     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 84 [XME_DI11    400.00] TO BUS 1248 [LDIVAC1     400.00] CKT 1
50_131(BG-45:TR-03)              OPEN BRANCH FROM BUS 251 [VBURGA11    400.00] TO BUS 300 [VTMI2411    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 79 [XNS_BA11    400.00] TO BUS 1298 [TBABES11    400.00] CKT 1
46_98(BG-35:RS-14)               OPEN BRANCH FROM BUS 253 [VCAREV11    400.00] TO BUS 306 [VVARNA11    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 2162 [JBOR 21     400.00] TO BUS 2168 [JHDJE111    400.00] CKT 1
47_3(BG-36:BG-45)                OPEN BRANCH FROM BUS 253 [VCAREV11    400.00] TO BUS 278 [VMIZIA11    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 251 [VBURGA11    400.00] TO BUS 300 [VTMI2411    400.00] CKT 1
46_1(BG-35:BG-36)                OPEN BRANCH FROM BUS 253 [VCAREV11    400.00] TO BUS 306 [VVARNA11    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 253 [VCAREV11    400.00] TO BUS 278 [VMIZIA11    400.00] CKT 1
65_1(HR-14:HR-15)                OPEN BRANCH FROM BUS 846 [HMELIN1     400.00] TO BUS 855 [HVELEB1     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 846 [HMELIN1     400.00] TO BUS 854 [HTUMBR1     400.00] CKT 1
76_88(MK-12:RS-44)               OPEN BRANCH FROM BUS 987 [YSK  41     400.00] TO BUS 989 [YSK  51     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 2173 [JKOSB 11    400.00] TO BUS 2232 [JUROS211    400.00] CKT 1
125_3(RO-56:RO-59)               OPEN BRANCH FROM BUS 1042 [RBRAS41     400.00] TO BUS 1084 [RDIRS41     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 1046 [RBRAZ41     400.00] TO BUS 1084 [RDIRS41     400.00] CKT 1
91_37(RO-13:RO-59)               OPEN BRANCH FROM BUS 1037 [RBRAD41     400.00] TO BUS 1222 [RTINT41A    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 1046 [RBRAZ41     400.00] TO BUS 1084 [RDIRS41     400.00] CKT 1
85_45(RO-05:RO-61)               OPEN BRANCH FROM BUS 103 [XRO_MU11    400.00] TO BUS 1184 [RROSI41     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 1112 [RGADA41     400.00] TO BUS 1139 [RIERN41     400.00] CKT 1
110_4(RO-36:RO-40)               OPEN BRANCH FROM BUS 1117 [RGIAL412    400.00] TO BUS 1146 [RLACS411    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 1060 [RCERN41     400.00] TO BUS 1073 [RCONS411    400.00] CKT 1
18_185(BG-01:TR-25)              OPEN BRANCH FROM BUS 69 [XBG_TH11    400.00] TO BUS 248 [VBLAGO11    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 1281 [TAMBAR11    400.00] TO BUS 1382 [TIKITL11    400.00] CKT 1
201_2(TR-23:TR-25)               OPEN BRANCH FROM BUS 1275 [TALIBY11    400.00] TO BUS 1491 [TUMRAN11    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 1281 [TAMBAR11    400.00] TO BUS 1382 [TIKITL11    400.00] CKT 1
80_123(ME-04:TR-25)              OPEN BRANCH FROM BUS 929 [OPODG21     400.00] TO BUS 931 [ORPRIB1     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 1281 [TAMBAR11    400.00] TO BUS 1382 [TIKITL11    400.00] CKT 1
205_1(TR-27:TR-28)               OPEN BRANCH FROM BUS 1298 [TBABES11    400.00] TO BUS 1376 [THAMIT11    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 1298 [TBABES11    400.00] TO BUS 1493 [TUNIMA11    400.00] CKT 1
201_6(TR-23:TR-29)               OPEN BRANCH FROM BUS 1275 [TALIBY11    400.00] TO BUS 1491 [TUMRAN11    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 1313 [TBEYKZ11    400.00] TO BUS 1446 [TPSKOY11    400.00] CKT 1
142_4(RS-11:RS-16)               OPEN BRANCH FROM BUS 2158 [JBGD8 11    400.00] TO BUS 2189 [JOBREN11    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 2168 [JHDJE111    400.00] TO BUS 2205 [JRPDRM12    400.00] CKT 1
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Figure 4.29 Branch Flow Overloading Probability Indices for the SEE region – winter high load 2012

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                                 AREA 5 BUSES WITH VOLTAGE LESS THAN 0.900
                             FREQ. DURATION    PROB.   IMPACT MAX VIO. NO. OF
<- BUS WITH VOLTAGE VIOLATION ->  (OC/Y)  (HOUR)     (H/Y)    (PU)          CONT. <----- WORST CONTINGENCY ------>
ENTIRE SYSTEM                    0.0009     1.3      0.0     0.00                5
   247 VBELOS51     110.00       0.0003     1.0      0.0     0.00   0.8810       2 47_3(BG-36:BG-45)
   251 VBURGA11     400.00       0.0007     1.2      0.0     0.00   0.8688       4 47_3(BG-36:BG-45)
   252 VBURGA51     110.00       0.0003     1.0      0.0     0.00   0.8837       2 47_3(BG-36:BG-45)
   253 VCAREV11     400.00       0.0003     1.5      0.0     0.00   0.8235       2 46_1(BG-35:BG-36)
   262 VDOBR221     220.00       0.0003     1.0      0.0     0.00   0.8795       2 47_3(BG-36:BG-45)
   268 VHIMKO51     110.00       0.0001     1.0      0.0     0.00   0.8871       1 47_3(BG-36:BG-45)
   273 VMADAR21     220.00       0.0007     1.2      0.0     0.00   0.8645       4 47_3(BG-36:BG-45)
   304 VTVAR151     110.00       0.0003     1.0      0.0     0.00   0.8791       2 47_3(BG-36:BG-45)
   305 VTVAR221     220.00       0.0003     1.0      0.0     0.00   0.8730       2 47_3(BG-36:BG-45)
   307 VVARNA21     220.00       0.0001     1.0      0.0     0.00   0.8891       1 47_3(BG-36:BG-45)

                                AREA 10 BUSES WITH VOLTAGE LESS THAN 0.900
                             FREQ. DURATION    PROB.   IMPACT MAX VIO. NO. OF
<- BUS WITH VOLTAGE VIOLATION ->  (OC/Y)  (HOUR)     (H/Y)    (PU)          CONT. <----- WORST CONTINGENCY ------>
ENTIRE SYSTEM                    0.0008     0.3      0.0     0.00                4
   946 YDELCE5      110.00       0.0003     0.5      0.0     0.00   0.8972       1 68_4(MK-01:MK-07)
   962 YKOCAN5      110.00       0.0008     0.3      0.0     0.00   0.8937       4 68_4(MK-01:MK-07)
   969 YMKAME5      110.00       0.0008     0.3      0.0     0.00   0.8935       4 68_4(MK-01:MK-07)

                                AREA 11 BUSES WITH VOLTAGE LESS THAN 0.900
                             FREQ. DURATION    PROB.   IMPACT MAX VIO. NO. OF
<- BUS WITH VOLTAGE VIOLATION ->  (OC/Y)  (HOUR)     (H/Y)    (PU)          CONT. <----- WORST CONTINGENCY ------>
ENTIRE SYSTEM                    0.8292    10.9      9.0     0.56              164
  1082 RCTSV 5      110.00       0.0006     7.0      0.0     0.00   0.8399       2 121_3(RO-51:RO-54)
  1131 RIASI22      220.00       0.0006     7.0      0.0     0.00   0.8939       2 121_3(RO-51:RO-54)
  1162 RORAD41      400.00       0.0003     7.0      0.0     0.00   0.8981       1 85_48(RO-05:RO-64)
  1181 RROMN 5      110.00       0.2780    10.8      3.0     0.07   0.7883      89 121_3(RO-51:RO-54)
  1182 RROMN41      400.00       0.2780    10.8      3.0     0.20   0.7555      89 121_3(RO-51:RO-54)
  1209 RSUCE 5      110.00       0.0006     7.0      0.0     0.00   0.8383       2 121_3(RO-51:RO-54)
  1210 RSUCE22      220.00       0.2780    10.8      3.0     0.01   0.8298      89 121_3(RO-51:RO-54)
  1211 RSUCE41      400.00       0.8289    10.9      9.0     0.28   0.7633     163 121_3(RO-51:RO-54)

CONTINGENCY LEGEND:
<----- CONTINGENCY LABEL ------> EVENTS
47_3(BG-36:BG-45)                OPEN BRANCH FROM BUS 253 [VCAREV11    400.00] TO BUS 278 [VMIZIA11    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 251 [VBURGA11    400.00] TO BUS 300 [VTMI2411    400.00] CKT 1
46_1(BG-35:BG-36)                OPEN BRANCH FROM BUS 253 [VCAREV11    400.00] TO BUS 306 [VVARNA11    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 253 [VCAREV11    400.00] TO BUS 278 [VMIZIA11    400.00] CKT 1
68_4(MK-01:MK-07)                OPEN BRANCH FROM BUS 80 [XTH_DU11    400.00] TO BUS 948 [YDUBRO1    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 940 [YBITOL1     400.00] TO BUS 948 [YDUBRO1     400.00] CKT 1
121_3(RO-51:RO-54)               OPEN BRANCH FROM BUS 1125 [RGUTI41     400.00] TO BUS 1203 [RSMIR411    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 1026 [RBACS41     400.00] TO BUS 1182 [RROMN41     400.00] CKT 1
85_48(RO-05:RO-64)               OPEN BRANCH FROM BUS 103 [XRO_MU11    400.00] TO BUS 1184 [RROSI41     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 1162 [RORAD41     400.00] TO BUS 1184 [RROSI41     400.00] CKT 1
```

Figure 4.30 Bus Voltage Violation Probability Indices for the SEE region – winter high load 2012

Figure 4.31 Individual SEE transmission networks reliability assessment: probability of overloadings, busbars undervoltages and loss of load during 2012 winter high load (third Wednesday in January 2012)

4.5.2 Expected short-time frame planned SEE transmission network (2015)

Basic power flow data for analyzed scenario is given in the following figure. It presents individual countries generation, demand, losses and interchanges at the model. There were several lines loading violations and busbars undervoltages in the base case scenario, located in Bulgaria, Kosovo, Slovenia and Turkey. This model was corrected in order to avoid base case branches overloading and unacceptable voltage deviations, because this was necessary to perform reliability assessment (PSS/E doesn't calculate "Multi-level AC contingency solution" correctly if there are base case violations at the model). Nevertheless, it was estimated by Authors that base case overloadings and voltage deviations are caused by incorrect modeling, not by real problems which may be expected in the transmission network.

PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS(R)E THU, SEP 13 2012 14:16
SECI REGIONAL MODEL AREA TOTALS
MAXIMUM LOAD 1030 - WINTER 2015 IN MW/MVAR

X-- AREA --X	FROM ------AT AREA BUSES------- GENE- RATION	FROM IND GENERATN	TO IND MOTORS	TO LOAD	TO BUS SHUNT	TO GNE BUS DEVICES	TO LINE SHUNT	FROM CHARGING	TO LOSSES	-NET INTERCHANGE- TO TIE LINES	TO TIES + LOADS	DESIRED NET INT
10	1276.8	0.0	0.0	1536.5	0.0	0.0	0.0	0.0	40.3	-300.0	-300.0	-300.0
AL	425.1	0.0	0.0	555.2	-108.0	0.0	0.0	602.6	392.8	187.7	187.7	
20	8818.8	0.0	0.0	7603.7	0.0	0.0	14.5	0.0	200.5	1000.0	1000.0	1000.0
BG	3232.0	0.0	0.0	3045.8	191.5	0.0	123.0	3136.4	2602.4	405.8	405.8	
30	3144.5	0.0	0.0	2603.2	0.0	0.0	0.0	0.0	53.4	488.0	488.0	488.0
BA	642.6	0.0	0.0	714.5	0.0	0.0	0.0	910.0	597.3	240.8	240.8	
40	3102.1	0.0	0.0	3483.0	0.0	0.0	0.0	0.0	54.1	-435.0	-435.0	-435.0
HR	342.9	0.0	0.0	1074.2	0.0	0.0	0.0	1416.9	692.1	-6.5	-6.5	
60	1554.3	0.0	0.0	1731.0	0.0	0.0	0.2	0.0	23.1	-200.0	-200.0	-200.0
MK	396.8	0.0	0.0	529.7	0.0	0.0	2.5	447.8	271.3	41.1	41.1	
70	10238.7	0.0	0.0	8968.4	0.0	0.0	81.2	0.0	189.0	1000.1	1000.1	1000.0
RO	438.6	0.0	0.0	2745.2	100.7	0.0	235.6	4650.8	2204.6	-196.8	-196.8	
75	3398.5	0.0	0.0	2514.0	0.0	0.0	8.7	0.0	51.8	824.0	824.0	824.0
SI	955.2	0.0	0.0	811.0	0.0	0.0	53.6	609.2	745.5	-45.7	-45.7	
80	54594.7	0.0	0.0	54622.0	-0.0	0.0	0.0	0.0	772.7	-800.0	-800.0	-800.0
TR	4617.0	0.0	0.0	7792.0	1175.4	0.0	0.0	17234.7	12960.3	-75.9	-75.9	
90	7218.3	0.0	0.0	7240.5	0.0	0.0	11.4	0.0	166.3	-200.0	-200.0	-200.0
RS	1946.1	0.0	0.0	2389.5	0.0	0.0	66.5	1850.6	1929.6	-589.0	-589.0	
91	928.0	0.0	0.0	877.5	0.5	0.0	2.2	0.0	27.7	20.0	20.0	20.0
ME	131.2	0.0	0.0	318.4	-33.1	0.0	16.3	283.7	223.2	-109.9	-109.9	
COLUMN	94274.8	0.0	0.0	91179.8	0.5	0.0	118.3	0.0	1579.0	1397.1	1397.1	1397.0
TOTALS	13127.5	0.0	0.0	19975.5	1326.5	0.0	497.5	31142.6	22619.1	-148.4	-148.4	

Figure 4.32 Load flow base case – winter maximum load 2015

Future outage statistic data were determined from historic data for each country, using methodology for future lines unavailability prediction described in Chapter 2.3. Rough assumption for older lines (>40 years) has been made that 50 % of 400 kV lines unavailability (50 % of total number of forced outages) is due to a transmission line age. This assumption has been made because causes of single forced outages were not known to the authors, so we assumed that 50 % of all accidental failures were caused by older lines deterioration. Unavailability of lines younger than 40 years in observed time frame is defined as average value in time period 2008 – 2010 or 2009 – 2011. Prediction of future 400 kV lines unavailability according to the methodology described in Chapter 2.3 was not performed for older Romanian and Bulgarian lines, so average unavailability for these lines was used during Reliability assessment (real data about 400 kV lines in Romania were missing, while Bulgarian TSO provided average forced outages values only, not data for successive three-year period). Future lines 400 kV unavailability prediction for 2015 could be found in the Appendix.

There is significant number of 400 kV lines in different countries which will exceed their expected lifetime of 40 years until observed time horizon. Five of them are in Bulgaria, one in Croatia, twenty-eight in Romania, ten in Serbia, two in Slovenia and ten in Turkey.

Analyzing contingences and probabilistic indices for each SEE country, and monitoring only branches under jurisdiction of national TSO's, reliability assessments give the following results.

There are no critical situations in Albania during analyzed operation regime. Under-voltage situations are possible but with probability close to 0 % (Figure 4.33). Under analyzed situation loss of any 400 kV line in Albania, or any combination of 400 kV lines in Albania, will not jeopardize Albanian transmission system security.

Some transmission lines overloadings and under-voltage situations may be expected in Bulgaria, but with very low probability close to 0 % - Figure 4.34. Frequency of critical failures is 0,0 occurrences per year and average duration of single failure is 0,9 hours.

Transmission lines overloadings may be expected in Bosnia and Herzegovina too (Figure 4.35). Probability of overloadings in the Bosnian network is 0,002 % only (0,2 hours per year). Loss of load may be expected with probability 0,001 % (0,1 hour/year). Unacceptable voltage deviation situations are not probable. Average annual number (frequency) of critical failures is 0,22 and average duration of single failure is 0,7 hours.

There are no critical situations during analyzed operation regime In Croatia so probabilistic indices could not be calculated. Under analyzed situation loss of any 400 kV line or combination of 400 kV lines in Croatia will not jeopardize Croatian transmission system security.

Transmission lines overloadings may be expected in Macedonia (Figure 4.36) observing multiple forced outages of domestic 400 kV lines, but with extremely low probability close to 0 %.

Transmission lines overloadings may be expected in Montenegro (Figure 4.37) with probability of 0,1 % (8,9 hours per year). Unacceptable voltage deviation situations or loss of load situations are not probable.

Under-voltage, branch overloading and loss of load situations may be expected in Romania but with very low probability (close to 0 %), if lines 400 kV availability is going to be as it is prescribed by the Reliability Normative (Figure 4.38). Having in mind that Romania is a country with the largest number of old 400 kV transmission lines, Transelectrica will have to conduct appropriate maintaining and revitalization activities to satisfy prescribed reliability data.

Transmission lines overloadings may be expected in Serbia and Kosovo (Figure 4.39). Both countries were modeled in PSS/E using the same area code so they are observed together here. Probability of overloadings is 0,05 % (4,2 hours per year). Average annual number of critical failures is 3,05 and average duration of single failure is 1,4 hours. There is also very low probability (0,05 %) that loss of load or busbars under-voltage situations (probability close to 0 %) in Serbia and Kosovo may happen during observed operational regime.

Some transmission lines overloadings may be expected in Slovenia also but with probability close to 0 % (Figure 4.40). Average annual number of critical failures is 0,0064 and average duration of single failure is 0,1 hours. Some critical contingences were detected which lead to impossibility to find convergent AC power flow solution.

Transmission lines overloadings and loss of load situations may be expected in Turkey (only European part of Turkey was observed and included into probabilistic analysis) - Figure 4.41. Probability of overloadings is 0,002 % (0,2 hours per year). Average annual number of critical failures is 14,19 and average duration of single failure is 1,2 hours. Loss of load probability is 0,19 % under analyzed operational condition.

Individual SEE transmission systems reliability indices are summarized in Table 4.3 and Figure 4.47. Multiple forced outages of 400 kV lines within jurisdiction of individual TSO's in the region will cause no problems in the network in general. Some minor problems, mainly with branches overloading or loss of load situations are probable in Montenegro, Serbia and Kosovo and Turkey. Probability of critical situations occurrence is extremely low. Albanian, Bulgarian, Bosnian, Croatian, Macedonian, Romanian and Slovenian network are not going to face any difficulties concerning 400 kV lines multiple forced outages during winter high load or peak load situations.

Figure 4.42 - Figure 4.46 presents reliability indices for the Southest Europe region, observing it as a single power system and electricity market. Probabilistic indices refer to the winter maximum load situation in 2015, and they take into account multiple forced outages of all 400 kV lines in the region. Due to large number of possible lines outages combination, calculation was limited to simultaneous forced outage of two lines 400 kV in the Region. All transmission lines and transformers in the Southeast Europe region including Slovenia and Turkey were monitored during contingences.

The following probabilistic indices were observed:

- System Reliability Indices Summary (Figure 4.42)
- System Load Curtailment Probabilistic Indices (Figure 4.43)
- Bus Load Curtailment Probability Indices (Figure 4.44)
- Branch Flow Overloading Probability Indices (Figure 4.45)
- Bus Voltage Violation Probability Indices (Figure 4.46)

Transmission network overloadings under analyzed operational condition may be expected with probability of 0,2 %, (23,9 occurrences per year and 0,8 hours as average duration of single outage). Under-voltage situations are possible in Albania, Romania and Serbia including Kosovo but not probable (probability close to 0 %). Loss of load in the region may be expected with probability of 0,26 % (22,8 hours per year).

Problems in the regional transmission system during winter peak load in 2015, comprising under-voltage situations, branches overloading situations and loss of load due to 400 kV lines forced outages, are possible with probability of 0,44 % (38,4 hours per year, average number of failures is 40,6 and average duration of single failure is 0,9 hours).

Possible branches overloading problems are detected in Bosnia and Herzegovina, Romania, Montenegro, Turkey and Serbia. Probability of branches overloading is low and close to 0 % for all critical branches.

Loss of load is possible in Romania and Turkey. Several power plants may loose their own consumption and go out of operation due to 400 kV lines forced outages in Bosnia and Herzegovina and Serbia.

<-- F A I L U R E C R I T E R I A -->	FREQ. (OC/Y)	DURATION (HOURS)	PROB. (H/Y)	IMPACT	NO. OF CONT.	WORST. VIOL.	<----- WORST CONTINGENCY ------>
AREA 10 BUS WITH VOLTAGE < 0.900	0.0086	0.7	0.0	0.00	1	0.868	1_5(AL-01:AL-06)
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL	0.0086	0.7	0.0		1		

Figure 4.33 System Reliability Indices Summary for Albania – winter maximum load 2015

<-- F A I L U R E C R I T E R I A -->	FREQ. (OC/Y)	DURATION (HOURS)	PROB. (H/Y)	IMPACT	NO. OF CONT.	WORST. VIOL.	<----- WORST CONTINGENCY ------>
AREA 20 BUS WITH VOLTAGE < 0.900	0.0000	0.6	0.0	0.00	1	0.871	11_2_9(BG-11:BG-13:BG-22)
OVERLOAD (%)	0.0000	0.9	0.0	0.00	11	138.016	11_2_9(BG-11:BG-13:BG-22)
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL	0.0000	0.9	0.0		11		

Figure 4.34 System Reliability Indices Summary for Bulgaria – winter maximum load 2015

<-- F A I L U R E C R I T E R I A -->	FREQ. (OC/Y)	DURATION (HOURS)	PROB. (H/Y)	IMPACT	NO. OF CONT.	WORST. VIOL.	<----- WORST CONTINGENCY ------>
OVERLOAD (%)	0.2222	0.7	0.2	0.15	22	213.558	1_4_7(BA-01:BA-05:BA-12)
LOSS OF LOAD (MW)	0.1262	0.7	0.1	2.11	8	25.000	1_4_7(BA-01:BA-05:BA-12)
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL	0.2222	0.7	0.2		22		

Figure 4.35 System Reliability Indices Summary for Bosnia and Herzegovina – winter maximum load 2015

<-- F A I L U R E C R I T E R I A -->	FREQ. (OC/Y)	DURATION (HOURS)	PROB. (H/Y)	IMPACT	NO. OF CONT.	WORST. VIOL.	<----- WORST CONTINGENCY ------>
OVERLOAD (%)	0.0000	0.0	0.0	0.00	2	102.485	2_6_2(MK-02:MK-08:MK-10)
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL	0.0000	0.0	0.0		2		

Figure 4.36 System Reliability Indices Summary for Macedonia – winter maximum load 2015

<-- F A I L U R E C R I T E R I A -->	FREQ. (OC/Y)	DURATION (HOURS)	PROB. (H/Y)	IMPACT	NO. OF CONT.	WORST. VIOL.	<----- WORST CONTINGENCY ------>
OVERLOAD (%)	1.5000	6.0	8.9	0.11	1	101.230	ME-01
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL	1.5000	6.0	8.9		1		

Figure 4.37 System Reliability Indices Summary for Montenegro – winter maximum load 2015

<-- F A I L U R E C R I T E R I A -->	FREQ. (OC/Y)	DURATION (HOURS)	PROB. (H/Y)	IMPACT	NO. OF CONT.	WORST. VIOL.	<----- WORST CONTINGENCY ------>
AREA 70 BUS WITH VOLTAGE < 0.900	0.0012	6.9	0.0	0.00	201	0.870	26_29_3(RO-28:RO-60:RO-63)
OVERLOAD (%)	0.0013	6.9	0.0	0.00	142	301.822	11_6_1(RO-13:RO-19:RO-20)
LOSS OF LOAD (MW)	0.0002	6.9	0.0	0.24	111	209.515	1_35_2(RO-01:RO-39:RO-43)
NOT CONVERGE	0.0000	4.7	0.0		2		
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL	0.0026	6.9	0.0		454		

Figure 4.38 System Reliability Indices Summary for Romania – winter maximum load 2015

<-- F A I L U R E C R I T E R I A -->	FREQ. (OC/Y)	DURATION (HOURS)	PROB. (H/Y)	IMPACT	NO. OF CONT.	WORST. VIOL.	<----- WORST CONTINGENCY ------>
AREA 90 BUS WITH VOLTAGE < 0.900	0.0025	0.9	0.0	0.00	46	0.612	3_19_18(RS-03:RS-22:RS-40)
OVERLOAD (%)	3.0469	1.4	4.2	11.82	743	414.338	3_13_22(RS-03:RS-16:RS-38)
LOSS OF LOAD (MW)	3.0437	1.4	4.2	119.48	670	35.000	1_1_36(RS-01:RS-02:RS-38)
NOT CONVERGE	0.0001	0.2	0.0		21		
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL	3.0470	1.4	4.2		786		

Figure 4.39 System Reliability Indices Summary for Serbia and Kosovo – winter maximum load 2015

<-- F A I L U R E C R I T E R I A -->	FREQ. (OC/Y)	DURATION (HOURS)	PROB. (H/Y)	IMPACT	NO. OF CONT.	WORST. VIOL.	<----- WORST CONTINGENCY ------>
OVERLOAD (%)	0.0064	0.1	0.0	0.00	3	100.190	3_13(SI-03:SI-16)
NOT CONVERGE	1.0040	0.7	0.7		5		
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL	1.0104	0.7	0.7		8		

Figure 4.40 System Reliability Indices Summary for Slovenia – winter maximum load 2015

<-- F A I L U R E C R I T E R I A -->	FREQ. (OC/Y)	DURATION (HOURS)	PROB. (H/Y)	IMPACT	NO. OF CONT.	WORST. VIOL.	<----- WORST CONTINGENCY ------>
OVERLOAD (%)	0.3195	0.7	0.2	0.07	8	236.871	39_1(TR-39:TR-40)
LOSS OF LOAD (MW)	13.8718	1.2	16.6	3901.16	57	235.110	1_3(TR-01:TR-04)
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL	14.1913	1.2	16.8		65		

Figure 4.41 System Reliability Indices Summary for Turkey – winter maximum load 2015

Table 4.3 Individual SEE countries reliability indices (winter peak load 2015)

Country	Voltage violations probability (%)	Branch overload probability (%)	Loss of load probability (%)	TOTAL PROBABILITY (%)
Albania	0,00	0,00	0,00	0,00
Bosnia and Herzegovina	0,00	0,00	0,00	0,00
Bulgaria	0,00	0,00	0,00	0,00
Croatia	0,00	0,00	0,00	0,00
Macedonia	0,00	0,00	0,00	0,00
Montenegro	0,00	0,10	0,00	0,10
Romania	0,00	0,00	0,00	0,00
Serbia and Kosovo	0,00	0,05	0,05	0,10
Slovenia	0,00	0,00	0,00	0,00
Turkey	0,00	0,00	0,19	0,19

```
    Including system ties:             Disable

                                                                           FREQ. DURATION   PROB.    IMPACT NO. OF   WORST.
<--             F A I L U R E  C R I T E R I A             -->  (OC/Y)  (HOURS)   (H/Y)            CONT.   VIOL.  <----- WORST CONTINGENCY ------>
AREA 10 BUS WITH VOLTAGE < 0.900                                 0.0086      0.7      0.0      0.00      1    0.868 1_5(AL-01:AL-06)
AREA 70 BUS WITH VOLTAGE < 0.900                                 0.0011      7.0      0.0      0.00      4    0.887 163_3(RO-60:RO-63)
AREA 90 BUS WITH VOLTAGE < 0.900                                 0.0195      1.5      0.0      0.00      5    0.800 176_38(RS-07:RS-45)
OVERLOAD (%)                                                    23.9450      0.8     19.4     13.27    613  405.554 185_22(RS-16:RS-38)
LOSS OF LOAD (MW)                                               19.0075      1.2     22.8   4396.25    734  235.110 1_237(AL-01:TR-04)
NOT CONVERGE                                                     1.1219      0.7      0.8              143
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL                                 40.5705      0.9     38.4              965

