Balkans and Regional Energy Market Partnership Program: Preparation for Large Scale Wind Integration in Southeast Europe's Power System

Southeast Europe Cooperation Initiative Transmission System Planning Project (SECI)
Cooperative Agreement EEE-A-02-00054-00

June 29, 2012

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Prepared for:

United States Agency for International Development
and United States Energy Association

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TERMS OF REFERENCE

Background

The support of renewable energy sources is one of the key issues in European energy policy. The European Union has set a binding target of 20% of its energy supply to come from wind and other renewable sources by 2020. In order to achieve this 20% energy target, more than one-third of the European electrical demand would have to come from renewables, with wind power expected to deliver 12-14%. Harnessing the sustainable power of wind is an intensive development that is impacting electric transmission systems in order to cope with escalating oil prices, climate change, environmental degradation, dwindling fossil fuel stocks and dependence on foreign energy supplies.

Europe now imports more than one half of its energy needs; a figure that is expected to climb to 70% in the next 20 to 30 years. By 2030, oil imports are likely to rise from 76% to 88% and gas imports from 50% to 81%, compared to 2000. Indigenous fossil fuel resources, such as the North Sea, are in rapid decline. The European wind industry's installed capacity of 65 GW is enough to provide power for the equivalent of 35 million average EU households. Wind energy allowed EU nations to avoid paying fuel costs of 5.4 billion Euros last year.

Electric power systems are facing rapidly changing wind generation technology that directly impacts power system operation, control and development. 40% of all new electricity generating capacity installed in 2008 in the EU was wind power. Initially, TSO's are exposed to new technical conditions in the system that must be defined and planned for in advance. The capacity of power systems to absorb significant amounts of wind power should be determined by technical and practical constraints but, to date, these determinations have been made more by economics and regulatory rules. Recent studies have shown that a penetration of 20% of power from wind is feasible, usually without posing any serious technical or practical problems. But, small countries with larger WPP integration, like those in SEE, are facing special problems regarding balancing and regulation.

SEE countries that are working toward EU membership are gradually adopting the same targets and schemes as are in place in the EU. In 2007, 15 European electricity transmission system operators from 13 countries (Belgium, Czech Republic, Denmark, Germany, Ireland, Greece, United Kingdom, Poland, Spain, Portugal, France, Netherlands and Austria) established an initiative called European Wind Energy Study (EWIS). The objective of EWIS is to set up a model for large scale wind power integration within Europe. In the short term (2008), the study aimed to find solutions for the integration of wind turbines in the European synchronous power systems. For the longer term, the goal is to make common pan-European recommendations in order to facilitate integration of wind power at a larger scale.
Based upon the same basic idea as the EWIS, this proposed wind integration project is focused on South East Europe (SEE) and its special needs. For several years, SEE has lagged behind Europe in wind integration. However, now SEE TSO's are facing many of the same challenges

involving large scale integration of wind power plants. It is important to realize that in most of the SEE countries, WPP integration is still at the very beginning level. While power systems in SEE are being built and upgraded to western European standards, it is clear that all of the technical, operational, market and regulatory aspects related to the large scale integration of wind power are still being developed in South East Europe. To date, there is no common project on this issue among system operators in the region even though interest in WPP construction has grown at a very fast rate.

Detailed WPP integration analysis will require a large set of input data, both from the WPP side (site, location, wind turbine type and size, wind measurement data etc.) and from the power system side (power system models, ancillary services, load curves, operational characteristics of the existing plants etc.). The SECI Regional Transmission System Planning Working Group has for many years been focused on the long term planning horizon of the transmission systems (2015 and 2020). This expertise will be very helpful in studying the future impacts of large scale wind integration and to identify problems and issues that must be solved by the target years.

Project Goals and Objectives

The goal of this project is to develop the needed expertise, technical standards and modeling results in the SEE region to effectively plan for the integration of large scale wind that is anticipated through 2020.

specific wind integration objectives that this project will target are:

<u>Objective #1</u> - To collect wind integration studies, integration technical standards and appropriate wind integration data from Europe, the USA and SEE TSO's as inputs to Objective #2 and #3 described below.

<u>Objective #2</u> - To utilize the existing SEE Regional Transmission Planning Models (in PSS/E format), that have been updated for 2015 and 2020, to include refined wind production forecasts and predict the impact of wind in this mid to long term planning horizon.

<u>Objective #3</u> - To utilize appropriate best practice wind integration technical standards identified to develop a reference document for use by SECI participants.

Scope of the Work

The Scope of Work that supports each objective is summarized as follows:

<u>Objective #1</u> - To collect wind integration studies, integration technical standards and appropriate data from Europe, the USA and SEE TSO's in order to develop best practices in key areas of wind integration.

The analysis should be built on the most recent international work and case studies in this area such as the work conducted in the frame of the IEA Task Force 25 on "Design and Operation of Power Systems with Large Amounts of Wind Power" and EWIS findings. Information to be collected and analyzed includes:

- collecting of all relevant studies and analyses that have been prepared so far on this topic within the regional countries,
- collecting WPP project data on the national levels for different project development phases (wind capacity measurements, licensing phase, construction and operation phase),
- collecting and comparison of experiences on wind atlas or wide area wind measurements in each TSO,
- collecting and comparison of the rules and experiences on ancillary services in regional countries and its applicability for large scale WPP integration,
- collecting and comparison of the existing balancing rules and experiences as well as regulation abilities in each power system in the region and estimated additional balancing power needs,
- Collecting and comparison of the standards and regulations currently in force in the region that apply to connecting new WPP to the grid. These findings should be briefly evaluated in the context of international experiences and, as applicable, recommendations for their further development will be presented,

Objective #2 - To utilize the existing SEE Regional Transmission Planning Models (in PSS/E format), that have been updated for 2015 and 2020, to include refined wind production forecasts and predict the impact of wind in this mid to long term planning horizon.

- Perform regional steady-state analyses identifying possible transmission grid constraints and the need for grid reinforcements due to expected WPP integration in several development scenarios that will be developed by the project for 2015 and 2020.
- Calculate estimated balancing power needs and availability to determine import and export opportunities for regulation needs.

Objective #3 - To utilize appropriate best practice wind integration technical standards identified to develop a reference document for use by SECI participants.

The expected project results and findings include:

- Best practices in wind integration identified from national, regional and global information collected and analysed during the project,
- needs for grid reinforcement and/or balancing power needs from implementing wind energy projects in different planned locations according to the projections of the national wind energy programs,
- an estimate of the maximum wind energy capacity that selected locations could support without a need for major changes (and excessive costs) to the existing power system at that location and/or at the national level.

Preparation for Large Scale Wind Integration in SEE Power System

<u>Draft Time Line</u>

September 2010 –
SECI participants approve ToR and establish task groups and task group leaders.

October 2010 –
EKC and EIHP prepare information request (questionnaire) for wind integration technical standards information and a questionnaire to collect wind data from SEE TSO's and send these draft documents to the appropriate Task Group Leader (TGL) for review and comment. Task Group leaders will consult task group members for comments on questionnaires.

November 2010 –
Comments on Questionnaires are due back to EKC and EIHP, each questionnaire is finalized based on comments and is sent to the appropriate TGL for distribution to all participants.

EKC and EIHP initiate a review of international wind integration technical standards information in accordance with Objective #1 of the ToR.

December 2010 -
SECI participants work to gather needed information and data to complete the Questionnaires.

January 2011 –
SECI participants send the completed questionnaires to the TGL's for review and tabulation. TGL sends the data to EKC and EIHP where the data will be compiled and analyzed for presentation at a planned SECI Working Group meeting in February.

EIHP and EKC prepare a draft report and presentation on International Wind Integration Technical Standards for presentation at the Wind Integration Work Shop in February.

February 2011 -
Wind Integration Work Shop and SECI Working Group Meeting.
Participants agree on Regimes and Scenarios to be studied and approve the collected input data for modeling.

March 2011 -
EKC and EIHP to begin model modifications based on agreed modeling data for all regimes and scenarios.

April 2011 -
Modeling work continues; EIHP and EKC will prepare a draft document of Wind Integration Technical Standards and send this document to the TGL for Technical Standards. The TGL will send this to task group members for comments.

May2011 -
SECI Working Group Meeting
This agenda will include an update on modeling progress and any results obtained to date as well as the presentation of the Wind Integration Technical Standards draft report.

June 2011 –
Modeling work continues and Wind Integration Technical Standard document is finalized.

July 2011 –
Draft modeling results are sent to all participants by the Network Analysis TGL for review and comments.

August 2011 –
SECI participants review and comment on modeling results and the Technical Standards draft document.

September 2011-
SECI Working Group Meeting
This agenda will include approval of the modeling results and the Technical Standards Reference Paper.

October 2011 –
EIHP, EKC and USEA to prepare a draft report for this phase of the project.

November 2011 –
Draft report is distributed to all participants for comments.

December 2011 –
Draft report is revised to include participant comments and prepared for final approval at the next planned Working Group meeting.

1. INTRODUCTION

This Study is a part of continuing efforts of SECI Regional Transmission Planning Working Group on the harmonized transmission system planning in South East Europe. After working group establishment in 2001 detailed regional power system models for 2005, 2010, 2015 and 2020 were developed and harmonized in details, while at the same time several study activities have been undertaken.

The first study within this group was untitled “Regional Electricity Interconnection Study” [7] from 2002 and it was dealing with regional power system modeling and common transmission system development. The most important regional generation investment study was finished and issued in 2004 [1]. It was untitled “Regional Balkans Infrastructure Study (REBIS) – Electricity and Generation Investment Study (GIS)”. The aim of the study was to determine optimal size, location and timing for construction of new production capacities as well as reinforcement of main interconnection transmission capacity in the SEE region over the next 15 years (2005 – 2020). Within this study transmission system analyses were done by EIHP and EKC under SECI umbrella. Due to a number of significant changes that emerged since 2004, concerning primarily the growth of gas price and the decrease of imported coal price, the updating of original GIS was required. Consequently, in 2007 the study untitled „Evaluation of Investments in Transmission Network to Sustain Generation and Market Development in SEE” [4] was launched and issued by the same aforementioned group of authors in order to revise and identify an indicative priority list of investments in main transmission interconnections and internal lines between the countries and sub-regions to sustain investments in power generation and support market exchanges over the updated GIS study horizon. Finally, in 2007 the study untitled “Transmission Network Investment Criteria” [3] was also issued by EIHP and EKC under the same background of the SECI Transmission System Planning Group. Its aim was to establish transmission system planning criteria and methodology for regional transmission project prioritization. In 2009 impact of uncertainties on regional transmission system was evaluated in detailed study report.

The Study given in this document is continuation of all aforementioned activities. Namely, during all those studies transmission planners were faced to different uncertainties, even before introduction of market conditions in power system. Introduction of market environment makes transmission planning more difficult. Locations and capacities of new power plants, their biding behavior, existence of the present ones in the future, consumer’s reaction on instantaneous electricity price (price elasticity), electricity and power trading, hydrological conditions, branches and generators availability, regulatory aspects etc., are hard to be predicted even for the purpose of short-term planning. Network development based on deterministic power flow analyses of several possible system conditions will not give the clear picture of future transmission system operating conditions and transmission system investments will not be satisfactory evaluated, especially concerning a risk that is caused due to some uncertainties. WPPs introduce additional level of uncertainty.

Region of South East Europe with regard to this study comprises of 12 power systems and system operators covering Slovenia, Croatia, Bosnia and Herzegovina, Serbia, Kosovo, Macedonia, Albania, Montenegro, Romania, Bulgaria, Turkey and Greece. Generally, most of the countries already consume a relatively high proportion of energy from renewable sources compared with EU Member States. Increasing the proportion of renewable energy sources in the energy mix has not been a priority until relatively recently. Consequently the policy, legal, regulatory and institutional frameworks designed to support renewable energy development are at early stage in most SEE countries. Despite that, RES investors' interest in the region is rapidly growing and RES share in 2020 could exceed 20% at the regional level.

The highest interests are expected in wind power plant projects, which are currently on the relatively low level of integration in the region. Transmission System Operators (TSOs) need to meet a number of challenges associated with integrating increasing levels of wind power into their power systems. These challenges come out from the nature of the power output from wind turbines that:

- cannot be dispatched;
- have significant variability due to the changing wind speed; and
- have significant uncertainty in wind forecasting.

Most of the time WPPs operate at partial load, depending on the wind speed. From the point of view of the power system, wind turbines can be regarded as production assets with an average power corresponding to 20 to 40% of the rated power, with peaks that are three to five times higher. So, for TSOs the following information is important:

- the WPP generation variability and the extent to which can be forecasted;
- the WPP inclusion in energy balance and daily load curve;
- WPP capabilities in providing ancillary services.

The variability of wind power output tends to decrease as more turbines are distributed over a given area, while the output variability increases with the time scale involved. In this sense it is important to monitor wider geographical area, especially having in mind relatively small but well connected power systems as those in SEE. The second to second and minute to minute variability of large scale wind power is generally relatively small, whereas the variability over several hours can be large even where wind turbines are widely distributed. Thus, for time scales from several hours to day-ahead, forecasting of wind power production by the TSO is crucial.

In SEE currently there is a large gap in between national WPP targets (if any), investors' interest and wind energy potential from one side and level of WPP integration from the other side. Currently, there are 131 WPP project in operation in the region, with more than 3100 MW of its installed capacity and more than 1700 new WPP projects under development. TSOs mainly have no experience in power system operation with WPPs share. Moreover, forecasting and balancing mechanism is generally very comfort to WPPs, with practically no obligations for WPPs. At the same time SCADA systems and generation units are most usually obsolete and ancillary service mechanism is not fully defined or applied. Accordingly, TSOs are facing to big challenges for large WPP integration with many issues to be resolved in very near future. So far, the average time spent from the very beginning of WPP project in SEE till the contract on wind turbine purchase was 3 – 5 years. Wind turbine delivery, construction and testing assume additional 1.5 - 2 years. Altogether, average time spent for WPP project development was very long - about 5 – 7 years.

This study is supposed to cover some of these issues on the regional level with its main target to evaluate and discuss impact of WPP production to transmission network, to establish close cooperation between TSOs regarding WPP impact on power system operation, to discuss balancing and legal issues on WPP integration, to suggest measures in order to ensure safe and secure system operation and to discuss transmission network enhancement in line with WPP construction forecasts on regional level with linkage with Ten Years Network Development Plan and inclusion of SEE TSOs in this plan.

Knowing that all input data, analyzed scenarios and detailed models were defined and harmonized by the responsible TSOs for the given timeframe of 2020, this Study can be taken as one of the most detailed study on common regional approach to large scale wind integration in South East Europe so far.

2. CURRENT STATUS OF WIND ENERGY SECTOR

This section covers current status of wind energy sector on the global, European, regional and national level.

2.1. GLOBAL VIEW

Wind power plants integration in power systems has gradually evolved over the last 30 years from simple constant speed turbines to fully variable speed systems that enable active output control. In much of the older generation technology, the wind turbine rotor speed is fixed by the frequency of the electricity grid, and the turbine operates below its peak efficiency in most of its operational wind speed range. This has proven to be a cost-effective and robust concept and it has been scaled up and optimized. At a given site, a single modern wind turbine annually produces 200 times more electricity and at less than half the cost per kWh than its equivalent twenty five years ago[1]. In last decade global wind industry is one of the fastest growing technologies. Global values are shown in Table 2-1 and Figure 2 -1.

Table 2-1 Global developments of wind industry

Year:	Installed MW	Increase %	Cumulative MW	Increase %
2004	8,154		47,912	
2005	11,542	42%	59,399	24%
2006	15,016	30%	74,306	25%
2007	19,791	32%	94,005	27%
2008	28,190	42%	122,158	30%
2009	38,103	35%	160,084	31%
Average growth - 5 years		**36.1%**		**27.3%**

Source: BTM Consult ApS - March 2010

[1] EWEA

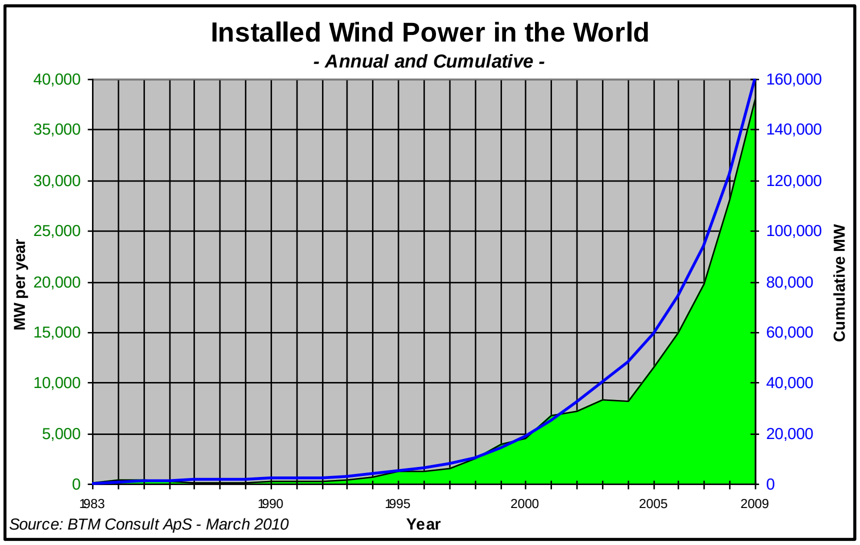

Figure 2-1 Installed Wind Power in the World

2.2. EUROPEAN VIEW

Europe is importing about 60% of its energy needs, and that share is likely to increase substantially in the next two decades unless a major shift occurs in Europe's supply strategy. Most of Europe's oil comes from the Middle East and the larger share of its gas from just three countries: Russia, Algeria and Norway. At the same time, due to its ageing infrastructure and constant demand growth, massive investment in generation plants and grids are required. Over the next 12 years, 360 GW of new electricity capacity – 50% of current EU electricity generating capacity – needs to be built to replace ageing power plants to meet the expected increase in demand[2].

Consequently, EU is strongly targeting and supporting renewables in its energy future. In June 2010 the European Commission's Joint Research Centre highlighted that provisional Eurostat data showed that in "2009 about 19.9% (608 TWh) of the total net Electricity Generation (3,042 TWh) came from Renewable Energy sources"[3]. Hydro power contributed the largest share with 11.6%, followed by wind with 4.2%, biomass with 3.5% and solar with 0.4%." It went on to conclude "that if the current growth rates of the above-mentioned Renewable Electricity Generation Sources can be maintained, up to 1600 TWh (45 – 50%) of renewable electricity could be generated in 2020." Wind currently provides more than 5% of Europe's electricity. On 7 October 2009, the European Commission published its Communication on "Investing in the Development of Low Carbon Technologies5 (SET-Plan)" stating that wind power would be "capable of contributing up to 20% of EU electricity by 2020 and as much as 33% by 2030" were

[2] European Commission Communication 'Second Strategic Energy Review: An EU Energy Security and Solidarity Action Plan', (SEC(2008) 2871)

[3] Renewable Energy Snapshots 2010. European Commission Joint Research Centre Institute for Energy

the industry's needs fully met. Expected (maximum) increase in EU's share of electricity provided by wind power is shown on the following Figure 2-2.

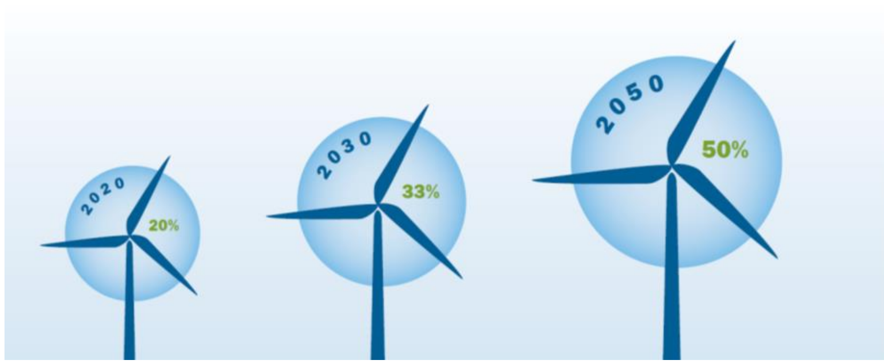

Figure 2-2 Expected increase in EU's share of electricity provided by wind power (Source: EWEA)

Clearly, Europe is global wind industry leader. Around 66% of total wind turbines worldwide is produced in Europe. Cumulative wind power plant capacity in Europe by end of 2010 is shownon the following Figure.