CONTINGENCY LEGEND:
<----- CONTINGENCY LABEL ------> EVENTS
1_5(AL-01:AL-06)                 OPEN BRANCH FROM BUS 2 [XZE_KA11    400.00] TO BUS 10020 [AZEMLA1     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 10010 [AELBS21     400.00] TO BUS 10020 [AZEMLA1     400.00] CKT 1
163_3(RO-60:RO-63)               OPEN BRANCH FROM BUS 28034 [RSIBIU1     400.00] TO BUS 28036 [RIERNU1     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 28037 [RGADAL1     400.00] TO BUS 28039 [RROSIO1     400.00] CKT 1
176_38(RS-07:RS-45)              OPEN BRANCH FROM BUS 184 [XRI_PE11    400.00] TO BUS 34086 [JPEC 31     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 34070 [JTKOSB2     400.00] TO BUS 34086 [JPEC 31     400.00] CKT 1
185_22(RS-16:RS-38)              OPEN BRANCH FROM BUS 34010 [JHDJE11     400.00] TO BUS 34055 [JTDRMN1     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 34040 [JRPMLA1     400.00] TO BUS 34065 [JTENTB11    400.00] CKT 1
1_237(AL-01:TR-04)               OPEN BRANCH FROM BUS 2 [XZE_KA11    400.00] TO BUS 10020 [AZEMLA1     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 60000 [TKROMA1     400.00] TO BUS 60112 [TGEBZE1     400.00] CKT 1
```

Figure 4.42 System Reliability Indices Summary for the SEE region – winter maximum load 2015

```
                                      FREQ. DURATION    PROB.      I.P.      E.U.E. NO. OF <----- WORST CONTINGENCY ------>
<--  LOAD CURTAILMENTS (MW)  -->      (OC/Y)  (HOUR)     (H/Y)     (MW/Y)     (MWH/Y)  CONT.
 20.0 -- 30.0                        2.3898      1.3      3.0      59.74      74.69    265 1_197(AL-01:RS-29)
 30.0 -- 40.0                        1.1382      1.4      1.6      39.84      57.27    268 1_206(AL-01:RS-38)
 60.0 -- 70.0                        0.0399      0.7      0.0       2.71       1.76      1 255_5(TR-21:TR-26)
 200.0-- 210.0                       0.0002      7.0      0.0       0.03       0.23      2 144_2(RO-39:RO-43)
 230.0-- 240.0                      15.4395      1.2     18.1    3629.97    4262.29    198 1_237(AL-01:TR-04)
ENTIRE SYSTEM                       19.0075      1.2     22.8    3732.29    4396.25    734

CONTINGENCY LEGEND:
<----- CONTINGENCY LABEL ------> EVENTS
1_197(AL-01:RS-29)               OPEN BRANCH FROM BUS 2 [XZE_KA11    400.00] TO BUS 10020 [AZEMLA1     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 34030 [JOBREN11    400.00] TO BUS 34060 [JTENTA11    400.00] CKT 1
1_206(AL-01:RS-38)               OPEN BRANCH FROM BUS 2 [XZE_KA11    400.00] TO BUS 10020 [AZEMLA1     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 34040 [JRPMLA1     400.00] TO BUS 34065 [JTENTB11    400.00] CKT 1
255_5(TR-21:TR-26)               OPEN BRANCH FROM BUS 60008 [TUNIMR1     400.00] TO BUS 60036 [TKAPTN1     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 60009 [THAMIT1     400.00] TO BUS 60036 [TKAPTN1     400.00] CKT 2
144_2(RO-39:RO-43)               OPEN BRANCH FROM BUS 28017 [RCONST1     400.00] TO BUS 28069 [RTARIV1     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 28019 [RTULCE1A    400.00] TO BUS 28020 [RISACC1A    400.00] CKT 1
1_237(AL-01:TR-04)               OPEN BRANCH FROM BUS 2 [XZE_KA11    400.00] TO BUS 10020 [AZEMLA1     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 60000 [TKROMA1     400.00] TO BUS 60112 [TGEBZE1     400.00] CKT 1
```

Figure 4.43 System Load Curtailment Probabilistic Indices for the SEE region – winter maximum load 2015

<BUS WITH LOAD CURTAILMENT (MW)>		LOAD (MW)	FREQ. (OC/Y)	DURATION (HOUR)	A.I.P. (MW/OC)	I. P. (MW/Y)	E.U.E. (MWH/Y)	B.I.P.	B.E.U.	NO. OF CONT.	<----- WORST CONTINGENCY ------>
ENTIRE SYSTEM		150608.7	19.0075	1.20	196.36	3732.29	4396.25	0.0248	0.0292	734	
60000 TKROMA1	400.00	235.1	15.4395	1.17	235.11	3629.97	4262.29	15.4395	18.1289	198	1_237(AL-01:TR-04)
60036 TKAPTN1	400.00	67.7	0.0399	0.65	67.74	2.71	1.76	0.0399	0.0260	1	255_5(TR-21:TR-26)
14008 WTSTANG	22.000	25.0	0.1233	0.68	25.00	3.08	2.08	0.1233	0.0832	1	11_7(BA-05:BA-12)
35025 JTENTAT5	15.000	25.0	1.3908	0.54	25.00	34.77	18.87	1.3908	0.7549	132	1_197(AL-01:RS-29)
35026 JTENTAT6	15.000	25.0	0.8757	2.45	25.00	21.89	53.74	0.8757	2.1496	132	1_198(AL-01:RS-30)
35031 JTENTBT1	21.000	35.0	0.5859	2.57	35.00	20.51	52.66	0.5859	1.5045	134	1_206(AL-01:RS-38)
35032 JTENTBT2	21.000	35.0	0.5522	0.24	35.00	19.33	4.61	0.5522	0.1318	134	1_207(AL-01:RS-39)
28250 ROSTRO5	110.00	1.1	0.0002	7.00	1.11	0.00	0.00	0.0002	0.0011	2	144_2(RO-39:RO-43)
28252 RMACIN5	110.00	6.0	0.0002	7.00	6.00	0.00	0.01	0.0002	0.0011	2	144_2(RO-39:RO-43)
28253 RISACC5A	110.00	4.8	0.0002	7.00	4.78	0.00	0.01	0.0002	0.0011	2	144_2(RO-39:RO-43)
28254 RTULCE5A	110.00	75.8	0.0002	7.00	75.83	0.01	0.08	0.0002	0.0011	2	144_2(RO-39:RO-43)
28255 RTULCE5B	110.00	110.9	0.0002	7.00	110.91	0.02	0.12	0.0002	0.0011	2	144_2(RO-39:RO-43)
28256 RBABAD5	110.00	2.8	0.0002	7.00	2.78	0.00	0.00	0.0002	0.0011	2	144_2(RO-39:RO-43)
28257 RBAIA 5A	110.00	3.8	0.0002	7.00	3.78	0.00	0.00	0.0002	0.0011	2	144_2(RO-39:RO-43)
28260 RZEBIL5	110.00	2.7	0.0002	7.00	2.67	0.00	0.00	0.0002	0.0011	2	144_2(RO-39:RO-43)
28285 RTOPOL51	110.00	1.7	0.0002	7.00	1.67	0.00	0.00	0.0002	0.0011	2	144_2(RO-39:RO-43)

CONTINGENCY LEGEND:

<----- CONTINGENCY LABEL ------>	EVENTS
1_237(AL-01:TR-04)	OPEN BRANCH FROM BUS 2 [XZE_KA11 400.00] TO BUS 10020 [AZEMLA1 400.00] CKT 1
	OPEN BRANCH FROM BUS 60000 [TKROMA1 400.00] TO BUS 60112 [TGEBZE1 400.00] CKT 1
255_5(TR-21:TR-26)	OPEN BRANCH FROM BUS 60008 [TUNIMR1 400.00] TO BUS 60036 [TKAPTN1 400.00] CKT 1
	OPEN BRANCH FROM BUS 60009 [THAMIT1 400.00] TO BUS 60036 [TKAPTN1 400.00] CKT 2
11_7(BA-05:BA-12)	OPEN BRANCH FROM BUS 14401 [WBLUK61 400.00] TO BUS 14410 [WTSTAN1 400.00] CKT 1B
	OPEN BRANCH FROM BUS 14410 [WTSTAN1 400.00] TO BUS 16402 [WTUZL41 400.00] CKT 1B
1_197(AL-01:RS-29)	OPEN BRANCH FROM BUS 2 [XZE_KA11 400.00] TO BUS 10020 [AZEMLA1 400.00] CKT 1
	OPEN BRANCH FROM BUS 34030 [JOBREN11 400.00] TO BUS 34060 [JTENTA11 400.00] CKT 1
1_198(AL-01:RS-30)	OPEN BRANCH FROM BUS 2 [XZE_KA11 400.00] TO BUS 10020 [AZEMLA1 400.00] CKT 1
	OPEN BRANCH FROM BUS 34030 [JOBREN11 400.00] TO BUS 34061 [JTENTA12 400.00] CKT 2
1_206(AL-01:RS-38)	OPEN BRANCH FROM BUS 2 [XZE_KA11 400.00] TO BUS 10020 [AZEMLA1 400.00] CKT 1
	OPEN BRANCH FROM BUS 34040 [JRPMLA1 400.00] TO BUS 34065 [JTENTB11 400.00] CKT 1
1_207(AL-01:RS-39)	OPEN BRANCH FROM BUS 2 [XZE_KA11 400.00] TO BUS 10020 [AZEMLA1 400.00] CKT 1
	OPEN BRANCH FROM BUS 34040 [JRPMLA1 400.00] TO BUS 34066 [JTENTB12 400.00] CKT 2
144_2(RO-39:RO-43)	OPEN BRANCH FROM BUS 28017 [RCONST1 400.00] TO BUS 28069 [RTARIV1 400.00] CKT 1
	OPEN BRANCH FROM BUS 28019 [RTULCE1A 400.00] TO BUS 28020 [RISACC1A 400.00] CKT 1

Figure 4.44 Bus Load Curtailment Probabilistic Indices for the SEE region – winter maximum load 2015

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<---------- O V E R L O A D E D   L I N E S --------->   FREQ. DURATION   PROB.   IMPACT MAX VIO. NO. OF
<------ F R O M --------> <-------- T O ---------->CKT   (OC/Y)   (HOUR)   (H/Y)    (PU)    (%)    CONT. <----- WORST CONTINGENCY ------>
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL                         23.9450     0.8    19.4   13.27     0.00    613
   316 XTR_HN51     110.00  14137 WTREBI5     110.00 1   0.0073     1.8     0.0    0.00   102.95      1 15_71(BA-09:ME-01)
 14202 WTREBI2      220.00  14405 WTREBI1     400.00 1   0.0363     1.1     0.0    0.00   105.41      1 14_80(BA-08:ME-12)
 16006 WTKAKAG7     15.750  16208 WTKAKA21    220.00 1   0.1883     0.7     0.1    0.14   212.57      2 11_7(BA-05:BA-12)
 28023 RFOCSA2      220.00  28076 RBARBO2     220.00 1   0.0008     7.0     0.0    0.00   109.17      1 154_2(RO-51:RO-53)
 28035 RTURC 1G     400.00  29113 RTURCEG4    24.000 1   0.0004     7.0     0.0    0.00   300.62      3 125_1(RO-19:RO-20)
 28074 RL.SAR2      220.00  28075 RFILES2     220.00 1   0.0008     7.0     0.0    0.00   104.60      1 154_2(RO-51:RO-53)
 28075 RFILES2      220.00  28076 RBARBO2     220.00 1   0.0008     7.0     0.0    0.00   111.15      1 154_2(RO-51:RO-53)
 30051 LHEMARH1     10.500  31053 LHM_OT5     110.00 1   0.1565     3.0     0.5    0.00   100.49     17 81_138(HR-12:SI-03)
 34010 JHDJE11      400.00 3WNDTR B1           WND 1 1   3.4046     1.3     4.5    4.20   251.78    532 172_35(RS-03:RS-38)
 34010 JHDJE11      400.00 3WNDTR B2           WND 1 2   1.1863     1.4     1.7    0.05   103.09    329 185_13(RS-16:RS-29)
 34083 JSMED311     400.00  34710 JSMED351    110.00 A   0.0000     0.0     0.0    0.00   112.35      1 182_1(RS-13:RS-14)
 34125 JDREN12      220.00  34471 JDREN15     110.00 1   0.0052     0.9     0.0    0.00   103.53      2 176_38(RS-07:RS-45)
 34455 JDJAK15      110.00  34456 JDJAK25     110.00 1   0.0052     0.9     0.0    0.00   125.33      2 176_38(RS-07:RS-45)
 34620 JNSAD151     110.00  34625 JNSAD351    110.00 1   0.0001     0.1     0.0    0.00   117.38      3 197_5(RS-28:RS-33)
 34710 JSMED351     110.00  34711 JSMED352    110.00 1   0.0007     0.0     0.0    0.00   110.85      2 182_1(RS-13:RS-14)
 34804 JVALJ15      110.00  34807 JVALJ352    110.00 2   0.0000     0.1     0.0    0.00   102.52      1 180_5(RS-11:RS-16)
 35001 JHDJERH1     15.750 3WNDTR B1           WND 2 1   3.4046     1.3     4.5    8.38   405.55    532 185_22(RS-16:RS-38)
 35002 JHDJERH2     15.750 3WNDTR B1           WND 3 1   3.4020     1.3     4.5    0.11   102.38    529 33_165(BG-13:RS-29)
 35003 JHDJERH3     15.750 3WNDTR B2           WND 2 2   1.2324     1.4     1.7    0.06   103.45    395 185_13(RS-16:RS-29)
 35004 JHDJERH4     15.750 3WNDTR B2           WND 3 2   1.2324     1.4     1.7    0.06   103.45    395 185_13(RS-16:RS-29)
 35005 JHDJERH5     15.750 3WNDTR B3           WND 2 3   0.0014     0.5     0.0    0.00   100.58      2 175_32(RS-06:RS-38)
 36050 OHNOVI51     110.00  36055 OTIVAT51    110.00 1  19.8316     0.7    14.0    0.18   108.69     41 15_71(BA-09:ME-01)
 36058 OLASTV51     110.00  36060 OBUDVA51    110.00 A   0.0363     1.1     0.0    0.01   119.34      1 14_80(BA-08:ME-12)
 60010 TBABAE3      154.00  60020 THAMIT3     154.00 1   0.0399     0.7     0.0    0.00   101.15      1 252_1(TR-18:TR-19)
 60051 TAMBRL1      400.00  60057 TAMBAA3     154.00 1   0.0399     0.7     0.0    0.01   147.13      1 273_1(TR-39:TR-40)
 60051 TAMBRL1      400.00  60058 TAMBAB3     154.00 2   0.0399     0.7     0.0    0.04   236.87      1 273_1(TR-39:TR-40)
 60053 TIKITL1      400.00  60101 TYNBOS1     400.00 1   0.0399     0.7     0.0    0.00   114.66      1 282_1(TR-48:TR-49)
 60053 TIKITL1      400.00  60101 TYNBOS1     400.00 2   0.0399     0.7     0.0    0.00   114.66      1 281_2(TR-47:TR-49)
 60053 TIKITL1      400.00  60101 TYNBOS1     400.00 3   0.0399     0.7     0.0    0.00   114.66      1 281_1(TR-47:TR-48)
 60056 TDAVUT1      400.00  60101 TYNBOS1     400.00 1   0.0399     0.7     0.0    0.00   115.76      1 288_1(TR-54:TR-55)
 60056 TDAVUT1      400.00  60101 TYNBOS1     400.00 2   0.0399     0.7     0.0    0.00   115.76      1 287_2(TR-53:TR-55)
 60056 TDAVUT1      400.00  60101 TYNBOS1     400.00 3   0.0399     0.7     0.0    0.00   115.76      1 287_1(TR-53:TR-54)

CONTINGENCY LEGEND:
<----- CONTINGENCY LABEL ------> EVENTS
15_71(BA-09:ME-01)              OPEN BRANCH FROM BUS 14404 [WTGACK1     400.00] TO BUS 18401 [WMOST41     400.00] CKT 1
                                OPEN BRANCH FROM BUS 13 [XTR_PG11    400.00] TO BUS 36017 [OLASTV11    400.00] CKT A
14_80(BA-08:ME-12)              OPEN BRANCH FROM BUS 14404 [WTGACK1     400.00] TO BUS 14405 [WTREBI1     400.00] CKT 1
                                OPEN BRANCH FROM BUS 36005 [OPODG211    400.00] TO BUS 36017 [OLASTV11    400.00] CKT A
11_7(BA-05:BA-12)               OPEN BRANCH FROM BUS 14401 [WBLUK61     400.00] TO BUS 14410 [WTSTAN1     400.00] CKT 1B
                                OPEN BRANCH FROM BUS 14410 [WTSTAN1     400.00] TO BUS 16402 [WTUZL41     400.00] CKT 1B
154_2(RO-51:RO-53)              OPEN BRANCH FROM BUS 28022 [RSMIRD1     400.00] TO BUS 28024 [RGUTIN1     400.00] CKT 1
                                OPEN BRANCH FROM BUS 28024 [RGUTIN1     400.00] TO BUS 28031 [RBRASO1     400.00] CKT 1
125_1(RO-19:RO-20)              OPEN BRANCH FROM BUS 28002 [RURECH1     400.00] TO BUS 28030 [RURECH1G    400.00] CKT 1
                                OPEN BRANCH FROM BUS 28002 [RURECH1     400.00] TO BUS 28030 [RURECH1G    400.00] CKT 2
81_138(HR-12:SI-03)             OPEN BRANCH FROM BUS 20037 [HERNES11    400.00] TO BUS 20203 [HZERJA11    400.00] CKT 1
                                OPEN BRANCH FROM BUS 71 [XME_DI11    400.00] TO BUS 31410 [LDIVAC1     400.00] CKT 1
172_35(RS-03:RS-38)             OPEN BRANCH FROM BUS 79 [XSA_SU11    400.00] TO BUS 34050 [JSUBO31     400.00] CKT 1
                                OPEN BRANCH FROM BUS 34040 [JRPMLA1     400.00] TO BUS 34065 [JTENTB11    400.00] CKT 1
185_13(RS-16:RS-29)             OPEN BRANCH FROM BUS 34010 [JHDJE11     400.00] TO BUS 34055 [JTDRMN1     400.00] CKT 1
                                OPEN BRANCH FROM BUS 34030 [JOBREN11    400.00] TO BUS 34060 [JTENTA11    400.00] CKT 1
182_1(RS-13:RS-14)              OPEN BRANCH FROM BUS 34001 [JBGD8 1     400.00] TO BUS 34083 [JSMED311    400.00] CKT A
                                OPEN BRANCH FROM BUS 34005 [JBOR 21     400.00] TO BUS 34010 [JHDJE11     400.00] CKT 1
176_38(RS-07:RS-45)             OPEN BRANCH FROM BUS 184 [XRI_PE11    400.00] TO BUS 34086 [JPEC 31     400.00] CKT 1
                                OPEN BRANCH FROM BUS 34070 [JTKOSB2     400.00] TO BUS 34086 [JPEC 31     400.00] CKT 1
197_5(RS-28:RS-33)              OPEN BRANCH FROM BUS 34030 [JOBREN11    400.00] TO BUS 34040 [JRPMLA1     400.00] CKT 2
                                OPEN BRANCH FROM BUS 34031 [JOBREN12    400.00] TO BUS 34040 [JRPMLA1     400.00] CKT 1
180_5(RS-11:RS-16)              OPEN BRANCH FROM BUS 34001 [JBGD8 1     400.00] TO BUS 34030 [JOBREN11    400.00] CKT 1
                                OPEN BRANCH FROM BUS 34010 [JHDJE11     400.00] TO BUS 34055 [JTDRMN1     400.00] CKT 1
185_22(RS-16:RS-38)             OPEN BRANCH FROM BUS 34010 [JHDJE11     400.00] TO BUS 34055 [JTDRMN1     400.00] CKT 1
                                OPEN BRANCH FROM BUS 34040 [JRPMLA1     400.00] TO BUS 34065 [JTENTB11    400.00] CKT 1
33_165(BG-13:RS-29)             OPEN BRANCH FROM BUS 12430 [VSTOLN1     400.00] TO BUS 12490 [VMIZIA1     400.00] CKT 1
                                OPEN BRANCH FROM BUS 34030 [JOBREN11    400.00] TO BUS 34060 [JTENTA11    400.00] CKT 1
175_32(RS-06:RS-38)             OPEN BRANCH FROM BUS 85 [XPF_DJ11    400.00] TO BUS 34010 [JHDJE11     400.00] CKT 1
                                OPEN BRANCH FROM BUS 34040 [JRPMLA1     400.00] TO BUS 34065 [JTENTB11    400.00] CKT 1
252_1(TR-18:TR-19)              OPEN BRANCH FROM BUS 60007 [TBABA11     400.00] TO BUS 60008 [TUNIMR1     400.00] CKT 1
                                OPEN BRANCH FROM BUS 60007 [TBABA11     400.00] TO BUS 60009 [THAMIT1     400.00] CKT 1
273_1(TR-39:TR-40)              OPEN BRANCH FROM BUS 60051 [TAMBRL1     400.00] TO BUS 60053 [TIKITL1     400.00] CKT 1
                                OPEN BRANCH FROM BUS 60051 [TAMBRL1     400.00] TO BUS 60053 [TIKITL1     400.00] CKT 2
282_1(TR-48:TR-49)              OPEN BRANCH FROM BUS 60053 [TIKITL1     400.00] TO BUS 60101 [TYNBOS1     400.00] CKT 2
                                OPEN BRANCH FROM BUS 60053 [TIKITL1     400.00] TO BUS 60101 [TYNBOS1     400.00] CKT 3
281_2(TR-47:TR-49)              OPEN BRANCH FROM BUS 60053 [TIKITL1     400.00] TO BUS 60101 [TYNBOS1     400.00] CKT 1
                                OPEN BRANCH FROM BUS 60053 [TIKITL1     400.00] TO BUS 60101 [TYNBOS1     400.00] CKT 3
281_1(TR-47:TR-48)              OPEN BRANCH FROM BUS 60053 [TIKITL1     400.00] TO BUS 60101 [TYNBOS1     400.00] CKT 1
                                OPEN BRANCH FROM BUS 60053 [TIKITL1     400.00] TO BUS 60101 [TYNBOS1     400.00] CKT 2
288_1(TR-54:TR-55)              OPEN BRANCH FROM BUS 60056 [TDAVUT1     400.00] TO BUS 60101 [TYNBOS1     400.00] CKT 2
                                OPEN BRANCH FROM BUS 60056 [TDAVUT1     400.00] TO BUS 60101 [TYNBOS1     400.00] CKT 3
287 2(TR-53:TR-55)              OPEN BRANCH FROM BUS 60056 [TDAVUT1     400.00] TO BUS 60101 [TYNBOS1     400.00] CKT 1
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Figure 4.45 Branch Flow Overloading Probability Indices for the SEE region – winter maximum load 2015

AREA 10 BUSES WITH VOLTAGE LESS THAN 0.900

<- BUS WITH VOLTAGE VIOLATION ->			FREQ. (OC/Y)	DURATION (HOUR)	PROB. (H/Y)	IMPACT (PU)	MAX VIO.	NO. OF CONT.	<----- WORST CONTINGENCY ------>
ENTIRE SYSTEM			0.0086	0.7	0.0	0.00		1	
10020	AZEMLA1	400.00	0.0086	0.7	0.0	0.00	0.8676	1	1_5(AL-01:AL-06)
10096	AKORCE5	110.00	0.0086	0.7	0.0	0.00	0.8954	1	1_5(AL-01:AL-06)
10098	AZEMLK5	110.00	0.0086	0.7	0.0	0.00	0.8955	1	1_5(AL-01:AL-06)
10100	ABISTR3	154.00	0.0086	0.7	0.0	0.00	0.8994	1	1_5(AL-01:AL-06)

AREA 70 BUSES WITH VOLTAGE LESS THAN 0.900

<- BUS WITH VOLTAGE VIOLATION ->			FREQ. (OC/Y)	DURATION (HOUR)	PROB. (H/Y)	IMPACT (PU)	MAX VIO.	NO. OF CONT.	<----- WORST CONTINGENCY ------>
ENTIRE SYSTEM			0.0011	7.0	0.0	0.00		4	
28017	RCONST1	400.00	0.0002	7.0	0.0	0.00	0.8989	1	144_1(RO-39:RO-40)
28463	RLECHI5	110.00	0.0005	7.0	0.0	0.00	0.8936	1	163_3(RO-60:RO-63)
28464	RSARAT5A	110.00	0.0005	7.0	0.0	0.00	0.8964	1	163_3(RO-60:RO-63)
28465	RVIISO51	110.00	0.0005	7.0	0.0	0.00	0.8996	1	163_3(RO-60:RO-63)
28466	RBISTR5	110.00	0.0005	7.0	0.0	0.00	0.8960	1	163_3(RO-60:RO-63)
28950	RROMAN1	400.00	0.0003	7.0	0.0	0.00	0.8969	1	139_18(RO-34:RO-54)
29172	RSUGAGG1	15.750	0.0007	7.0	0.0	0.00	0.8869	2	163_3(RO-60:RO-63)

AREA 90 BUSES WITH VOLTAGE LESS THAN 0.900

<- BUS WITH VOLTAGE VIOLATION ->			FREQ. (OC/Y)	DURATION (HOUR)	PROB. (H/Y)	IMPACT (PU)	MAX VIO.	NO. OF CONT.	<----- WORST CONTINGENCY ------>
ENTIRE SYSTEM			0.0195	1.5	0.0	0.00		5	
184	XRI_PE11	400.00	0.0028	0.9	0.0	0.00	0.8516	1	87_127(ME-02:RS-45)
34082	JSOMB31	400.00	0.0000	0.1	0.0	0.00	0.8804	1	172_38(RS-03:RS-41)
34086	JPEC 31	400.00	0.0052	0.9	0.0	0.00	0.8249	2	176_38(RS-07:RS-45)
34451	JDECAN5	110.00	0.0052	0.9	0.0	0.00	0.8225	2	176_38(RS-07:RS-45)
34455	JDJAK15	110.00	0.0052	0.9	0.0	0.00	0.8673	2	176_38(RS-07:RS-45)
34456	JDJAK25	110.00	0.0052	0.9	0.0	0.00	0.8811	2	176_38(RS-07:RS-45)
34521	JISTOK5	110.00	0.0052	0.9	0.0	0.00	0.8404	2	176_38(RS-07:RS-45)
34526	JSKEN 5	110.00	0.0052	0.9	0.0	0.00	0.8775	2	176_38(RS-07:RS-45)
34535	JKLINA5	110.00	0.0052	0.9	0.0	0.00	0.8519	2	176_38(RS-07:RS-45)
34646	JPEC 35	110.00	0.0052	0.9	0.0	0.00	0.8415	2	176_38(RS-07:RS-45)
34647	JPEC 25	110.00	0.0123	1.4	0.0	0.00	0.8025	3	176_38(RS-07:RS-45)
34655	JPEC 5	110.00	0.0052	0.9	0.0	0.00	0.8004	2	176_38(RS-07:RS-45)
35221	JHGAZIH1	6.3000	0.0195	1.5	0.0	0.00	0.8635	4	176_38(RS-07:RS-45)
35222	JHGAZIH2	6.3000	0.0195	1.5	0.0	0.00	0.8635	4	176_38(RS-07:RS-45)

CONTINGENCY LEGEND:

<----- CONTINGENCY LABEL ------>	EVENTS
1_5(AL-01:AL-06)	OPEN BRANCH FROM BUS 2 [XZE_KA11 400.00] TO BUS 10020 [AZEMLA1 400.00] CKT 1
	OPEN BRANCH FROM BUS 10010 [AELBS21 400.00] TO BUS 10020 [AZEMLA1 400.00] CKT 1
144_1(RO-39:RO-40)	OPEN BRANCH FROM BUS 28017 [RCONST1 400.00] TO BUS 28069 [RTARIV1 400.00] CKT 1
	OPEN BRANCH FROM BUS 28017 [RCONST1 400.00] TO BUS 28973 [RCERNA1 400.00] CKT 1
163_3(RO-60:RO-63)	OPEN BRANCH FROM BUS 28034 [RSIBIU1 400.00] TO BUS 28036 [RIERNU1 400.00] CKT 1
	OPEN BRANCH FROM BUS 28037 [RGADAL1 400.00] TO BUS 28039 [RROSIO1 400.00] CKT 1
139_18(RO-34:RO-54)	OPEN BRANCH FROM BUS 28014 [RSUCEA1A 400.00] TO BUS 28950 [RROMAN1 400.00] CKT 1
	OPEN BRANCH FROM BUS 28025 [RBACAU1 400.00] TO BUS 28950 [RROMAN1 400.00] CKT 1
87_127(ME-02:RS-45)	OPEN BRANCH FROM BUS 184 [XRI_PE11 400.00] TO BUS 36001 [ORIBAR11 400.00] CKT 1
	OPEN BRANCH FROM BUS 34070 [JTKOSB2 400.00] TO BUS 34086 [JPEC 31 400.00] CKT 1
172_38(RS-03:RS-41)	OPEN BRANCH FROM BUS 79 [XSA_SU11 400.00] TO BUS 34050 [JSUBO31 400.00] CKT 1
	OPEN BRANCH FROM BUS 34050 [JSUBO31 400.00] TO BUS 34082 [JSOMB31 400.00] CKT 1
176_38(RS-07:RS-45)	OPEN BRANCH FROM BUS 184 [XRI_PE11 400.00] TO BUS 34086 [JPEC 31 400.00] CKT 1
	OPEN BRANCH FROM BUS 34070 [JTKOSB2 400.00] TO BUS 34086 [JPEC 31 400.00] CKT 1

Figure 4.46 Bus Voltage Violation Probability Indices for the SEE region – winter maximum load 2015

Figure 4.47 Individual SEE transmission networks reliability assessment: probability of overloadings and/or busbars undervoltages during 2015 winter maximum load

4.5.3 Expected mid-time frame planned SEE transmission network (2020)

Basic power flow data for analyzed scenario is given in the following figure. It presents individual countries generation, demand, losses and interchanges at the model. SECI winter peak load model for 2020 was used. (version 35). There were several lines loading violations and busbars undervoltages in the base case scenario, located in Bulgaria, Kosovo, Serbia, Slovenia and Turkey. This model was corrected in order to avoid base case branches overloading and unacceptable voltage deviations, because this was necessary to perform reliability assessment. It was estimated by Authors that base case overloadings and voltage deviations are caused by incorrect modeling, not by real problems which may be expected in the transmission network.

PTI INTERACTIVE POWER SYSTEM SIMULATOR--PSS(R)E TUE, NOV 06 2012 10:04
SECI REGIONAL MODEL AREA TOTALS
MAXIMUM LOAD 10:30 - WINTER 2020 IN MW/MVAR

X-- AREA --X	FROM GENE-RATION	------AT AREA FROM IND GENERATN	BUSES------- TO IND MOTORS	TO LOAD	TO BUS SHUNT	TO GNE BUS DEVICES	TO LINE SHUNT	FROM CHARGING	TO LOSSES	-NET INTERCHANGE- TO TIE LINES	TO TIES + LOADS	DESIRED NET INT
10	1817.3	0.0	0.0	1765.2	0.0	0.0	0.0	0.0	52.1	0.0	0.0	0.0
AL	561.6	0.0	0.0	636.1	-112.0	0.0	0.0	607.1	439.1	205.5	205.5	
20	9612.9	0.0	0.0	8377.4	0.0	0.0	15.2	0.0	220.3	1000.0	1000.0	1000.0
BG	3608.1	0.0	0.0	3336.1	224.5	0.0	179.3	3304.2	2891.2	281.2	281.2	
30	3515.3	0.0	0.0	2662.5	0.0	0.0	0.6	0.0	102.0	750.2	750.2	750.0
BA	747.8	0.0	0.0	207.8	0.0	0.0	1.3	966.4	1006.8	498.4	498.4	
40	3592.8	0.0	0.0	4436.2	0.0	0.0	0.0	0.0	156.2	-999.6	-999.6	-1000.0
HR	609.5	0.0	0.0	1114.4	0.0	0.0	0.0	1627.0	1438.5	-316.4	-316.4	
60	1904.8	0.0	0.0	1974.4	0.0	0.0	0.2	0.0	30.3	-100.0	-100.0	-100.0
MK	528.3	0.0	0.0	609.6	0.0	0.0	2.5	471.5	371.3	16.4	16.4	
70	12013.5	0.0	0.0	10166.6	0.0	0.0	85.8	0.0	260.9	1500.2	1500.2	1500.0
RO	624.6	0.0	0.0	3140.4	105.4	0.0	240.8	5594.3	3065.4	-333.1	-333.1	
75	4431.2	0.0	0.0	2887.0	0.0	0.0	9.8	0.0	119.2	1415.2	1415.2	1415.0
SI	1905.4	0.0	0.0	863.0	0.0	0.0	62.0	880.6	1621.2	239.9	239.9	
80	77476.5	0.0	0.0	77342.9	0.0	0.0	0.0	0.0	933.5	-800.0	-800.0	-800.0
TR	6900.5	0.0	0.0	11034.0	1001.3	0.0	0.0	22771.8	17845.0	-208.0	-208.0	
90	8833.6	0.0	0.0	7867.4	0.0	0.0	12.8	0.0	203.3	750.1	750.1	750.0
RS	2446.0	0.0	0.0	2621.5	0.0	0.0	81.4	2083.0	2370.2	-544.2	-544.2	
91	1609.9	0.0	0.0	1022.9	0.5	0.0	3.5	0.0	32.9	550.0	550.0	550.0
ME	257.0	0.0	0.0	365.1	-33.2	0.0	20.6	419.3	375.4	-51.6	-51.6	
COLUMN	124807.9	0.0	0.0	118502.5	0.5	0.0	127.9	0.0	2110.7	4066.2	4066.2	4065.0
TOTALS	18189.0	0.0	0.0	23928.1	1186.0	0.0	587.9	38725.2	31424.1	-211.9	-211.9	

Figure 4.48 Load flow base case – winter maximum load 2020

Future outage statistic data were determined from historic data for each country, using methodology for future lines unavailability prediction described in Chapter 2.3. Rough assumption for older lines (>40 years) has been made that 50 % of 400 kV lines unavailability (50 % of total number of forced outages) is due to a transmission line age. This assumption has been made because causes of single forced outages were not known to the authors, so we assumed that 50 % of all accidental failures were caused by older lines deterioration. Unavailability of lines younger than 40 years in observed time frame is defined as average value in time period 2008 – 2010 or 2009 – 2011. Prediction of future 400 kV lines unavailability according to the methodology described in Chapter 2.3 was not performed for older Romanian and Bulgarian lines, so average unavailability for these lines was used during Reliability assessment. Older lines 400 kV unavailability prediction for 2020 could be found in the Appendix.

There are many 400 kV lines in different countries which will exceed their expected lifetime of 40 years until observed time horizon. Eight of them are in Bulgaria, seven in Bosnia and Herzegovina, ten in Croatia, three in Kosovo, four in Macedonia, thirty-eight in Romania, twenty-four in Serbia, nine in Slovenia and fourteen in Turkey. Among them, three lines 400 kV in Bulgaria, fourteen in Romania and two in Serbia will be even older than 50 years up to observed time frame.

Analyzing contingences and probabilistic indices for each SEE country, and monitoring only branches under jurisdiction of national TSO's, reliability assessments give the following results.

Under-voltage and branches overloading situations in Albania are possible as a consequence of multiple 400 kV lines outages but with probability close to 0 % (Figure 4.49). One may conclude that under analyzed peak load situation in 2020 loss of any 400 kV line in Albania, or any combination of 400 kV lines in Albania, will not jeopardize Albanian transmission system security.

Transmission lines overloadings may be expected in Bosnia and Herzegovina (Figure 4.50). Probability of overloadings in the Bosnian network is 0,32 % only (27,6 hours per year). Loss of load may be expected but with probability close to 0 %. Unacceptable voltage deviation situations are not probable. Average annual number (frequency) of critical failures is 20,48 and average duration of single failure is 1,3 hours.

Some transmission lines overloadings and under-voltage situations may be expected in Bulgaria, but with very low probability close to 0 % - Figure 4.51. Frequency of critical failures is 0,0044 occurrences per year and average duration of single failure is 1,1 hours.

Croatian transmission network as planned in 2020 may experience some branches overloading as a consequence of 400 kV lines forced outages with probability of 0,5 % (49,6 hours per year). Unacceptable voltage deviations or loss of load are not probable (Figure 4.52).

Transmission branches overloading and under-voltage situations may be expected in Macedonia (Figure 4.53) observing multiple forced outages of domestic 400 kV lines, but with extremely low probability close to 0 %.

Transmission branches overloading and under-voltage situations may be expected in Montenegro (Figure 4.54) but with probability close to 0 %. Loss of load situations are not probable. Is should be stressed that faults on converter station near Lastva SS have not been analyzed within this Reliability assessment so further investigations about that kind of fault could be necessary.

Under-voltage, branch overloading and loss of load situations may be expected in Romania but with very low probability (close to 0 %), if lines 400 kV availability is going to be as it is prescribed by the Reliability Normative (Figure 4.55). Problems may be expected with frequency of failures 0,0033 occurrences per year and 6,9 hours of average duration of single occurrence.

Transmission branches overloading during winter peak load in 2020 may be expected in Serbia and Kosovo (Figure 4.56). Both countries were modeled in PSS/E using the same area code so they are observed together here. Probability of overloadings is 0,71 % (62,6 hours per year). Average annual number of critical failures is 38,49 and average duration of single failure is 1,6 hours. There is also very low probability (0,14 %) that loss of load or busbars under-voltage situations (probability close to 0 %) in Serbia and Kosovo may happen during observed operational regime.

Some transmission branches overloading may be expected in Slovenia with probability 0,96 % or 62,6 hours per year (Figure 4.57). Average annual number of critical failures is 7,81 and average duration of single failure is 10,8 hours. Under-voltage situations are possible with related probability of 0,93 % (4,2 occurrences/year and 19,5 hours is average duration of single failure).

Transmission branches overloading and loss of load situations may be expected in European part of Turkey (Figure 4.58). Probability of overloadings is close to 0 % (0,3 hours per year). Average annual number of critical failures is 16,16 and average duration of single failure is 1,1 hours. Loss of load probability is 0,19 % under analyzed operational condition.

Individual SEE transmission systems reliability indices are summarized in Table 4.4 and Figure 4.64. Multiple forced outages of 400 kV lines within jurisdiction of individual TSO's in the region will cause no problems in the network in general. Some minor problems, mainly with branches overloading or loss of load situations are probable in Bosnia and Herzegovina, Croatia, Serbia and Kosovo, Slovenia and Turkey. Probability of critical situations occurrence is extremely low. Albanian, Bulgarian, Macedonian and Romanian network are not going to face any difficulties concerning 400 kV lines multiple forced outages during winter high load or peak load situations.

Figure 4.59 - Figure 4.63 presents reliability indices for the Southest Europe region, observing it as a single power system and electricity market. Probabilistic indices refer to the winter maximum load situation in 2020, and they take into account multiple forced outages of all 400 kV lines in the region. Due to large number of possible lines outages combination, calculation was limited to simultaneous forced outage of two lines 400 kV in the Region. All transmission lines and transformers in the Southeast Europe region including Slovenia and Turkey were monitored during contingences.

The following probabilistic indices were observed:

- System Reliability Indices Summary (Figure 4.59)
- System Load Curtailment Probabilistic Indices (Figure 4.60)
- Bus Load Curtailment Probability Indices (Figure 4.61)
- Branch Flow Overloading Probability Indices (Figure 4.62)
- Bus Voltage Violation Probability Indices (Figure 4.63)

SEE Transmission system in 2020, as planed by national TSOs, may experience critical situations concerning under-voltage situations, branches overloading and loss of load situations caused by 400 kV lines forced outages during peak load situation with probability of 8,1 % (707,7 hours per year). Number of critical situations is 194,67 occurrences/year and average duration of single failure is 3,6 hours.

Under-voltage situations are detected during reliability analysis as possible in Albania, Bosnia and Herzegovina, Romania, Slovenia, Montenegro, Serbia and Kosovo. Probability of such critical situations is close to 0 % for all above mentioned countries except Slovenia where probability of under-voltage situations rise up to 1,03 %.

Branches overloading may be expected with probability of 7,86 % (688,4 hours per year). Number of critical situations related to transmission branches overloading is 177,59 occurrences/year and average duration of single failure is 3,9 hours. Majority of branches overloading is related to transformers 400/x kV, 220/110 kV and lines 220 kV and 110 kV. Lines 400 kV are in general not jeopardized by 400 kV lines multiple forced outages.

Loss of load during winter peak load in 2020 may be expected with probability 0,36 % (31,2 hours per year), but it is mostly related to power plants own consumption disturbances and radial feeding of substations 110/x kV.

One may conclude that SEE transmission system in 2020 could experience worsening of reliability indices comparing them with planned system in 2015 and existing transmission system, which is expected as a consequence of 400 kV lines ageing process.

<-- F A I L U R E C R I T E R I A -->	FREQ. (OC/Y)	DURATION (HOURS)	PROB. (H/Y)	IMPACT	NO. OF CONT.	WORST. VIOL.	<----- WORST CONTINGENCY ------>
AREA 10 BUS WITH VOLTAGE < 0.900	0.0086	0.7	0.0	0.00	1	0.900	1_9(AL-01:AL-11)
OVERLOAD (%)	0.0086	0.7	0.0	0.00	1	100.772	1_9(AL-01:AL-11)
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL	0.0086	0.7	0.0		1		

Figure 4.49 System Reliability Indices Summary for Albania – winter maximum load 2020

<-- F A I L U R E C R I T E R I A -->	FREQ. (OC/Y)	DURATION (HOURS)	PROB. (H/Y)	IMPACT	NO. OF CONT.	WORST. VIOL.	<----- WORST CONTINGENCY ------>
OVERLOAD (%)	20.4835	1.3	27.6	0.12	51	180.222	1_16_1(BA-01:BA-18:BA-19)
LOSS OF LOAD (MW)	0.0026	0.5	0.0	0.03	10	25.000	3_2_7(BA-03:BA-05:BA-12)
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL	20.4835	1.3	27.6		51		

Figure 4.50 System Reliability Indices Summary for Bosnia and Herzegovina – winter maximum load 2020

<-- F A I L U R E C R I T E R I A -->	FREQ. (OC/Y)	DURATION (HOURS)	PROB. (H/Y)	IMPACT	NO. OF CONT.	WORST. VIOL.	<----- WORST CONTINGENCY ------>
AREA 20 BUS WITH VOLTAGE < 0.900	0.0000	0.6	0.0	0.00	1	0.830	11_2_9(BG-11:BG-13:BG-22)
OVERLOAD (%)	0.0044	1.1	0.0	0.00	44	168.520	11_2_9(BG-11:BG-13:BG-22)
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL	0.0044	1.1	0.0		44		

Figure 4.51 System Reliability Indices Summary for Bulgaria – winter maximum load 2020

<-- F A I L U R E C R I T E R I A -->	FREQ. (OC/Y)	DURATION (HOURS)	PROB. (H/Y)	IMPACT	NO. OF CONT.	WORST. VIOL.	<----- WORST CONTINGENCY ------>
OVERLOAD (%)	6.0855	7.1	43.5	69.83	42	162.229	2_10_4(HR-02:HR-12:HR-17)
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL	6.0855	7.1	43.5		42		

Figure 4.52 System Reliability Indices Summary for Croatia – winter maximum load 2020

<-- F A I L U R E C R I T E R I A -->	FREQ. (OC/Y)	DURATION (HOURS)	PROB. (H/Y)	IMPACT	NO. OF CONT.	WORST. VIOL.	<----- WORST CONTINGENCY ------>
AREA 60 BUS WITH VOLTAGE < 0.900	0.0000	0.0	0.0	0.00	1	0.895	8_2_2(MK-08:MK-10:MK-12)
OVERLOAD (%)	0.0000	0.0	0.0	0.00	1	117.195	8_2_2(MK-08:MK-10:MK-12)
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL	0.0000	0.0	0.0		1		

Figure 4.53 System Reliability Indices Summary for Macedonia – winter maximum load 2020

<-- F A I L U R E C R I T E R I A -->	FREQ. (OC/Y)	DURATION (HOURS)	PROB. (H/Y)	IMPACT	NO. OF CONT.	WORST. VIOL.	<----- WORST CONTINGENCY ------>
AREA 91 BUS WITH VOLTAGE < 0.900	0.0031	3.0	0.0	0.00	4	0.850	1_1_7(ME-01:ME-02:ME-12)
OVERLOAD (%)	0.0118	3.7	0.0	0.01	18	278.325	1_6_1(ME-01:ME-10:ME-11)
NOT CONVERGE	0.0131	9.7	0.1		6		
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL	0.0249	6.8	0.2		24		

Figure 4.54 System Reliability Indices Summary for Montenegro – winter maximum load 2020

<-- F A I L U R E C R I T E R I A -->	FREQ. (OC/Y)	DURATION (HOURS)	PROB. (H/Y)	IMPACT	NO. OF CONT.	WORST. VIOL.	<----- WORST CONTINGENCY ------>
AREA 70 BUS WITH VOLTAGE < 0.900	0.0010	6.9	0.0	0.00	419	0.802	55_1_1(RO-60:RO-61:RO-62)
OVERLOAD (%)	0.0026	6.9	0.0	0.00	334	240.110	10_7_1(RO-12:RO-19:RO-20)
LOSS OF LOAD (MW)	0.0001	6.9	0.0	0.15	57	219.931	1_37_1(RO-01:RO-43:RO-44)
NOT CONVERGE	0.0000	4.7	0.0		1		
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL	0.0033	6.9	0.0		708		

Figure 4.55 System Reliability Indices Summary for Romania – winter maximum load 2020

<-- F A I L U R E C R I T E R I A -->	FREQ. (OC/Y)	DURATION (HOURS)	PROB. (H/Y)	IMPACT	NO. OF CONT.	WORST. VIOL.	<----- WORST CONTINGENCY ------>
AREA 90 BUS WITH VOLTAGE < 0.900	0.5210	0.1	0.1	0.00	55	0.858	3_7_31(RS-03:RS-10:RS-41)
OVERLOAD (%)	38.4886	1.6	62.6	34.59	689	442.331	6_7_25(RS-06:RS-13:RS-38)
LOSS OF LOAD (MW)	6.1807	2.1	12.7	332.71	192	35.000	2_1_35(RS-02:RS-03:RS-38)
NOT CONVERGE	0.0003	0.2	0.0		18		
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL	38.4889	1.6	62.6		710		

Figure 4.56 System Reliability Indices Summary for Serbia and Kosovo – winter maximum load 2020