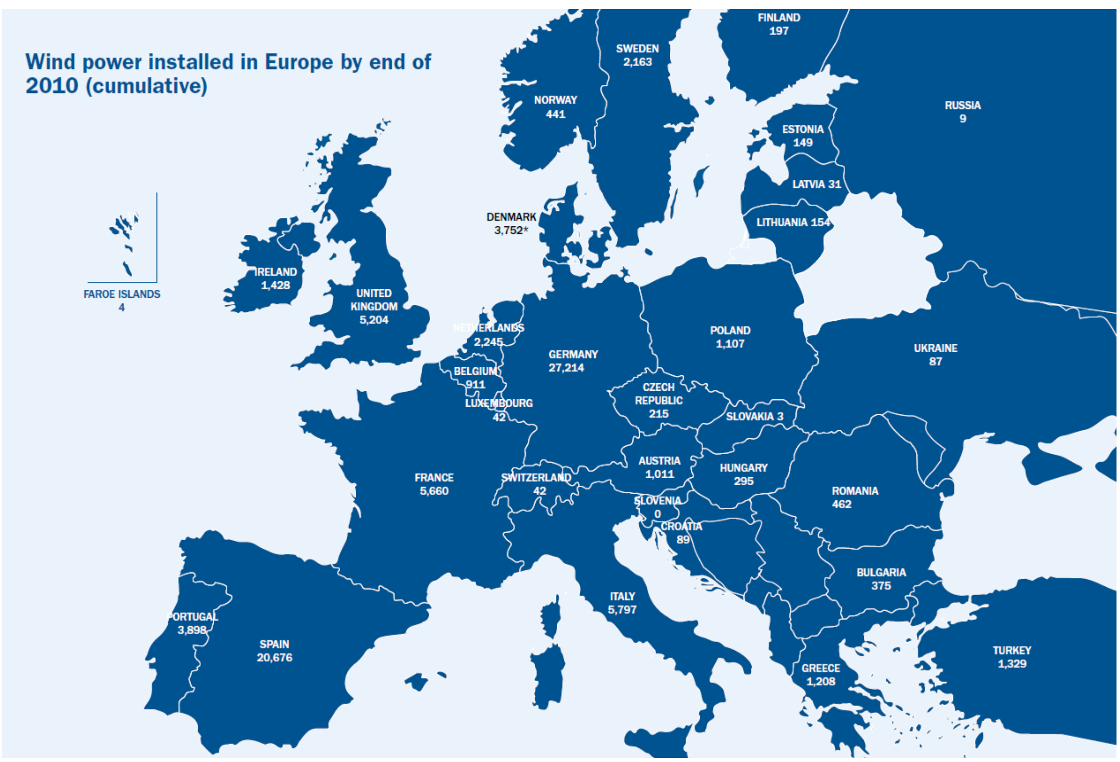

Figure 2-3 Cumulative WPP capacity in 2010 in European countries (Source: EWEA)

The following Figure shows installed WPP capacity per capita in European countries and in SEE.

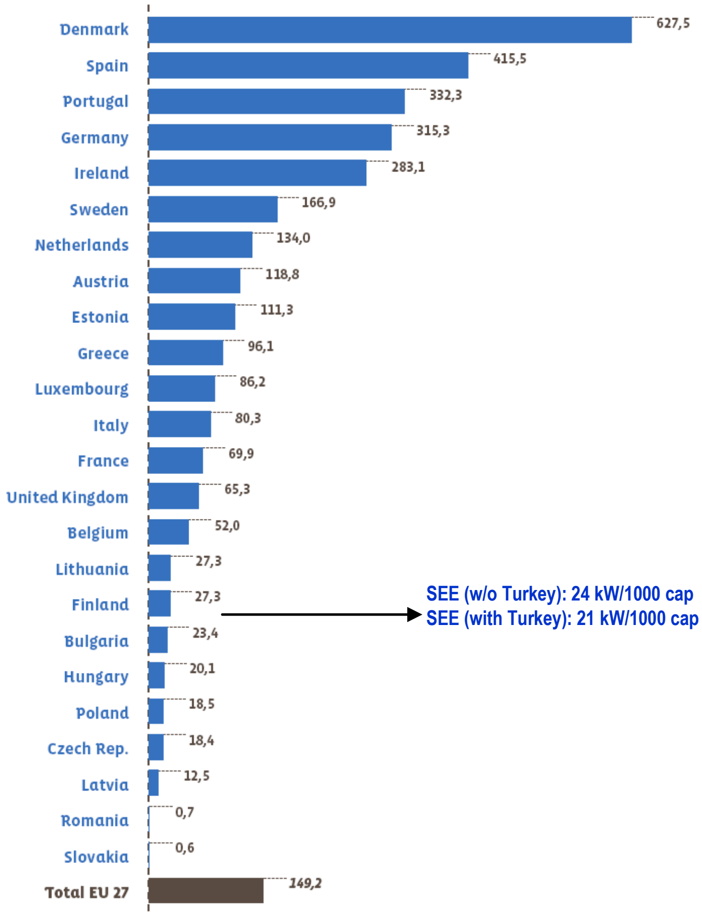

Figure 2-4 WPP installed capacity per capita (Source: EWEA)

Taken together the Action Plans show that the EU-27 will meet 20,7 % of its 2020 energy consumption from renewables. The National Action Plans show that one third (34%) of EU electricity demand will be supplied from renewables by 2020. Wind energy will generate 14% of Europe's total electricity demand in 2020 (494 TWh from 213 GW installed capacity), more than any other renewable source, up from 4,2% in 2009. Ireland will be the country with the highest wind energy penetration level at 36,4% of its total electricity demand, followed by Denmark at 31%.

15 Member States even plan to exceed their national target given in Action Plan, led by Bulgaria at +2,8% above their target, Spain (+2,7%), Greece (+2,2%), Hungary (+1,7%) and Germany (+1,6%). 10 Member States will meet their national target, and just two Member States, Luxembourg (-2,1%) and Italy (-0,9%), have informed the European Commission that they envisage using the cooperation mechanisms to meet their national targets. This shows that vast majority of EU countries clearly force additional usage of renewables (RES) technologies, particularly wind power.

The 34% of EU electricity demand met by RES in 2020 is made up of 14.1% from wind energy (10% onshore, 4% offshore), 10.5% from hydro, 6.6% from biomass, 2.7% from solar photovoltaic, 0.5% from CSP, 0.3% from geothermal and 0.1% from ocean.

In the following table RES share per Member States are given.

Table 2-2 Renewable share per Member State (%)

Country	National binding target established by EU Directive 28/2009/EC	NREAP target	above / below Target
Austria	34%	34.2%	+ 0.2 %
Belgium	13%	13%	0%
Bulgaria	16%	18,8%	+ 2.8%
Cyprus	13%	13%	0%
Czech Republic	13%	13.5%	+ 0.5%
Denmark	30%	30.4%	+ 0.4%
Estonia	25%	25%	0%
Finland	38%	38%	0%
France	23%	23%	0%
Germany	18%	19.6%	+ 1.6%
Greece	18%	20.2%	+ 2.2%
Hungary	13%	14.7%	+ 1.7%
Ireland	16%	16%	0%
Italy	17%	16.1%	- 0.9%
Latvia	40%	40%	0%
Lithuania	23%	24%	+ 1%
Luxembourg	11%	8.9%	- 2.1%
Malta	10%	10.2%	+ 0.2%
Netherlands	14%	14.5%	+ 0.5%
Poland	15%	15.5%	+ 0.5%
Portugal	31%	31%	0%
Romania	24%	24%	0%
Slovakia	14%	15.3%	+ 1.3%
Slovenia	25%	25.3%	+ 0.3%
Spain	20%	22.7%	+ 2.7%
Sweden	49%	50.2%	+ 1.2%
United Kingdom	15%	15%	0%

Source: EWEA analysis of the 27 NREAPs

2.3. REGIONAL VIEW

Due to the relatively high starting point, the overall target for the seven regional Energy Community contracting parties (Croatia, BiH, Macedonia, Montenegro, Serbia, Kosovo and Albania) is 24% compared with the EU's 20%. This is an overall increase of 7% from the 2005 position compared with around 11.5% increase for the EU, due to their higher GDP per capita and hence higher 'residual effort' required[4]. All countries in SEE are having Action Plans finalized or in preparation.

Most of the SEE countries have implementation strategies and action programs for RES which include features of the required national action plan[5]. They are either part of wider programs or have a strong focus on specific measures and technologies. They don't match all specific requirements that are set out in the new RES Directive, and the various documents would need to be adjusted accordingly to fit the purpose of being used as action plans. RES targets per regional countries are given in the following table[4].

Table 2-3 Renewable targets per regional countries

Country	RES target
Albania	18% RES in total primary energy supply by 2020 4% WPPs in power generation by 2020 5% biofuels by 2010, 15% by 2015 2% of total power production from RES (producers with capacity > 100MW)
Bosnia and Herzegovina	None
Croatia	20% RES in final energy consumption by 2020 9-10% of WPP in final electricity consumption 10% biofuels in final consumption of gasoline and diesel by 2020 35% RESe in power generation by 2020
Montenegro	More than 20% RES in final energy consumption by 2020 Only analysis of future share of SHPP, but no targets set out New Energy Law (2009) to set indicative targets for RES
Serbia	1.5-2% RES in final energy consumption by 2015 4.5% RES in total energy production by 2010 20% reduction of energy consumption by 2020
Kosovo	7.78% RESe and RESth of total energy production (reviewed annually for ten years) by 2016
Macedonia	30% energy intensity reduction compared to 2006 by 2020 > 20% RES in final energy consumption by 2020 10% biofuels in total consumption of transport fuels by 2020 30% GHG emissions reduction (20% in coal-based power generation) by 2020
Turkey	30% RES in power generation by 2023 Capacity targets for wind (20000 MW), geothermal (600 MW), and maximisation of hydro and solar power potential

In 2010 energy generated from RES in SEE was produced mainly in HPPs. However, the share of other RES such as wind and solar energy started to gather pace, especially in Romania and

4 EWEA Analyses of NREAP 4.1.2011

5 Study on the Implementation of the New EU Renewables Directive in the Energy Community, IPA, NTUA, 2010

Bulgaria. The segment provides substantial opportunities for investors as lots of conventional power plants need rehabilitation or decommissioning, while the countries' wind resources are quite promising. In terms of wind (and solar) resources the SEE region is also attractive for investors with planned investments in wind and solar facilities exceeding 6.4 bln €. In Romania the Spanish Iberdrola plans to build the world's largest onshore wind-park by 2017 (2,500 MW). Most of the SEE countries have introduced feed-in tariffs to promote the construction of RES power plants in order to meet the aims in the EU's RES Directive 2009/28/EC, which envisages that 20% of the total energy consumption in the union should be covered by RES.

Inputs given in this section are collected through TSO questionnaire, activities of Energy Community Regulatory Board (ECRB)[6] and other public sources. In the following sections country wind speed maps are generated from Sander + Partner’s World Wind Atlas. For a regional re-analysis SANDER + PARTNER GmbH uses the weather model „mm5”. This model was developed at Penn State University and NCAR (National Center for Atmospheric Research, Boulder, USA) and contributions from many international research groups. To develop a weather model like mm5, it took more than 100 men-years. mm5 is one of the world leading weather model. It is used in more than 50 countries for weather prediction and other purposes of meteorology or air quality. The weather model uses many different input data: global meteorological data available on a grid of about 2.5° or observations from the WMO (World Meteorological Organization) achieved from several 1000 meteo-stations, weather balloons, ship- or aircraft observers and many other observations.

According to the regional TSO questionnaire from late 2010, in the region there are 131 WPPs in operation with total installed capacity of more than 3100 MW, mostly in Greece and Turkey, as shown on the following Figure. It is important to point out that these values are changing on the monthly level, since lot of WPP projects are under development. Average installed WPP installed capacity is 23 MW.

[6] Regulatory Perspectives on RES in Energy Community, N. Stefanović, ECRB EWG Chairman, Joint TSO-Utility Regulator Workshop on Integration and Cross Border Trade of RES in Regional Transmission Networks, Istanbul, March 2011

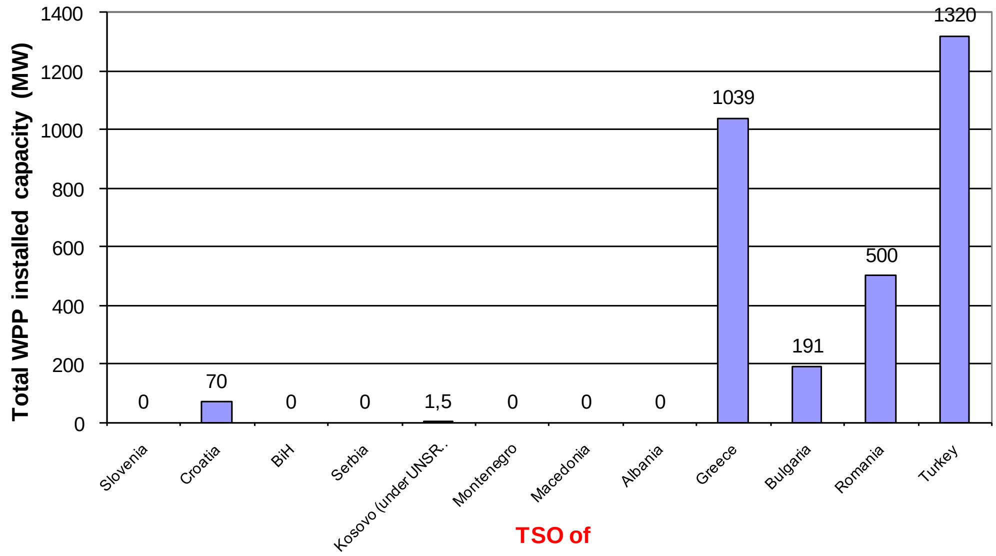

Figure 2-5 Total WPP installed capacity in the region (end of 2010)

The same values are geographically presented on the following figure where total WPP installed capacity is given along with a year of first WPP commissioning.

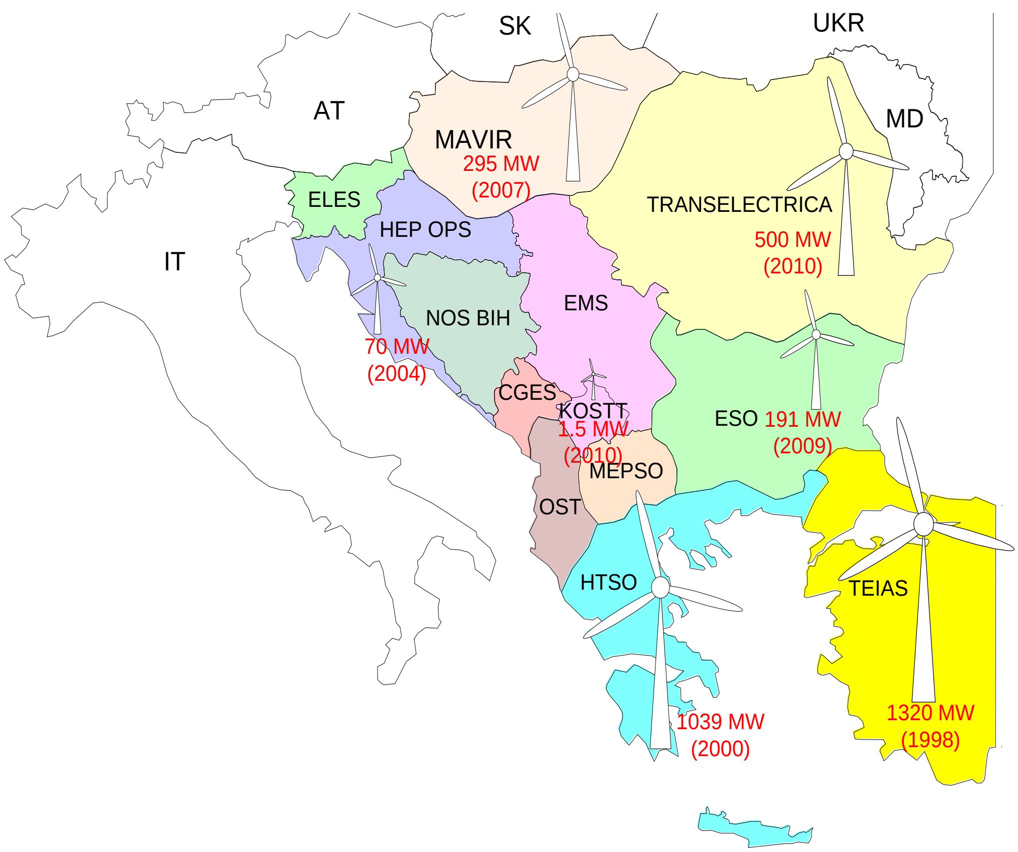

Figure 2-6 Total WPP capacity in the region (2010) and a year of first WPP commissioning

Besides already existing 131 WPP projects, in the region there are 1731 WPP project under development (13 times more projects are under development than there are existing WPP projects), mostly in Greece and Turkey, as shown on the following figure.

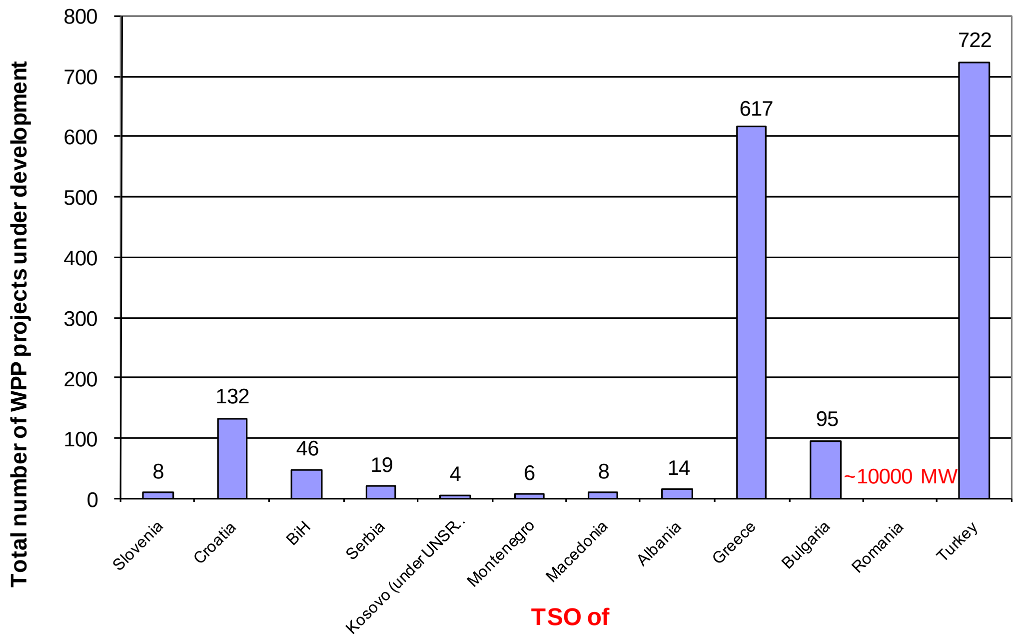

Figure 2-7 Total number of WPP projects under development in the region (end of 2010)

Regional overview can be obtained putting all above mentioned details together.