```
                                                                     FREQ.  DURATION    PROB.     IMPACT NO. OF   WORST.
<--             F A I L U R E   C R I T E R I A              -->    (OC/Y)   (HOURS)    (H/Y)             CONT.   VIOL.  <----- WORST CONTINGENCY ------>
AREA 75 BUS WITH VOLTAGE < 0.900                                    4.2065     19.5      81.8       0.32      2    0.897 2_1(SI-02:SI-03)
OVERLOAD (%)                                                        7.8073     10.8      84.4      12.48     13  104.055 2_1(SI-02:SI-03)
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL                                     7.8073     10.8      84.4                13
```

Figure 4.57 System Reliability Indices Summary for Slovenia – winter maximum load 2020

```
                                                                     FREQ.  DURATION    PROB.     IMPACT NO. OF   WORST.
<--             F A I L U R E   C R I T E R I A              -->    (OC/Y)   (HOURS)    (H/Y)             CONT.   VIOL.  <----- WORST CONTINGENCY ------>
OVERLOAD (%)                                                        0.3195      0.7       0.2       0.07      8  236.871 39_1(TR-39:TR-40)
LOSS OF LOAD (MW)                                                  13.8718      1.2      16.6    3901.16     57  235.110 1_3(TR-01:TR-04)
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL                                    14.1913      1.2      16.8                65
```

Figure 4.58 System Reliability Indices Summary for Turkey – winter maximum load 2020

Table 4.4 Individual SEE countries reliability indices (winter peak load 2020)

Country	Voltage violations probability (%)	Branch overload probability (%)	Loss of load probability (%)	TOTAL PROBABILITY (%)
Albania	0,00	0,00	0,00	0,00
Bosnia and Herzegovina	0,00	0,32	0,00	0,32
Bulgaria	0,00	0,00	0,00	0,00
Croatia	0,00	0,50	0,00	0,50
Macedonia	0,00	0,00	0,00	0,00
Montenegro	0,00	0,00	0,00	0,00
Romania	0,00	0,00	0,00	0,00
Serbia and Kosovo	0,00	0,71	0,14	0,71
Slovenia	0,93	0,96	0,00	0,96
Turkey	0,00	0,00	0,19	0,21

```
                                                                   FREQ.  DURATION    PROB.     IMPACT NO. OF   WORST.
<--            F A I L U R E   C R I T E R I A            -->  (OC/Y)   (HOURS)    (H/Y)               CONT.   VIOL.  <----- WORST CONTINGENCY ------>
AREA 10 BUS WITH VOLTAGE < 0.900                                0.0029       0.3      0.0       0.00       2     0.898 107_7(ME-01:ME-11)
AREA 30 BUS WITH VOLTAGE < 0.900                                0.0192       0.2      0.0       0.00       1     0.865 13_102(BA-03:ME-12)
AREA 70 BUS WITH VOLTAGE < 0.900                                0.0002       7.0      0.0       0.00       2     0.891 141_52(RO-05:RO-62)
AREA 75 BUS WITH VOLTAGE < 0.900                                9.9526       9.1     90.6       0.36      98     0.895 97_175(HR-12:SI-03)
AREA 90 BUS WITH VOLTAGE < 0.900                                0.5539       0.2      0.1       0.00      72     0.861 215_38(RS-03:RS-41)
AREA 91 BUS WITH VOLTAGE < 0.900                                0.0222       0.6      0.0       0.00       2     0.853 107_8(ME-01:ME-12)
OVERLOAD (%)                                                  177.5871       3.9    688.4     128.35    4205   435.445 218_32(RS-06:RS-38)
LOSS OF LOAD (MW)                                              21.8534       1.4     31.2    5612.55     405   292.700 13_289(BA-03:TR-04)
NOT CONVERGE                                                    1.8504       0.7      1.3                 70
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL                               194.6735       3.6    707.7               4402

CONTINGENCY LEGEND:
<----- CONTINGENCY LABEL ------> EVENTS
107_7(ME-01:ME-11)               OPEN BRANCH FROM BUS 13 [XTR_PG11    400.00] TO BUS 36017 [OLASTV11    400.00] CKT A
                                 OPEN BRANCH FROM BUS 36005 [OPODG211    400.00] TO BUS 36011 [OANDRI11    400.00] CKT 1
13_102(BA-03:ME-12)              OPEN BRANCH FROM BUS 13 [XTR_PG11    400.00] TO BUS 14405 [WTREBI1    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 36005 [OPODG211    400.00] TO BUS 36017 [OLASTV11    400.00] CKT A
141_52(RO-05:RO-62)              OPEN BRANCH FROM BUS 84 [XRO_MU11    400.00] TO BUS 28039 [RROSIO1    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 28037 [RGADAL1    400.00] TO BUS 28038 [RCLUJ 1    400.00] CKT 1
97_175(HR-12:SI-03)              OPEN BRANCH FROM BUS 20037 [HERNES11    400.00] TO BUS 20203 [HZERJA11    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 71 [XME_DI11    400.00] TO BUS 31410 [LDIVAC1    400.00] CKT 1
215_38(RS-03:RS-41)              OPEN BRANCH FROM BUS 79 [XSA_SU11    400.00] TO BUS 34060 [JSUBO31    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 34050 [JSUBO31    400.00] TO BUS 34082 [JSOMB31    400.00] CKT 1
107_8(ME-01:ME-12)               OPEN BRANCH FROM BUS 13 [XTR_PG11    400.00] TO BUS 36017 [OLASTV11    400.00] CKT A
                                 OPEN BRANCH FROM BUS 36005 [OPODG211    400.00] TO BUS 36017 [OLASTV11    400.00] CKT A
218_32(RS-06:RS-38)              OPEN BRANCH FROM BUS 85 [XPF_DJ11    400.00] TO BUS 34010 [JHDJE11    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 34040 [JRPMLA1    400.00] TO BUS 34065 [JTENTB11    400.00] CKT 1
13_289(BA-03:TR-04)              OPEN BRANCH FROM BUS 13 [XTR_PG11    400.00] TO BUS 14405 [WTREBI1    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 60000 [TKROMA1    400.00] TO BUS 60112 [TGEBZE1    400.00] CKT 1
```

Figure 4.59 System Reliability Indices Summary for the SEE region – winter maximum load 2020

```
                                       FREQ. DURATION    PROB.      I.P.      E.U.E. NO. OF <----- WORST CONTINGENCY ------>
<--  LOAD CURTAILMENTS (MW)  -->      (OC/Y)  (HOUR)     (H/Y)     (MW/Y)     (MWH/Y)  CONT.
 20.0 -- 30.0                         5.5028     2.1      11.6     137.57     289.45    137 13_228(BA-03:RS-29)
 30.0 -- 40.0                         1.1103     1.5       1.6      38.86      56.49    138 13_237(BA-03:RS-38)
 150.0-- 160.0                        0.0399     0.7       0.0       6.05       3.93      1 319_5(TR-21:TR-26)
 210.0-- 220.0                        0.0001     7.0       0.0       0.02       0.15      1 174_1(RO-43:RO-44)
 290.0-- 300.0                       15.2003     1.2      18.0    4449.13    5262.53    128 13_289(BA-03:TR-04)
ENTIRE SYSTEM                        21.8534     1.4      31.2    4631.63    5612.55    405

CONTINGENCY LEGEND:
<----- CONTINGENCY LABEL ------> EVENTS
13_228(BA-03:RS-29)              OPEN BRANCH FROM BUS 13 [XTR_PG11    400.00] TO BUS 14405 [WTREBI1     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 34030 [JOBREN11    400.00] TO BUS 34060 [JTENTA11    400.00] CKT 1
13_237(BA-03:RS-38)              OPEN BRANCH FROM BUS 13 [XTR_PG11    400.00] TO BUS 14405 [WTREBI1     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 34040 [JRPMLA1     400.00] TO BUS 34065 [JTENTB11    400.00] CKT 1
319_5(TR-21:TR-26)               OPEN BRANCH FROM BUS 60008 [TUNIMR1     400.00] TO BUS 60036 [TKAPTN1     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 60009 [THAMIT1     400.00] TO BUS 60036 [TKAPTN1     400.00] CKT 2
174_1(RO-43:RO-44)               OPEN BRANCH FROM BUS 28019 [RTULCE1A    400.00] TO BUS 28020 [RISACC1A    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 28019 [RTULCE1A    400.00] TO BUS 28069 [RTARIV1     400.00] CKT 1
13_289(BA-03:TR-04)              OPEN BRANCH FROM BUS 13 [XTR_PG11    400.00] TO BUS 14405 [WTREBI1     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 60000 [TKROMA1     400.00] TO BUS 60112 [TGEBZE1     400.00] CKT 1
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Figure 4.60 System Load Curtailment Probabilistic Indices for the SEE region – winter maximum load 2020