The following figure shows wind speed mean value for the whole region. Obviously, the largest wind energy potential is found on the Greek, Turkish, Romanian and Bulgarian shore. Croatia, BiH, Montenegro and Albania are also having promising wind potential.

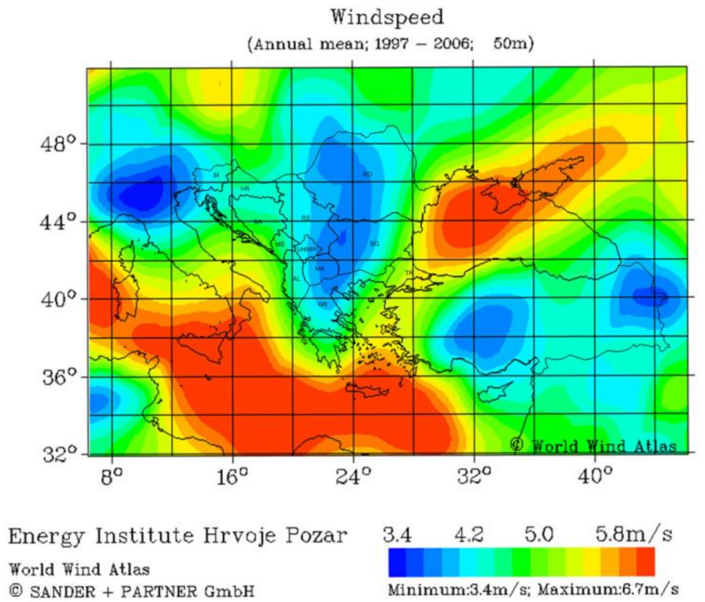

Figure 2-8 Wind speed map of South and Eastern Europe

For illustration purposes only, the following figure shows average wind speed mean values per each system, taken out of the World Wind Atlas. Please note that these values are just mezoscale mean values on the resolution 250x250 km and can not be used for WPP micrositing purposes. Obviously, wind speed mean value is in the range of 4,2 m/s and 6,3 m/s, which is potentially interesting for detailed investigation of WPP sites.

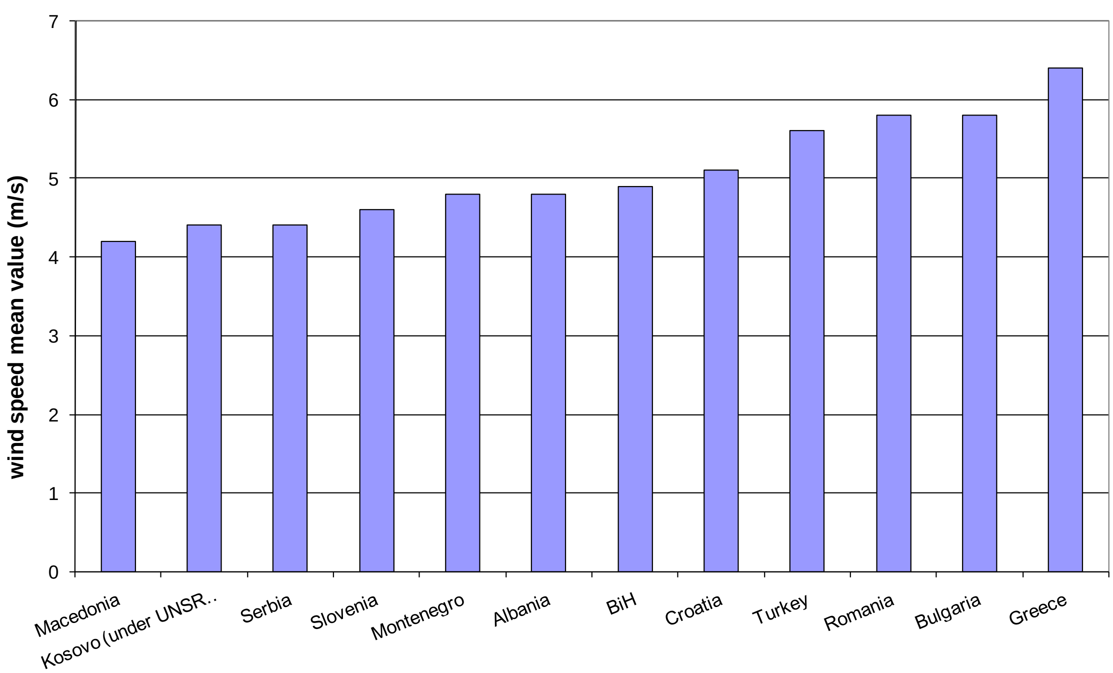

Figure 2-9 Wind speed mean values of South and Eastern Europe systems

2.4. COUNTRY VIEW

2.4.1. Albania

Albanian power system is fully relying on hydro generation. Moreover, HPPs currently in operation represent only a third of the exploitable hydro potential.

There are no WPPs installed so far, but there are 7 WPP projects that applied for grid connection with its total installed capacity of 1370 MW. Albania is having very promising wind energy potential (up to wind speed mean value of 4,8 m/s at 50 m above the ground, for given large spatial resolution of 250 km[7]), as shown on the following figure. Wind atlas for whole country territory is prepared by Ministry of Energy. One of the largest WPP projects in the world (500 MW) is planned on Albanian shore. In accordance to the Energy Strategy and Albania conditions, it is estimated that by 2020, 4% of the generated power may come from wind energy (cca 400 GWh/year). This implies to give priority to the construction of 20 WPPs situated along the Albanian Adriatic cost. Lot of WPP projects are in preparation and study phase. According to preliminary estimates, the total WPP installed capacity that is currently under preparation reaches 3000 MW.

The government is making a political incentive for the construction of renewable energy sources. It has signed a series of concessionary contracts with private companies, both domestic and foreign, for the construction of new hydropower plants. Some of them are already in operation and many others are in process of construction.

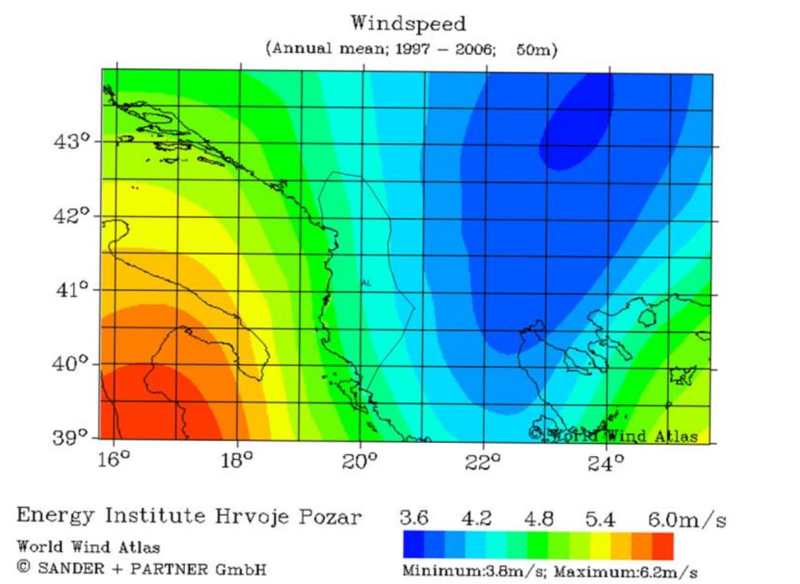

Figure 2-10 Wind speed map of Albania with annual mean values in the period 1997 – 2006, 50 m above the ground

[7] Note that it is not maximum wind speed mean value in the country, but interpolated averaged mean value at the resolution of about 250 km

Even though national RES integration target is not officially adopted, it is expected to be on the level of 267 MW of HPPs and 50 MW of WPPs up to 2015 and 633 MW of HPPs and 200 MW of WPPs up to 2020. TSO within ENTSO-E system development group forecasted to reach 130 MW in 2020.

Legislative framework for RES is partly defined. There is the Power Sector Law adopted in 2003 that is amended for RES. There are no any additional technical requirements for WPP connection and operation (Wind Grid Code). WPP integration study on the country level was prepared for the purpose of Wind Park Moncada connection (500 MW), which is planned to be connected to Italian power system through HVDC submarine cable. There is country level study underway, expected to finalized till the end of 2011.

For more intensive WPP integration in Albania there are several limiting factors:

- Lack of legislative framework,
- Limited available system reserve,
- Limited network absorption capability in the WPP areas and
- Lack of investments.

2.4.2. Bosnia and Herzegovina

Compared to the other countries the share of RES in Bosnia and Herzegovina is relatively high. In this respect the biggest part is related to large HPPs. With total installed generation capacity of about 4400 MW BiH gets 40 percent of its electricity from hydro power, while the rest comes from coal-fired plants. In addition, a 430 MW pumping plant in Čapljina is in an advanced stage of revitalization, while 11 other HPP projects are in the pipeline, for a capacity exceeding 323 MW.

Unlike other countries in the region, which rely on imports to cover much of their consumption, BiH is able to export power, helped by its hydro potential. Generally, other renewable energy in BiH remains largely unexploited, but it's not for lack of potential. Rather, the country suffers from a lack of clear state-level legislation as well as complex government structure with around 30 different federal, state and municipal governments. That is undermining WPP development efforts. Currently, there are no WPPs in operation and no experience in WPP integration. But, there are 47 WPP projects in different development phases, mostly located in southern part of the country with the largest wind potential, as shown on the following figure (up to wind speed mean value of 4.9 m/s at 50 m above the ground). Its total planned capacity is more than 3000 MW.

For 15 projects there are wind speed measurements on the site. In the Southern region of Herzegovina, construction of the first two WPPs: Mesihovina (44 MW) and Podveležje (46 MW) have been under way since September 2010.

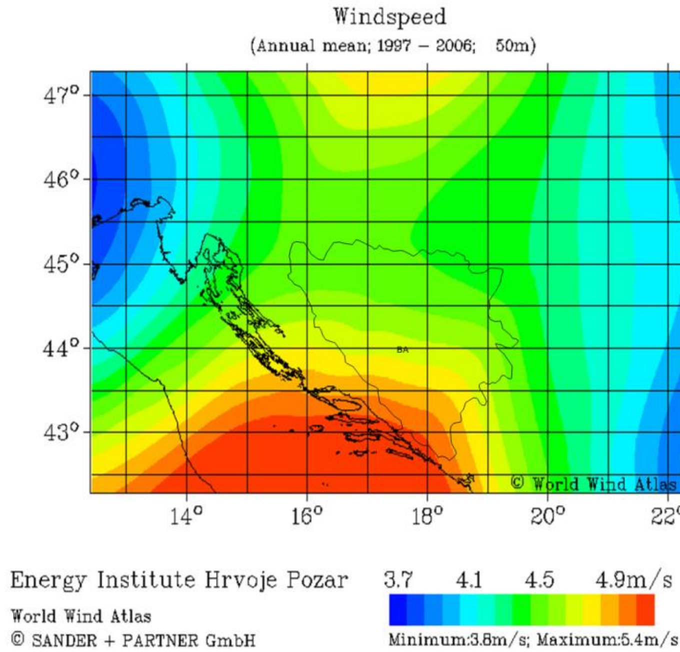

Figure 2-11 Wind speed map of BiH with annual mean values in the period 1997 – 2006, 50 m above the ground

Ministries at the entity level (two) are policy makers and responsible for promotion of RES by defining the energy strategy they are in charge to set the RES targets. Legislative framework for WPP (RES) integration is not fully defined. Currently, RES target on BiH level is not set yet, while Decree on RES is recently adopted in both entities separately. Within ENTSO-E system development group it is forecasted to reach 490 MW of WPPs in 2020. Grid code upgrade proposal which contains a chapter "Technical requirements for WPP connection" is adopted in May 2011 by the State Regulatory Commission (SERC).

Wind atlas of Bosnia and Herzegovina is prepared and available in the Ministry of Foreign Affairs and Economic Relations of BiH. Study on WPP integration untitled "*Power Network Analysis for Wind Power Integration and Market Rules Advice for BiH*" in the frame of EBRD Western Balkans Sustainable Energy Direct Financing Facility - Institutional Capacity Building Project is expected to be finished by the end of 2011.

For more intensive WPP integration in BiH there are several limiting factors:

- Complex WPP development procedure,
- Lack of legislative framework,
- Limited available system reserve and
- Limited network absorption capability in the WPP areas.

2.4.3. Bulgaria

Bulgaria is also having significant share of RES, mainly in large HPPs. Bulgaria increased output from renewable energy sources by 67% in 2010 to 5509 GWh as new hydropower plants, wind and solar parks went into operation. In last few years there is a large interest in wind power plant projects. Dozens of Austrian, Spanish, U.S. and German companies have rushed to build new wind (and solar) power plants, raising WPP installed capacity to 375 MW at the end of 2010 from 103 MW in 2008 and solar to 10 MW from 1.4 MW two years ago. The largest WPP in Bulgaria is the 156-MW "St. Nikola" (AES Geo Energy) near the Black Sea town of Kavarna, which started operating in 2009.

Till February 2011 total installed WPP capacity connected to the transmission grid was 191 MW. In the following three months additional WPP capacity was connected, making total of 247 MW as of July 2011. But, there are lot of WPPs connected to distribution grid, which makes overall WPP total of 488 MW in Bulgaria in July 2011. In summer 2011, WPP grid connection applications to the transmission grid of Bulgaria were at the level of 14,000 MW. Yes, this was true , but as you said on page 30 in April 2011 the parliament approved a new law on RES. Also, as you said, New law on RES demands investors to pay connection fee of 50 000 lv per MW (~25 000 €/MW) for WPPs larger than 5 MW and 25 000 lv/MW for smaller WPPs. That was the reason why lot of investors gave up with the investments in new wind farms. TSO made new calculations and the final account is that the new WPP applications which will be connected to transmission grid will be at the level of 2829 MW.

Besides these WPPs in operation, currently there are 15 projects in construction phase, 20 more projects in licensing phase and 60 projects in wind potential measurement phase. Total installed capacity of all expected WPP projects connected to transmission network goes up to 3000 MW, mainly located in North-Eastern region of Dobrudja, as shown on the following figures (up to wind speed mean value of 5.8 m/s at 50 m above the ground). The problem is that in these regions the transmission grid is not strong enough to accommodate the wind generation. More detailed wind atlas is not available for whole country territory.

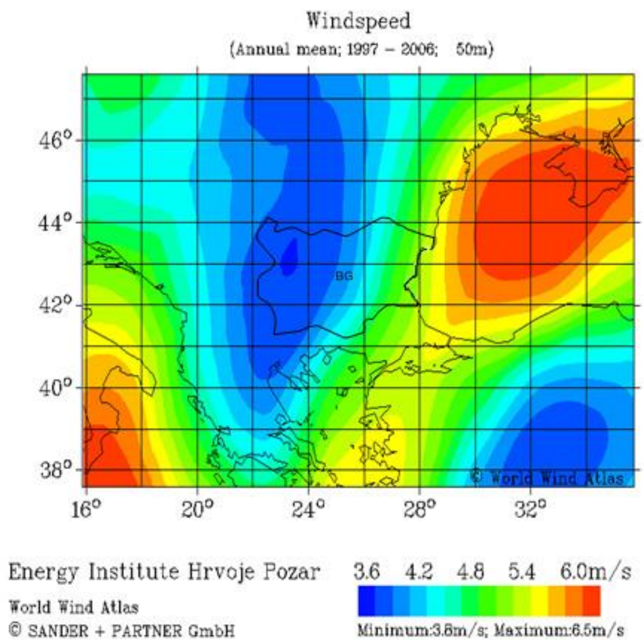

Figure 2-12 Wind speed map of Bulgaria

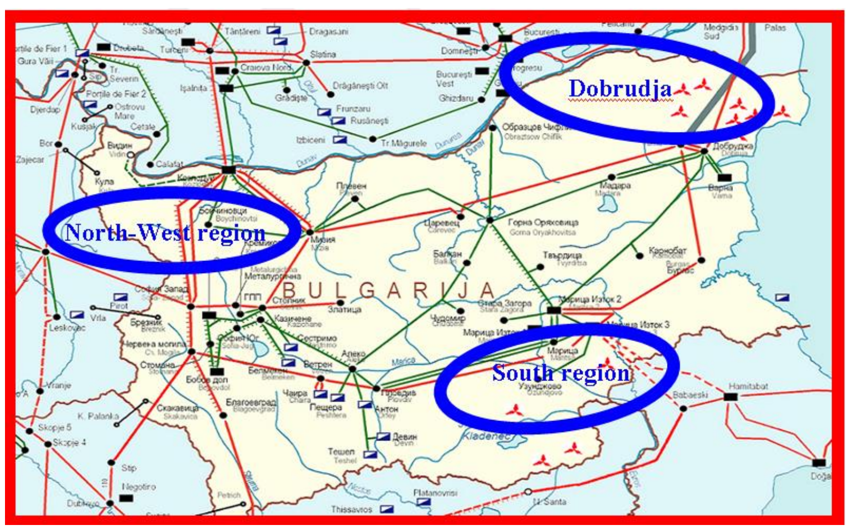

Figure 2-13 Most promising WPP locations in Bulgaria

National target for RES in Bulgaria is defined. According to EC directive 2009/28/EC national target for RES penetration is set to 16% (~2000 MW) of the gross final consumption till 2020. TSO within ENTSO-E system development group forecasted to reach 1500 MW in 2020. Legislative framework for RES is partly defined. WPP integration study on country level was not prepared so far. Studies were done for individual WPP connection purposes only.

For more effective WPP integration in Bulgaria there are two limiting factors:

- Available system reserve and
- Network absorption capability in the WPP areas.

Significant changes in RES sector in Bulgaria happened in April 2011 when new law on RES was approved. It aims to cool a surge in solar and wind power projects that threatens to overwhelm its ageing power grid and boost electricity prices[8].

The law changes the government's obligatory purchase of electricity produced from renewable energy generators at high, fixed prices, which has led to a jump in projects totaling over 6000 MW, well above the country's grid capacity.

The government aims to put a cap on wind and solar projects to keep electricity prices at affordable levels and avoid public discontent. In a bid to unclog the system, the new law demands that investors pay a connection fee of 50000 levs ($36,820) per planned installed MW when signing a preliminary contract.

It also calls for the preferential price to be fixed at the time that the wind or solar energy park is built, and not when a preliminary contract is signed, as the initial law draft envisioned. It also decreases the obligatory long-term purchase power contracts to 20 from 25 years for solar energy and to 12 from 15 for wind.

Under the new law, the energy regulator will set annual preferential feed-in tariffs, which pay per unit of electricity produced from low-carbon energy by the end of June each year.

The government said the measures would scare away speculators and also encourage investors to speed up projects and not wait for solar panels and wind turbine prices to drop.

There are some indications that the preferential price for electricity from photovoltaic installations is likely to be cut by 30 percent in June, while the cut for wind will be smaller. On the other side, investors do not oppose the cut in the feed-in tariffs, but the lack of predictability and the fact they would have to build an installation before they know at what price the power will be purchased.

The new law establishes better incentives for green energy from biomass and waste disposal, which unlike solar and wind will create more jobs, officials say. There are no biomass energy plants in Bulgaria at present.

[8] Reuters.com; April 21, 2011

2.4.4. Croatia

The share of RES in electricity consumption Croatia depends on the hydrology (up to 40%), since its biggest part refers to large HPPs. In addition, other RES accounted around 2% of total electricity production. Even though WPP integration process started more than 10 years ago, currently there are 6 WPPs (58 wind turbines) in operation, with total installed capacity of about 79 MW. In the period January – May 2011 maximum WPP generation was 72 MW, average WPP generation was 22,5 MW, with usage factor of 0,28 (equivalent to of 2452 full load hours on annual level). Maximum WPP share in total daily consumption was 4,4% (May 29, 2011). On the monthly level in average WPPs covered 1,3% of the total system consumption.

At the same time, there are 132 WPP projects in different development phases, mostly located in southern part of the country with the largest wind potential (up to wind speed mean value of 5.1 m/s at 50 m above the ground), as shown on the following figure, with its total planned capacity more than 5000 MW. Recently Croatian Hydro-meteorological service (DHMZ) prepared wind atlas for Croatia. It is not fully publicly available and it is not fully applicable for wind energy purposes. It can be used for indicative purposes only.

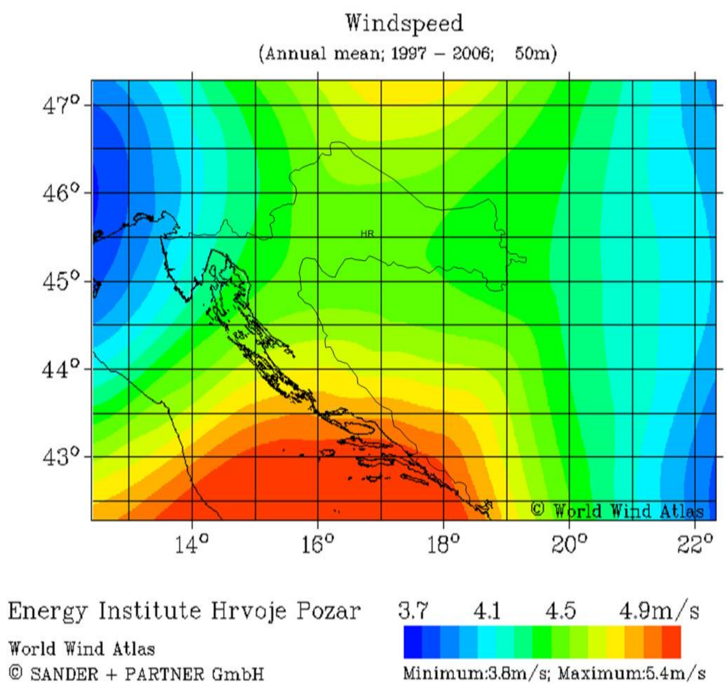

Figure 2-14 Wind speed map of Croatia

The first WPP in Croatia was commissioned in 2004. There are total of 101 MW in 5 WPPs with already issued construct permit and its construction is expected in the following short-term period. In addition, 6 WPP projects with its installed capacity of 259 MW have location permit issued. Another 4 WPPs have grid connection consent issued as a precondition for location permit. Its geographical diversity and installed capacities are shown on the following figure.

Figure 2-15 The most developed WPP project location and size in Croatia (end 2010)

In 1997 the Government ignited national wind energy program - ENWIND. In 1998 and 2001 there followed two publications (untitled ENWIND 1 and 2) that were dealing with wind energy potential, locations, procedures and other aspects of wind energy usage. In 2006 and 2010 Croatian TSO realized technical studies on possibility for WPP integration in Croatian power system and relevant integration costs. Other activities on WPP integration in Croatia were dominantly focused on WPP project development procedure and the definition of incentive system and feed-in tariffs. The Croatian Energy Strategy has been published in 2009 and it defines the target of 35% of the final electricity consumption (end-use of electricity) from RES by 2020, or more precisely, 9-10% from WPPs, which assumes total planned installed capacity of about 1200 MW by 2020. TSO within ENTSO-E system development group forecasted to reach 800 MW in 2020.

Legislative framework for WPP (RES) integration is fully defined since 2007. Till the end of 2011 it is expected that Law on RES will be adopted.

For more efficient process of WPP integration in Croatia there are two main limiting factors:

- Complex WPP development procedure and
- Available system reserve.

2.4.5. Macedonia

Having a share up to 40% of RES in the final energy consumption, mostly from the biomass and HPPs, Macedonia has also been listed among countries with relatively high use of RES. At the same time there are no WPPs in operation and no experience in WPP integration. But, there are 2 WPP projects that applied in 2009 with its total installed capacity of 250 MW. In addition there are 6 more WPP projects with applications for grid connection. The largest wind potential is shown on the following two figures (up to wind speed mean value of 4.2 m/s at 50 m above the ground). Detailed wind energy resource atlas and site screening of the Republic of Macedonia was prepared in 2005. It is the property of national generation company ELEM and it is not publicly available. It is expected that among the first ELEM will build 15 to 18 wind turbines with 2 to 3 MW of capacity each in the next two years. It is located in Bogdanci in the south of Macedonia, close to the Greek border, with the overall capacity of 37 MW. Besides that, one large WPP (~200 MW) is under preparation in the area of Štip in eastern Macedonia. Due to quite attractive wind potential and legislative framework (guaranteed incentives for 20 years) it is expected to have significant WPP growth in the next few years.

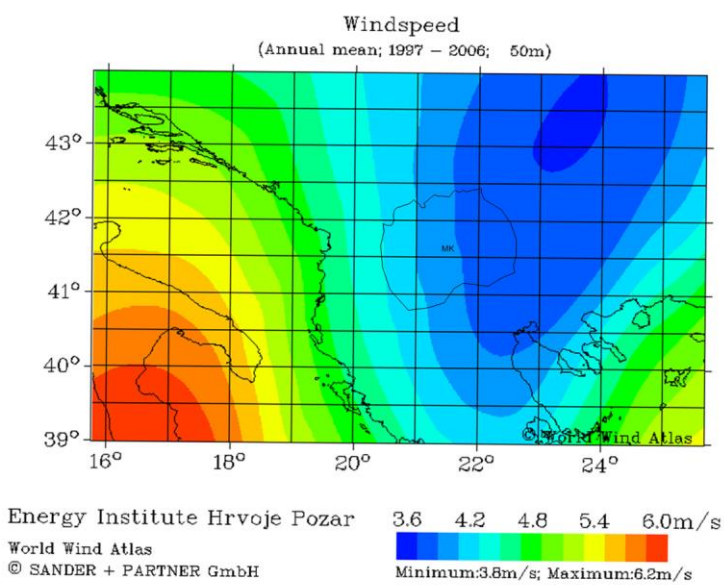

Figure 2-16 Wind speed map of Macedonia

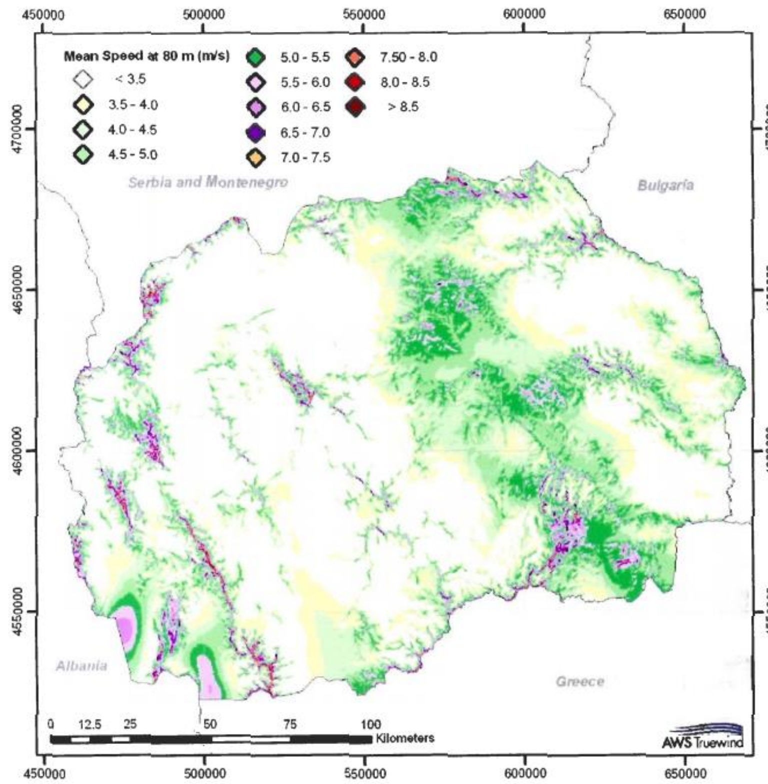

Figure 6. Wind Speed Map of Macedonia at the Height of 80m

Figure 2-17 More detailed wind speed map of Macedonia (Source: MEPSO)

RES development target is set to 21.5% of final energy consumption by 2020 out of which 4,2% is to be covered by WPPs. RES legislative framework is partly defined, while technical requirements for WPPs and Market Code are still missing.

New Energy Law entered into force by end of February 2011. In accordance with new Energy Law and taking in consideration Directive 2009/28/EC of the European Parliament, for the purpose of implementing the Strategy on RES, the Government of Macedonia, on the proposal from the Ministry, shall adopt Action Plan for RES covering a period of 10 years. Action Plan for RES shall define measures aimed to promote use of RES, and shall contain in particular: expected gross final consumption of electricity, fuels for transport, heating and cooling energy, targets set and annual dynamics for the increased share of energy generated from RES in the energy consumption; measures aimed at achieving the targets; the overview of relevant policies and measures on the promotion of the use of RES; specific measures aimed at addressing administrative barriers, information and training measures and appropriate transmission and distribution systems development and upgrade; incentives related to electricity generation, heating and cooling energy, biomass transport and use; possible joint projects with other countries, in the light of attaining the targets set in the Strategy on RES; funding sources; holders of activities and deadlines for the implementation of anticipated activities. Action plan is prepared with technical support, provided by USAID, and it is planed to be adopted by the end of 2011. In parallel, "*Wind Power Integration Study for Republic of Macedonia*" is under preparation and it is expected to be finalized by summer 2011.

TSO within ENTSO-E system development group forecasted to reach 150 MW in 2020.

For more intensive WPP integration in Macedonia there are several limiting factors:

- Complex WPP development procedure,
- Lack of legislative framework and
- Available system reserve.

2.4.6. Greece

Greece is one of the regional leaders in RES integration having the largest regional wind potential in the region of SEE (up to wind speed mean value of 6.4 m/s at 50 m above the ground), as shown on the following figure. Wind atlas for Greece is prepared and publicly available[9]. The first WPP in Greece was commissioned in 2000, while today there are 81 WPPs connected to transmission network, with total installed capacity of 1039 MW. In addition, there are 60 WPPs currently under construction, 216 WPPs in licensing phase and 401 projects are in wind measurement phase.

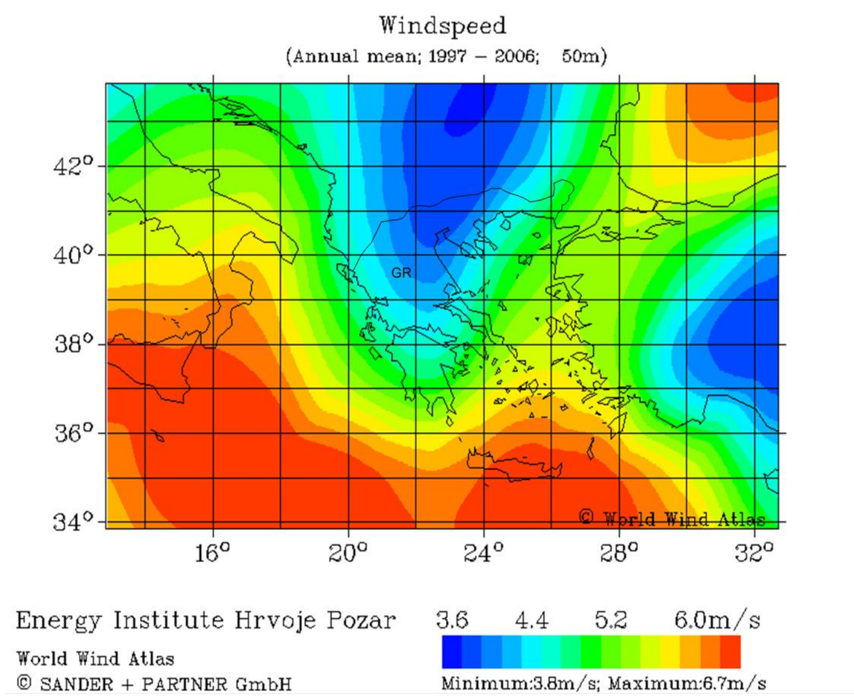

Figure 2-18 Wind speed map of Greece

The following figure shows existing and future WPP projects in Greece (with PSS/E model node numbers). Clearly, most of the projects are located on the southern part of the country.

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9 http://aims.cres.gr/grwind150/viewer.htm , http://www.cres.gr/kape/datainfo/maps.htm

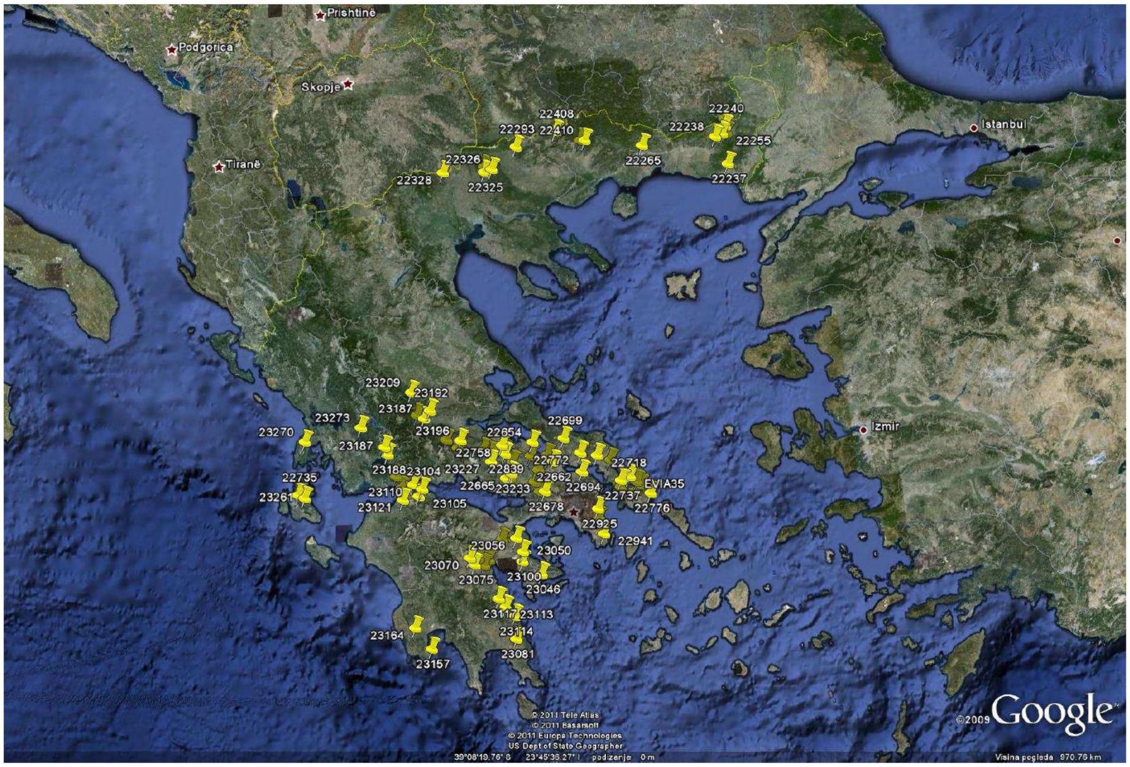

Figure 2-19 WPP projects in Greece with corresponding PSS/E node numbers

Legislative framework for RES is fully defined in Greece, with relevant Law 3851/2010 "*Accelerating the development of Renewable Energy Sources to deal with climate change and other regulations addressing issues under the authority of the Ministry of Environment, Energy and Climate Change*". National target for WPPs is set to 7500 MW till 2020, but TSO within ENTSO-E system development group forecasted to reach 6800 MW.

For more efficient process of WPP integration in Greece the main limiting factors are objections by the people, the local communities and permission acquiring difficulties.

2.4.7. Montenegro

One of the main characteristics of power generation in Montenegro is high dependence on hydrogical conditions (~75% of total installed generation capacity is in HPPs), meaning large share of RES. There are no WPPs in operation, but there are 4 WPP projects in wind measurement phase and additional 2 WPP projects in licensing phase. Total installed capacity of 2 most developed WPP projects is about 170 MW, with 96 MW in the first phase. Moreover, in Montenegro concessions for two most promising locations for WPPs were offered in public tendering procedure for the 20 years period of time (Krnovo and Možura).

The largest wind potential is shown on the following figure (up to wind speed mean value of 4.8 m/s at 50 m above the ground). So far, there are no detailed wind energy resource atlas and site screening for Montenegro.

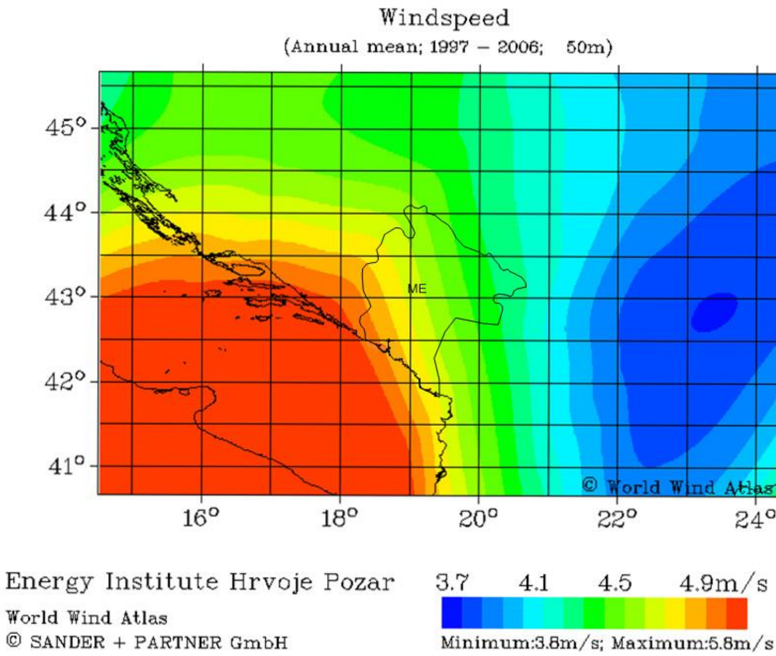

Figure 2-20 Wind speed map of Montenegro

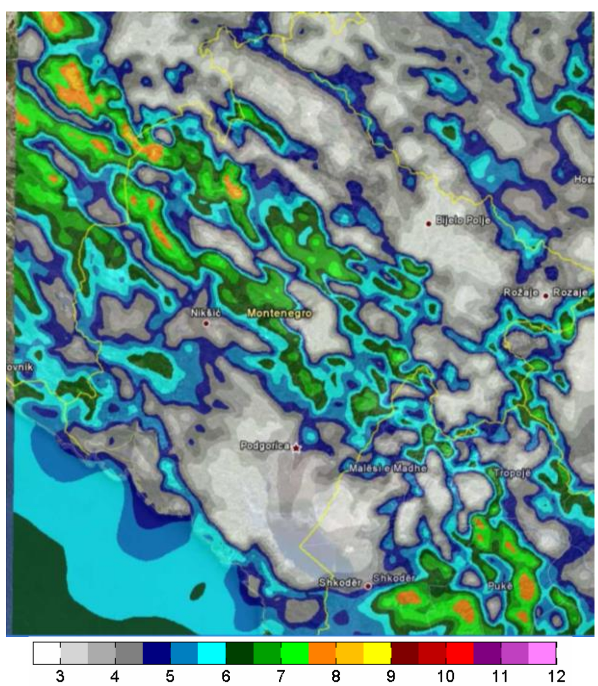

Figure 2-21 Yearly average wind speed (m/s) 80 m above the ground (Source: CGES)

The following figure shows location and size of above mentioned 6 WPP Projects.