<BUS WITH LOAD CURTAILMENT (MW)>			LOAD (MW)	FREQ. (OC/Y)	DURATION (HOUR)	A.I.P. (MW/OC)	I. P. (MW/Y)	E.U.E. (MWH/Y)	B.I.P.	B.E.U.	NO. OF CONT.	<----- WORST CONTINGENCY ------>
ENTIRE SYSTEM			189030.1	21.8534	1.43	211.94	4631.63	5612.55	0.0245	0.0297	405	
16017	WTKAKAG8	15.750	24.0	0.0021	0.51	24.00	0.05	0.03	0.0021	0.0010	1	27_1(BA-18:BA-19)
35025	JTENTAT5	15.000	25.0	2.5205	0.70	25.00	63.01	44.22	2.5205	1.7688	68	13_228(BA-03:RS-29)
35026	JTENTAT6	15.000	25.0	2.9802	3.29	25.00	74.50	245.21	2.9802	9.8082	68	13_229(BA-03:RS-30)
35031	JTENTBT1	21.000	35.0	0.5666	2.62	35.00	19.83	51.94	0.5666	1.4839	69	13_237(BA-03:RS-38)
35032	JTENTBT2	21.000	35.0	0.5437	0.24	35.00	19.03	4.55	0.5437	0.1300	69	13_238(BA-03:RS-39)
60000	TKROMA1	400.00	292.7	15.2003	1.18	292.70	4449.13	5262.53	15.2003	17.9793	128	13_289(BA-03:TR-04)
60036	TKAPTN1	400.00	151.6	0.0399	0.65	151.56	6.05	3.93	0.0399	0.0260	1	319_5(TR-21:TR-26)
28250	ROSTRO5	110.00	1.2	0.0001	7.00	1.22	0.00	0.00	0.0001	0.0007	1	174_1(RO-43:RO-44)
28252	RMACIN5	110.00	6.6	0.0001	7.00	6.57	0.00	0.00	0.0001	0.0007	1	174_1(RO-43:RO-44)
28253	RISACC5A	110.00	5.2	0.0001	7.00	5.23	0.00	0.00	0.0001	0.0007	1	174_1(RO-43:RO-44)
28254	RTULCE5A	110.00	83.0	0.0001	7.00	83.00	0.01	0.06	0.0001	0.0007	1	174_1(RO-43:RO-44)
28255	RTULCE5B	110.00	112.0	0.0001	7.00	111.99	0.01	0.08	0.0001	0.0007	1	174_1(RO-43:RO-44)
28256	RBABAD5	110.00	3.0	0.0001	7.00	3.04	0.00	0.00	0.0001	0.0007	1	174_1(RO-43:RO-44)
28257	RBAIA 5A	110.00	4.1	0.0001	7.00	4.14	0.00	0.00	0.0001	0.0007	1	174_1(RO-43:RO-44)
28260	RZEBIL5	110.00	2.9	0.0001	7.00	2.92	0.00	0.00	0.0001	0.0007	1	174_1(RO-43:RO-44)
28285	RTOPOL51	110.00	1.8	0.0001	7.00	1.82	0.00	0.00	0.0001	0.0007	1	174_1(RO-43:RO-44)

CONTINGENCY LEGEND:

<----- CONTINGENCY LABEL ------>	EVENTS
27_1(BA-18:BA-19)	OPEN BRANCH FROM BUS 16218 [WTKAKA11 400.00] TO BUS 16401 [WSAR101 400.00] CKT 1
	OPEN BRANCH FROM BUS 16218 [WTKAKA11 400.00] TO BUS 16402 [WTUZL41 400.00] CKT 1
13_228(BA-03:RS-29)	OPEN BRANCH FROM BUS 13 [XTR_PG11 400.00] TO BUS 14405 [WTREBI1 400.00] CKT 1
	OPEN BRANCH FROM BUS 34030 [JOBREN11 400.00] TO BUS 34060 [JTENTA11 400.00] CKT 1
13_229(BA-03:RS-30)	OPEN BRANCH FROM BUS 13 [XTR_PG11 400.00] TO BUS 14405 [WTREBI1 400.00] CKT 1
	OPEN BRANCH FROM BUS 34030 [JOBREN11 400.00] TO BUS 34061 [JTENTA12 400.00] CKT 2
13_237(BA-03:RS-38)	OPEN BRANCH FROM BUS 13 [XTR_PG11 400.00] TO BUS 14405 [WTREBI1 400.00] CKT 1
	OPEN BRANCH FROM BUS 34040 [JRPMLA1 400.00] TO BUS 34065 [JTENTB11 400.00] CKT 1
13_238(BA-03:RS-39)	OPEN BRANCH FROM BUS 13 [XTR_PG11 400.00] TO BUS 14405 [WTREBI1 400.00] CKT 1
	OPEN BRANCH FROM BUS 34040 [JRPMLA1 400.00] TO BUS 34066 [JTENTB12 400.00] CKT 2
13_289(BA-03:TR-04)	OPEN BRANCH FROM BUS 13 [XTR_PG11 400.00] TO BUS 14405 [WTREBI1 400.00] CKT 1
	OPEN BRANCH FROM BUS 60000 [TKROMA1 400.00] TO BUS 60112 [TGEBZE1 400.00] CKT 1
319_5(TR-21:TR-26)	OPEN BRANCH FROM BUS 60008 [TUNIMR1 400.00] TO BUS 60036 [TKAPTN1 400.00] CKT 1
	OPEN BRANCH FROM BUS 60009 [THAMIT1 400.00] TO BUS 60036 [TKAPTN1 400.00] CKT 2
174_1(RO-43:RO-44)	OPEN BRANCH FROM BUS 28019 [RTULCE1A 400.00] TO BUS 28020 [RISACC1A 400.00] CKT 1
	OPEN BRANCH FROM BUS 28019 [RTULCE1A 400.00] TO BUS 28069 [RTARIV1 400.00] CKT 1

Figure 4.61 Bus Load Curtailment Probabilistic Indices for the SEE region – winter maximum load 2020

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<---------- O V E R L O A D E D   L I N E S --------->   FREQ. DURATION   PROB.  IMPACT MAX VIO. NO. OF
<------ F R O M --------> <-------- T O ---------->CKT   (OC/Y)  (HOUR)   (H/Y)   (PU)    (%)    CONT. <----- WORST CONTINGENCY ------>
SUBSYSTEM 'ENTIRE SYSTEM' TOTAL                        177.5913     3.9   688.4  128.36    0.00  4207
   111 XPR_MR21     220.00  20168 HTE SI21    220.00 2   0.0126     0.7     0.0    0.00  111.82     1 97_4(HR-12:HR-17)
   153 XPE_DI21     220.00  20126 HPEHLI21    220.00 1   0.0068     1.0     0.0    0.00  117.71     1 99_173(HR-15:SI-03)
   327 XBU_KO51     110.00  20011 HBUJE51     110.00 1   0.0068     1.0     0.0    0.00  107.64     1 99_173(HR-15:SI-03)
   328 XMA_IB51     110.00  20092 HMATUL51    110.00 1   9.2775     9.6    89.1    0.40  133.93    79 99_173(HR-15:SI-03)
 12883 VHSMIR5      110.00  12895 VH_BOT5     110.00 1   0.0015     1.3     0.0    0.00  102.91     1 40_11(BG-11:BG-22)
 14001 WTUGLJ5      20.000  14402 WTUGLJ1     400.00 1   0.0671     0.9     0.1    0.02  175.97     2 27_1(BA-18:BA-19)
 14149 WTUGLJ5      110.00  14402 WTUGLJ1     400.00 1  21.0456     1.3    28.3    0.10  108.01    11 16_81(BA-06:HR-12)
 20008 HBLATO51     110.00  20250 HWFPONIK    110.00 1   0.0430     0.7     0.0    0.00  105.86     1 22_64(BA-12:HR-01)
 20010 HBRINJ21     220.00  20059 HESENJ      220.00 1   2.6496    15.8    41.8    8.81  146.99    25 97_4(HR-12:HR-17)
 20010 HBRINJ21     220.00  20502 HBRINJ11    400.00 1   2.6496    15.8    41.8   12.84  159.93    25 97_4(HR-12:HR-17)
 20018 HCRIKV51     110.00  20061 HEVINODO    110.00 1   2.6496    15.8    41.8    8.34  141.52    25 97_4(HR-12:HR-17)
 20034 HDUNAT51     110.00  20139 HRAB51      110.00 1   0.0126     0.7     0.0    0.00  113.79     1 97_4(HR-12:HR-17)
 20058 HESENJ       110.00  20529 HNOVI51     110.00 1   2.6496    15.8    41.8    9.25  137.54    25 97_4(HR-12:HR-17)
 20058 HESENJ       110.00  20530 HBRINJ51    110.00 1   2.6496    15.8    41.8    3.58  130.85    25 97_4(HR-12:HR-17)
 20059 HESENJ       220.00  20096 HMELIN21    220.00 1   2.6496    15.8    41.8   14.32  157.62    25 97_4(HR-12:HR-17)
 20084 HKRK51       110.00  20115 HOMISA51    110.00 1   0.0126     0.7     0.0    0.00  104.18     1 97_4(HR-12:HR-17)
 20087 HL.OSI51     110.00  20121 HOTOCA51    110.00 1   2.6617    15.7    41.8    7.46  142.49    26 97_4(HR-12:HR-17)
 20102 HMRACL51     110.00  20103 HMRACL21    220.00 1   0.0126     0.7     0.0    0.00  105.89     1 97_4(HR-12:HR-17)
 20102 HMRACL51     110.00  20103 HMRACL21    220.00 2   0.0126     0.7     0.0    0.00  107.89     1 97_4(HR-12:HR-17)
 20102 HMRACL51     110.00  20103 HMRACL21    220.00 3   0.0126     0.7     0.0    0.00  107.89     1 97_4(HR-12:HR-17)
 20102 HMRACL51     110.00  20176 HTUMBR51    110.00 1   0.0126     0.7     0.0    0.00  105.08     1 97_4(HR-12:HR-17)
 20102 HMRACL51     110.00  20176 HTUMBR51    110.00 2   0.0126     0.7     0.0    0.00  105.08     1 97_4(HR-12:HR-17)
 20103 HMRACL21     220.00  20168 HTE SI21    220.00 2   0.1942     0.7     0.1    0.00  123.79    13 97_4(HR-12:HR-17)
 20112 HNOVAL51     110.00  20139 HRAB51      110.00 1   2.6496    15.8    41.8    2.62  126.72    25 97_4(HR-12:HR-17)
 20121 HOTOCA51     110.00  20530 HBRINJ51    110.00 1   2.6496    15.8    41.8    3.18  132.11    25 97_4(HR-12:HR-17)
 20135 HPOZEG51     110.00  20149 HS.BRO51    110.00 1   0.0334     0.6     0.0    0.00  108.02     3 97_4(HR-12:HR-17)
 20167 HTESIS51     110.00  20168 HTE SI21    220.00 1   0.0126     0.7     0.0    0.00  101.66     1 97_4(HR-12:HR-17)
 28035 RTURC 1G     400.00  29113 RTURCEG4    24.000 1   0.0002     7.0     0.0    0.00  113.97     1 179_7(RO-48:RO-55)
 30043 LHEDOBH1     10.500  31048 LHDOBL5     110.00 1  14.0612     6.7    93.6    1.63  101.77   263 22_66(BA-12:HR-03)
 30044 LHEDOBH2     10.500  31048 LHDOBL5     110.00 1  14.0612     6.7    93.6    1.63  101.77   263 22_66(BA-12:HR-03)
 30045 LHEDOBH3     10.500  31048 LHDOBL5     110.00 1  14.0612     6.7    93.6    1.63  101.77   263 22_66(BA-12:HR-03)
 30077 LHSELIH      6.3000  31178 LHSELI5     110.00 1   9.9614     9.1    90.6    3.37  108.08    99 99_173(HR-15:SI-03)
 30078 LHDOLEH      6.3000  31179 LHDOLE5     110.00 1   9.9614     9.1    90.6    3.37  108.08    99 99_173(HR-15:SI-03)
 31050 LILBIS5      110.00  31093 LPIVKA5     110.00 1   9.6462     9.3    89.6    2.19  144.51    90 99_173(HR-15:SI-03)
 31405 LOKROG1      400.00  31430 LBERIC1     400.00 1   3.9493     0.7     2.8    0.05  102.81   147 271_17(SI-02:SI-19)
 31405 LOKROG1      400.00  31430 LBERIC1     400.00 2   3.9493     0.7     2.8    0.05  102.81   147 271_17(SI-02:SI-19)
 34010 JHDJE11      400.00 3WNDTR B1           WND 1 1  55.9662     5.1   284.3   11.91  267.36  2302 218_32(RS-06:RS-38)
 34010 JHDJE11      400.00 3WNDTR B2           WND 1 2  28.9911     5.1   148.6    0.87  103.02  1273 218_32(RS-06:RS-38)
 34025 JNSAD31      400.00  34625 JNSAD351    110.00 1   1.4303     1.0     1.4    0.13  113.14    66 214_24(RS-02:RS-26)
 34025 JNSAD31      400.00  34626 JNSAD352    110.00 2   1.4303     1.0     1.4    0.27  127.44    66 214_24(RS-02:RS-26)
 34125 JDREN12      220.00  34471 JDREN15     110.00 1   1.1279     2.3     2.6    0.12  105.38    71 107_159(ME-01:RS-55)
 34240 JTKOSB2      220.00  34241 JKOBSP2     220.00 1  17.8353     2.4    43.6    0.55  109.45   482 122_144(MK-02:RS-55)
 34390 JBOGAT5      110.00  34690 JSABA352    110.00 1   0.0090     0.3     0.0    0.00  107.63     1 16_233(BA-06:RS-37)
 34455 JDJAK15      110.00  34456 JDJAK25     110.00 1   1.1279     2.3     2.6    0.19  108.95    71 107_159(ME-01:RS-55)
 34626 JNSAD352     110.00  34735 JSRBOB5     110.00 1   1.4303     1.0     1.4    0.18  126.79    66 214_24(RS-02:RS-26)
 34656 JPECIN5      110.00  34691 JSABA351    110.00 1   3.7495     0.4     1.4    0.00  119.16    60 16_233(BA-06:RS-37)
 35001 JHDJERH1     15.750 3WNDTR B1           WND 2 1 122.2832     4.0   486.8   25.31  435.44  2942 218_32(RS-06:RS-38)
 35002 JHDJERH2     15.750 3WNDTR B1           WND 3 1  55.7657     5.9   328.9    1.02  102.36  3190 27_223(BA-18:RS-38)
 35003 JHDJERH3     15.750 3WNDTR B2           WND 2 2  61.1343     5.6   339.6    1.44  103.38  3337 13_237(BA-03:RS-38)
 35004 JHDJERH4     15.750 3WNDTR B2           WND 3 2  61.1343     5.6   339.6    1.44  103.38  3337 13_237(BA-03:RS-38)
 35005 JHDJERH5     15.750 3WNDTR B3           WND 2 3   0.0017     0.5     0.0    0.00  103.38     4 218_32(RS-06:RS-38)
 36030 OHPERU51     110.00  36521 OHPERUH1    10.500 1   0.0251     0.6     0.0    0.00  100.01     4 13_102(BA-03:ME-12)
 36030 OHPERU51     110.00  36522 OHPERUH2    10.500 2   0.0251     0.6     0.0    0.00  100.01     4 13_102(BA-03:ME-12)
 36030 OHPERU51     110.00  36523 OHPERUH3    10.500 3   0.0251     0.6     0.0    0.00  100.01     4 107_8(ME-01:ME-12)
 36030 OHPERU51     110.00  36524 OHPERUH4    10.500 4   0.0251     0.6     0.0    0.00  100.01     4 13_102(BA-03:ME-12)
 36030 OHPERU51     110.00  36525 OHPERUH5    10.500 5   0.0251     0.6     0.0    0.00  100.01     4 13_102(BA-03:ME-12)
 36030 OHPERU51     110.00  36526 OHPERUH6    10.500 6   0.0224     0.6     0.0    0.00  262.41     3 113_1(ME-10:ME-11)
 36060 OBUDVA51     110.00  36120 OPODG251    110.00 A   0.0222     0.6     0.0    0.01  141.14     2 107_8(ME-01:ME-12)
 36095 OPODG151     110.00  36110 OPODG351    110.00 1   0.0222     0.6     0.0    0.00  107.47     2 107_8(ME-01:ME-12)
 60002 TLAPSB1      400.00  60044 TGELB21     400.00 1   0.0399     0.7     0.0    0.01  127.64     1 306_22(TR-08:TR-30)
 60002 TLAPSB1      400.00  60044 TGELB21     400.00 2   0.0399     0.7     0.0    0.01  127.64     1 305_23(TR-07:TR-30)
 60051 TAMBRL1      400.00  60057 TAMBAA3     154.00 1   0.0399     0.7     0.0    0.01  151.75     1 337_1(TR-39:TR-40)
 60051 TAMBRL1      400.00  60058 TAMBAB3     154.00 2   0.0399     0.7     0.0    0.03  232.92     1 337_1(TR-39:TR-40)
 60053 TIKITL1      400.00  60101 TYNBOS1     400.00 1   0.0399     0.7     0.0    0.00  104.34     1 346_1(TR-48:TR-49)
 60053 TIKITL1      400.00  60101 TYNBOS1     400.00 2   0.0399     0.7     0.0    0.00  104.34     1 345_2(TR-47:TR-49)
 60053 TIKITL1      400.00  60101 TYNBOS1     400.00 3   0.0399     0.7     0.0    0.00  104.34     1 345_1(TR-47:TR-48)
 60056 TDAVUT1      400.00  60101 TYNBOS1     400.00 1   0.0399     0.7     0.0    0.00  102.27     1 352_1(TR-54:TR-55)
 60056 TDAVUT1      400.00  60101 TYNBOS1     400.00 2   0.0399     0.7     0.0    0.00  102.27     1 351_2(TR-53:TR-55)
 60056 TDAVUT1      400.00  60101 TYNBOS1     400.00 3   0.0399     0.7     0.0    0.00  102.27     1 351_1(TR-53:TR-54)
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CONTINGENCY LEGEND:
<----- CONTINGENCY LABEL ------> EVENTS
97_4(HR-12:HR-17)                OPEN BRANCH FROM BUS 20037 [HERNES11    400.00] TO BUS 20203 [HZERJA11    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 20097 [HMELIN11    400.00] TO BUS 20502 [HBRINJ11    400.00] CKT 1
99_173(HR-15:SI-03)              OPEN BRANCH FROM BUS 20097 [HMELIN11    400.00] TO BUS 20177 [HTUMBR11    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 71 [XME_DI11    400.00] TO BUS 31410 [LDIVAC1     400.00] CKT 1
40_11(BG-11:BG-22)               OPEN BRANCH FROM BUS 12420 [VMETAL1     400.00] TO BUS 12431 [VSOFIW1     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 12434 [VZLATI1     400.00] TO BUS 12480 [VPLOVD1     400.00] CKT 1
27_1(BA-18:BA-19)                OPEN BRANCH FROM BUS 16218 [WTKAKA11    400.00] TO BUS 16401 [WSAR101     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 16218 [WTKAKA11    400.00] TO BUS 16402 [WTUZL41     400.00] CKT 1
16_81(BA-06:HR-12)               OPEN BRANCH FROM BUS 14402 [WTUGLJ1     400.00] TO BUS 16402 [WTUZL41     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 20037 [HERNES11    400.00] TO BUS 20203 [HZERJA11    400.00] CKT 1
22_64(BA-12:HR-01)               OPEN BRANCH FROM BUS 14410 [WTSTAN1     400.00] TO BUS 16402 [WTUZL41     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 11 [XMO_KO11    400.00] TO BUS 20078 [HKONJS11    400.00] CKT 1
179_7(RO-48:RO-55)               OPEN BRANCH FROM BUS 28020 [RISACC1A    400.00] TO BUS 28028 [RRAHMAN1    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 28028 [RRAHMAN1    400.00] TO BUS 28974 [RMEDGI1     400.00] CKT 1
22_66(BA-12:HR-03)               OPEN BRANCH FROM BUS 14410 [WTSTAN1     400.00] TO BUS 16402 [WTUZL41     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 71 [XME_DI11    400.00] TO BUS 20097 [HMELIN11    400.00] CKT 1
271_17(SI-02:SI-19)              OPEN BRANCH FROM BUS 10 [XKA_KO11    400.00] TO BUS 31450 [LKOZJK1     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 80 [XRE_DI11    400.00] TO BUS 31411 [LDIVAC2     400.00] CKT 1
218_32(RS-06:RS-38)              OPEN BRANCH FROM BUS 85 [XPF_DJ11    400.00] TO BUS 34010 [JHDJE11     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 34040 [JRPMLA1     400.00] TO BUS 34065 [JTENTB11    400.00] CKT 1
214_24(RS-02:RS-26)              OPEN BRANCH FROM BUS 74 [XER_SM11    400.00] TO BUS 34045 [JSMIT21     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 34025 [JNSAD31     400.00] TO BUS 34078 [JSRBOB1     400.00] CKT A
107_159(ME-01:RS-55)             OPEN BRANCH FROM BUS 13 [XTR_PG11    400.00] TO BUS 36017 [0LASTV11    400.00] CKT A
                                 OPEN BRANCH FROM BUS 34071 [JTKOSC1     400.00] TO BUS 34086 [JPEC 31     400.00] CKT A
122_144(MK-02:RS-55)             OPEN BRANCH FROM BUS 81 [XSK_KB11    400.00] TO BUS 26111 [YSK 5 1     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 34071 [JTKOSC1     400.00] TO BUS 34086 [JPEC 31     400.00] CKT A
16_233(BA-06:RS-37)              OPEN BRANCH FROM BUS 14402 [WTUGLJ1     400.00] TO BUS 16402 [WTUZL41     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 34040 [JRPMLA1     400.00] TO BUS 34045 [JSMIT21     400.00] CKT 1
27_223(BA-18:RS-38)              OPEN BRANCH FROM BUS 16218 [WTKAKA11    400.00] TO BUS 16401 [WSAR101     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 34040 [JRPMLA1     400.00] TO BUS 34065 [JTENTB11    400.00] CKT 1
13_237(BA-03:RS-38)              OPEN BRANCH FROM BUS 13 [XTR_PG11    400.00] TO BUS 14405 [WTREBI1     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 34040 [JRPMLA1     400.00] TO BUS 34065 [JTENTB11    400.00] CKT 1
13_102(BA-03:ME-12)              OPEN BRANCH FROM BUS 13 [XTR_PG11    400.00] TO BUS 14405 [WTREBI1     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 36005 [0PODG211    400.00] TO BUS 36017 [0LASTV11    400.00] CKT A
107_8(ME-01:ME-12)               OPEN BRANCH FROM BUS 13 [XTR_PG11    400.00] TO BUS 36017 [0LASTV11    400.00] CKT A
                                 OPEN BRANCH FROM BUS 36005 [0PODG211    400.00] TO BUS 36017 [0LASTV11    400.00] CKT A
113_1(ME-10:ME-11)               OPEN BRANCH FROM BUS 36001 [0RIBAR11    400.00] TO BUS 36011 [0ANDRI11    400.00] CKT 1
                                 OPEN BRANCH FROM BUS 36005 [0PODG211    400.00] TO BUS 36011 [0ANDRI11    400.00] CKT 1
306_22(TR-08:TR-30)              OPEN BRANCH FROM BUS 60002 [TLAPSB1     400.00] TO BUS 60044 [TGELB21     400.00] CKT 2
                                 OPEN BRANCH FROM BUS 60043 [TGELIB1     400.00] TO BUS 60044 [TGELB21     400.00] CKT 1
305_23(TR-07:TR-30)              OPEN BRANCH FROM BUS 60002 [TLAPSB1     400.00] TO BUS 60044 [TGELB21     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 60043 [TGELIB1     400.00] TO BUS 60044 [TGELB21     400.00] CKT 1
337_1(TR-39:TR-40)               OPEN BRANCH FROM BUS 60051 [TAMBRL1     400.00] TO BUS 60053 [TIKITL1     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 60051 [TAMBRL1     400.00] TO BUS 60053 [TIKITL1     400.00] CKT 2
346_1(TR-48:TR-49)               OPEN BRANCH FROM BUS 60053 [TIKITL1     400.00] TO BUS 60101 [TYNBOS1     400.00] CKT 2
                                 OPEN BRANCH FROM BUS 60053 [TIKITL1     400.00] TO BUS 60101 [TYNBOS1     400.00] CKT 3
345_2(TR-47:TR-49)               OPEN BRANCH FROM BUS 60053 [TIKITL1     400.00] TO BUS 60101 [TYNBOS1     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 60053 [TIKITL1     400.00] TO BUS 60101 [TYNBOS1     400.00] CKT 3
345_1(TR-47:TR-48)               OPEN BRANCH FROM BUS 60053 [TIKITL1     400.00] TO BUS 60101 [TYNBOS1     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 60053 [TIKITL1     400.00] TO BUS 60101 [TYNBOS1     400.00] CKT 2
352_1(TR-54:TR-55)               OPEN BRANCH FROM BUS 60056 [TDAVUT1     400.00] TO BUS 60101 [TYNBOS1     400.00] CKT 2
                                 OPEN BRANCH FROM BUS 60056 [TDAVUT1     400.00] TO BUS 60101 [TYNBOS1     400.00] CKT 3
351_2(TR-53:TR-55)               OPEN BRANCH FROM BUS 60056 [TDAVUT1     400.00] TO BUS 60101 [TYNBOS1     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 60056 [TDAVUT1     400.00] TO BUS 60101 [TYNBOS1     400.00] CKT 3
351_1(TR-53:TR-54)               OPEN BRANCH FROM BUS 60056 [TDAVUT1     400.00] TO BUS 60101 [TYNBOS1     400.00] CKT 1
                                 OPEN BRANCH FROM BUS 60056 [TDAVUT1     400.00] TO BUS 60101 [TYNBOS1     400.00] CKT 2
```

Figure 4.62 Branch Flow Overloading Probability Indices for the SEE region – winter maximum load 2020

```
                                        AREA 10 BUSES WITH VOLTAGE LESS THAN 0.900
                                     FREQ. DURATION   PROB.   IMPACT MAX VIO. NO. OF
<- BUS WITH VOLTAGE VIOLATION ->    (OC/Y)  (HOUR)    (H/Y)    (PU)           CONT. <----- WORST CONTINGENCY ------>
ENTIRE SYSTEM                       0.0029    0.3      0.0     0.00              2
 10481 AWKAPG1      20.000          0.0029    0.3      0.0     0.00   0.8987     2 107_7(ME-01:ME-11)
 10482 AWKAPG2      20.000          0.0029    0.3      0.0     0.00   0.8985     2 107_7(ME-01:ME-11)
 10483 AWKAPG3      20.000          0.0029    0.3      0.0     0.00   0.8985     2 107_7(ME-01:ME-11)

                                        AREA 30 BUSES WITH VOLTAGE LESS THAN 0.900
                                     FREQ. DURATION   PROB.   IMPACT MAX VIO. NO. OF
<- BUS WITH VOLTAGE VIOLATION ->    (OC/Y)  (HOUR)    (H/Y)    (PU)           CONT. <----- WORST CONTINGENCY ------>
ENTIRE SYSTEM                       0.0192    0.2      0.0     0.00              1
    13 XTR_PG11     400.00          0.0192    0.2      0.0     0.00   0.8651     1 13_102(BA-03:ME-12)