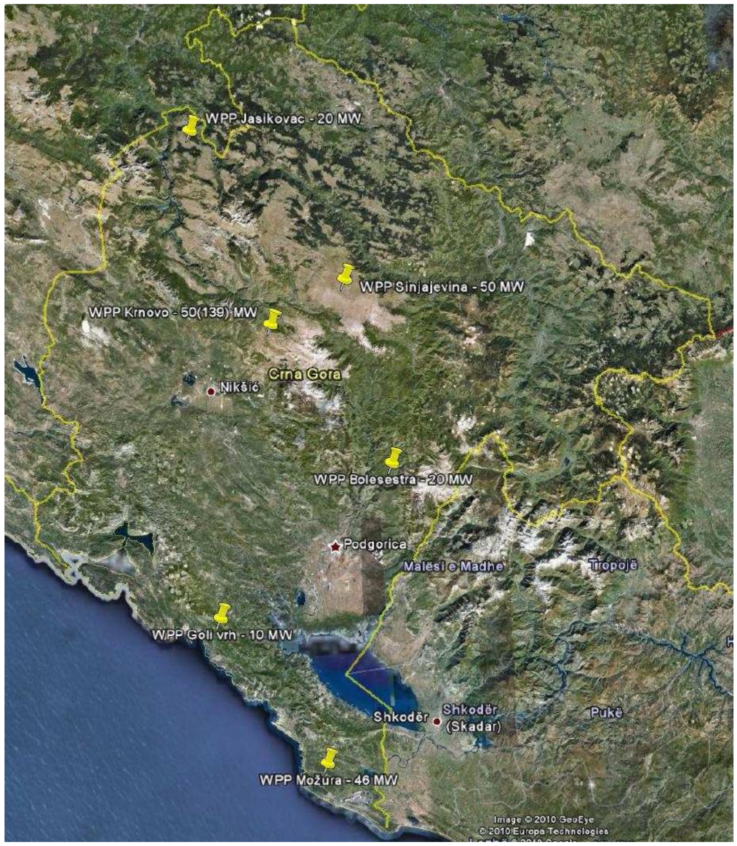

Figure 2-22 WPP projects location and size in Montenegro

Legislative framework for RES in Montenegro is not fully defined yet. The national indicative target for RES is still not defined, while WPP grid code requirements are also missing. TSO within ENTSO-E system development group forecasted to reach 180 MW in 2020.

Contracting parties of the Energy Community Treaty are under obligation to calculate mandatory RES target. Preliminary calculation for Montenegro is set to 29.5% by 2020. "*Montenegro Wind Integration Study*" in the frame of EBRD Western Balkans Sustainable Energy Direct Financing Facility - Institutional Capacity Building Project is expected to be finished by the mid this year.

During 2011, new Grid Code was drafted comprising Connection Code which also defines technical requirements for operation and connection of WPPs to the transmission network. The new Grid Code is expected to be adopted by the end of 2011.

For more intensive WPP integration in Montenegro there are two limiting factors:

- Lack of legislative framework and
- Available system reserve.

2.4.8. Serbia

The country's existing around 8400 MW of generating capacity is dominated by coal-fired plants (62% of total installed generation capacity corresponds to thermal power plants, 34% to hydro power plants and the remaining to combined heat plants). Large part of coal-fired power plants may have to be decommissioned by 2020, which means that other resources have to be built. It opens possibility to integrate WPPs. The potential for renewable energy remains largely untapped in Serbia, but officials say that this is about to change soon.

According to investors' findings, Serbia shows promising conditions for the installation of large WPPs, particularly in a number of areas located in the country's North and East. According to Serbia's Ministry of mining and energy before more detailed wind integration study, the country's total estimated wind power capacity to be connected to the system is 1300 MW, approximately 15% of the nation's total capacity. Ministry documents show locations in the north-eastern part of the country have a high wind potential based on wind speeds. Other locations potentially suitable for wind energy development include Midzor, Suva Mt., Vršački Breg, Tupiznica, Krepoljin and Deli Jovan. The first WPPs are scheduled to become operational by the end of 2012.

The largest wind potential is shown on the following figure (Figure 2-23) (up to total wind speed mean value of 4,4 m/s at 50 m above the ground). Local "Koshava" wind blowing is from south-east most time of the year. Microlocation measurements shows that the average wind speed could go up to 5 to 6 m/s. Total annual wind energy potential in Serbia is estimated up to 15,600 MWh/a.

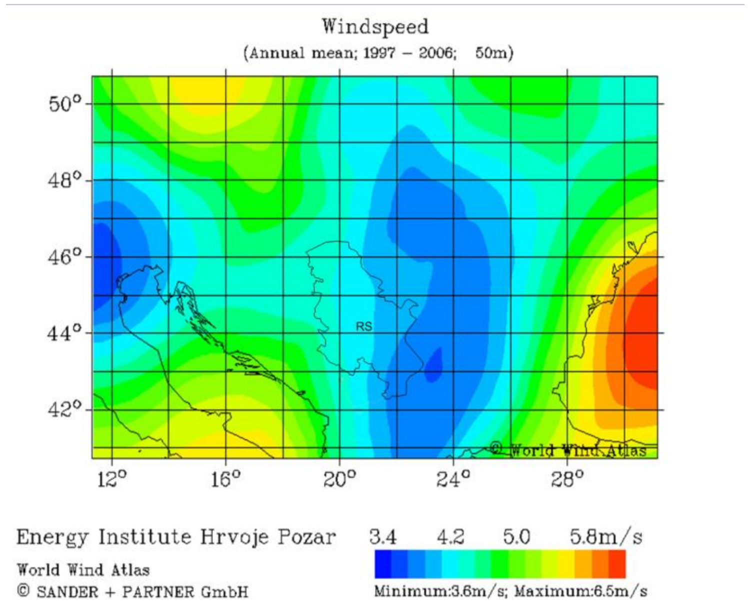

Figure 2-23 Wind speed map of Serbia

There is detailed wind energy resource atlas for Serbia available. Specific wind potential areas in Serbia are given on the following Figure.

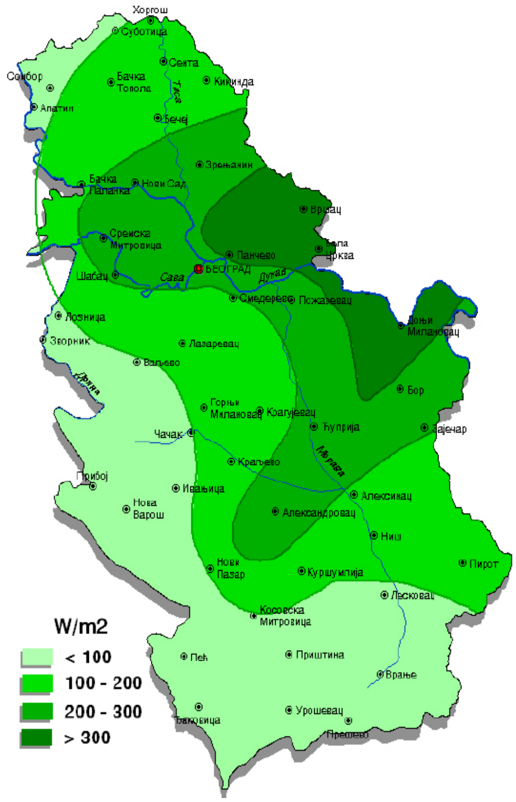

Figure 2-24 Wind potential areas in Serbia (source: EMS)

Generally, basic characteristics of WPP integration in Serbia at the moment are as follows:

- Large wind speed variations all over the country
- Higher wind potential in lower regions
- Good conditions for shipment of wind mills
- Higher wind potential in colder periods
- Wind blows relatively constant in colder periods
- North east is region of special interest with its usage factor near 30%, higher than European average, as shown in details on the following Figure.

Figure 2-25 Wind potential areas in North-East Serbia (source: EMS)

Currently, there are no WPPs in operation in Serbia, but there are about 20 wind parks in projects list with around 3000 MW capacity. Almost all WPP projects already have energy permission. At the moment they are issuing papers concerning grid connection technical conditions. Only one project is near to get site construction permission from the authorities. More than 75% of represented capacity is located in Norther part of the country (Vojvodina region), while the biggest single wind park capacity is 400 MW. It is important to point out that there is a short distance between preferred WPP regions and main load centre – Belgrade area.

Tariff system for RES in Serbia is currently based on feed-in tariff principle. Currently fixed feed tariff in Serbia is defined for maximum 450 MW.

By 2015 about 20% increase of electricity production from RES is envisaged in Serbia. TSO within ENTSO-E system development group forecasted to reach 2500 MW in 2020 for Serbia and Kosovo together. Legislative framework for RES in Serbia is not fully defined yet.

It is expected that Serbia's new energy law package will go far enough to unlock the country's potential for wind power. So far, it lacked guarantees output to be connected to the grid. Investors were unable to arrange to sell electricity from WPPs, since there were no clear power purchase agreement procedures as it is the main precondition to actually build WPPs i.e. to make projects bankable. A special government decree allows Serbia to buy locally generated electricity from new, non-polluting sources at 9.5 c€/kWh, twice the current retail rate. Investors' opinion is that there are "hardly any beneficiaries of this" because the broader framework is lagging. "*Wind Integration Study for Serbia*" was adopted in April 2011.

For more intensive WPP integration in Serbia there are several limiting factors:

- Wind energy potential,
- Tariff system on RES,
- Complex WPP development procedure and
- Available system reserve.

2.4.9. *Slovenia*

Without taking into account 50% of capacity of nuclear power plant Krško (~400 MW), Slovenia has relatively large share of RES generation, mainly in large hydro (1071 MW). So far there are no WPPa in operation (besides 2 MW of pilot projects), but there are 3 WPP projects in construction phase and 5 WPP projects in licensing phase. The following figure shows wind speed mean values on territory of Slovenia (up to wind speed mean value of 4.6 m/s at 50 m above the ground). There is no wind atlas on the country level.

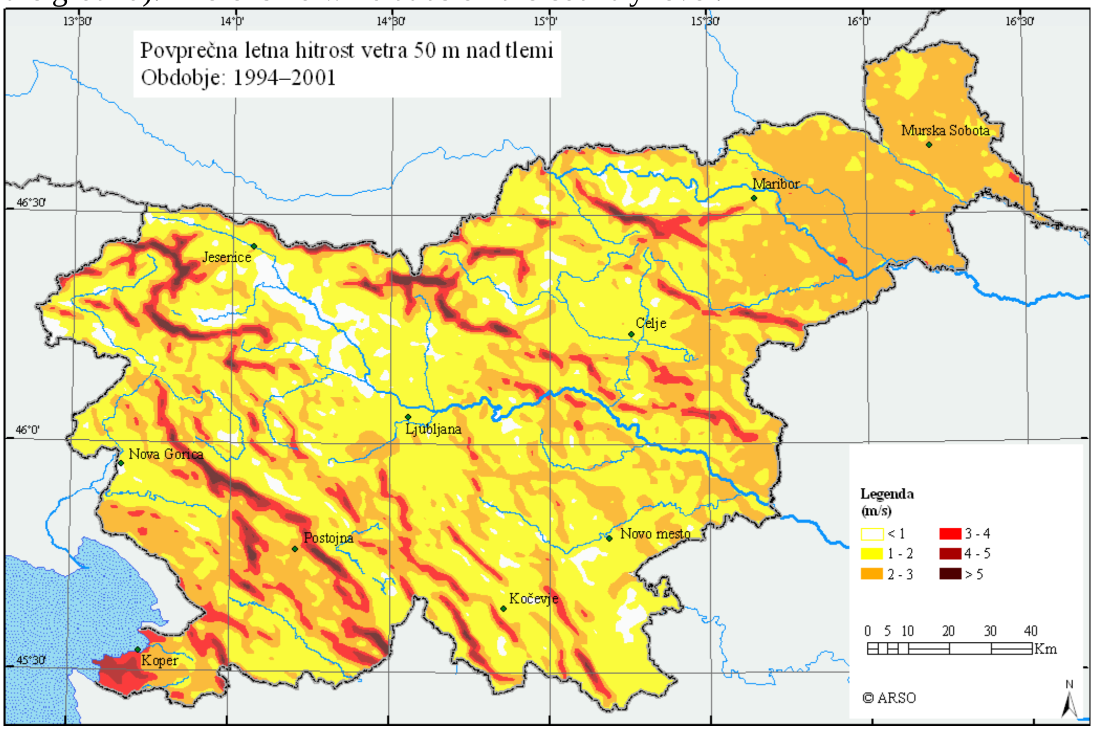

Figure 2-26 Average yearly wind speed map of Slovenia (50 m above the ground, 1971-2000) (Source: ARSO)

Ministry of Economy defined a National Action Plan for RES until the year 2020 as well as tools for promoting RES to reach 2020 targets there should be WPPs with installed capacity of 106 MW till 2020, less then in solar power plants – 139 MW.. According to National Action Plan for RES till 2020 there will be WPPs with installed capacity of 106 MW, less then in solar power plants – 139 MW. TSO within ENTSO-E system development group forecasted to reach 440 MW of WPPs in 2020. WPP integration study on the country/TSO level was requested by the TSO and done by the investors.

For more intensive WPP integration in Slovenia there are two limiting factors:

- Wind energy potential (as shown on the precious figure) and
- Network absorption capability in the WPP areas.

Generally, in comparison to the other regional countries chances for significant WPP developments in Slovenia are quite small, due to relatively low wind potential, as well as lot of touristic resorts in the mountains that could have been interesting for WPP sites. Also, in terms of RES targets Slovenia is more oriented to hydro and solar resources (in 2010 in Slovenia there were 23 MW of newly installed solar power plants).

2.4.10. Romania

In Romania RES generation has priority status. When the study input data were collected (late 2010), there were about 500 MW of WPPs in operation in Romania. But, year and a half later this value is more than double (01.01.2012 - 1140 MW). This spectacular increase of installed WPP capacity shows how dynamic the process is, as well as the future expectations. It was commissioned in 2010. In addition, since 2007 there are about 10000 MW of WPP applications for grid connection. Grid access contracts are signed for more than 3000 MW, while technical permits are granted for additional 4400 MW of WPPs, while additional 13000 MW of WPPs completed grid connection studies. According to the present generation structure the total amount of renewable energy possible to be integrated in Romanian PS, without significant restriction is around 3000 MW installed power. Based on the existing plans for generation development, on medium term the limit mention above may go up to around 5000 MW of WPP installed power. Romanian commitments toward the EU for medium and long term are around 4000 MW of WPPs. WPP generation export is not an option for the time being. In long term development horizon, in order to operate over 4000 MW installed RES generation, the existing power transmission network needs significant reinforcements. It is estimated that total investments program (for transmission lines only) exceeds 250 mil. €. Additional reinforcements are also needed in several distribution network areas.

The following figures show wind energy potential in Romania (up to wind speed mean value of 5,8 m/s at 50 m above the ground). There is no detailed wind atlas for whole country. There is a rough wind map in Energy Strategy, but the level of detail is missing.

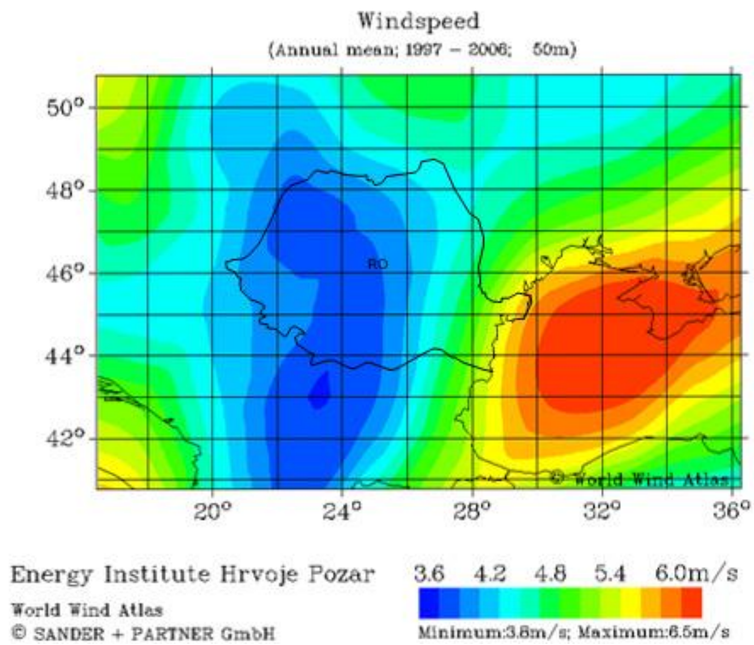

Figure 2-27 Wind speed map of Romania

Figure 2-28 WPP projects location in Romania (Source: Transelectrica)

Romania has fully defined legislative framework for RES. National RES target is set to 33% until 2010, 35% until 2015 and 38% until 2020. TSO within ENTSO-E system development group forecasted to reach 4000 MW in 2020. RES financial support is based on "green certificates", mandatory quotas of "green certificates" for suppliers, while producers are financially responsible for generation imbalances. Technical conditions for access to the grid are established as a standard and it is planned to become part of the Technical Grid Code. WPP integration study on the country level was prepared, as well as set of WPP connection studies for each specific location.

For more effective WPP integration in Romania there are two limiting factors:

- Available system reserve and
- Network absorption capability in the WPP areas.

It is estimated that half a billion euro is the volume of immediate investments the national transmission system operator Transelectrica must make for the thousands of MW worth of RES projects to become reality.

2.4.11. Turkey

By its size and potential Turkey is very different that the rest of regional countries. Last year Turkey's total energy demand was around 209 TWh. Its wind potential is among the largest in Europe with the wind speed mean value 50 m above the ground up to 5,6 m/s, as shown on the following figure. The wind atlas of Turkey is publicly available[10]. More detailed wind atlas shows that wind speed mean values at the level 30 m above the ground go even up to 10 m/s.

Currently, there are 39 WPPs in operation with total installed capacity of 1320 MW. The first WPP in Turkey was commissioned in 1998. In last few years interest in WPP project development grew intensively. At the moment there are 2283 MW of 66 WPPs under construction, 3483 MW of 76 WPPs has been licensed and additional 8474 MW is under evaluation. All together in Turkey there are 722 WPP projects in different development phases with total capacity of about 78000 MW. It is expected that till 2013 11600 MW of WPPs are to be connected to the system. It is interesting to mention that WPP projects were over-promoted since in only 1 day (Nov. 2007) the total installed capacity of the applications jumped over 70000 MW! It took almost 3 years to solve this problem since many projects were overlapping and the available wind connection capacity was limited.