                                        AREA 70 BUSES WITH VOLTAGE LESS THAN 0.900
                                     FREQ. DURATION   PROB.   IMPACT MAX VIO. NO. OF
<- BUS WITH VOLTAGE VIOLATION ->    (OC/Y)  (HOUR)    (H/Y)    (PU)           CONT. <----- WORST CONTINGENCY ------>
ENTIRE SYSTEM                       0.0002    7.0      0.0     0.00              2
 28038 RCLUJ 1      400.00          0.0002    7.0      0.0     0.00   0.8909     2 141_52(RO-05:RO-62)
 28463 RLECHI5      110.00          0.0001    7.0      0.0     0.00   0.8981     1 141_52(RO-05:RO-62)

                                        AREA 75 BUSES WITH VOLTAGE LESS THAN 0.900
                                     FREQ. DURATION   PROB.   IMPACT MAX VIO. NO. OF
<- BUS WITH VOLTAGE VIOLATION ->    (OC/Y)  (HOUR)    (H/Y)    (PU)           CONT. <----- WORST CONTINGENCY ------>
ENTIRE SYSTEM                       9.9526    9.1     90.6     0.36             98
 30088 LTETOLT42    10.500          9.9526    9.1     90.6     0.18   0.8952    98 97_175(HR-12:SI-03)
 30089 LTETOLT5     10.500          9.9526    9.1     90.6     0.18   0.8952    98 97_175(HR-12:SI-03)

                                        AREA 90 BUSES WITH VOLTAGE LESS THAN 0.900
                                     FREQ. DURATION   PROB.   IMPACT MAX VIO. NO. OF
<- BUS WITH VOLTAGE VIOLATION ->    (OC/Y)  (HOUR)    (H/Y)    (PU)           CONT. <----- WORST CONTINGENCY ------>
ENTIRE SYSTEM                       0.5539    0.2      0.1     0.00             72
 34082 JSOMB31      400.00          0.5428    0.1      0.1     0.00   0.8610    69 215_38(RS-03:RS-41)
 34264 JAPATI5      110.00          0.0000    0.1      0.0     0.00   0.8911     1 215_38(RS-03:RS-41)
 34647 JPEC 25      110.00          0.0112    1.2      0.0     0.00   0.8956     3 107_159(ME-01:RS-55)
 34655 JPEC  5      110.00          0.0069    0.5      0.0     0.00   0.8975     2 107_159(ME-01:RS-55)
 34732 JSOMB15      110.00          0.0000    0.1      0.0     0.00   0.8967     1 215_38(RS-03:RS-41)
 34733 JSOMB25      110.00          0.0000    0.1      0.0     0.00   0.8890     1 215_38(RS-03:RS-41)

                                        AREA 91 BUSES WITH VOLTAGE LESS THAN 0.900
                                     FREQ. DURATION   PROB.   IMPACT MAX VIO. NO. OF
<- BUS WITH VOLTAGE VIOLATION ->    (OC/Y)  (HOUR)    (H/Y)    (PU)           CONT. <----- WORST CONTINGENCY ------>
ENTIRE SYSTEM                       0.0222    0.6      0.0     0.00              2
 36017 OLASTV11     400.00          0.0222    0.6      0.0     0.00   0.8535     2 107_8(ME-01:ME-12)
 36050 OHNOVI51     110.00          0.0031    3.0      0.0     0.00   0.8979     1 107_8(ME-01:ME-12)
 36053 OBIJEL51     110.00          0.0222    0.6      0.0     0.00   0.8910     2 107_8(ME-01:ME-12)
 36055 OTIVAT51     110.00          0.0222    0.6      0.0     0.00   0.8888     2 107_8(ME-01:ME-12)
 36057 OKOTOR51     110.00          0.0222    0.6      0.0     0.00   0.8889     2 107_8(ME-01:ME-12)
 36058 OLASTV51     110.00          0.0031    3.0      0.0     0.00   0.8928     1 107_8(ME-01:ME-12)
 36180 OLUSTI51     110.00          0.0222    0.6      0.0     0.00   0.8878     2 107_8(ME-01:ME-12)
 36301 OLASTV_1     35.000          0.0031    3.0      0.0     0.00   0.8922     1 107_8(ME-01:ME-12)