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10 http://www.eie.gov.tr/english/index-e.html

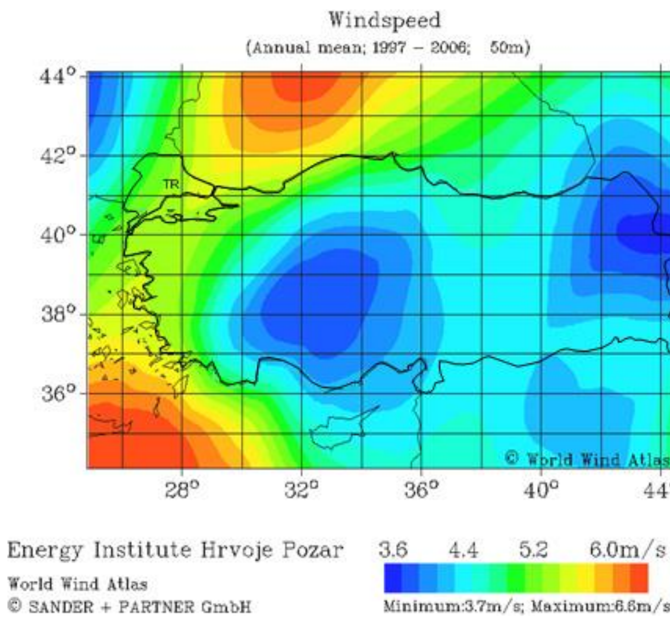


Figure 2-29 Wind speed map of Turkey

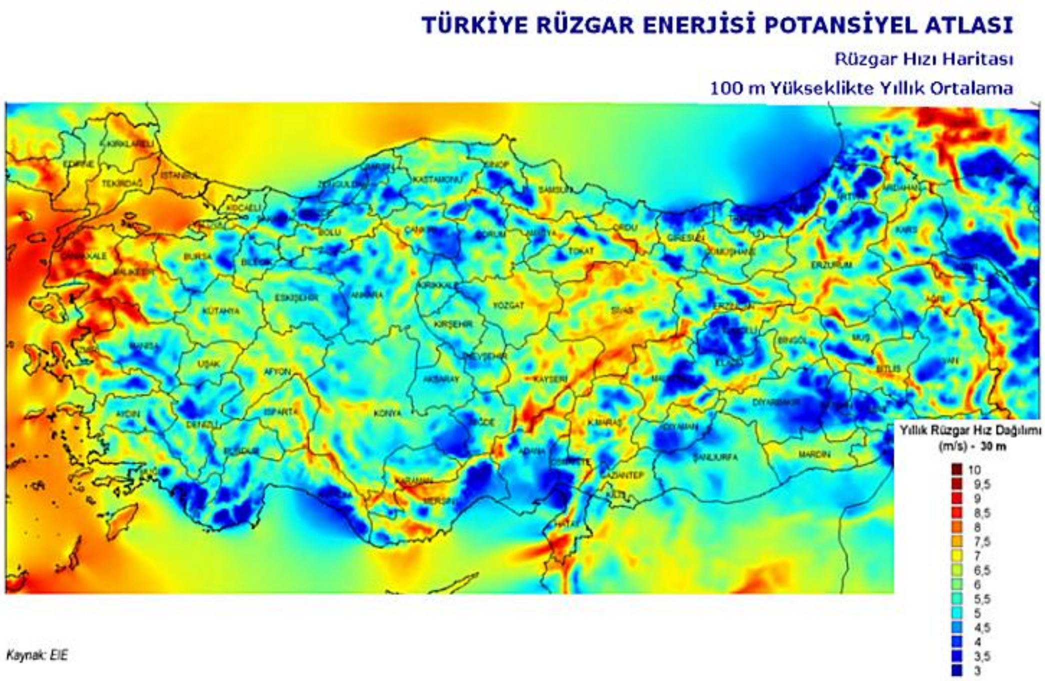


Figure 2-30 More detailed wind speed map of Turkey (Source: TEIAS)

RES legislative framework is fully defined. RES targets are set to 20 GW till 2023 and 30% from WPPs till 2023. In December 2010 Turkish Parliament adopted new law regulating the renewable energy sources market in Turkey and the new tariffs of RES.

Grid Code for WPPs was updated in 2010. WPP integration study on the country level is prepared. Turkish Electricity Transmission Corporation is responsible to prepare WPP integration studies and to define the available capacity for connecting wind generation in the country.

For more intensive WPP integration in Turkey there are two limiting factors:

- Limited available system reserve and
- Limited network absorption capability in the WPP areas.

2.4.12. Kosovo

Kosovo derives almost all its electricity (around 95%) from coal. The amount of energy produced during 2010 from RES is currently around 3% of total used energy during 2010 (total consumption is around 3,2 TWh). Since 2010, there are 3 wind turbines in operation, with total installed capacity 1.5 MW located on the mountain near Pristina's airport. In addition, there are 3 WPP applications for grid connection with its total installed capacity of 158 MW. Connection agreement is signed for 30 MW WPP with connection to 110 kV transmission grid. The following figure shows wind speed mean values on territory of Kosovo (up to wind speed mean value of 4,2 m/s at 50 m above the ground). Currently, there is no wind atlas for Kosovo, but one year wind speed measurements were accomplished in 2010 by the Ministry of Energy. It is expected that the collected data and wind atlas will be published very soon.

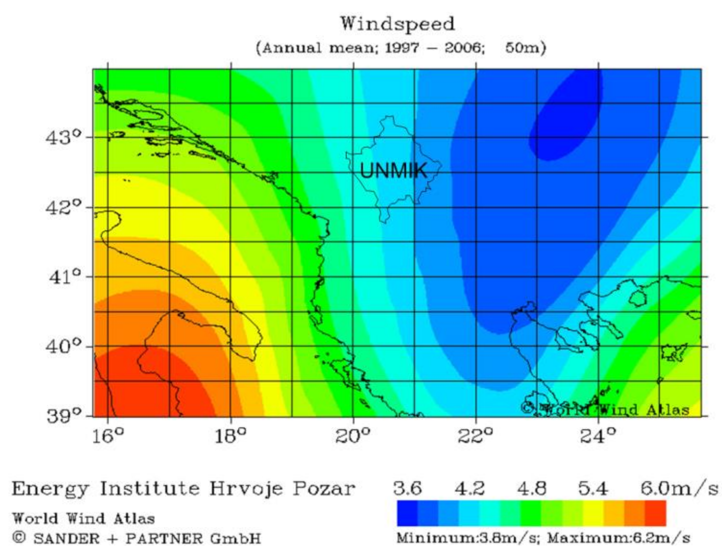


Figure 2-31 Wind speed map of Kosovo

The following two figures show geographical positions of two currently most advanced WPP projects under development.

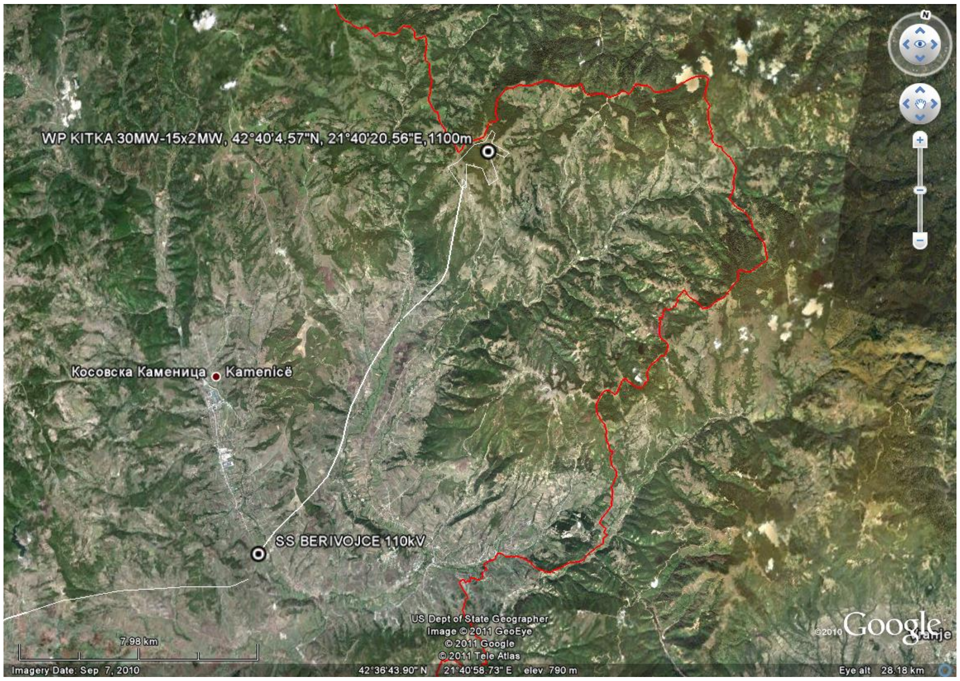


Figure 2-32 Geographical position of WPP Kitka (15x2MW=30MW) connected to SS Berivojce 110kV (Source: KOSTT)

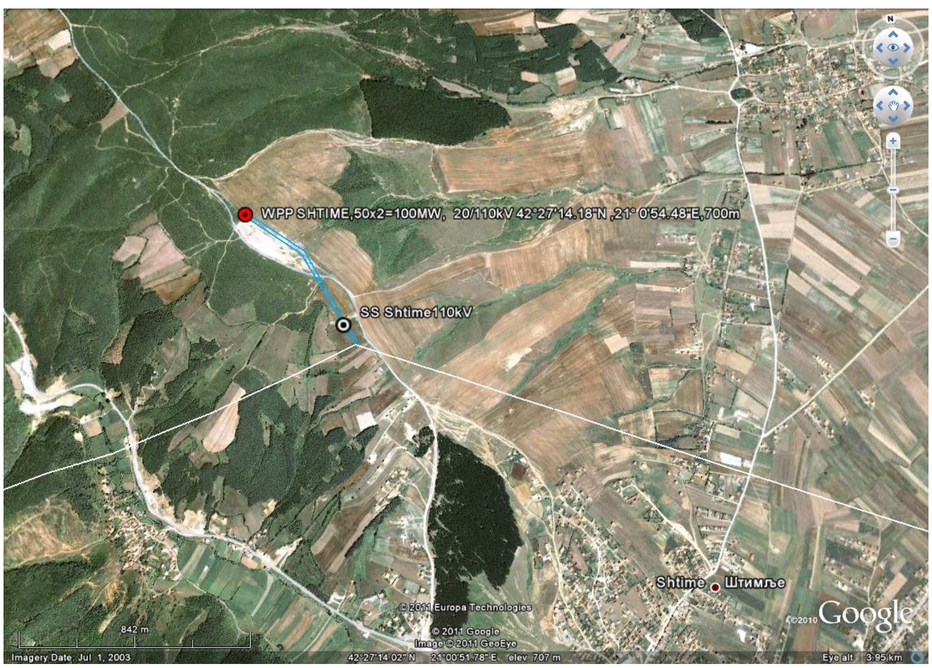


Figure 2-33 Geographical position of WPP Shtime wind Park (50x2MW=100 MW) connected to SS Shtime 110kV (Source: KOSTT)

Legislative framework for RES in Kosovo is not fully defined yet. National RES target is expected to be approved soon, based on draft document prepared by the regulatory agency. *Grid*

Code for Wind Powered Generating Stations (PO-KO-005) is adopted in 2010. WPP integration study does not exist. The studies were done for specific WPP connection purposes only.

For more intensive WPP integration in Kosovo there are two limiting factors:

- Wind energy potential (as shown on the previous figure) and
- Available system reserve.

3. RELEVANT STUDIES AND ANALYSES ON WPP INTEGRATION IN THE REGION

In this section the most important findings of existing WPP integration studies were presented. Since this study is dealing with regional approach to WPP integration, it is of utmost importance to keep in mind country specifics and development plans, especially WPP integration targets.

WPP integration is very challenging topic for every power system. Accordingly, there were studies on the WPP integration on the system level commissioned mostly by the regional TSOs, as shown on the following figure.

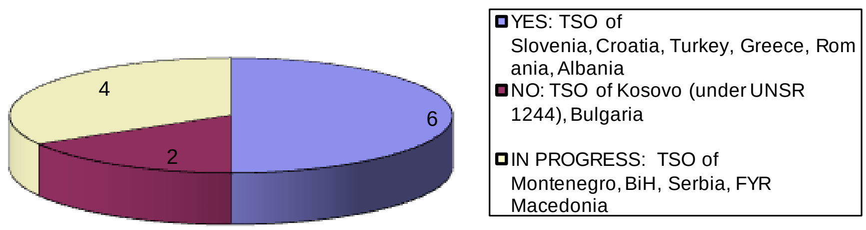


Figure 3-1 National WPP integration studies available

The following sections give available summaries of above mentioned WPP integration studies.

3.1. ALBANIA

EBRD and Albanian Ministry of Economy, Trade and Energy with collaboration of Albanian TSO are engaged in a study untitled “Capacity Building for Renewable Energy Investment in Albania”. The specific objectives of this project are:

1. Capacity building of large HPP
2. Wind Power Integration that consist to:
   - to enable OST to determine the appropriate levels of Wind Power Capacity which may be connected to the national grid and appropriate operational and technical parameters for management of connected WPP capacity,
   - to identify and evaluate necessary grid investment in order to increase the WPP capacity that could be connected.

The project started in mid 2011 and it is expected to be finalized till the end of 2011.

3.2. BOSNIA AND HERZEGOVINA

Under EBRD framework titled “Western Balkans Sustainable Energy Direct Financing Facility” there is a study project on wind integration in BiH. The Study is currently under preparation and it is expected to be finalized till the end of 2011. With permission of study beneficiary (ISO) here are given the main draft study results. In BiH there are very few WPPs that have been under way since 2010 while there are other 15 - 20 projects in different development phases. The following figure shows potential WPP locations (regions) within BiH.

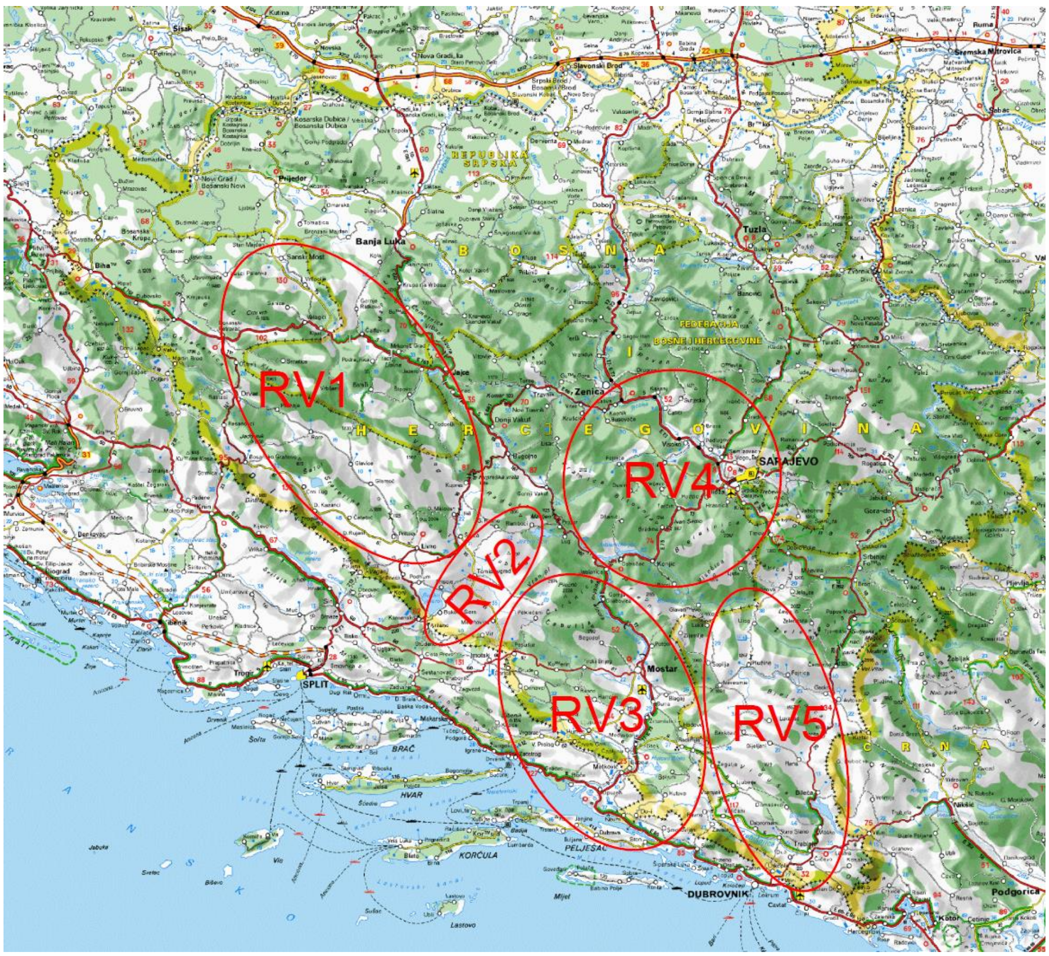


Figure 3-2 Potential WPP regions in BiH

With the WPP productivity assumption of around 2300 FLH, following scenario limits are defined:

a) 150 MW
b) 200 MW
c) 300 MW
d) 600 MW
e) 900 MW - concentrated
f) 900 MW - wide distribution
g) 1300 MW - concentrated
h) 1300 MW - wide distribution

The following table shows expected productivity per each WPP integration scenario. Having in mind all input conservative assumptions, these values are quite promising.

Scenario	300 MW	600 MW	900 MW - wide	900 MW - conc.	1300 MW - wide	1300 MW - conc.
Productivity (FLH)	2283	2510	2534	2393	2332	2378

The results of this analysis are presented in a graph that shows expected 10-min WPP generation variation ranges for all scenarios.

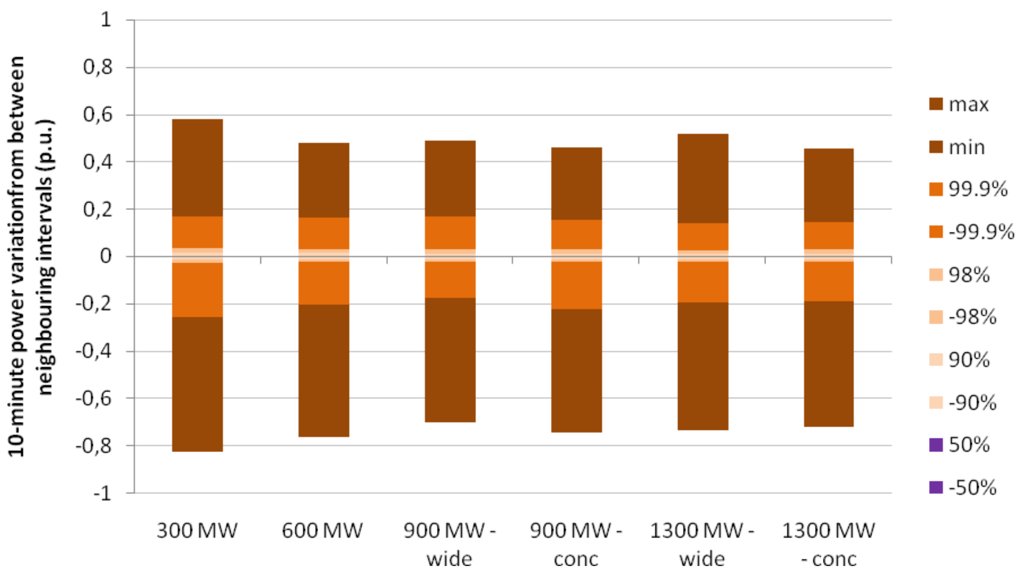


Figure 3-3 10-min WPP generation variations in BiH per each scenario

The graphs show that 99.9% of all 10-minute variations in 10 years occur in the range of roughly ±20% of total WPP installed capacity. However, the maximum range of variations is much wider, ranging from around -75% to 50% of total installed capacity. The large difference between the range in which 99.9% of all variations occur and in which the 100% of all variations occur is due to the fact that the maximum variations are a random event and the longer the analysed period, the larger the maximum variation. Of course, the theoretical maximum is -1 p.u. or 1 p.u. for instant loss of all wind power, or instant switching on of all wind power to full power, but in practice that is almost impossible. The range in which 50% of all variations occur is so narrow (roughly ±0.3% of total installed capacity).

Based upon above mentioned calculations required regulation capacities are also calculated, as given in the following table.

	300 MW	600 MW	900 MW - wide	900 MW - conc	1300 MW - wide	1300 MW - conc
Installed capacity (MW)	340	625	938	889	1297	1285
Share of time	**Required regulation capacity (MW)**					
98% of time (inadequate 175 hours a year)	59	97	139	140	192	190
99.9% of time (inadequate 9 hours a year)	120	207	287	284	357	380
Maximum - once in **ten** years	217	397	500	490	544	608

BiH is in relatively good position with respect to available HPP capacity capable for secondary control. But, in reality there are problems how to motivate generating companies to participate in ancillary service mechanism.

3.3. BULGARIA

Even though there was no officially published WPP integration studies on the national level in Bulgaria, different analyses and documents were prepared to accommodate large WPP integration. According to EC directive 2009/28/EC national target for RES penetration in Bulgaria is defined as 11% of the gross final consumption of energy at the year 2010, 13% for 2015 and 16% for 2020. The implementation of Directive 2009/28/EC EU, in the part concerning electrical power and network real time control (without disturbing the interconnection exchanges schedules) is possible, if only installation of no more than 1,800 MW WPP and 600 MW PVPP is permitted.