CONTINGENCY LEGEND:
<----- CONTINGENCY LABEL ------> EVENTS
107_7(ME-01:ME-11)                OPEN BRANCH FROM BUS 13 [XTR_PG11    400.00] TO BUS 36017 [OLASTV11    400.00] CKT A
                                  OPEN BRANCH FROM BUS 36005 [OPODG211    400.00] TO BUS 36011 [OANDRI11    400.00] CKT 1
13_102(BA-03:ME-12)               OPEN BRANCH FROM BUS 13 [XTR_PG11    400.00] TO BUS 14405 [WTREBI1     400.00] CKT 1
                                  OPEN BRANCH FROM BUS 36005 [OPODG211    400.00] TO BUS 36017 [OLASTV11    400.00] CKT A
141_52(RO-05:RO-62)               OPEN BRANCH FROM BUS 84 [XRO_MU11    400.00] TO BUS 28039 [RROSIO1     400.00] CKT 1
                                  OPEN BRANCH FROM BUS 28037 [RGADAL1     400.00] TO BUS 28038 [RCLUJ 1     400.00] CKT 1
97_175(HR-12:SI-03)               OPEN BRANCH FROM BUS 20037 [HERNES11    400.00] TO BUS 20203 [HZERJA11    400.00] CKT 1
                                  OPEN BRANCH FROM BUS 71 [XME_DI11    400.00] TO BUS 31410 [LDIVAC1     400.00] CKT 1
215_38(RS-03:RS-41)               OPEN BRANCH FROM BUS 79 [XSA_SU11    400.00] TO BUS 34050 [JSUBO31     400.00] CKT 1
                                  OPEN BRANCH FROM BUS 34050 [JSUBO31     400.00] TO BUS 34082 [JSOMB31     400.00] CKT 1
107_159(ME-01:RS-55)              OPEN BRANCH FROM BUS 13 [XTR_PG11    400.00] TO BUS 36017 [OLASTV11    400.00] CKT A
                                  OPEN BRANCH FROM BUS 34071 [JTKOSC1     400.00] TO BUS 34086 [JPEC 31     400.00] CKT A
107_8(ME-01:ME-12)                OPEN BRANCH FROM BUS 13 [XTR_PG11    400.00] TO BUS 36017 [OLASTV11    400.00] CKT A
                                  OPEN BRANCH FROM BUS 36005 [OPODG211    400.00] TO BUS 36017 [OLASTV11    400.00] CKT A
```

Figure 4.63 Bus Voltage Violation Probability Indices for the SEE region – winter maximum load 2020

Figure 4.64 Individual SEE transmission networks reliability assessment: probability of overloadings and/or busbars undervoltages during 2020 winter maximum load

5 CRITICAL PARTS OF SEE TRANSMISSION NETWORK ACCORDING TO RELIABILITY INDICATORS

According to the reliability indices calculated for existing SEE transmission system topology, expected future short-time and mid-time frame network topology, referring to winter peak or high load operational conditions (3rd Wednesday in January in 2012, 2015 and 2020), one may conclude that SEE transmission system reliability is satisfactory high, and problems with transmission branches overloading or over-voltage/under-voltage busbars situations could be expected with very low probability. This conclusion was made observing forced outages of 400 kV lines only, which show very high level of availability due to forced outages, based on data provided by regional Transmission System Operators. It is reasonable to expect less favorable situation concerning reliability indices if additional outages of lines 220 kV, 150 kV and 110 kV are observed, since present network ageing problems are mostly reflected to these voltage levels.

By using existing transmission network model some limitations were noticed on Slovenian – Croatian border (line 220 kV Pehlin – Divaca that is jeopardized by the outage of Melina – Divaca line 400 kV) with probability of 0,41 %. Transformer 400/110 kV in Dobrudja subststion in Bulgaria may be overloaded (related probability is 0,01 %). Transformers 400/150 kV in two substations in Turkey (PSS/E names AMBAR and AMBDG) may be at risk of being overloaded with probability of 0,2 %. High load flow interchanges between Slovenia and Italy using phase shifting transformers in the Divača substations (2x600 MVA) may lead to non-convergent situations at the model after some contingences. One line 220 kV and transformer 220/110 kV in Bulgaria, transformer 400/220 kV in Croatia (Melina SS), two lines 110 kV in Macedonia together with two transformers 400/110 kV (Skopje 4), several transformers 400/220 kV and 400/110 kV in Romania, line 220 kV in Serbia (Beograd 3 – Obrenovac), one more transformer 400/110 kV in Turkey together with one line 150 kV, are at risk of overloading but related probabilities are close to 0 %.

Voltage violations for existing network topology may be expected in Romania at 400 kV and 220 kV voltage levels in the Suceava substation and at 400 kV and 110 kV voltage levels in the Roman Nord substation (probability of undervoltages is between 0,03 % and 0,1 %). Under-voltage problems are possible at 400 kV, 220 kV and 110 kV nodes in Bulgaria, and at 110 kV nodes in Macedonia, but with probability close to 0 %.

Loss of load may be expected in Romania (range 20 MW – 30 MW, probability 0,02 %), Bosnia and Herzegovina (range 160 MW – 170 MW, probability 0,36 %) and Turkey (range 80 MW – 90 MW and range 210 MW – 220 MW with probability of 0,21 %). Loss of load may happen in Albania, Croatia, Bulgaria and Serbia but with probability close to 0 %.

Observing planned transmission network short time frame model (winter peak 2015) some limitations were noticed concerning the 110 kV line Tivat – Herceg Novi in Montenegro (probability of overloadings 0,16 %). Transmission branches overloading may happen in Bosnia and Herzegovina, Romania, Serbia and Turkey but with probability close to 0 %.

Voltage violations for short time frame network topology may be expected in Albania, Romania, Serbia and Kosovo but with probability close to 0 %. Overvoltages have not been detected at the model.

Loss of load may be expected in Serbia (range 20 MW – 30 MW and range 30 MW – 40 MW, probability 0,05 %), and Turkey (range 230 MW – 240 MW, probability of 0,21 %). Majority of loss of load is related to power plants self consumption, with radial connection to the network 400 kV.

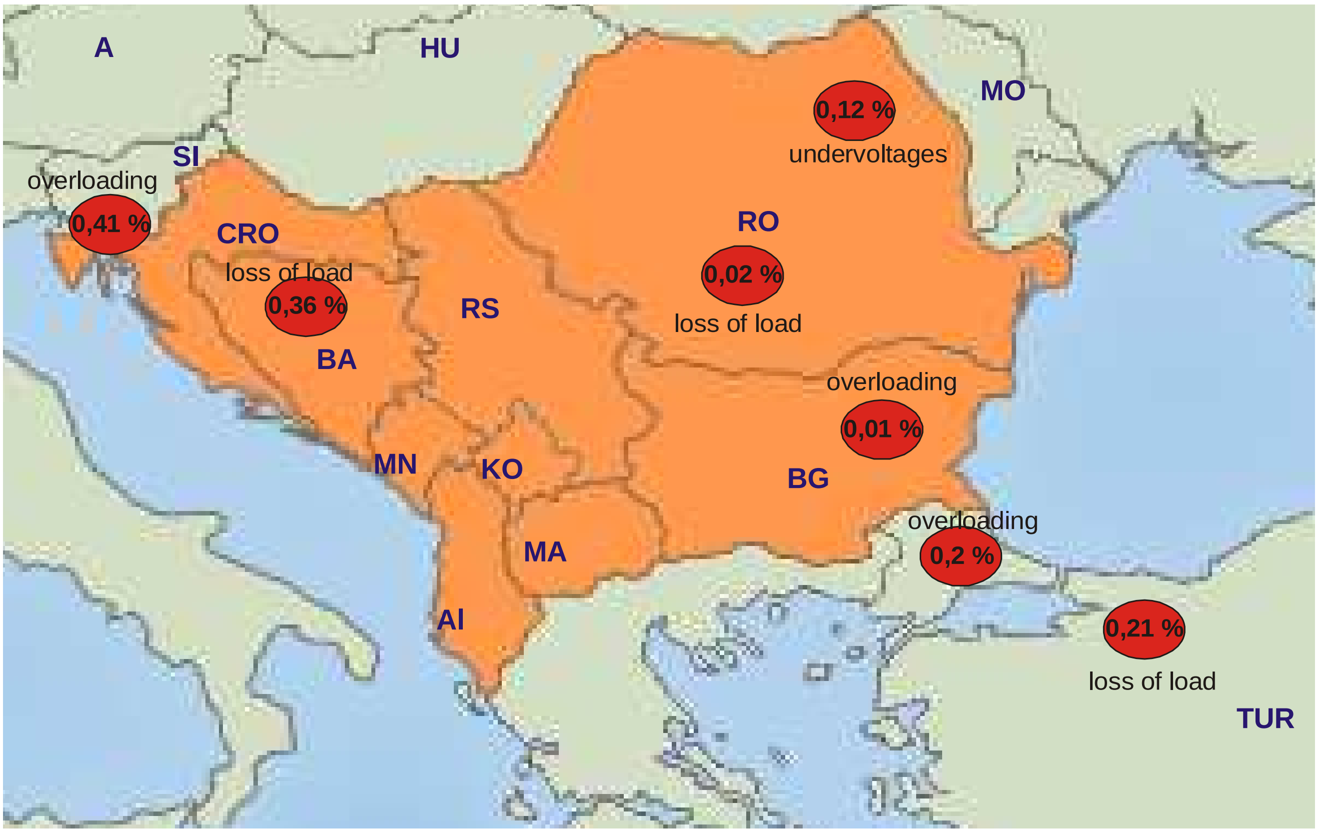

Figure 5.1 Critical areas in the SEE transmission system and probability of network overloadings, voltage problems and loss of load expectation (existing network topology - 2012)

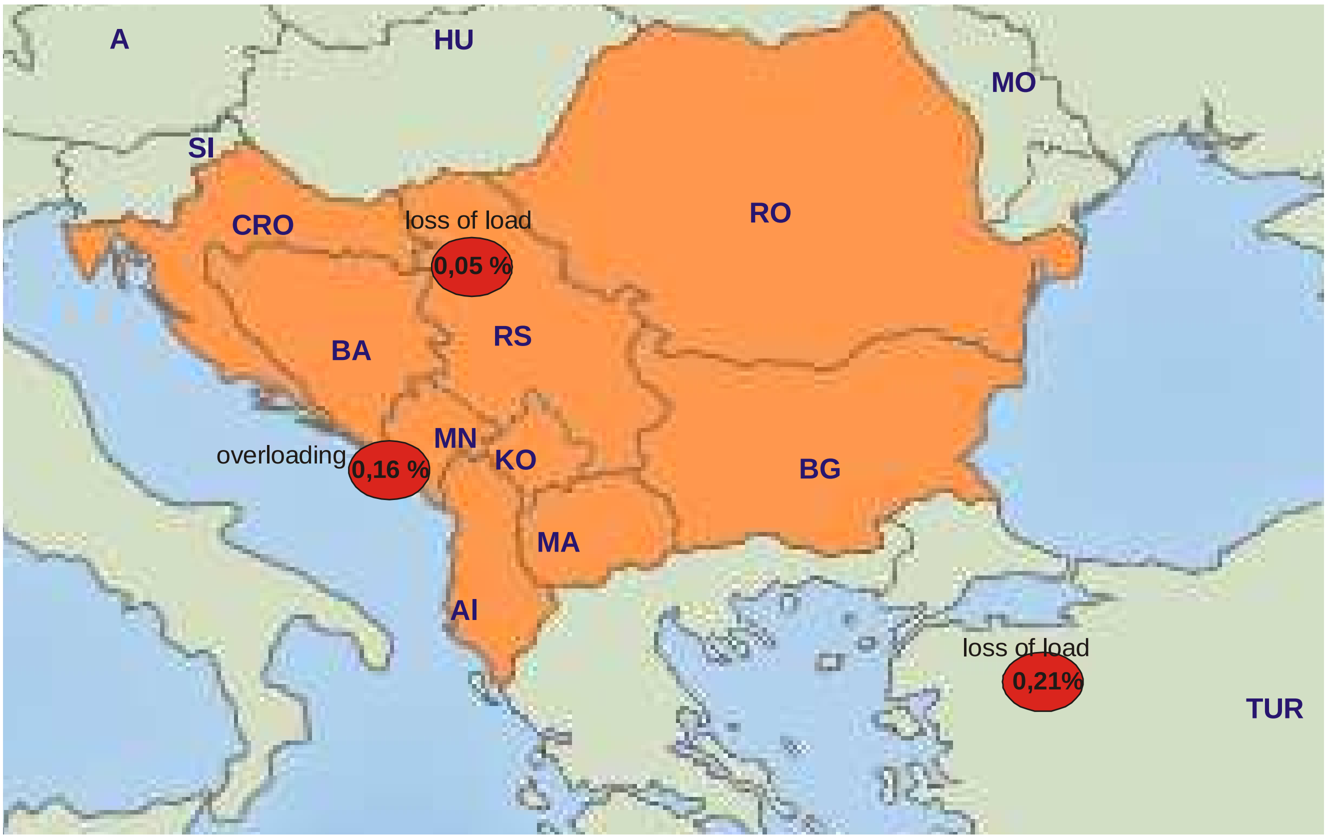

Figure 5.2 Critical areas in the SEE transmission system and probability of network overloadings, voltage problems and loss of load expectation (short time frame future network topology - 2015)

It seems that SEE transmission system in 2015 will keep high level of reliability concerning 400 kV lines forced outages, but for sure this problem is mitigated by extremely robust TSOs development plans. Many new 400 kV, 220 kV and 110(150) kV lines which are planned for construction will strengthen national transmission systems, and together with relatively large number of new interconnection lines planned for construction, could hide a problem with 400 kV lines (together with other transmission branches 220 kV and 110 kV) ageing. Such robust transmission development plans by SEE Transmission System Operators could be especially influential observing 2020 reliability indices when many existing 400 kV lines (**117 lines 400 kV**) will be **older than 40 years**.

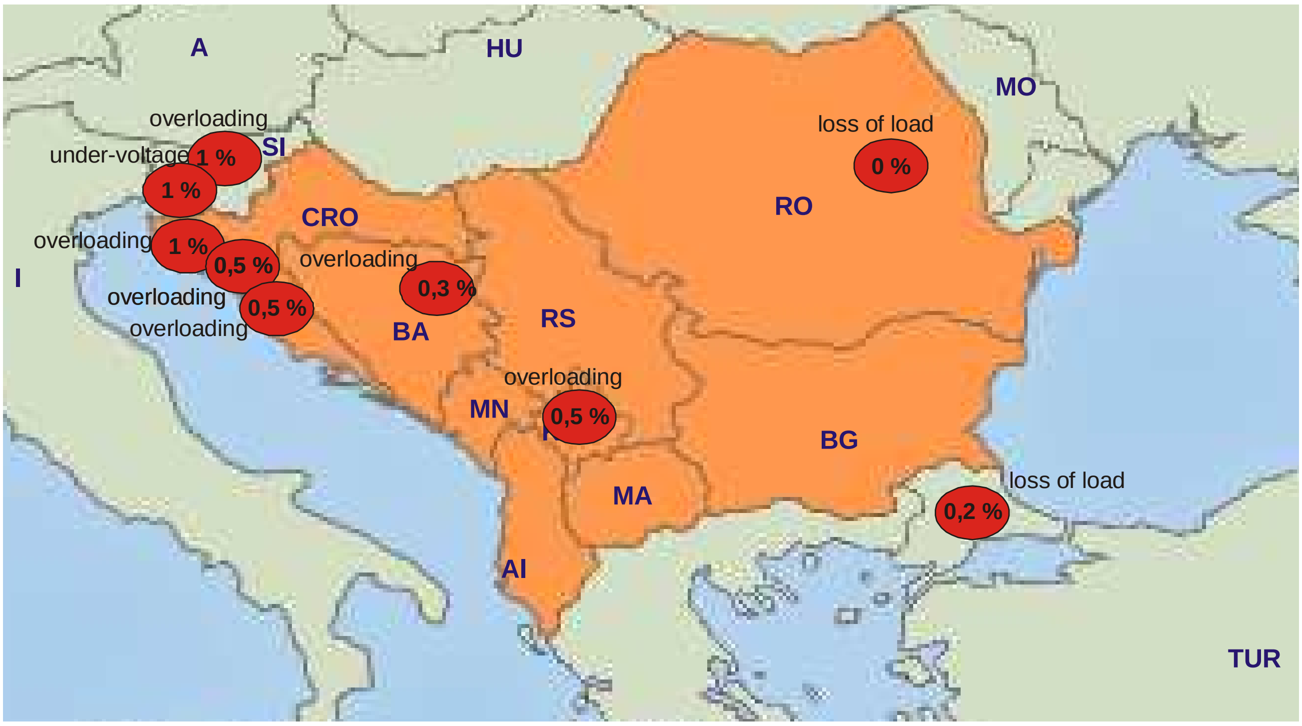

Figure 5.3 Critical areas in the SEE transmission system and probability of network overloading, voltage problems and loss of load expectation (mid time frame future network topology - 2020)

Observing planned transmission network mid time frame model (winter peak 2020) worsening of reliability indices could be noticed, especially with branches overloading related to 400 kV lines multiple forced outages. This could be a result of 400 kV lines ageing and large number of older lines, but also could be a result of other influential factors like power plants construction, load growth etc.

For 2020 limitations were noticed concerning 220 and 110 kV tie lines between Croatia and Slovenia (Pehlin – Divaca, Matulji – I. Bistrica, Buje – Koper), 220 kV tie line between Croatia and Bosnia (CCGT Sisak – Prijedor 2), transformer 400/110 kV in the Ugljevik SS (Bosnia and Herzegovina), lines 220 kV and 110 kV around Senj and Brinje in Croatia, lines 110 kV in Lika area and along northern coastline of Croatia, 220 kV line in Kosovo (small impedance line in TPP Kosovo B substation).

Voltage violations for short time frame network topology may be expected only in Slovenia concerning generators in TETO (PSS/E node LTETOLT). Overvoltage situations were not detected at the model. Loss of load may be expected in Serbia (range 20 MW – 30 MW and range 30 MW – 40 MW, probability 0,15 %), and Turkey (range 290 MW – 300 MW, probability of 0,21 %). Loss of load possible problems were detected for certain number of 110 kV nodes in Romania, but with probability close to 0 %.

6 EVALUATION AND PRIORITIZATION OF INVESTMENTS IN NETWORK REINFORCEMENT AND/OR NETWORK REVITALIZATION ACCORDING TO RELIABILITY INDICATORS

This Chapter gives general suggestions on network reinforcements and revitalization priorities based on reliability analysis described within this Report.

Since network reinforcements are subject of more detailed analysis which deal with many possible system conditions, reliability analysis conducted in this study are not sufficient to determine necessary transmission network reinforcements, but some suggestions may be given:

- network 400 kV in the SEE region shows high level of availability and critical situations which occur as a consequence of 400 kV lines outages have very low probability,
- significant investments in 400 kV network development are not visible since network 400 kV in the SEE region is generally well meshed and highly available,
- construction of new lines 400 kV will be probably motivated by new power plants construction and market transactions in the future,
- motivation for new 400 kV interconnection lines construction should be based primarily on market and economic rationalization.

In order to keep high level of 400 kV lines availability transmission system operators will have to continuously conduct appropriate maintenance and revitalization activities. It may be expected that older lines 400 kV will be the most important candidates for revitalization activities in the future, concerning this voltage level (significant revitalization activities will be directed to the networks 220 kV, 150 kV-110 kV but this is not a scope of this report).

Suggestions on 400 kV lines revitalization activities prioritization which are given in this chapter are based on the following criteria:

1. lines 400 kV age with respect to year 2015;
2. lines 400 kV average unavailability in the past;
3. expected improvement of SEE transmission system reliability indices after line revitalization;

It should be stressed that this is very simplified procedure because decision about revitalization activities is strongly dependent on different factors, like actual condition of specific line 400 kV, regulatory requests, connection of new power plants or substations at this line, fulfillment of technical requests, maintenance and revitalization costs, etc. This means that prioritization lists which are determined according to previously mentioned criteria, and given in this Report are only indicative.

For the first criterion lines 400 kV are ranked according to their age in 2015. Age of transmission lines is important factor in evaluation of revitalization activities, but not the only one because older lines may have still very high availability. Furthermore, older lines may have lost their significance within the system so revitalization of these lines may not satisfy the most important system needs. Age of transmission lines should be considered as general indication of revitalization candidates, but deeper analyses are necessary to make further selection for revitalization activities and prioritize them.

Lines 400 kV unavailability due to forced outages in the past, as second criterion for revitalization activities prioritization, are indicative because they tell a lot about lines condition, but without clear distinction between forced and planned outages, and their causes, it is not possible to prioritize revitalization activities without going much more deeper into number and duration of outages and their causes. Furthermore, transmission lines are more or less significant for proper functioning of a power system, so increased unavailability of some line doesn't mean that system security or normal system operation will be jeopardized as a consequence of that.

Reliability analyses described in Chapter 4.5 gives reliability indicators for the SEE transmission system during expected winter peak load situations in 2015 and 2020. Prioritization based on this criterion is determined according to the system problem probabilistic indices (over-loadings, over-voltages, under-voltages, loss of load) for two set of individual lines 400 kV unavailability data. System problem probability indices for 2020 (this time frame was used because system problem probability indices are much higher than those related to 2015, so influence of individual lines 400 kV decreased unavailability after revitalization activities could be more visible) were calculated for the base case model using statistical data for 400 kV lines concerning the number of outages and average duration of single outage, observing SEE transmission network in total (Figure 4.59). System problems at the base case model may occur with probability of 707,7 h/y (8,0788 %). It was assumed that 50 % of lines 400 kV unavailability due to forced outages is caused by a line age, and that revitalization activities at each transmission line are going to decrease number of forced outages in a way that number of internal failures due to a line age is zero. SEE transmission system problem probability indices are calculated repeatedly, with assumption that each line 400 kV, that is a candidate for revitalization (candidates are lines 400 kV which are older than 40 years referring to 2015), has decreased number of forced outages per year relating to statistical data in the past and estimation for a future (Appendix 3), while keeping number of outages for the other lines the same. Transmission lines 400 kV are then ranked according to a difference in system problem probability indices before and after line revitalization.

Usage of the first criterion gives revitalization list shown in Table 6.1. One may notice that the oldest lines 400 kV in the Southeast Europe are located mainly in Romania (first 14 lines 400 kV in the list). Due to missing data about real statistical unavailability in the past for these lines Authors are also missing clearer view on their actual condition and reliability parameters today.

Usage of the second criterion gives revitalization list shown in Table 6.2. The worst unavailability data in the past were noticed for lines 400 kV Hamitabad – Maritsa East 3 between Turkey and Bulgaria and Konjsko – Velebit in Croatia. Lines 400 kV in Romania are included in the list but their unavailability data were not measured and values from Reliability Normative were used (real unavailability for lines 400 kV in Romania was unknown to the authors). Relatively large unavailability of these lines could be a consequence of lines length or unfavorable weather conditions across line route, not necessary a consequence of their age. More accurate estimation of revitalization priorities according to this criterion should be based on causes of outages for each considered line.

Usage of the third criterion gives revitalization list shown in Table 6.3. One may notice that probabilities of network limits violations are almost the same no matter of number of forced outages for individual lines 400 kV. Difference in probability for the first line in the prioritization list and the last one is only 9,7 hours/year (0,11 %), which means that revitalization of the first line, resulting in smaller number of outages for this line will decrease probability of system problems occurrence for 0,11 % only, comparing it with the last line on the list. This is mainly because planned network in 2020 is robust so individual 400 kV line revitalization activities are not going to improve system performance significantly observing winter peak load situation in 2020. This influence would be even less visible observing winter peak load situation in 2015 due to much better system problem probability indices.

Table 6.1 Older lines 400 kV in the SEE transmission system (ranked according to their age)

Line 400 kV	Country	Year of construction	Age (2012)	Age (2015)	Unavailability (%)
Urechesti - Urech1G	Romania	1960	52	55	0,01
Urechesti - Urech1G	Romania	1960	52	55	0,01
Rosiori - Mukacevo	Romania	1962	50	53	0,03
Gadalin - Rosiori	Romania	1963	49	52	0,08
Iernut - Gadalin	Romania	1963	49	52	0,03
Slatina - Bucuresti Sud	Romania	1965	47	50	0,11
Tantareni - Sibiu	Romania	1966	46	49	0,17
Sibiu Sud - Iernut	Romania	1966	46	49	0,05
Gura Ialomitei - Lacu Sarat	Romania	1966	46	49	0,04
Lacu Sarat - Smardan	Romania	1967	45	48	0,02
Smardan - Gutinas	Romania	1969	43	46	0,09
Brasov - Sibiu Sud	Romania	1969	43	46	0,08
Urechesti - Domnesti	Romania	1970	42	45	0,17
Portile De Fier - Slatina	Romania	1970	42	45	0,11
Varna - Carevec	Bulgaria	1970	42	45	0,02
Carevec - Mizia	Bulgaria	1970	42	45	0,02
Varna - Dobrudja	Bulgaria	1970	42	45	0,01
Beograd 8 - Drmno	Serbia	1970	42	45	0,00
Đerdap 1 - Drmno	Serbia	1970	42	45	0,00
Mintia - Sibiu	Romania	1971	41	44	0,08
Urechesti - Portile De Fier	Romania	1971	41	44	0,05
Sofia West - Niš 2	Serbia	1971	41	44	0,00
Bor 2 - Đerdap 1	Serbia	1971	41	44	0,00
Portile de Fier - Đerdap 1	Serbia	1972	40	43	0,01
Mizia - Stolnik	Bulgaria	1972	40	43	0,01
Portile De Fier - Djerdap	Romania	1972	40	43	0,00
Tantareni - Bradu	Romania	1974	38	41	0,13
Gutinas - Brasov	Romania	1974	38	41	0,08
Novi Sad 3 - Mladost 2	Serbia	1974	38	41	0,06
Tantareni - Urechesti	Romania	1974	38	41	0,05
Arad - Sandorfalva	Romania	1974	38	41	0,04
Kamitabad - Maritsa/bg	Turkey	1975	37	40	0,52
Konjsko - Obrovac (Velebit)	Croatia	1975	37	40	0,11
Darste - Brazi Vest	Romania	1975	37	40	0,07
Rahman - Dobrudja	Romania	1975	37	40	0,06
Rahman - Medgidia Sud	Romania	1975	37	40	0,05
Constanta Nord - Cernavoda	Romania	1975	37	40	0,05
Domnesti - Brazi Vest	Romania	1975	37	40	0,04
Gura Ialomitei - Cernavoda 1	Romania	1975	37	40	0,04
Isaccea - Rahman	Romania	1975	37	40	0,04
Metalurgichna - Sofia Zapad	Bulgaria	1975	37	40	0,01
Niš 2 - Kosovo B	Serbia/Kosovo	1975	37	40	0,00
Novi Sad 3 - Mladost 1	Serbia	1975	37	40	0,00
Obrenovac - Mladost 1	Serbia	1975	37	40	0,00
Krško-Maribor	Slovenia	1975	37	40	0,00
Podlog-Maribor	Slovenia	1975	37	40	0,00

Table 6.2 Older lines 400 kV in the SEE transmission system (ranked according to their unavailability due to forced outages in the near past)

Line 400 kV	Country	Year of construction	Age (2012)	Age (2015)	Unavailability (%)
Kamitabad - Maritsa/bg	Turkey	1975	37	40	0,52
Tantareni - Sibiu	Romania	1966	46	49	0,17
Urechesti - Domnesti	Romania	1970	42	45	0,17
Tantareni - Bradu	Romania	1974	38	41	0,13
Slatina - Bucuresti Sud	Romania	1965	47	50	0,11
Portile De Fier - Slatina	Romania	1970	42	45	0,11
Konjsko - Obrovac (Velebit)	Croatia	1975	37	40	0,11
Smardan - Gutinas	Romania	1969	43	46	0,09
Mintia - Sibiu	Romania	1971	41	44	0,08
Brasov - Sibiu Sud	Romania	1969	43	46	0,08
Gutinas - Brasov	Romania	1974	38	41	0,08
Gadalin - Rosiori	Romania	1963	49	52	0,08
Darste - Brazi Vest	Romania	1975	37	40	0,07
Rahman - Dobrudja	Romania	1975	37	40	0,06
Novi Sad 3 - Mladost 2	Serbia	1974	38	41	0,06
Urechesti - Portile De Fier	Romania	1971	41	44	0,05
Sibiu Sud - Iernut	Romania	1966	46	49	0,05
Rahman - Medgidia Sud	Romania	1975	37	40	0,05
Constanta Nord - Cernavoda	Romania	1975	37	40	0,05
Tantareni - Urechesti	Romania	1974	38	41	0,05
Gura Ialomitei - Lacu Sarat	Romania	1966	46	49	0,04
Domnesti - Brazi Vest	Romania	1975	37	40	0,04
Gura Ialomitei - Cernavoda 1	Romania	1975	37	40	0,04
Isaccea - Rahman	Romania	1975	37	40	0,04
Arad - Sandorfalva	Romania	1974	38	41	0,04
Iernut - Gadalin	Romania	1963	49	52	0,03
Rosiori - Mukacevo	Romania	1962	50	53	0,03
Varna - Carevec	Bulgaria	1970	42	45	0,02
Lacu Sarat - Smardan	Romania	1967	45	48	0,02
Carevec - Mizia	Bulgaria	1970	42	45	0,02
Varna - Dobrudja	Bulgaria	1970	42	45	0,01
Urechesti - Urech1G	Romania	1960	52	55	0,01
Urechesti - Urech1G	Romania	1960	52	55	0,01
Metalurgichna - Sofia Zapad	Bulgaria	1975	37	40	0,01
Portile de Fier - Đerdap 1	Serbia	1972	40	43	0,01
Mizia - Stolnik	Bulgaria	1972	40	43	0,01
Niš 2 - Kosovo B	Serbia/Kosovo	1975	37	40	0,00
Sofia West - Niš 2	Serbia	1971	41	44	0,00
Portile De Fier - Djerdap	Romania	1972	40	43	0,00
Novi Sad 3 - Mladost 1	Serbia	1975	37	40	0,00
Beograd 8 - Drmno	Serbia	1970	42	45	0,00
Đerdap 1 - Drmno	Serbia	1970	42	45	0,00
Obrenovac - Mladost 1	Serbia	1975	37	40	0,00
Bor 2 - Đerdap 1	Serbia	1971	41	44	0,00
Krško-Maribor	Slovenia	1975	37	40	0,00
Podlog-Maribor	Slovenia	1975	37	40	0,00

Table 6.3 Older lines 400 kV in the SEE transmission system (ranked according to their influence on the system probabilistic indices during 2020 winter peak load situation)

Line 400 kV	Country	Year of construction	Age		Past average unavailability (%)	Probabilistic indices - probability of problems (hours/y)		Difference (hours/year)	Number of outages in 2020	
			2012	2015		before revitalization	after revitalization		before revitalization	after revitalization
Novi Sad 3 - Mladost 2	SR	1974	38	41	0,06	707,7	698,0	-9,7	4,80	2,80
Novi Sad 3 - Mladost 1	SR	1975	37	40	0,00	707,7	698,0	-9,7	4,80	2,80
Konjsko - Obrovac (Velebit)	HR	1975	37	40	0,11	707,7	698,1	-9,6	8,10	4,70
Tantareni - Sibiu	RO	1966	46	49	0,17	707,7	700,4	-7,3	1,00	0,50
Urechesti - Domnesti	RO	1970	42	45	0,17	707,7	700,7	-7,0	1,04	0,52
Tantareni - Bradu	RO	1974	38	41	0,13	707,7	701,4	-6,3	0,78	0,39
Portile De Fier - Slatina	RO	1970	42	45	0,11	707,7	702,4	-5,3	0,67	0,34
Slatina - Bucuresti Sud	RO	1965	47	50	0,11	707,7	702,6	-5,1	0,70	0,35
Gutinas - Brasov	RO	1974	38	41	0,08	707,7	703,7	-4,0	0,49	0,25
Darste - Brazi Vest	RO	1975	37	40	0,07	707,7	703,7	-4,0	0,46	0,23
Gadalin - Rosiori	RO	1963	49	52	0,08	707,7	703,9	-3,8	0,48	0,24
Brasov - Sibiu Sud	RO	1969	43	46	0,08	707,7	704,0	-3,7	0,49	0,25
Mintia - Sibiu	RO	1971	41	44	0,08	707,7	704,0	-3,7	0,50	0,25
Smardan - Gutinas	RO	1969	43	46	0,09	707,7	704,3	-3,4	0,54	0,27
Gura Ialomitei - Lacu Sarat	RO	1966	46	49	0,04	707,7	705,3	-2,4	0,27	0,14
Tantareni - Urechesti	RO	1974	38	41	0,05	707,7	705,3	-2,4	0,28	0,14
Sibiu Sud - Iernut	RO	1966	46	49	0,05	707,7	705,6	-2,1	0,32	0,16
Urechesti - Portile De Fier	RO	1971	41	44	0,05	707,7	705,8	-1,9	0,33	0,17
Iernut - Gadalin	RO	1963	49	52	0,03	707,7	706,2	-1,5	0,20	0,10
Arad - Sandorfalva	RO	1974	38	41	0,04	707,7	706,4	-1,3	0,22	0,11
Urechesti - Urech1G	RO	1960	52	55	0,01	707,7	706,7	-1,0	0,06	0,03
Urechesti - Urech1G	RO	1960	52	55	0,01	707,7	706,7	-1,0	0,06	0,03
Rahman - Dobrudja	RO	1975	37	40	0,06	707,7	707,0	-0,7	0,38	0,19
Kamitabad - Maritsa/bg	TR	1975	37	40	0,52	707,7	707,0	-0,7	27,70	18,70
Mizia - Stolnik	BG	1972	40	43	0,02	707,7	707,3	-0,4	0,50	0,25
Rosiori - Mukacevo	RO	1962	50	53	0,03	707,7	707,4	-0,3	0,16	0,08
Varna - Dobrudja	BG	1970	42	45	0,01	707,7	707,5	-0,2	0,50	0,25

Line 400 kV	Country	Year of construction	Age		Past average unavailability (%)	Probabilistic indices - probability of problems (hours/y)		Difference (hours/year)	Number of outages in 2020	
			2012	2015		before revitalization	after revitalization		before revitalization	after revitalization
Varna - Carevec	BG	1970	42	45	0,00	707,7	707,5	-0,2	0,50	0,25
Carevec - Mizia	BG	1970	42	45	0,00	707,7	707,5	-0,2	0,50	0,25
Metalurgichna - Sofia Zapad	BG	1975	37	40	0,00	707,7	707,6	-0,1	0,50	0,25
Domnesti - Brazi Vest	RO	1975	37	40	0,04	707,7	707,6	-0,1	0,25	0,13
Gura Ialomitei – Cernavoda 1	RO	1975	37	40	0,04	707,7	707,6	-0,1	0,25	0,12
Constanta Nord - Cernavoda	RO	1975	37	40	0,05	707,7	707,6	-0,1	0,28	0,14
Isaccea - Rahman	RO	1975	37	40	0,04	707,7	707,6	-0,1	0,22	0,11
Rahman - Medgidia Sud	RO	1975	37	40	0,05	707,7	707,6	-0,1	0,30	0,15
Beograd 8 - Drmno	SR	1970	42	45	0,00	707,7	707,6	-0,1	1,40	1,00
Đerdap 1 - Drmno	SR	1970	42	45	0,00	707,7	707,6	-0,1	1,40	1,00
Sofia West - Niš 2	SR	1971	41	44	0,00	707,7	707,6	-0,1	2,80	2,00
Portile de Fier - Đerdap 1	SR	1972	40	43	0,01	707,7	707,6	-0,1	5,50	4,10
Niš 2 - Kosovo B	SR/K	1975	37	40	0,00	707,7	707,6	-0,1	1,60	0,90
Lacu Sarat - Smardan	RO	1967	45	48	0,02	707,7	707,7	0,0	0,13	0,07
Portile De Fier - Djerdap	RO	1972	40	43	0,00	707,7	707,7	0,0	0,00	0,00
Bor 2 - Đerdap 1	SR	1971	41	44	0,00	707,7	707,7	0,0	1,40	1,00
Obrenovac - Mladost 1	SR	1975	37	40	0,00	707,7	707,7	0,0	1,30	0,90
Krško-Maribor	SLO	1975	37	40	0,00	707,7	707,7	0,0	0,00	0,00
Podlog-Maribor	SLO	1975	37	40	0,00	707,7	707,7	0,0	0,00	0,00

7 CONCLUSIONS

The region of Southeast Europe has been passing through very intensive political and economic changes in the last 20 years. One aspect of the transition processes is an establishment of common regulatory framework named the Energy Community. Transmission system in the region operates under 400 kV, 220 kV and 110 (150) kV voltage levels. Transmission network is well meshed and support significant market transactions in different directions.

Regional transmission system has been developed after Word War II and there are significant amount of aged equipment. Having in mind expected lifetime of the transmission equipment it is reasonable to assume that all equipment installed in 60's and 70's is approaching the end of its lifetime. It is expected that investments needed for network revitalization may be several times higher than investments needed for the network reinforcements in the mid-term and long-term future.

The main task of this Report was to collect data on the SEE 400 kV transmission network age and availability, and to give basic overview of statistical data in different countries. Furthermore, these data was used for transmission network reliability assessment related to present, short and mid term future network topology (2012, 2015, 2020). Forced outages of 400 kV lines have been taken into observation only, due to many transmission lines and transformers in the region.

Based on questionnaire distributed among SEE TSO’s (including Turkey and Slovenia) and observing average age of network assets (overhead lines and transformers) the worst situation appears in Romania and Bulgaria. In Romania average age of observed network elements exceed 40 years for all three transmission levels. Transmission elements having high average age are in Bosnia and Herzegovina (220 kV, 110 kV elements), Croatia (220 kV, 110 kV), Montenegro (220 kV, 110 kV), Serbia (220 kV, 110 kV) and Slovenia (220 kV, 110 kV) also. Average age of network in Albania, Kosovo, Macedonia and Turkey is significantly below critical value.

Data related to individual 400 kV lines number of forced outages per year and average single duration of forced outages per year were collected from all SEE TSO’s for three-year time period 2008-2010 or 2009-2011.

Average age of all 400 kV lines in the Southest Europe including Slovenia and Turkey is 28 years. Average number of annual forced outages for all 400 kV lines is 3,4 while average duration of a single forced outage is 3,4 hours. This makes SEE transmission system quite reliable at this moment, with average annual unavailability of 400 kV lines due to forced outages of 0,1 % (one 400 kV line will be around ten hours per year out of operation due to forced outages in average). Furthermore, one may conclude that critical contingences which may jeopardize system security or restrict market activities have very low probability. This means that consumers and market players in the SEE region will not suffer often from transmission system restrictions caused by accidental disturbances in the 400 kV transmission network, despite the age of transmission system and its present condition.

Reliability assessment of individual countries in the Southeast Europe transmission grid, as well as regional SEE transmission grid, was performed using PSS/E (version 33) and outage statistic data provided by individual TSO’s. Reliability assessment was performed for existing network configuration (2012), short time frame expected configuration (year 2015) and mid time frame expected configuration (year 2020), during winter high load or peak load conditions. Reliability assessment for all analyzed time frames proves high reliability of SEE transmission system.

Nevertheless, worsening of reliability indices for 2020, comparing them with 2015, is visible and among possible causes ageing of 400 kV lines has strong impact on that. Reliability indices may be worsened in 2015 also, if very robust individual TSOs development plans are not going to be conducted in planned time frame. Such robust transmission development plans by SEE Transmission System Operators could be especially influential observing 2020 reliability indices when many existing 400 kV lines (117 lines 400 kV) will be older than 40 years.

Based on reliability indices critical network areas are detected. In general, critical areas are related to different transformer stations 400/x kV and 220/110 kV, and few 220 kV and 110 kV lines in the region. Network 400 kV is not going to be jeopardized by 400 kV lines forced outages during winter high load or peak load situations for all three analyzed time frames. This proves that regional market transactions will be feasible and not disturbed by network 400 kV limitations.

Since network reinforcements are subject of more detailed analysis which deal with many possible system conditions, reliability analysis conducted in this study were not sufficient to determine necessary transmission network reinforcements, but some suggestions were given:

- network 400 kV in the SEE region shows high level of availability and critical situations which occur as a consequence of 400 kV lines outages have very low probability,
- significant investments in 400 kV network development are not visible since network 400 kV in the SEE region is generally well meshed and highly available,
- construction of new lines 400 kV will be probably motivated by new power plants construction and market transactions in the future,
- motivation for new 400 kV interconnection lines construction should be based primarily on market and economic rationalization.

Suggestions on 400 kV lines revitalization activities which are given in this Report are based on the following criteria:

1. lines 400 kV age with respect to year 2015;
2. lines 400 kV average unavailability in the past;
3. expected improvement of SEE transmission system reliability indices after line revitalization;