In order to increase of the transmission capacity in this region, are replaced conductors of 4 OHL 110 kV with new high temperature and will be built two new substations 400/110 kV and six new lines.
According to study, collaborated in Central Dispatching, the technical potentials for control of the Bulgarian EPS with respect of the existing and planned development of generation shows, that providing of the quality of control and security of EPS, according to the ENTSO-E standard, is possible if the installed capacity of renewables has not to exceed: WPP 1800 MW; Solar 600MW

The limiting values of renewables will be revised and actualized each year with respect of the actual development of the grid and existing power for regulation.

3.4. CROATIA

Study activities on WPP integration in Croatian power systems started in 2006. So far there were several studies analyzing different technical, economical and regulatory aspects of WPP integration. Based upon these studies and due to currently available reserve capacities TSO decided to set the maximum level of possible WPP integration to 360 MW. Since there are lot of projects under development (more than 150) it is expected that this level of WPP integration is going to be reached in the following few years. The latest study was commissioned in 2010. Within this study the wind farms development will be analyzed in phases from 400 MW to 1200 MW of total installed capacity in 200 MW steps. Those results with five main scenarios depending on the total WPP installed capacity:

a) 400 MW,
b) 600 MW,
c) 800 MW,
d) 1000 MW and
e) 1200 MW (it was set as WPP target for 2020 in National Energy Strategy).

The following figure shows promising total annual energy yield per each scenario.

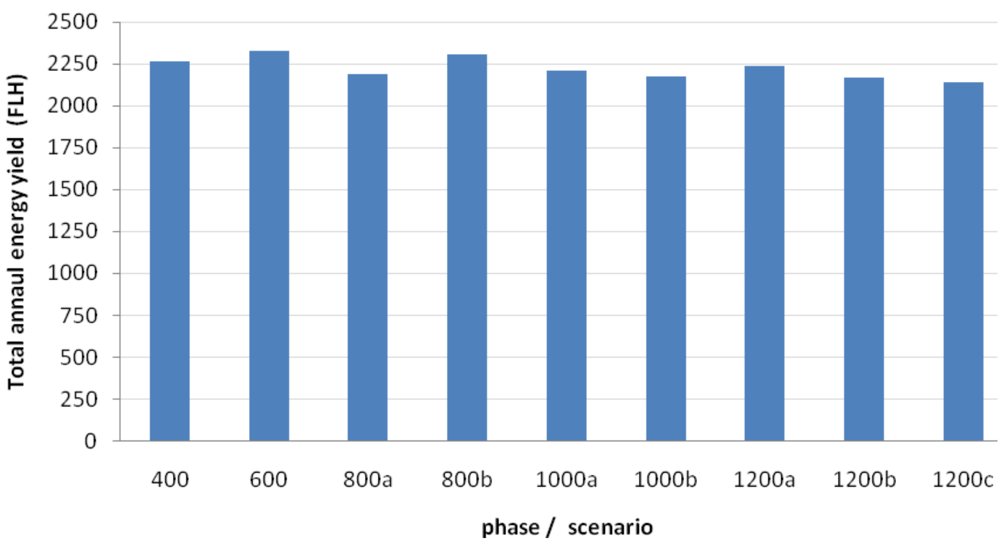


Figure 3-4 Total annual energy yield in Croatia per each scenario

The main problems in WPP integration in Croatia are small diversification of WPP locations (most of them are located in the range of 200-300 km with similar wind conditions) and lack of system reserve capacities. Currently, ancillary service (AS) mechanism is not fully developed yet. There is no AS or balancing market, since there is only one (dominant) generation company.

The following figure shows relatively high expectation of hourly WPP production variations per each scenario. Green columns indicate maximum and minimum variations, while red columns are ±standard deviation of hourly production variation. In the graph, the positive variation is a decrease in power and vice versa.

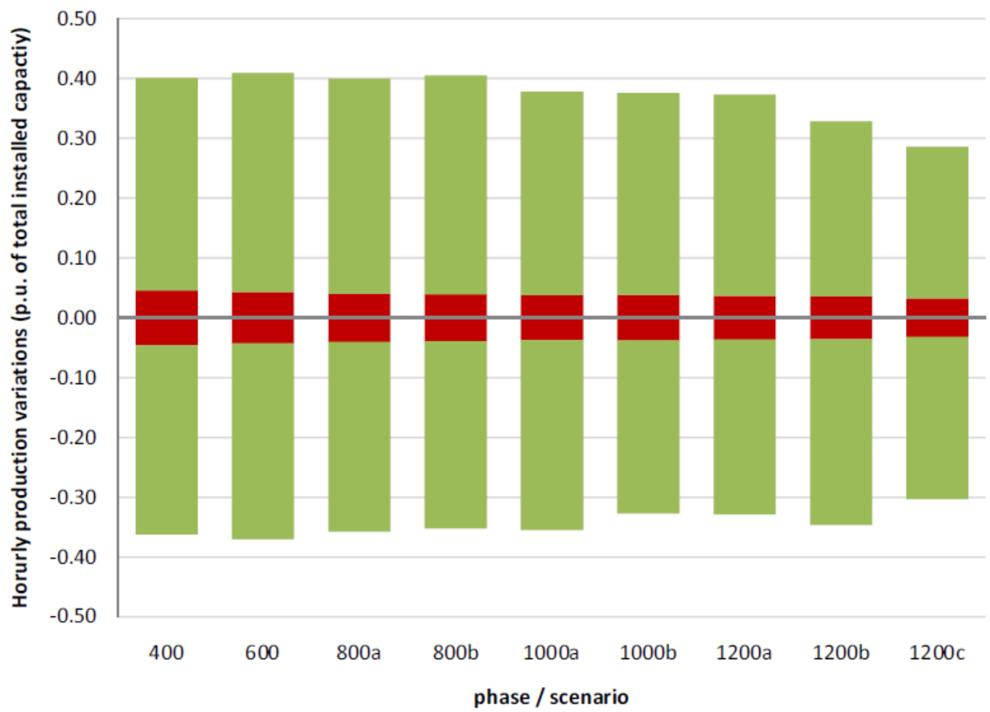


Figure 3-5 Hourly WPP generation variations in Croatia per each scenario

The following Figure indicates the levels of upward and downward regulation that may need to be held as reserve against non-forecasted variations in wind output in different wind development scenarios. Broadly speaking, for example, at a 99% confidence interval, for the scenario 1000a (ie 1000 MW of wind capacity), the TSO will need to hold 136 MW of tertiary reserve flexibility that can be instructed to increase or decrease output within 1 hour to cope with non-forecasted variations in energy delivered from wind farms. Within that reserve portfolio, about 91 MW to 100 MW will need to be able to respond within 10-minutes. For 100% of the time 30-40% of WPP installed capacity needs to be in reserve to cover non-forecasted variations. But, with installation of wind forecaster, the need for reserve capacity will be significantly decreased.

	95% of the time	99% of the time
	Hourly variation range (MW)	
400	±41	±72
600	±58	±101
800a	±78	±120
800b	±70	±118
1000a	±85	±136
1000b	±88	±137
1200a	±102	±153
1200b	±103	±160
1200c	±89	±138
	10-minute variation range (MW)	
910 MW	±58	±91
400	±34	±47

In parallel, it was calculated that different parties are going to face different costs.

WPP developers will face:

a) Costs of construction (not evaluated in this report)
b) Cost of network reinforcement – between 13.6 mil.€ and 21.7 mil.€ over the period 2010 to 2020; costs for each investor will vary by location. This might be considered a cost of 1.36 mil.€ per year although, given that these transmission assets will be depreciated over many years, the actual annual cost will be considerably lower.

Additional cost of up to 39-42 mil.€ per year by 2020 will be faced in order to procure reserves against wind volatility; this cost will be passed through to consumers – the additional cost per kWh would be 0,0015 €.

Conventional generators would face lower load factors in operation of their plants. This will result in some higher costs to consumers. We have not precisely modeled this cost but, utilizing the WASP model 'objective function' we calculated that increased deployment of wind will lead to a discounted additional cost to consumer of 194 mil.€ over the period from 2010 to 2030; this includes the cost of investments in the wind farms that consumers will pay for through feed-in tariffs. The conventional generation net cost of supporting wind farms would therefore be very roughly 0,0003 €/kWh.

Many of these costs are very approximate but all seem relatively modest, with the biggest ongoing cost being the need to provide reserve against the unpredictability of wind deployment.

3.5. GREECE

A high wind penetration is expected in the Hellenic Interconnected Power System, promoted by the favorable legislative framework dictated by the European Union policies for the environment but also from the very good wind conditions. Ambitious targets set by the National Renewable Energy Plan, reach the level of 6500 MW of installed wind power for the year 2020.

Due to this situation HTSO conducted a number of studies with the collaboration of the National Technical University of Athens (NTUA) in order to assess the impact of high wind penetration in the operation of the interconnected national power system.

The investigation conducted during these studies, covered the simulation of the dynamic behavior of the system, the impact of different wind penetration levels on the production of conventional units and the overall reliability of the power system. The findings of the studies mentioned above, regarding the dynamic behavior of the system can be summarized as follows:

- A fault ride through capability of wind turbines installed in the Hellenic interconnected power system is a necessity, in order to avoid the loss of significant generation due to low voltage conditions caused by normally cleared faults in the transmission system.
- The impact of high wind penetration in small signal stability and system damping is considered modest.
- Operation of large wind farms in voltage control mode can be beneficial towards avoiding voltage instability issues.

Impact of high wind penetration on the operation of conventional units and system reliability, was assessed using a methodology based on the Monte-Carlo sequential simulation approach. Examination of these issues highlighted a number of important consequences, including the following:

- Under high wind penetration conditions, operating hours of combined cycle power plants decreases. Indicatively, this decrease has been estimated to range from 5150 hours/year in a scenario of 3000 MW installed wind production to 4640 h/year in a scenario of 5500 MW of wind power. This issue is a direct consequence of wind penetration on the operation of conventional plants, in an open market environment and lead to the conclusion that there will be an impact to the economics of the new producers entering the Hellenic electric energy market.
- The total energy produced by wind farms (in the examined scenarios) that cannot be absorbed by the system due to security constraints is quite small. However, the frequency and duration of the respective events deserves further consideration
- The geographic distribution of the wind penetration is very important since the concentration to one area has an obvious impact on network security issues. In addition, it has a very significant impact on the issues dealt by this analysis since it may lead to significant and fast variations of the produced wind energy with severe impact on system regulation capability and security.

Overall, the most important finding of the above studies was the emerging necessity of taking legislative actions aiming at the obligation of FRT capability for wind turbines, the right to the HTSO to curtail wind power under specific system constraints and recently to foresee the possibility of wind turbines to participate in voltage and frequency control.

The overall conclusion is that a high wind penetration level in the order of 40% of the future peak load is possible. However, the increase of wind penetration should be done gradually, so that the adequate feedback on the system behaviour is received.

3.6. MACEDONIA

In Macedonia "Study for integration of wind power plants in the Macedonian transmission system"
was prepared by KEMA in June, 2011. The study included the following issues:

- to estimate the possibilities for WPP integration in Macedonian power system,
- to suggest the amendments to the Grid Code with technical requirements for connection of WPPs
- to identify the capacity of wind development from the grid view-point,
- to asses the grid investments due to wind penetration.

One of the most important conclusions is referring to the reserve capacity needed to handle WPPs. The impact of WPP installed capacity to required system reserve was notified as approximately linear. For WPP range between 150 MW and 600 MW the reserve requirements can be expected to:

- Increase by about 10% of every MW of wind power installed beyond the first 150 MW in case of upward reserves
- Increase by about 25% of every MW of wind power installed beyond the first 150 MW in case of downward reserves

Required system reserve capacities per each scenario in day-ahead and hour-ahead time domain are given on the following Figure.

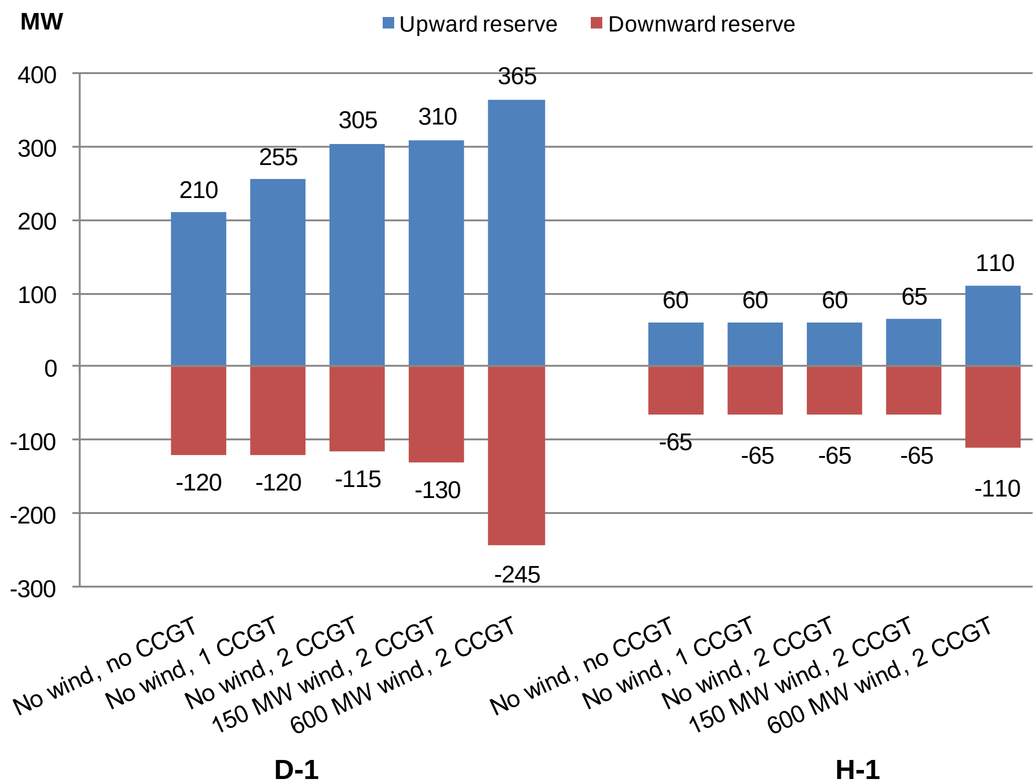


Figure 3-6 Required system reserve per each WPP scenario in Macedonia (source: MEPSO)

It was concluded that the current transmission network can support 150 MW wind power with reasonable reinforcements. It might be technically possible to accommodate even up to 600 MW of wind power, whilst ensuring the availability of sufficient volumes of reserve power. Operation of new CCGTs will provide additional flexibility to the system but also will require increased secondary and tertiary reserves on a day-ahead level. Planned PSPP Chebren and HPP Galishte may significantly contribute to the reserve capacity but time of their construction is questionable. It is necessary to introduce Wind Code requirements in updated Grid Code and to establish Day Ahead and Intra Day trading as potential mechanisms for mutual exchange of reserves and balancing energy, support regional initiatives.

Increase of installed WPP can only be achieved with optimization of operational dispatch and with flexible adjustment of cross-border exchanges on an hourly basis.

3.7. MONTENEGRO

Under EBRD framework untitled “Western Balkans Sustainable Energy Direct Financing Facility” there is a study project on wind integration in Montenegro. The Study has been approved recently. With permission of study beneficiary (TSO) here are given the main study results. In Montenegro there are two WPP projects under preparation (Krnovo (50 MW) and Možura (46 MW)), while other locations are nominated as potentially interesting, as shown on the following figure. For these two WPPs feasibility studies are in progress, expecting to be completed before end of 2011.

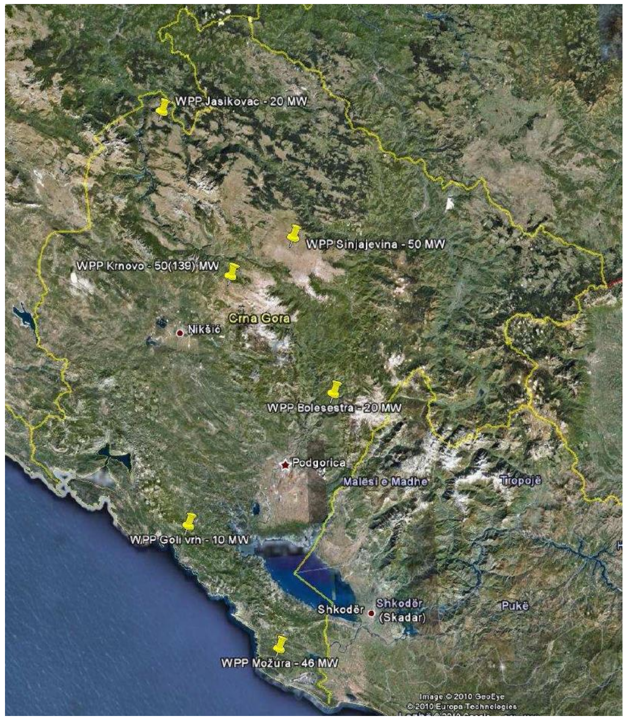


Figure 3-7 Potential WPP locations in Montenegro

In Montenegro there is a considerable gap between WPP potential and the degree to which the power system is prepared for WPP integration. Forecasting and balancing mechanisms are not defined and consequently there are no specified obligations for WPPs. Equally, the ancillary services mechanism (including payment arrangements) are not defined in detail even though the SCADA system and existing generation units show good potential for facilitating WPP integration. As a result the TSO is facing challenging conditions for WPP integration with many issues that need to be resolved in the very near future.

The Montenegrin power system is currently capable of handling approximately 46 MW of WPP installed capacity in all system states. This is constrained by the amount of reserve capacity currently constantly available (±26 MW). Additional reserve should be procured if further WPP is installed, as outlined in the following scenarios:

Scenario A: 96 MW of WPP → ±55 MW of reserve to cover all expected WPP generation changes

Scenario B: 185MW of WPP → ±140MW of reserve to cover all expected WPP generation changes

Scenario C: 285MW of WPP → ±175 MW of reserve to cover all expected WPP generation changes

In order to gain a better understanding of the production variations of wind farms, four specific frequencies of occurrences (probabilities of 50%, 45%, 4% and 1%) are determined and for each the frequency of positive and negative variations are calculated on the basis of real data. The results are presented on the following figure.