Decision about revitalization activities is strongly dependent on different factors, like actual condition of specific line 400 kV, regulatory requests, connection of new power plants and/or substations at this line, fulfillment of technical requests, maintenance and revitalization costs, etc. This means that prioritization lists which are determined according to previously mentioned criteria are only indicative.

In order to keep high level of 400 kV lines availability transmission system operators will have to continuously conduct appropriate maintenance and revitalization activities. It may be expected that older lines 400 kV will be the most important candidates for revitalization activities in the mid and long term future, but significant revitalization activities should be directed in short and mid term future period to the networks 220 kV and 110 kV (150 kV).

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9 APPENDIX

1. Questionnaire responses

2. Average number and duration of 400 kV lines forced outages

3. Prediction of 400 kV lines future unavailability due to forced outages

ALBANIA

QUESTIONNAIRE
SEE Transmission Network Reliability Assessment

This questionnaire was prepared in order to determine the aim and scope of work for new SECI TSP project: "SEE Transmission Network Reliability Assessment". Questionnaire is going to be distributed among SECI TSP members.

1. Does your TSO collect and analyze the data on transmission network reliability?

☒ **Yes**
☐ No

Additional comments:____

____

2. If yes, for how long period of time transmission network reliability data are collected?

☐ Less then last 5 years
☐ 5 - 10 years
☒ **More than 10 years**

Additional comments:____

____

3. Are the network reliability data available?

☐ Yes, to the public
☒ **Yes, for TSO internal analyses**
☐ No, it is treated as commercial secret

Additional comments:____

____

4. What is the level of details of the collected reliability data?

☐ Just on the system level
☐ For each voltage level
☐ For each group of elements (lines, cables, transformers....)
☒ **For each network element**

Additional comments:____

____

5. What kind of element outage data are collected?

☐ Outage frequency
☐ Outage duration
☒ **Outage causes**
☐ Other (please specify):____

Additional comments:____

____

6. Does your country/TSO have legislative framework on power network reliability requirements?

☐ Yes, we have fully defined legislative framework
(specify relevant acts____)
☒ **Yes, we have partly defined legislative framework**
(specify missing acts____)
☐ No

Additional comments:____

____

7. What are the criteria for transmission network reconstruction and revitalization?

☐ Supply interruption
☐ Network element ageing
☒ **Network element reliability**
☐ Present condition of network element
☐ Other (please specify):____
☐ No specific criteria

Additional comments:____

____

8. Dou you take into account network revitalization plan during transmission system planning studies?

☒ **No**
☐ Yes, network planning studies determine revitalization activities also
☐ Yes, but network revitalization activities are not determined by planning studies

Additional comments:____

____

9. Were there any transmission network reliability studies on the country/TSO level?

☒ **Yes (specify:____)**

☐ No, studies were done for specific connection purposes only

☐ No reliability studies so far

Please submit main study conclusions:____

____

10. What are the most specific problems with network reliability in your country?

☐ Network ageing

☒ **Extreme climate conditions**

☐ Lack of maintenance

☐ Lack of regulatory framework

☐ Other (please specify):____

☐ No problems

Additional comments:____

____

11. Do you believe that network age significantly decrease its reliability in your country?

☐ Yes

☒ **No**

☐ Moderate impact

Additional comments:____

____

12. What is the average age of the network elements in your country?

☐ 400 kV lines (____10_____years)

☐ 220 kV lines (____25_____years)

☐ 110 kV lines (____35_____years)

☐ Transformers (___ 15_____years)

Additional comments:____

____

13. If you are able to provide reliability data for lines, transformers and machines, what kind of data you may share?

☐ Generic data
☐ Individual data
☒ **Combination of both**

Additional comments:____

____

14. If you are able to provide reliability data for lines, transformers and machines, for which time period data could be provided?

☒ **Only one year**
☐ Average 3-years data
☐ Average 5-years data
☐ Average 10-years data
☐ Other

Additional comments:____

____

BULGARIA

QUESTIONNAIRE
SEE Transmission Network Reliability Assessment

This questionnaire was prepared in order to determine the aim and scope of work for new SECI TSP project: "SEE Transmission Network Reliability Assessment". Questionnaire is going to be distributed among SECI TSP members.

1. Does your TSO collect and analyze the data on transmission network reliability?

☒ Yes
☐ No

Additional comments:____

____

2. If yes, for how long period of time transmission network reliability data are collected?

☒ Less then last 5 years
☐ 5 - 10 years
☐ More than 10 years

Additional comments:____

____

3. Are the network reliability data available?

☐ Yes, to the public
☒ Yes, for TSO internal analyses
☐ No, it is treated as commercial secret

Additional comments:____

____

4. What is the level of details of the collected reliability data?

☒ Just on the system level
☐ For each voltage level
☐ For each group of elements (lines, cables, transformers....)
☐ For each network element

Additional comments:____

____

5. What kind of element outage data are collected?

☒ Outage frequency
☒ Outage duration
☒ Outage causes
☐ Other (please specify):____

Additional comments:____

____

6. Does your country/TSO have legislative framework on power network reliability requirements?

☒ Yes, we have fully defined legislative framework
(specify relevant acts: Grid code, Regulation for the activity of the operators of the transmission and distribution networks)
☐ Yes, we have partly defined legislative framework
(specify missing acts____)
☐ No

Additional comments:____

____

7. What are the criteria for transmission network reconstruction and revitalization?

☒ Supply interruption
☒ Network element ageing
☒ Network element reliability
☐ Present condition of network element
☐ Other (please specify):____
☐ No specific criteria

Additional comments:____

____

8. Dou you take into account network revitalization plan during transmission system planning studies?

☐ No
☒ Yes, network planning studies determine revitalization activities also
☐ Yes, but network revitalization activities are not determined by planning studies

Additional comments:____

____

9. Were there any transmission network reliability studies on the country/TSO level?

☐ Yes (specify:____)

☒ No, studies were done for specific connection purposes only

☐ No reliability studies so far

Please submit main study conclusions:____

____

10. What are the most specific problems with network reliability in your country?

☒ Network ageing

☐ Extreme climate conditions

☐ Lack of maintenance

☐ Lack of regulatory framework

☐ Other (please specify):____

☐ No problems

Additional comments:____

____

11. Do you believe that network age significantly decrease its reliability in your country?

☐ Yes

☐ No

☒ Moderate impact

Additional comments:____

____

12. What is the average age of the network elements in your country?

☒ 400 kV lines (___35______years)

☒ 220 kV lines (___45______years)

☒ 110 kV lines (___50______years)

☒ Transformers (___35_____years)

Additional comments:____

____

13. If you are able to provide reliability data for lines, transformers and machines, what kind of data you may share?

☐ Generic data
☐ Individual data
☐ Combination of both

Additional comments: Combination of both if it is required by the project.

____

14. If you are able to provide reliability data for lines, transformers and machines, for which time period data could be provided?

☒ Only one year
☐ Average 3-years data
☐ Average 5-years data
☐ Average 10-years data
☐ Other

Additional comments:____

____

BOSNIA AND HERZEGOVINA

QUESTIONNAIRE
SEE Transmission Network Reliability Assessment

This questionnaire was prepared in order to determine the aim and scope of work for new SECI TSP project: "SEE Transmission Network Reliability Assessment". Questionnaire is going to be distributed among SECI TSP members.

1. Does your TSO collect and analyze the data on transmission network reliability?

☒ Yes
☐ No

Additional comments:____

____

2. If yes, for how long period of time transmission network reliability data are collected?

☐ Less then last 5 years
☒ 5 - 10 years
☐ More than 10 years

Additional comments:____

____

3. Are the network reliability data available?

☐ Yes, to the public
☒ Yes, for TSO internal analyses
☐ No, it is treated as commercial secret

Additional comments:____

____

4. What is the level of details of the collected reliability data?

☐ Just on the system level
☐ For each voltage level
☐ For each group of elements (lines, cables, transformers....)
☒ For each network element

Additional comments: 110 kV and higher

____

5. What kind of element outage data are collected?

☐ Outage frequency
☒ Outage duration
☒ Outage causes
☐ Other (please specify):_______________________________________

Additional comments:____

____

6. Does your country/TSO have legislative framework on power network reliability requirements?

☐ Yes, we have fully defined legislative framework
(specify relevant acts____)
☒ Yes, we have partly defined legislative framework (Grid code)
☐ No

Additional comments:____

____

7. What are the criteria for transmission network reconstruction and revitalization?

☒ Supply interruption
☒ Network element ageing
☐ Network element reliability
☒ Present condition of network element
☐ Other (please specify):_______________________________________
☐ No specific criteria

Additional comments:____

____

8. Dou you take into account network revitalization plan during transmission system planning studies?

☐ No
☒ Yes, network planning studies determine revitalization activities also
☐ Yes, but network revitalization activities are not determined by planning studies

Additional comments:____

____

9. Were there any transmission network reliability studies on the country/TSO level?

☐ Yes (specify:____)
☒ No, studies were done for specific connection purposes only
☐ No reliability studies so far

Please submit main study conclusions:______________________________________

____

10. What are the most specific problems with network reliability in your country?

☒ Network ageing
☐ Extreme climate conditions
☐ Lack of maintenance
☐ Lack of regulatory framework
☐ Other (please specify):____
☐ No problems

Additional comments:____

____

11. Do you believe that network age significantly decrease its reliability in your country?

☐ Yes
☐ No
☒ Moderate impact

Additional comments:____

____

12. What is the average age of the network elements in your country?

☒ 400 kV lines (30.4 years)
☒ 220 kV lines (42 years)
☒ 110 kV lines (37.5 years)
☒ Transformers (27.4 years)

Additional comments:____

____

13. If you are able to provide reliability data for lines, transformers and machines, what kind of data you may share?

☐ Generic data
☒ Individual data
☐ Combination of both

Additional comments:____

____

14. If you are able to provide reliability data for lines, transformers and machines, for which time period data could be provided?

☐ Only one year
☐ Average 3-years data
☒ Average 5-years data
☐ Average 10-years data
☐ Other

Additional comments:____

____

CROATIA

QUESTIONNAIRE
SEE Transmission Network Reliability Assessment

This questionnaire was prepared in order to determine the aim and scope of work for new SECI TSP project: "SEE Transmission Network Reliability Assessment". Questionnaire is going to be distributed among SECI TSP members.

1. Does your TSO collect and analyze the data on transmission network reliability?

- [x] Yes
- [ ] No

Additional comments:____

____

2. If yes, for how long period of time transmission network reliability data are collected?

- [ ] Less then last 5 years
- [ ] 5 - 10 years
- [x] More than 10 years

Additional comments:____

____

3. Are the network reliability data available?

- [ ] Yes, to the public
- [x] Yes, for TSO internal analyses
- [ ] No, it is treated as commercial secret

Additional comments:____

____

4. What is the level of details of the collected reliability data?

- [ ] Just on the system level
- [ ] For each voltage level
- [ ] For each group of elements (lines, cables, transformers....)
- [x] For each network element

Additional comments:____

5. What kind of element outage data are collected?

☒ Outage frequency
☒ Outage duration
☒ Outage causes
☐ Other (please specify):____________________

Additional comments:____________________

6. Does your country/TSO have legislative framework on power network reliability requirements?

☒ Yes, we have fully defined legislative framework
(specify relevant acts_ **Grid Code**____________________)
☐ Yes, we have partly defined legislative framework
(specify missing acts____________________)
☐ No

Additional comments:____________________

7. What are the criteria for transmission network reconstruction and revitalization?

☐ Supply interruption
☒ Network element ageing
☐ Network element reliability
☒ Present condition of network element
☐ Other (please specify):____________________
☐ No specific criteria

Additional comments:____________________

8. Dou you take into account network revitalization plan during transmission system planning studies?

☐ No
☒ Yes, network planning studies determine revitalization activities also
☐ Yes, but network revitalization activities are not determined by planning studies

Additional comments:____________________

____

9. Were there any transmission network reliability studies on the country/TSO level?

☐ Yes (specify:____)
☒ No, studies were done for specific connection purposes only
☐ No reliability studies so far

Please submit main study conclusions:_______________________________________

____

10. What are the most specific problems with network reliability in your country?

☒ Network ageing
☐ Extreme climate conditions
☐ Lack of maintenance
☐ Lack of regulatory framework
☐ Other (please specify):____
☐ No problems

Additional comments:____

____

11. Do you believe that network age significantly decrease its reliability in your country?

☐ Yes
☐ No
☒ Moderate impact

Additional comments:____

____

12. What is the average age of the network elements in your country?

☒ 400 kV lines (_____**30**____years)
☒ 220 kV lines (_____**40**____years)
☒ 110 kV lines (_____**40**____years)
☒ Transformers (_____**30**____years)

Additional comments:____

____

13. If you are able to provide reliability data for lines, transformers and machines, what kind of data you may share?

- [ ] Generic data
- [ ] Individual data
- [x] Combination of both

Additional comments:____

____

14. If you are able to provide reliability data for lines, transformers and machines, for which time period data could be provided?

- [ ] Only one year
- [ ] Average 3-years data
- [ ] Average 5-years data
- [x] Average 10-years data
- [ ] Other

Additional comments:____

____

KOSOVO

QUESTIONNAIRE
SEE Transmission Network Reliability Assessment

This questionnaire was prepared in order to determine the aim and scope of work for new SECI TSP project: "SEE Transmission Network Reliability Assessment". Questionnaire is going to be distributed among SECI TSP members.

1. Does your TSO collect and analyze the data on transmission network reliability?

☒ Yes
☐ No

Additional comments:____

____

2. If yes, for how long period of time transmission network reliability data are collected?

☐ Less then last 5 years
☒ 5 - 10 years
☐ More than 10 years

Additional comments: From 2006 after establishment of KOSTT

____

3. Are the network reliability data available?

☐ Yes, to the public
☒ Yes, for TSO internal analyses
☐ No, it is treated as commercial secret

Additional comments: And ERO (Regulatory Office of Energy)

____

4. What is the level of details of the collected reliability data?

☐ Just on the system level
☐ For each voltage level
☒ For each group of elements (lines, cables, transformers....)
☐ For each network element

Additional comments:____

____

5. What kind of element outage data are collected?
☒ Outage frequency
☒ Outage duration
☒ Outage causes
☐ Other (please specify):____

Additional comments:____

____

6. Does your country/TSO have legislative framework on power network reliability requirements?
☐ Yes, we have fully defined legislative framework
(specify relevant acts____)
☒ Yes, we have partly defined legislative framework
(specify missing acts____)
☐ No

Additional comments:____

____

7. What are the criteria for transmission network reconstruction and revitalization?
☐ Supply interruption
☒ Network element ageing
☒ Network element reliability
☒ Present condition of network element
☐ Other (please specify):____
☐ No specific criteria

Additional comments:____

____

8. Dou you take into account network revitalization plan during transmission system planning studies?
☐ No
☒ Yes, network planning studies determine revitalization activities also
☐ Yes, but network revitalization activities are not determined by planning studies

Additional comments:____

____

9. Were there any transmission network reliability studies on the country/TSO level?

☐ Yes (specify:____)
☐ No, studies were done for specific connection purposes only
☒ No reliability studies so far

Please submit main study conclusions:____

____

10. What are the most specific problems with network reliability in your country?

☒ Network ageing
☐ Extreme climate conditions
☐ Lack of maintenance
☐ Lack of regulatory framework
☐ Other (please specify):____
☐ No problems

Additional comments:____

____

11. Do you believe that network age significantly decrease its reliability in your country?

☒ Yes
☐ No
☐ Moderate impact

Additional comments:____

____

12. What is the average age of the network elements in your country?

☐ 400 kV lines (____31_____years)
☐ 220 kV lines (____33_____years)
☐ 110 kV lines (____37_____years)
☐ Transformers (___18______years)

Additional comments:______ Three 220kV lines are older then 50Years, 8 110kV line are older then 52 Years

____

13. If you are able to provide reliability data for lines, transformers and machines, what kind of data you may share?

☒ Generic data
☐ Individual data
☐ Combination of both

Additional comments:____

____

14. If you are able to provide reliability data for lines, transformers and machines, for which time period data could be provided?

☐ Only one year
☒ Average 3-years data
☐ Average 5-years data
☐ Average 10-years data
☐ Other

Additional comments:____

____

MACEDONIA

QUESTIONNAIRE
SEE Transmission Network Reliability Assessment

This questionnaire was prepared in order to determine the aim and scope of work for new SECI TSP project: "SEE Transmission Network Reliability Assessment". Questionnaire is going to be distributed among SECI TSP members.

1. Does your TSO collect and analyze the data on transmission network reliability?

☒ Yes
☐ No

Additional comments:____

____

2. If yes, for how long period of time transmission network reliability data are collected?

☐ Less then last 5 years
☒ 5 - 10 years
☐ More than 10 years

Additional comments:____

____

3. Are the network reliability data available?

☐ Yes, to the public
☒ Yes, for TSO internal analyses
☐ No, it is treated as commercial secret

Additional comments:____

____

4. What is the level of details of the collected reliability data?

☐ Just on the system level
☐ For each voltage level
☐ For each group of elements (lines, cables, transformers....)
☒ For each network element

Additional comments: Data in raw format should be statistically analyzed.

____

5. What kind of element outage data are collected?
☐ Outage frequency
☒ Outage duration
☒ Outage causes
☐ Other (please specify):_______________________________________

Additional comments: Outages are recorded on chronological order during the year.

____

6. Does your country/TSO have legislative framework on power network reliability requirements?
☐ Yes, we have fully defined legislative framework
(specify relevant acts____)
☐ Yes, we have partly defined legislative framework
(specify missing acts____)
☒ No

Additional comments:____

____

7. What are the criteria for transmission network reconstruction and revitalization?
☒ Supply interruption
☒ Network element ageing
☐ Network element reliability
☒ Present condition of network element
☐ Other (please specify):_______________________________________
☐ No specific criteria

Additional comments:____

____

8. Dou you take into account network revitalization plan during transmission system planning studies?
☐ No
☐ Yes, network planning studies determine revitalization activities also
☒ Yes, but network revitalization activities are not determined by planning studies

Additional comments: Revitalization activities are input in planning process. They are checked and confirm only in references to adequacy of cross section.

9. Were there any transmission network reliability studies on the country/TSO level?

☐ Yes (specify:____________________)
☐ No, studies were done for specific connection purposes only
☒ No reliability studies so far

Please submit main study conclusions:____________________

10. What are the most specific problems with network reliability in your country?

☒ Network ageing
☒ Extreme climate conditions
☐ Lack of maintenance
☐ Lack of regulatory framework
☐ Other (please specify):____________________
☐ No problems

Additional comments: Climate conditions are outside of EU average conditions for design and operation of equipment.

11. Do you believe that network age significantly decrease its reliability in your country?

☐ Yes
☐ No
☒ Moderate impact

Additional comments:____________________

12. What is the average age of the network elements in your country?

☒ 400 kV lines (22 years)
☐ 220 kV lines (__________years)
☒ 110 kV lines (35.5 years)
☒ Transformers (23.9 years)

Additional comments: Transformers 400/110 kV

13. If you are able to provide reliability data for lines, transformers and machines, what kind of data you may share?

☐ Generic data
☐ Individual data
☒ Combination of both

Additional comments:

14. If you are able to provide reliability data for lines, transformers and machines, for which time period data could be provided?

☐ Only one year
☐ Average 3-years data
☒ Average 5-years data
☐ Average 10-years data
☐ Other

Additional comments:

MONTENEGRO

QUESTIONNAIRE
SEE Transmission Network Reliability Assessment

This questionnaire was prepared in order to determine the aim and scope of work for new SECI TSP project: "SEE Transmission Network Reliability Assessment". Questionnaire is going to be distributed among SECI TSP members.

1. Does your TSO collect and analyze the data on transmission network reliability?

■ Yes
☐ No

Additional comments:____

____

2. If yes, for how long period of time transmission network reliability data are collected?

☐ Less then last 5 years
☐ 5 - 10 years
■ More than 10 years

Additional comments:____

____

3. Are the network reliability data available?

☐ Yes, to the public
■ Yes, for TSO internal analyses
☐ No, it is treated as commercial secret

Additional comments:____

____

4. What is the level of details of the collected reliability data?

☐ Just on the system level
☐ For each voltage level
☐ For each group of elements (lines, cables, transformers....)
■ For each network element

Additional comments: no data is recorded on system level

____

5. What kind of element outage data are collected?

■ Outage frequency
■ Outage duration
■ Outage causes
☐ Other (please specify):____

Additional comments:____

____

6. Does your country/TSO have legislative framework on power network reliability requirements?

☐ Yes, we have fully defined legislative framework
(specify relevant acts____)
☐ Yes, we have partly defined legislative framework
(specify missing acts____)
■ No

Additional comments:____

____

7. What are the criteria for transmission network reconstruction and revitalization?

■ Supply interruption
■ Network element ageing
☐ Network element reliability
■ Present condition of network element
☐ Other (please specify):____
☐ No specific criteria

Additional comments: combination of three marked criterions___________________________

____

8. Dou you take into account network revitalization plan during transmission system planning studies?

☐ No
■ Yes, network planning studies determine revitalization activities also
☐ Yes, but network revitalization activities are not determined by planning studies

Additional comments:____

____

9. Were there any transmission network reliability studies on the country/TSO level?

■ Yes (specify: " POUZDANOST PRENOSNE MREŽE CRNE GORE", 2010)
☐ No, studies were done for specific connection purposes only
☐ No reliability studies so far

Please submit main study conclusions: In comparison to other systems typical vales, statistical data and parameters that describe reliability of the systems are up to 10times higher, for following reasons:
1. High level of atmospheric discharges as most frequent cause of line tripping (more than in other systems)
2. Average age of equipment in Montenegro is high and as consequence lower reliability
3. Transmission system of Montenegro is relatively small and parameters of one element have large influence on average and system values

10. What are the most specific problems with network reliability in your country?

■ Network ageing
■ Extreme climate conditions
☐ Lack of maintenance
☐ Lack of regulatory framework
☐ Other (please specify):____
☐ No problems

Additional comments:____

____

11. Do you believe that network age significantly decrease its reliability in your country?

☐ Yes
☐ No
■ Moderate impact

Additional comments: Depends on maintenance level

____

12. What is the average age of the network elements in your country?

☐ 400 kV lines (30 years)
☐ 220 kV lines (33 years)
☐ 110 kV lines (33 years)
☐ Transformers (24 years)

Additional comments:____

____

13. If you are able to provide reliability data for lines, transformers and machines, what kind of data you may share?

☐ Generic data
■ Individual data
☐ Combination of both

Additional comments:____

____

14. If you are able to provide reliability data for lines, transformers and machines, for which time period data could be provided?

☐ Only one year
☐ Average 3-years data
■ Average 5-years data
☐ Average 10-years data
☐ Other

Additional comments:____

____

ROMANIA

QUESTIONNAIRE
SEE Transmission Network Reliability Assessment

This questionnaire was prepared in order to determine the aim and scope of work for new SECI TSP project: "SEE Transmission Network Reliability Assessment". Questionnaire is going to be distributed among SECI TSP members.

1. Does your TSO collect and analyze the data on transmission network reliability?

☒ Yes
☐ No

Additional comments: ***Data is collected but it has to be processed in order to update lamda and miu according to the real behavior of the equipment. Reliability indices are calculated based on the specific normative.***

2. If yes, for how long period of time transmission network reliability data are collected?

☐ Less then last 5 years
☐ 5 - 10 years
☒ More than 10 years

Additional comments:____

____

3. Are the network reliability data available?

☐ Yes, to the public
☒ Yes, for TSO internal analyses
☐ No, it is treated as commercial secret

Additional comments: ***Processed data for each category of equipment for each voltage level is available for the public also***

4. What is the level of details of the collected reliability data?

☐ Just on the system level
☒ For each voltage level
☒ For each group of elements (lines, cables, transformers....)
☐ For each network element

Additional comments:____

____

5. What kind of element outage data are collected?

☒ Outage frequency
☒ Outage duration
☒ Outage causes
☐ Other (please specify):____

Additional comments:____

____

6. Does your country/TSO have legislative framework on power network reliability requirements?

☒ Yes, we have fully defined legislative framework
(specify relevant acts ***NTE 005 PE013/2005***)
☐ Yes, we have partly defined legislative framework
(specify missing acts____)
☐ No

Additional comments:____

____

7. What are the criteria for transmission network reconstruction and revitalization?

☐ Supply interruption
☒ Network element ageing
☒ Network element reliability
☒ Present condition of network element
☒ Other (please specify): Importance of the network element
☐ No specific criteria

Additional comments:____

____

8. Dou you take into account network revitalization plan during transmission system planning studies?

☐ No
☒ Yes, network planning studies determine revitalization activities also
☐ Yes, but network revitalization activities are not determined by planning studies

Additional comments:____

____

9. Were there any transmission network reliability studies on the country/TSO level?
☒ Yes (specify: ***Each two years - Study for calculation of reliability indices for network developing plan – NDP (the results of the study are included in the NDP) and commercial relations, done by TSO's consultant chosen by bidding process***)
☐ No, studies were done for specific connection purposes only
☐ No reliability studies so far

Please submit main study conclusions:

The maximum outage duration was calculated with 5% and 10% probabilities.

Rehabilitation of substations and lines, according to TSO rehabilitation plan, lead to better reliability indices.

For 2021 time horizon, for the most of the nodes, the number of maximum outages is 1/year, the maximum outage duration is less than 15 hours. Worse indices were obtained for: radial substations, substations with simple sectioned or no-sectioned bus bar or old substations.

10. What are the most specific problems with network reliability in your country?
☒ Network ageing
☐ Extreme climate conditions
☐ Lack of maintenance
☐ Lack of regulatory framework
☐ Other (please specify):____
☐ No problems

Additional comments:____

____

11. Do you believe that network age significantly decrease its reliability in your country?
☒ Yes
☐ No
☐ Moderate impact

Additional comments:____

____

12. What is the average age of the network elements in your country?

☐ 400 kV lines **(about 45 years)**
☐ 220 kV lines **(about 45 years)**
☐ 110 kV lines **(more than 50 years, they belong to DSOs)**
☐ Transformers **(about 40-45 years, BUT many of them were replaced or they will be replaced in the near future)**

Additional comments:____

____

13. If you are able to provide reliability data for lines, transformers and machines, what kind of data you may share?

☒ Generic data
☐ Individual data
☐ Combination of both

Additional comments: no available data for machines

14. If you are able to provide reliability data for lines, transformers and machines, for which time period data could be provided?

☐ Only one year
☐ Average 3-years data
☐ Average 5-years data
☒ Average 10-years data
☐ Other

Additional comments:____

____

SERBIA

QUESTIONNAIRE
SEE Transmission Network Reliability Assessment

This questionnaire was prepared in order to determine the aim and scope of work for new SECI TSP project: "SEE Transmission Network Reliability Assessment". Questionnaire is going to be distributed among SECI TSP members.

1. Does your TSO collect and analyze the data on transmission network reliability?

■ Yes
☐ No

Additional comments:____

____

2. If yes, for how long period of time transmission network reliability data are collected?

☐ Less then last 5 years
☐ 5 - 10 years
■ More than 10 years

Additional comments:____

____

3. Are the network reliability data available?

☐ Yes, to the public
■ Yes, for TSO internal analyses
☐ No, it is treated as commercial secret

Additional comments:____

____

4. What is the level of details of the collected reliability data?

☐ Just on the system level
☐ For each voltage level
☐ For each group of elements (lines, cables, transformers....)
■ For each network element

Additional comments:____

5. What kind of element outage data are collected?

■ Outage frequency
■ Outage duration
■ Outage causes
☐ Other (please specify):____________________

Additional comments:____________________

6. Does your country/TSO have legislative framework on power network reliability requirements?

■ Yes, we have fully defined legislative framework
(specify relevant acts_ **Grid Code**____________________)
☐ Yes, we have partly defined legislative framework
(specify missing acts____________________)
☐ No

Additional comments:____________________

7. What are the criteria for transmission network reconstruction and revitalization?

☐ Supply interruption
■ Network element ageing
☐ Network element reliability
■ Present condition of network element
☐ Other (please specify):____________________
☐ No specific criteria

Additional comments:____________________

8. Dou you take into account network revitalization plan during transmission system planning studies?

☐ No
■ Yes, network planning studies determine revitalization activities also
☐ Yes, but network revitalization activities are not determined by planning studies

Additional comments:____________________

____

9. Were there any transmission network reliability studies on the country/TSO level?

- [ ] Yes (specify:____)
- [x] No, studies were done for specific connection purposes only
- [ ] No reliability studies so far

Please submit main study conclusions:____

____

10. What are the most specific problems with network reliability in your country?

- [x] Network ageing
- [ ] Extreme climate conditions
- [ ] Lack of maintenance
- [ ] Lack of regulatory framework
- [ ] Other (please specify):____
- [ ] No problems

Additional comments:____

____

11. Do you believe that network age significantly decrease its reliability in your country?

- [ ] Yes
- [ ] No
- [x] Moderate impact

Additional comments:____

____

12. What is the average age of the network elements in your country?

- [x] 400 kV lines (_____**30**____years)
- [x] 220 kV lines (_____**40**____years)
- [x] 110 kV lines (_____**40**____years)
- [x] Transformers (_____**30**____years)

Additional comments:____

____

13. If you are able to provide reliability data for lines, transformers and machines, what kind of data you may share?

☐ Generic data
☐ Individual data
■ Combination of both

Additional comments:____

____

14. If you are able to provide reliability data for lines, transformers and machines, for which time period data could be provided?

☐ Only one year
☐ Average 3-years data
☐ Average 5-years data
■ Average 10-years data
☐ Other

Additional comments:____

____

SLOVENIA

QUESTIONNAIRE
SEE Transmission Network Reliability Assessment

This questionnaire was prepared in order to determine the aim and scope of work for new SECI TSP project: "SEE Transmission Network Reliability Assessment". Questionnaire is going to be distributed among SECI TSP members.

1. Does your TSO collect and analyze the data on transmission network reliability?

☒ Yes
☐ No

Additional comments:____

____

2. If yes, for how long period of time transmission network reliability data are collected?

☐ Less then last 5 years
☐ 5 - 10 years
☒ More than 10 years

Additional comments:____

____

3. Are the network reliability data available?

☒ Yes, to the public
☐ Yes, for TSO internal analyses
☐ No, it is treated as commercial secret

Additional comments: On our web side weekly, monthly and yearly reports of occurrences on transmission system can be found.

4. What is the level of details of the collected reliability data?

☐ Just on the system level
☐ For each voltage level
☒ For each group of elements (lines, cables, transformers....)
☒ For each network element

Additional comments: Transmission network in Slovenia is consisting of 400, 220 and 110 kV voltage levels.

5. What kind of element outage data are collected?

☒ Outage frequency
☒ Outage duration
☒ Outage causes
☐ Other (please specify):____

Additional comments:____

____

6. Does your country/TSO have legislative framework on power network reliability requirements?

☒ Yes, we have fully defined legislative framework
(specify relevant acts: Grid Code, General conditions/requirements of supply and consumption of electricity)
☐ Yes, we have partly defined legislative framework
(specify missing acts____)
☐ No

Additional comments: Documents are not translated in English language.

7. What are the criteria for transmission network reconstruction and revitalization?

☒ Supply interruption
☒ Network element ageing
☒ Network element reliability
☒ Present condition of network element
☒ Other (please specify): increase security of supply
☐ No specific criteria

Additional comments: The purpose of analysing the transmission network in the phase of planning the transmission network development is, on the basis of the condition and age of the network, forecasted generation, demand, transits of power flows and requirements of the common electricity market, detection of the possible overloads or congestions in the network, for which an optimal solution is determined in line with the planning criteria of the transmission network planning.

8. Do you take into account network revitalization plan during transmission system planning studies?

☐ No
☒ Yes, network planning studies determine revitalization activities also
☐ Yes, but network revitalization activities are not determined by planning studies

Additional comments:____

____

9. Were there any transmission network reliability studies on the country/TSO level?
☒ Yes (specify: every study includes reliability in connection with N-1 criterion)
☐ No, studies were done for specific connection purposes only
☐ No reliability studies so far

Please submit main study conclusions:___________________________________

____

10. What are the most specific problems with network reliability in your country?
☐ Network ageing
☐ Extreme climate conditions
☐ Lack of maintenance
☒ Lack of regulatory framework
☒ Other (please specify): complex legislations which require numbers of revisions, allowances, permits and approvals
☐ No problems

Additional comments:____

____

11. Do you believe that network age significantly decrease its reliability in your country?
☒ Yes
☐ No
☐ Moderate impact

Additional comments: Age in general decreases reliability of the grid, however, through proper maintenance works this can be avoided (as in Slovenia).

12. What is the average age of the network elements in your country?
☐ 400 kV lines (29,9 years)
☐ 220 kV lines (40,8 years)
☐ 110 kV lines (36,4 years)
☐ Transformers (33,7 years)

Additional comments:____

____

13. If you are able to provide reliability data for lines, transformers and machines, what kind of data you may share?

Generic data
☒ Individual data
☐ Combination of both

Additional comments: We cannot provide data which are not public available especially for generators

14. If you are able to provide reliability data for lines, transformers and machines, for which time period data could be provided?
☐ Only one year
☐ Average 3-years data
☐ Average 5-years data
☒ Average 10-years data
☐ Other

Additional comments:

Turkey

QUESTIONNAIRE
SEE Transmission Network Reliability Assessment

This questionnaire was prepared in order to determine the aim and scope of work for new SECI TSP project: "SEE Transmission Network Reliability Assessment". Questionnaire is going to be distributed among SECI TSP members.

1. Does your TSO collect and analyze the data on transmission network reliability?

☒ Yes
☐ No

Additional comments:____

____

2. If yes, for how long period of time transmission network reliability data are collected?

☐ Less then last 5 years
☐ 5 - 10 years
☒ More than 10 years

Additional comments:____

____

3. Are the network reliability data available?

☐ Yes, to the public
☒ Yes, for TSO internal analyses
☐ No, it is treated as commercial secret

Additional comments:____

____

4. What is the level of details of the collected reliability data?

☐ Just on the system level
☐ For each voltage level
☒ For each group of elements (lines, cables, transformers....)
☐ For each network element

Additional comments:____

____

5. What kind of element outage data are collected?

☒ Outage frequency
☒ Outage duration
☒ Outage causes
☐ Other (please specify):____

Additional comments:____

____

6. Does your country/TSO have legislative framework on power network reliability requirements?

☐ Yes, we have fully defined legislative framework
(specify relevant acts____)
☐ Yes, we have partly defined legislative framework
(specify missing acts____)
☒ No

Additional comments:____

____

7. What are the criteria for transmission network reconstruction and revitalization?

☒ Supply interruption
☒ Network element ageing
☐ Network element reliability
☒ Present condition of network element
☐ Other (please specify):____
☐ No specific criteria

Additional comments:____

____

8. Dou you take into account network revitalization plan during transmission system planning studies?

☐ No
☒ Yes, network planning studies determine revitalization activities also
☐ Yes, but network revitalization activities are not determined by planning studies

Additional comments:____

____

9. Were there any transmission network reliability studies on the country/TSO level?

☐ Yes (specify:____)
☒ No, studies were done for specific connection purposes only
☐ No reliability studies so far

Please submit main study conclusions:____

____

10. What are the most specific problems with network reliability in your country?

☒ Network ageing
☒ Extreme climate conditions
☐ Lack of maintenance
☐ Lack of regulatory framework
☐ Other (please specify):____
☐ No problems

Additional comments:____

____

11. Do you believe that network age significantly decrease its reliability in your country?

☐ Yes
☒ No
☐ Moderate impact

Additional comments:____

____

12. What is the average age of the network elements in your country?

☒ 400 kV lines (_____22____years)
☒ 220-154 kV lines (_____26____years)
☐ 110 kV lines (____-_____years)
☐ Transformers (____-_____years)

Additional comments:____

____

13. If you are able to provide reliability data for lines, transformers and machines, what kind of data you may share?

☐ Generic data
☐ Individual data
☒ Combination of both

Additional comments:____

____

14. If you are able to provide reliability data for lines, transformers and machines, for which time period data could be provided?

☐ Only one year
☐ Average 3-years data
☒ Average 5-years data
☐ Average 10-years data
☐ Other

Additional comments:____

____

Average number and duration of 400 kV (220 kV) lines forced outages

Albania

Line 400 kV	Circuit	F (pu) number of forced outages	D (hours) average duration of single outage	Year of construction	Age
Zemblak - Kardia	1	3,0	4,2	1984	28
Elbasan2 - Zemblak	1	5,0	0,8	1984	28
Line 220 kV	**Circuit**	**F (pu) number of forced outages**	**D (hours) average duration of single outage**	**Year of construction**	**Age**
Fierze - Prizren	1	14,0	1,9	1981	31
Fierze - Koman	1	10,0	2,0	1976	36
Fierze - Burrel	1	5,7	2,0	1978	34
Fierze - Titan	1	6,7	2,1	1978	34
Koman - V.Deja	1	4,0	5,5	1976	36
Koman - Tirana2	1	7,0	1,9	1986	26
Koman - Kolacem	1	1,7	1,9	1986	26
V.Deja (Koplik in 2010) - Podgorica	1	11,0	0,4	1972	40
V.Deja – Tirana	1	6,7	3,9	1971	41
	2	4,7	2,8	1971	41
V.Deja - Koplik	1	3,0	0,0	1972	40
Burrel - Elbasan1	1	10,3	4,3	1978	34
Tirana1 - Elbasan	1	7,0	2,8	1971	41
	2	5,7	2,6	1971	41
Tirana1 - Tirana2	1	3,0	1,6	1984	28
Tirana1 - Titan	1	5,7	2,1	1978	34
Elbasan1 - Elbasan2	1	3,7	1,7	1983	29
	2	1,3	0,0	2002	10
Elbasan1 - Fier	1	7,7	1,9	1973	39
Elbasan2 - Tirana2	1	6,3	1,9	1986	26
	2	2,3	1,9	1986	26
Fier - Rrashbull	1	12,0	0,4	1987	25
Fier - Babice	1	3,0	1,2	2006	6
Tirana2 - Rrashbull	1	4,0	1,6	1984	28
Tirana2 - Kolacem	1	2,0	1,9	1986	26
Babice - Vlore	1			2009	3

Bosnia and Herzegovina

Line	Circuit	F (pu) number of forced outages	D (hours) average duration of single outage	Year of construction	Age
Ugljevik - Ernestinovo	1	10	4,14	1976	36
Ugljevik - S.Mitrovica	1	15	0,55	2006	6
Ugljevik - Tuzla	1	5	4,02	1976	36
Tuzla - Banja Luka	1	20	1,35	1980	32
Tuzla - Sarajevo	1	6	2,01	1977	35
Sarajevo - Mostar	1	7	0,44	1979	33
Mostar - Konjsko	1	14	1,12	1976	36
Mostar - Gacko	1	5	2,57	1977	35
Gacko - Trebinje	1	29	1,36	1983	29
Trebinje - Podgorica	1	18	0,26	1983	29

Bulgaria

Line	Circuit	F (pu) number of forced outages	D (hours) average duration of single outage	Year of construction	Age
NPP Kozlodui - Sofia Zapad	1	2,5	12,8	1981	31
NPP Kozlodui - Sofia Zapad	2	0,5	2,2	1986	26
NPP Kozlodui - Sofia Zapad	3	1,0	2,3	1986	26
NPP Kozlodui - Mizia	1	0,5	0,3	1989	23
NPP Kozlodui - Mizia	2	0,0	0,0	1979	33
NPP Kozlodui - Mizia	3	0,5	1,2	1989	23
Sofia Zapad - Chervena Mogila	1	0,5	0,4	1986	26
Sofia Zapad - Chervena Mogila	2	0,0	0,0	1986	26
Chervena Mogila - Blagoevgrad	1	1,0	1,4	1986	26
Chervena Mogila - Blagoevgrad	2	0,0	0,0	1987	25
Chervena Mogila - Vetren	1	0,0	0,0	1990	22
Vetren - Plovdiv	1	0,5	1,3	1984	28
Plovdiv -MI1	1	0	0,0	1984	28
MI1 - MI3	1	0	0,0	1984	28
MI3 - MI2	1	0	0,0	1984	28
MI2 - Burgas	1	0,5	1,4	1984	28
Burgas - Varna	1	0,5	0,4	1978	34
Varna - Dobrudja	1	0,5	2,2	1970	42
Varna - Carevec	1	0,5	4,3	1970	42
Carevec - Mizia	1	0,5	3,2	1970	42
Mizia - Stolnik	1	0,5	1,0	1972	40
Stolnik - Metalurgichna	1	0	0,0	1989	23
Stolnik - Zlatica	1	0	0,0	1992	20
Zlatica - Plovdiv	1	1,5	15,7	2010	2
Metalurgichna - Sofia Zapad	1	0,5	1,4	1975	37
NPP Kozlodui - Tintareni	1	0,5	0,3	1986	26
NPP Kozlodui - Tintareni	2	0	0,0	1986	26
MI3 - Hamitabat	1	0,5	0,5	1984	28
MI3 - Hamitabat	2	0	0,0	1998	14

Line	Circuit	F (pu) number of forced outages	D (hours) average duration of single outage	Year of construction	Age
Blagoevgrad - Tessaloniki	1	0,5	0,4	1987	25
Chervena Mogila - Shtip	1	0	0,0	2009	3
Sofia Zapad - Nish	1	0	0,0	1982	30
Varna - Isaccea	1	0	0,0	1992	20
Dobrudja - Rahman	1	0	0,0	1980	32

Croatia

Line	Circuit	F (pu) number of forced outages	D (hours) average duration of single outage	Year of construction	Age
Ernestinovo - Pecs	1	-	-	2010	2
	2	-	-		
Ernestinovo - Ugljevik	1	2,3	1,9	1977	35
Ernestinovo - S.Mitrovica	1	0,0	0,0	1977	35
Ernestinovo - Žerjavinec	1	0,7	0,7	1977	35
Žerjavinec - Heviz	1	0,0	0,0	1999	13
	2	0,3	4,6		
Tumbri - Žerjavinec	1	0,0	0,0	1978	34
Tumbri - Krško	1	0,0	0,0	1978	34
	2	0,0	0,0		
Melina - Tumbri	1	0,7	1,0	1992	20
Melina - Obrovac (Velebit)	1	4,7	19,5	1979	33
Melina - Divača	1	1,3	0,5	1979	33
Konjsko - Obrovac (Velebit)	1	3,3	2,8	1975	37
Konjsko - Mostar	1	2,7	1,4	1976	36

Kosovo

Line	Circuit	F (pu) number of forced outages	D (hours) average duration of single outage	Year of construction	Age
Nish - Kosovo B	1	0,50	0,43	1977	35
Skopje 5 - Ferizaj 2 "(Uros.2)"	1	0,75	0,4	1978	34
Kosovo B - Ferizaj 2 "(Uros.2)"	1	0,00	0,0	1978	34
Kosova B - Peja 3	1	0,50	0,2	1983	29
Ribarevina - Peja 3	1	5,00	10,2	1983	29

Macedonia

Line	Circuit	F (pu) number of forced outages	D (hours) average duration of single outage	Year of construction	Age
Skopje 5 - Kosovo B (KS)	1	1,33	0,66	1978	34
Skopje 5 - Skopje 4	1	0,33	0,17	1978	34
Skopje 4 - Bitola 2	1	0,83	0,29	1996	16
Skopje 4 - Dubrovo	1	0,50	0,05	1978	34
Dubrovo - Stip	1	0,33	0,13	2002	10
Stip - Chervena Mogila (BG)	1	0,33	0,11	2009	3
Dubrovo - Bitola 2	1	0,67	0,72	1982	30
Bitola 2 - Florina (GR)	1	0,60	0,09	2007	5
Dubrovo - Thessaloniki (GR)	1	1,50	2,24	1978	34

Montenegro

Line	Circuit	F (pu) number of forced outages	D (hours) average duration of single outage	Year of construction	Age
Ribarevine – Kosovo					
Ribarevine – Pljevlja					
Ribarevine – Podgorica 2					
Podgorica 2 – Trebinje					
Podgorica 2 – Tirana					

Romania

Line	Circuit	F (pu) number of forced outages	D (hours) average duration of single outage	Year of construction	Age
Rahman - Dobrudja	1	0,377	14	1975	37
Tantareni - Kozloduy 1	1	0,398	14	1985	27
Tantareni - Kozloduy 2	2	0,398	14	1985	27
Arad - Sandorfalva	1	0,215	14	1974	38
Rosiori - Mukacevo	1	0,156	14	1962	50
Portile De Fier - Djerdap	1	0,002	14	1972	40
Nadab - Bekescsaba	1	0,082	14	2008	4
Tantareni - Urechesti	1	0,276	14	1974	38
Tantareni - Slatina	1	0,346	14	1978	34
Tantareni - Bradu	1	0,776	14	1974	38
Tantareni - Sibiu	1	1,040	14	1966	46
Tantareni - Turc 1G	1	0,039	14	1978	34
Tantareni - Turc 1G	2	0,039	14	1981	31
Urechesti - Portile De Fier	1	0,334	14	1971	41
Urechesti - Domnesti	1	1,039	14	1970	42
Urechesti - Urech1G	1	0,059	14	1960	52
Urechesti - Urech1G	2	0,059	14	1960	52
Mintia - Arad	1	0,543	14	1978	34
Mintia - Sibiu	1	0,504	14	1971	41
Portile De Fier - Slatina	1	0,674	14	1970	42
Portile De Fier - Resita	1	0,459	14	-	-
Slatina - Draganesti	1	0,136	14	2000	12
Slatina - Bucuresti Sud	1	0,699	14	1965	47
Arad - Nadab	1	0,134	14	2008	4
Nadab - Oradea Sud	1	0,296	14	2008	4
Domnesti - Bucuresti Sud	1	0,135	14	2002	10
Domnesti - Brazi Vest	1	0,253	14	1975	37
Bucuresti Sud - Pelicanu	1	0,470	14	2000	12
Bucuresti Sud - Gura Ialomitei	1	0,550	14	2002	10
Suceava - Roman Nord	1	0,392	14	1981	31

Line	Circuit	F (pu) number of forced outages	D (hours) average duration of single outage	Year of construction	Age
Pelicanu - Cernavoda	1	0,375	14	2000	12
Gura Ialomitei - Lacu Sarat	1	0,273	14	1966	46
Gura Ialomitei - Cernavoda 1	1	0,248	14	1975	37
Gura Ialomitei - Cernavoda 2	2	0,263	14	1999	13
Constanta Nord - Tulcea Vest	1	0,195	14	1985	27
Constanta Nord - Cernavoda	1	0,276	14	1975	37
Tulcea Vest - Isaccea	1	0,127	14	1976	36
Tulcea Vest - Tariverde	1	0,295	14	1985	27
Isaccea - Lacu Sarat	1	0,259	14	1976	36
Isaccea - Smardan 1	1	0,225	14	1987	25
Isaccea - Smardan 2	2	0,224	14	1987	25
Isaccea - Rahman	1	0,217	14	1975	37
Lacu Sarat - Smardan	1	0,133	14	1967	45
Smardan - Gutinas	1	0,537	14	1969	43
Gutinas - Bacau Sud	1	0,218	14	1980	32
Gutinas - Brasov	1	0,491	14	1974	38
Bacau Sud - Roman Nord	1	0,232	14	1980	32
Rahman - Medgidia Sud	1	0,296	14	1975	37
Brasov - Darste	1	0,052	14	1977	35
Brasov - Bradu	1	0,594	14	1980	32
Brasov - Sibiu Sud	1	0,494	14	1969	43
Darste - Brazi Vest	1	0,459	14	1975	37
Sibiu Sud - Iernut	1	0,322	14	1966	46
Iernut - Gadalin	1	0,200	14	1963	49
Gadalin - Cluj Est	1	0,079	14	1983	29
Gadalin - Rosiori	1	0,482	14	1963	49
Rosiori - Oradea Sud	1	0,523	14	1977	35
Cernavoda - Medgidia Sud	1	0,083	14	1986	26

Serbia

Line	Circuit	F (pu) number of forced outages	D (hours) average duration of single outage	Year of construction	Age
Beograd 8 - Drmno	1	0,25	0,07	1970	42
Đerdap 1 - Drmno	1	0,25	0,06	1970	42
Bor 2 - Đerdap 1	1	0,25	0,03	1971	41
Bor 2 - Niš 2	1	0,00	0,00	1973	39
Sofia West - Niš 2	1	0,75	0,10	1971	41
Portile de Fier - Đerdap 1	1	1,00	0,63	1972	40
Novi Sad 3 - Mladost 1	1	0,25	0,09	1975	37
Novi Sad 3 - Mladost 2	2	1,50	3,33	1974	38
Obrenovac - Mladost 1	1	0,25	0,05	1975	37
Obrenovac - Mladost 2	2	0,75	0,34	1979	33
Niš 2 - Kosovo B	1	0,75	0,10	1975	37
Mladost - Sremska Mitrovica 2	1	1,50	0,28	1977	35
Ernestinovo - Sremska Mitrovica 2	1	1,50	41,23	1977	35
Ugljevik Sremska Mitrovica 2	1	6,25	0,71	2005	7
Beograd 8 - Obrenovac	1	0,50	0,38	1976	36
Kosovo B - Urosevac 2	1	0,50	1,13	1977	35
Skoplje 5 - Uroševac 2	1	0,75	1,13	1977	35
Kragujevac 2 - Jagodina 4	1	0,25	0,08	1976	36
Niš 2 - Jagodina 4	1	0,00	0,00	1976	36
Obrenovac - TENT A G5	1	1,25	0,55	1979	33
Obrenovac - TENT A G6	1	0,75	2,61	1979	33
Obrenovac - Kragujevac 2	1	0,75	0,19	1978	34
Kosovo B - Peć 3	1	1,73	1,86	1977	35
Ribarevina - Peć 3	1	3,27	1,86	1977	35
Novi Sad 3 - Subotica 3	1	1,25	1,05	1979	33
Mladost - TENT B G1	1	0,50	2,74	1983	29
Mladost - TENT B G2	1	0,50	0,24	1983	29
Beograd 8 - Pančevo 2	1	0,00	0,00	1984	28
Pančevo 2 - Drmno	1	1,50	1,97	1987	25
Šandorfalva - Subotica 3	1	0,75	0,20	1988	24

Line	Circuit	F (pu) number of forced outages	D (hours) average duration of single outage	Year of construction	Age
Subotica 3 - Sombor 3	1	0,50	0,14	2006	6
Niš 2 - Leskovac 2	1	0,25	0,10	2009	3

Slovenia

Line	Circuit	F (pu) number of forced outages	D (hours) average duration of single outage	Year of construction	Age
Beričevo-Divača	1	0,0	0,0	1978	34
Beričevo-Okroglo I	1	0,0	0,0	1985	27
Beričevo-Okroglo II	2	0,0	0,0	1985	27
Beričevo-Podlog	1	0,0	0,0	1977	35
Divača-Melina	1	1,7	19,3	1977	35
Divača-Redipuglia	1	1,0	0,7	1980	32
Krško-Maribor	1	0,0	0,0	1975	37
Krško-Zagreb.1	1	0,0	0,0	1976	36
Krško-Zagreb.2	2	0,3	0,1	1976	36
Maribor-Kainachtal.473	1	0,0	0,0	1992	20
Maribor-Kainachtal.474	2	0,7	0,0	1992	20
Podlog-Maribor	1	0,0	0,0	1975	37
TE.Šoštanj-Podlog	1	0,0	0,0	1977	35

Turkey

Line	Circuit	F (pu) number of forced outages	D (hours) average duration of single outage	Year of construction	Age
ADA - TEPEOREN	1	5,33	0,51	1972	40
ADA - GOYNUK	1	2,50	0,09	1975	37
ADA - OSMANCA	1	2,67	0,12	1987	25
ADA - CAYIRHAN	1	3,33	0,45	1975	37
ADA - BURSAGAZ	1	4,00	0,62	1984	28
ADA - TEMELLI	1	18,00	10,86	1992	20
ADA1 DGCS - TEMELLI	1	26,33	4,67	1990	22
ADANA - YOLBULAN	1	3,67	0,17	1992	20
ADANA - ISKEN	1	5,00	0,59	2002	10
ADANA - SEYDISEHR	1	23,33	1,11	1985	27
AFYON 2 - SEYITOMER	1	5,67	0,34	1975	37
AFYON 2 - SEYDISEHR	1	12,00	0,39	1975	37
ALIAGA - MORSAN	1	2,33	0,09	2006	6
ALIBEYKOY - ATISALANI	1	7,00	2,61	2005	7
ALIBEYKOY - UMRANIYE	1	3,00	1,00	1984	28
ALIBEYKOY - YILDIZTEP	1	6,67	0,32	2001	11
ALTINKAYA - CARSAMBA	1	4,00	0,26	1990	22
AMBAR.D.G - IKITELLI	1	5,33	0,78	1989	23
ATATURK - HILVAN	1	3,00	0,24	1990	22
ATATURK - S.URFA	1	3,00	0,08	1999	13
ATATURK - G.ANTEP 2	1	6,33	0,65	1993	19
ATATURK - YESILHISA	1	52,00	3,08	1993	19
ATATURK - YESILHISAR	1	33,67	1,47	1993	19
ATISALANI - IKITELLI	1	4,33	0,12	2005	7
BAGLUM - KAYABASI	1	71,00	0,59	2003	9
BALIKESIR - SOMA	1	7,67	12,67	1984	28
BATMAN 2 - KIZILTEP2	1	3,33	0,91	1997	15
BEKIRLI - SOMA	1	3,50	0,12	2009	3
BUR SAN. - TUTES B	1	4,33	3,29	1977	35
BURSA DG - BAND DGKC	1	9,50	3,41	2002	10

Line	Circuit	F (pu) number of forced outages	D (hours) average duration of single outage	Year of construction	Age
BURSA SAN. - BALIKESİR	1	7,00	0,45	1984	28
CARSAMBA - H.UGURLU	2	1,67	1,75	1980	32
CAYIRHAN - SINCAN	1	4,00	0,21	1985	27
D.BAKIR 3 - BATMAN 2	1	3,67	0,38	1993	19
D.BAKIR 3 - KARAKAYA	1	8,67	1,84	1991	21
DENIZLI 4 - AKSA ANT	1	14,67	0,42	2003	9
ELBISTA A - SINCAN	1	31,83	1,75	1986	26
ELBISTA A - SINCAN	1	31,83	1,75	1986	26
ELBISTA A - KAYS.KAP.	1	10,33	0,74	1983	29
ELBISTA A - KEB.SALT2	1	15,67	1,41	1982	30
ELBISTA A - ELBISTA B	1	5,33	1,78	1982	30
ELBISTA B - SINCAN	1	15,00	0,80	1986	26
ELBISTA B - SINCAN	1	15,00	0,80	1986	26
ELBISTA B - ANDIRIN	1	7,00	1,11	1982	30
ELBISTA B - ATATURK	1	26,33	1,32	1990	22
ERZIN - TOSCELIK	1	2,00	0,00	1992	20
ERZIN - ANDIRIN	1	4,00	0,34	1982	30
ERZURUM 3 - OZLUCE	1	34,00	0,46	1999	13
ERZURUM 3 - AGRI 2	1	35,67	2,43	2005	7
G.ANTEP 2 - ERZIN	1	18,00	0,32	1990	22
GERMENCIK - UZUNDERE	1	5,33	0,22	2006	6
GERMENCIK - YENIKOY	1	9,00	0,45	2006	6
GOKCEKAYA - SEYITOMER	1	4,00	0,18	1974	38
GOKCEKAYA - GOLBASI	1	8,33	0,15	1976	36
GOYNUK - GOKCEKAYA	1	2,50	0,09	1975	37
HABIBLER - ADA2 DGCS	1	6,33	2,12	1987	25
HABIPLER - UNIMAR	1	7,00	0,19	1999	13
HABIPLER - IKITELLI	1	2,00	0,55	1987	25
HABIPLER - ZEKERIYAK	1	8,67	0,77	2004	8
HAMITABAD - MARITSA/BG	1	9,00	5,01	1975	37
HAMITABAD - MARITSA/BG	1	10,00	0,09	2002	10

Line	Circuit	F (pu) number of forced outages	D (hours) average duration of single outage	Year of construction	Age
HAMITABAD - KAPTANCEL	1	1,67	0,93	2002	10
HAMITABAT - ALIBEYKOY	1	20,67	2,01	1988	24
HILVAN - KARAKAYA	1	4,67	2,14	1990	22
IKITELLI - UNIMAR	1	7,00	0,47	1989	23
ISIKLAR - SEYITOMER	1	5,33	0,71	1988	24
ISIKLAR - YATAGAN	2	3,67	0,18	1983	29
ISIKLAR - YATAGAN	1	5,67	0,62	1983	29
KANGAL - KEB.SALT2	1	7,33	1,15	1989	23
KANGAL - DECEKO	1	18,33	0,97	1989	23
KAPTANCEL - UNIMAR	1	2,67	0,13	2002	10
KARABIGA - BEKIRLI	1	3,50	0,12	2009	3
KARABIGA - BAND DGKC	1	9,50	1,33	2002	10
KARAKAYA - KEB.SALT2	1	3,67	0,49	1987	25
KARAKAYA - KEB.SALT2	2	3,00	1,79	1987	25
KAYABASI - KURSUNLU	1	49,33	1,17	1987	25
KAYABASI - DECEKO	1	32,00	0,25	1988	24
KAYS.KAP. - KEB.SALT2	1	14,67	9,39	1988	24
KAYS.KAP. - KEB.SALT2	1	20,00	3,27	1988	24
KEB.SALT2 - OZLUCE	1	28,67	0,44	1999	13
KIZILTEP2 - S.URFA380	1	7,00	0,45	2005	7
KONYA 4 - SEYDISEHIR	1	5,33	0,17	1994	18
KONYA 4 - YESILHISAR	1	29,33	1,43	2000	12
KURSUNLU - OSMANCA	1	6,33	4,06	1988	24
NEOSANTA/GR - BABAESKI	1	10,00	0,46	2006	6
OSMANCA - SINCAN	1	6,00	0,67	1986	26
OYMAPINAR - SEYDISEHR	1	4,00	0,54	1984	28
OYMAPINAR - VARSAK	1	2,00	0,96	1986	26
PASAKOY - ZEKERIYAK	1	2,33	0,13	2004	8
PASAKOY - ADA 1 DGCS	1	4,00	0,40	1986	26
SEYITOMER - TUTES B	1	2,00	0,19	1978	34
SINCAN - BAGLUM	1	2,00	2,69	2003	9

Line	Circuit	F (pu) number of forced outages	D (hours) average duration of single outage	Year of construction	Age
SINCAN - TEMELLI	1	8,33	0,03	1992	20
SOMA B - ALIAGA	1	2,67	0,24	1982	30
TEMELLI - YESILHISAR	1	53,33	1,82	1993	19
TEMELLI - YESILHISAR	1	55,33	2,69	1993	19
TEPEOREN - UMRANIYE	2	4,00	0,64	1971	41
TEPEOREN - UMRANIYE	1	5,33	0,31	1972	40
TIREBOLU - BORCKA	1	18,67	1,12	2006	6
TIREBOLU - CARSAMBA	1	6,00	0,38	2000	12
TOSCELIK - YOLBULAN	1	3,67	0,17	1992	20
VARSAK - AKSA ANT	1	5,00	1,62	2003	9
YATAGAN - DENIZLI 4	1	8,50	0,48	1998	14

Prediction of 400 kV lines future unavailability due to forced outages

Line 400 kV	Country	PREDICTION		
		2015	2020	2015 & 2020
		F (pu)	F (pu)	D (hours)
Carevec - Mizia	Bulgaria	0,5	0,5	3,2
Burgas - Varna	Bulgaria	0,5	0,5	2,2
Varna - Carevec	Bulgaria	0,5	0,5	4,3
Mizia - Stolnik	Bulgaria	0,5	0,5	1,0
Metalurgichna - Sofia Zapad	Bulgaria	0,5	0,5	1,4
Dobrudja - Rahman	Bulgaria	0,0	0,0	0,0
Konjsko - Obrovac (Velebit)	Croatia	3,3	8,1	2,8
Ernestinovo - Ugljevik	Croatia	2,3	6,5	1,9
Ernestinovo - S.Mitrovica	Croatia	0,0	0,0	0,0
Ernestinovo - Žerjavinec	Croatia	0,7	2,6	0,7
Tumbri - Žerjavinec	Croatia	0,0	0,0	0,0
Tumbri - Krško 1	Croatia	0,0	0,0	0,0
Tumbri - Krško 2	Croatia	0,0	0,0	0,0
Melina - Obrovac (Velebit)	Croatia	4,7	8,1	19,5
Melina - Divača	Croatia	1,3	3,8	0,5
Konjsko - Mostar	Croatia	2,7	6,8	1,4
Skopje 5 - Kosovo B (KS)	Macedonia	1,0	2,6	0,1
Skopje 5 - Skopje 4	Macedonia	0,7	1,6	0,3
Skopje 4 - Dubrovo	Macedonia	0,7	1,6	0,1
Dubrovo - Thessaloniki (GR)	Macedonia	1,3	2,3	2,5
Rahman - Dobrudja	Romania	0,4	0,4	14,3
Arad - Sandorfalva	Romania	0,2	0,2	14,3
Rosiori - Mukacevo	Romania	0,2	0,2	14,3
Portile De Fier - Djerdap	Romania	0,0	0,0	14,3
Tantareni - Urechesti	Romania	0,3	0,3	14,3
Tantareni - Slatina	Romania	0,3	0,3	14,3
Tantareni - Bradu	Romania	0,8	0,8	14,3
Tantareni - Sibiu	Romania	1,0	1,0	14,3
Tantareni - Turc 1G	Romania	0,0	0,0	14,3
Urechesti - Portile De Fier	Romania	0,3	0,3	14,3
Urechesti - Domnesti	Romania	1,0	1,0	14,3
Urechesti - Urech1G	Romania	0,1	0,1	14,3
Urechesti - Urech1G	Romania	0,1	0,1	14,3
Mintia - Arad	Romania	0,5	0,5	14,3
Mintia - Sibiu	Romania	0,5	0,5	14,3
Portile De Fier - Slatina	Romania	0,7	0,7	14,3
Slatina - Bucuresti Sud	Romania	0,7	0,7	14,3
Domnesti - Brazi Vest	Romania	0,3	0,3	14,3
Gura Ialomitei - Lacu Sarat	Romania	0,3	0,3	14,3
Gura Ialomitei - Cernavoda 1	Romania	0,2	0,2	14,3
Constanta Nord - Cernavoda	Romania	0,3	0,3	14,3
Tulcea Vest - Isaccea	Romania	0,1	0,1	14,3
Isaccea - Lacu Sarat	Romania	0,3	0,3	14,3
Isaccea - Rahman	Romania	0,2	0,2	14,3
Lacu Sarat - Smardan	Romania	0,1	0,1	14,3

Line 400 kV	Country	PREDICTION		
		2015	2020	2015 & 2020
		F (pu)	F (pu)	D (hours)
Smardan - Gutinas	Romania	0,5	0,5	14,3
Gutinas - Bacau Sud	Romania	0,2	0,2	14,3
Gutinas - Brasov	Romania	0,5	0,5	14,3
Bacau Sud - Roman Nord	Romania	0,2	0,2	14,3
Rahman - Medgidia Sud	Romania	0,3	0,3	14,3
Brasov - Darste	Romania	0,1	0,1	14,3
Brasov - Bradu	Romania	0,6	0,6	14,3
Brasov - Sibiu Sud	Romania	0,5	0,5	14,3
Darste - Brazi Vest	Romania	0,5	0,5	14,3
Sibiu Sud - Iernut	Romania	0,3	0,3	14,3
Iernut - Gadalin	Romania	0,2	0,2	14,3
Gadalin - Rosiori	Romania	0,5	0,5	14,3
Rosiori - Oradea Sud	Romania	0,5	0,5	14,3
Novi Sad 3 - Mladost 2	Serbia	2,0	4,8	4,4
Beograd 8 - Drmno	Serbia	1,3	1,4	0,1
Đerdap 1 - Drmno	Serbia	1,3	1,4	0,1
Sofia West - Niš 2	Serbia	2,6	2,8	0,1
Bor 2 - Đerdap 1	Serbia	1,3	1,4	0,0
Portile de Fier - Đerdap 1	Serbia	5,1	5,5	0,8
Novi Sad 3 - Mladost 1	Serbia	2,0	4,8	4,4
Obrenovac - Mladost 1	Serbia	0,3	1,3	0,1
Obrenovac - Mladost 2	Serbia	1,0	2,6	0,5
Niš 2 - Kosovo B	Serbia/Kosovo	0,7	1,6	0,1
Mladost - Sremska Mitrovica 2	Serbia	2,0	3,6	0,4
Ernestinovo - Sremska Mitrovica 2	Serbia	2,0	6,4	55,0
Beograd 8 - Obrenovac	Serbia	0,7	1,6	0,5
Kosovo B - Urosevac 2	Kosovo	0,5	0,9	1,4
Skoplje 5 - Uroševac 2	Kosovo/Macedonia	0,8	1,4	1,4
Kragujevac 2 - Jagodina 4	Serbia	0,3	1,3	0,1
Niš 2 - Jagodina 4	Serbia	0,0	0,0	0,0
Obrenovac - TENT A G5	Serbia	1,3	2,3	0,7
Obrenovac - TENT A G6	Serbia	1,0	2,6	3,5
Obrenovac - Kragujevac 2	Serbia	1,0	2,6	0,2
Kosovo B - Peć 3	Kosovo	1,4	2,0	2,4
Ribarevina - Peć 3	Kosovo	2,6	3,7	2,4
Novi Sad 3 - Subotica 3	Serbia	0,7	2,6	1,0
Krško-Maribor	Slovenia	0,0	0,0	0,0
Podlog-Maribor	Slovenia	0,0	0,0	0,0
Beričevo-Divača	Slovenia	0,0	0,0	0,0
Divača-Melina	Slovenia	1,7	4,2	19,3
Divača-Redipuglia	Slovenia	1,0	2,6	0,7
Krško-Zagreb.1	Slovenia	0,0	0,0	0,0
Krško-Zagreb.2	Slovenia	0,3	1,3	0,1
TE.Šoštanj-Podlog	Slovenia	0,0	0,0	0,0
Hamitabad - Maritsa/bg	Turkey	9,0	27,7	5,0