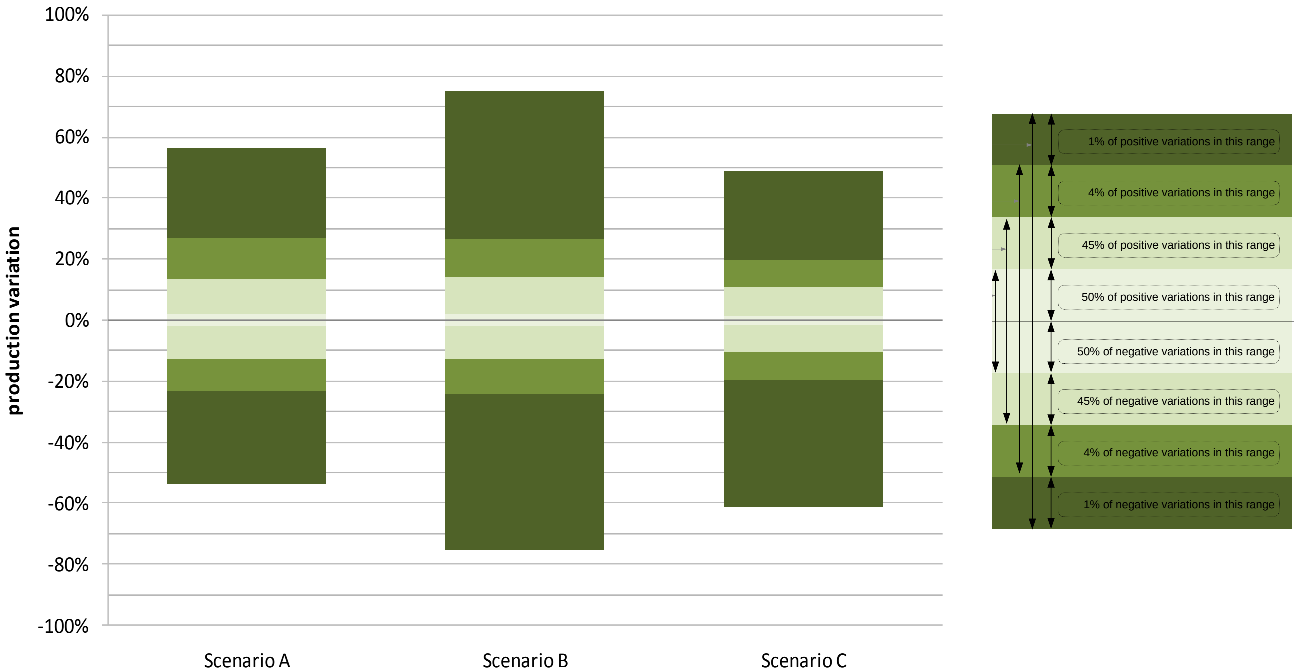


Figure 3-8 Hourly WPP generation variations in Montenegro per each scenario

Based on wind speed input used in above mentioned study the following table gives regulation capacities for all three WPP integration scenarios for three sub-scenarios (full coverage, adequate reserve in 99% of time, adequate reserve in 95% of time). Also, these values are calculated with assumption that there is no wind forecasting at all. It means that WPP generation changes are measured with respect to the generation in the previous hour.

	scenario A	scenario B	scenario C
total installed wind power (MW)	96	185	285
regulation capacity (MW)			
95% of time (insufficient for 438h/a)	13.2	25.7	30.9
99% of time (insufficient for 88h/a)	26.0	49.0	57.1
100% of time	54.2	139.0	175.3

This report provides a prioritization and cost estimation of network reinforcements ensuring secure take off of all electricity produced by wind power capacity. The analysis is based on three agreed scenarios of the development of wind power in Montenegro in the short to medium term (up to 2020). The estimation of costs has been done according to present unit prices of high-voltage equipment in the region.

According to the official CGES transmission development plan investments of 161,415,000 € are planned for the modernization and strengthening of the transmission system up to 2014. This includes around 3,000,000 € for the development of system control (NDC, SCADA, software and hardware, MMS, etc.). Investments for state estimation, training simulator, dynamic network configuration and outages analyzer in the existing SCADA system are also included in the plan. Besides investments in system control and the telecommunication network, the most important short-term investments for wind power plants integration will be:

- The construction of SS Zabljak;
- The operation of the 110 kV line Pljevlja1 – Zabljak under rated voltage (this allows WPP Jasikovac and WPP Sinjajevina to be connected to the network 110 kV);
- The construction of the 110 kV line Virpazar – Ulcinj (this assures double route for WPP Mozura production evacuation);
- The installation of a 400/110 kV transformer in Ribarevine (put in operation in December 2010; this removes network bottlenecks in the south-eastern part of a system, allowing wind projects like WPP Bolesestra to be developed).

The most significant expected network bottlenecks faced for WPPs integration are going to be caused by the WPP Krnovo connection to the grid with 139 MW of installed capacity in scenarios B and C. Some of the network bottlenecks will not be caused by wind power plants only, but as a consequence of mutual impact of wind turbines installation and new hydro power plants construction (HPP on Moraca river) and/or HVDC construction (Montenegro – Italy link).

Wind integration will impose additional costs for P/f frequency control that has to be assured from existing HPP Perucica and new planned HPPs, probably with additional construction of combined cycle power plant if IAP pipeline is going to be realized, especially if ancillary services market is not going to be established within the region.

The future generation market was modeled to assess the impact of increased wind penetration of future generation utilization. Due to the extent of importing in the current market, even with an increase in hydro resource as planned and a new thermal plant, prices at the margin will continue to be dominated by import prices for much of the year. The effect of increased wind penetration will be to displace both thermal plants and imports. For this reason, direct costs to consumers of paying the feed-in tariff are likely to be relatively modest. It is estimated that net costs to consumers of feed in tariffs (in million euros) will be as follows:

	2015	2020	2025
Scenario A	8.4	5.1	4.0
Scenario B	16.4	11.6	8.0
Scenario C	26.2	19.6	13.3

This is equivalent to the following additional costs in Euro cents per kWh.

	2015	2020	2025
Scenario A	0.17	0.09	0.07
Scenario B	0.33	0.22	0.14
Scenario C	0.53	0.36	0.23

Reserve costs are a different matter. We have looked at different strategies for procuring reserve against both wind non-availability and against unscheduled wind deliveries. Our analysis is on the basis that no useful forecasts of wind output are available at the day ahead stage, let alone a few hours ahead.

The analysis showed that the cheapest way of dealing with this variability was actually to assume that all wind delivered was unscheduled and was therefore spilled onto the system. CGES would then sell these surpluses to generators in the balancing regime by instructing turn down of output. This would earn revenue although it remains a cost to consumers because they will already have been paying for the scheduled conventional generation and imports that suppliers will have purchased. This reserve methodology has the following costs:

	Scenario A	Scenario B	Scenario C
Net cost to consumer (€/MWh of dispatched wind)			
2015	19.87	23.40	25.72
2020	13.31	17.13	20.92
2025	8.24	10.46	13.59
Net cost to consumer (€m)			
2015	4.61	10.99	18.44
2020	3.09	8.05	14.99
2025	1.91	4.91	9.74

3.8. ROMANIA

Study untitled „Power Grid Analysis for Wind Power Integration Services in Romania“ was adopted in April 2010. It covers different aspects of WPP integration. In this section the most important findings and conclusions are given.

3.8.1. International regulations regarding wind farm requirements

It has been considered the regulations of Great Britain, Denmark, USA, Germany and Spain, as the most representative countries and general UCTE requirements, as well as the conclusions of the first European study developed by ETSO The technical document proposed by Transelectrica is in line with the general requirements of the rest of the regulations. Specific comments to each one of the requirements are gathered in section 3.10. As a general comment, it is proposed to consider the following requirements:

- Wind farm will be submitted to the operating instructions supplied by the system operator, regardless the economic system or the dispatch priority established for this type of generation.
- The requested requirements could be submitted to certification fulfillment, required by the system operator. In some cases standard tests certifications will be acceptable.

3.8.2. Dimensioning of the operating reserves in systems with wind power generations

It is developed an analysis about the problems with wind power generation according to operating reserves (inertia, primary, secondary and tertiary reserve), according to the variability of wind power generation (in different periods, from sudden failure to schedule, diary and seasonal variations). Detailed examples of the operating mechanisms available for the system operator are shown, according to Spanish system. This system is considered as representative, of systems with weak interconnection and high level of wind farm integration. It is also shown, a wind power generation sizing proposal for Romanian system, based on a transient stability basic study (study with a single node; it does not represent a limitation in this case), the necessity to provide the operating reserves (in this system the limiting condition is the availability of tertiary reserve) and the specific operating conditions with the current generation, where is necessary to keep a minimum level of thermal power stations in off-peak scenario to dispose the necessary generation in peak condition; once the wind power generation is incorporated to the system, just by the replacement of thermal generation or even hydraulic generation, thermal power plants in off-peak operation would reduce their load level compared with current situation, to fulfill two requirements, primary availability and power availability in peak demand situation.

The conclusions indicate that most of the limitation would be provided by the tertiary reserve availability, which would give a maximum of 1,114 MW of installed wind generation. This limitation is based on a maximum capacity factor (generated power over installed power) of 70%. This value is taken from the statistic reference of Spanish case. Referring to the primary reserve and the necessity of disposing of thermal groups operating with low load in off-peak conditions to meet the next peak demand, it would be acceptable an installed wind power up to 3,673 MW, also taking into account a capacity factor of 70%.

The rest of the conclusions of the chapter are the following:

- To establish the priority of wind power production in the generation dispatch. Wind power operation has no relation with the demand curve, so the operation according to the resource is not always appropriate for the system.

- To take into account the minimum inertial generation criterion, which in Romanian system, cannot be considered as a limitation because of the importance of nuclear generation in the generation mix. It should be necessary to confirm that inertial values are correct, because the result depends on these values (especially in nuclear generation, the value is higher than the ones that were found in the available information)
- To establish, a priori, the reference incidence (wind power generation maximum failure). Recommendation: 70 % of installed power. It may be considered conservative, but in Romania, the generation will be concentrated in one area, therefore, the non availability condition may be common (atmospheric conditions).
- To establish a priori, if the participation of wind power generation in the frequency-power regulation is going to be considered. Recommendation: Request this as a connection requirement, but system reserves should be dimensioned independently. This recommendation is based on the following:
    - The consideration of the reference incidence (wind power generation maximum failure), which may have an atmospheric origin, totally independent from the operating conditions of the electric system.
    - Wind technology limitations, operating with low frequency, if they are accepted in the requirements.
    - The current dimension of primary reserve (63 MW) is based on the UCTE reference incidence. This reference incidence, 3,000 MW in the interconnected system, still considers generation failures like independent events, however, situation like Klaus Storm (year 2009) establish that in the interconnected system, generation failure situations with a common cause in a vast area may occur.
    - The same considerations may be applied according to the current dimension of the secondary maximum regulation band width, 600 MW, which is based on the UCTE criteria and in the conventional operation of the system, as well as the needs of tertiary regulation are based on the failure of the existing biggest group, but they never take into account a wind “reference incidence”
- To dimension the reserves in short-term:
    - Consider the possibility to increase the secondary band width. During the analysis of the Spanish case, there has been detected some conditions where the secondary current band width runs out.
    - Tertiary: is the limiting element for the installed wind power, considering the current availability. If wind failure reference incidence is considered as 70% of the installed power (maximum wind power capacity factor), the limitation will be 1,114 MW of installed wind power.
    - To consider the possibility to use an operating tool similar to the deviation management mechanisms in Spanish case, so the limit considered by the tertiary current availability, may be increased. Possibly, it just has sense if there are combined cycle power plants or peak power plants; because its use is limited to certain situations and it would complicate the operation of Romanian markets.

3.8.3. Long term adequacy studies. Capacity factor

This chapter summarizes different references to establish the capacity factor (ratio between generated power and installed power). The recommendation is to use a restrictive criterion and a capacity factor of 5-10% for the long-term adequacy studies, because there is no statistic experience in Romanian case.

3.8.4. Procedures for access and connection. Studies of the Electric System

In this chapter general access and connection procedures and the criteria used in the studies are explained. It is also checked the reference documentation in Romanian case. The recommendations are the following:

- Again, to establish the technical requirements prior to the network access studies
- It shall be compulsory for the developers to provide complete models of the facility, in form of equations and block diagrams, with all the specific parameters of the facility, as well as the templates used by the operator software in the dynamic studies.
- To establish a fulfillment certification protocol, where the standard certifications delivered by authorized entities may be considered for a part of the requirements.
- To establish a standard payment for the access studies, avoiding individual process of bidding acceptance (this process is valid and correct when there are few access requests, but it could be very long and inaccessible if there are too many applications).

3.8.5. Criteria for the distribution of costs and wind farm location

Main recommendations are the following:

- To establish a mechanism to determine the renewable generation to install during each period, which may take different administrative ways, like open tenders where the installed power capacity is put out to tender. This solution allows to keep the freedom principle in the generation promotion while the analysis of the needs of strengthen in the network, in a total uncertainty scenario, is avoided.
- To establish, with a technical criterion, a generation profile desirable in every period, establishing the connection points with a balance criterion, taking into account the location of the resource and the minimization of the lines to be built, but also taking into account the electric system necessities (for example, with the criteria of avoiding concentration of generation, avoiding unnecessary opening of current lines, and considering current transformation capacities, etc.).
- To establish the cost of the reinforcement of the network in every period, to distribute between the applicants who complete the connection process and the system operator (taking into account that new facilities of the network are going to be used by the existing generators, although their origin are not these existing generators)

- To determine shared connection facilities for the new applicants, in order to prevent a substantial increase of the number of network circuit breakers. To establish installed minimum power (MW) for the new shared generation circuit breaker. Shared facilities shall be paid by the facilities connected to the same point, with possibility of partial compensation if node capacity is increased in the following assignment period.
- To establish a standard price for some of the reinforcement equipment (for example, price of a new circuit breaker according to the voltage level, line circuit according to the voltage level and capacity, transformer according to voltage level and capacity, etc.).
- To establish the figure of the node representative, who shall be the speaker with the network owner and shall represent all the facilities connected to a node.
- To request the guarantees for every new application for the connection to the network, with refund once the facility connected to the network has started.
- To establish an administrative register of the renewable generation installations, where all the installation shall be registered until the power by periods is complete. To be registered, several administrative or economic guarantees may be set, like the guarantees mentioned before.
- The procedures of permitting of the new generation, connection to network facilities and new developments or modifications of existing network should go together; this must be known and accepted by the authority.

3.8.6. Organizational structure and resources to control renewable energy generation

This chapter summarizes the structure and resources of the control centers according to Spanish system. This system considers a control center for special regimen generation (renewable < 50 MW). This control center was visited by Transelectrica delegation in December 2009.

3.8.7. Steady state analysis of the network

The results of the loads and voltages steady state analysis indicate that acceptable wind power generation on each scenario reaches the following values.

Table 3-1 Acceptable wind power generation according to Network steady state analysis

	Generated wind power MW	Installed wind power (factor 0,7) MW
Winter peak 2019	3,198	4,568
Winter off-peak 2019	1,736	
Winter peak 2014	2,500	3,571
Winter off-peak 2014	1,549	

If it assumed that the increase of wind power generation is compensated for the thermal generation dispatch, without modification of the production of the nuclear or hydro power groups, and it is also assumed that an increase of 15% is acceptable according to exportation values in Romanian area.

The identified problems, in general minor problems except for several under-voltage values, do not seem to be related with the integration of wind power generation. Saturation in lines related to this cause is not detected. Network steady state analysis does not add additional limitations to the ones identified because of the operation reserves.

In order to a real time operation, it is necessary to take into account:

- It has been assumed that the capacity to compensate reactive power in the thermal generation redispatch is maintained at the corresponding nodes; therefore additional compensation elements may be necessary if complete groups are taken out of service.
- Wind generators must contribute to voltage control, according to the requirements of the previous chapters.
- The study is just a steady state condition, where the redispatch of the operating nuclear an hydro power units has been restricted in the base case, maintaining their initial production. In real operating conditions, acceptable thermal redispatch may not reach the dimension considered in this study, if as it was mentioned before, some groups must continue operative in off peak scenario to assure the demand of the next peak. Taking into account starting times, this should establish an additional limitation to the acceptable wind power production, considered in the steady state analysis.
- The increase of the considered interconnection must be studied with the system or systems which suffer this modification, due to existing commercial agreements.

According to the analysis, final conclusions are the followings:

- In the Romanian case, the restriction for the installation of wind power generation in 2014 and 2019 is established by the characteristics of the generation plants (without wind power generation), specifically by the availability of tertiary reserve and by the availability of a generation with a capacity of response fast enough to compensate the variations of generated wind power.
- Power network does not mean particularly restrictions in the different scenarios. The distribution of wind farms seems to be appropriate and overload and voltage problems were not detected. It may be necessary to add reactive compensation elements if in the generation redispatch, conventional groups are left out.
- Connections of the new generation must look for the existing network and not vice versa
- It is necessary to incorporate in the rules the technical requirements of wind farms previous to the installation
- It should be established a planning for the installation of the wind power generation for periods, so the integration may be developed in an orderly way and the complementary

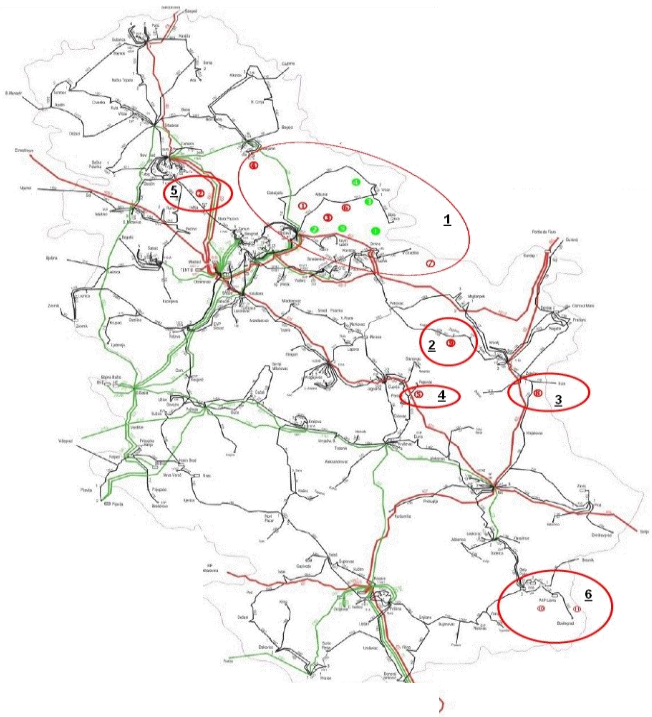
resources may be available to guarantee the safety and stable operation of the electric system.

3.9. SERBIA

Study titled “Wind Power Integration Serbia” was adopted in April 2011. It covers different aspects of WPP integration. With permission of study beneficiary (EMS) here are given the most important findings and conclusions are given.

The Serbian Energy Law requires the general development of utilization of renewable energy sources. Based on wind measurements and wind potential studies available so far especially the South Banat Region in Vojvodina Province is the preferred area of wind power utilization in Serbia. Altogether 16 projects were officially known in 2010 as per respective applications representing a total capacity of around 2,600 MW (see the following Figure), where 5 of them already got general energy permission by the Serbian Ministry of Energy and Mining. Most of the projects with about 75% of total capacity are located in South Banat. The current decision of Serbian Government defines a limit of 450 MW of wind power capacity covered by a special feed in tariff and all additional wind power is subject of free trade.

Based on the grid topologies, operation regimes and exchange scenarios network analysis was made to identify network limitations caused by wind power integration. Respective results were used for modification of grid connections to optimize wind power integration. With additional network upgrades, to resolve local bottlenecks, those calculations give the general result that the network limitations from transmission capacity point of view amount to maximum 2,000 MW of possible wind power in-feed. The study findings were that from transmission capacity point of view 2,000 MW of coincident WPPs require only few reinforcement and extension measures in the 110 kV network.



WPP	P (MW) per phase
Bela Anta	120
Belo Blato	10.5 + 10.5
Bela Crkva	37.5 + 150
Bavanistansko polje	188
Čibuk	50 + 250
Dolovo	150 + 200
Golubac - Krivača	112.8
Košava	50 + 67
Šušara	60
Vršac	100 + 300
Žagubica	63
Vrška čuka	189
Čestobrodica	50 + 230
Inđija	20
Milevska	66
Vardenik	102

Figure 3-9 WPP projects locations in Serbia (Source: EMS)

In the next step, integration of WPPs into Serbian power system was analyzed from the aspect of system reserve taking into account ramping capabilities of existing power plants. Under these circumstances the maximum wind power in-feed in Serbia amounts not less than 900 MW (1,000 MW of installed wind capacity by utilization factor of 0.90). Integration of the wind generation will require changes in power and transmission system operators' practice and involvement of more sophisticated software tools for prediction and management of system operation taking into account wind forecast management systems with forecasting scenarios for wind velocities. Need for more secondary power reserve was also identified in order to increase wind power penetration in the system

The economical effects of wind power in-feed were also investigated. Due to decreasing operation and full capacity hours of TPP generation costs were assumed to increase accordingly by inverse proportionality. So, conventional generation costs are assumed to increase by 1.5 c€/kWh till 2020 with a maximum wind power in-feed of 2,000 MW as per experience made in countries with high wind power penetration. The share of wind power generation costs amounts to 0.2 c€/kWh, which leads to total price increase of 1.7 c€/kWh. With an existing energy market the so-called merit-order effect, the switching-off of most inefficient and expensive TPP, occurs that can lead to a converse energy price decrease.

This part of the study shows the proposed connection points and lines of all wind power plants respectively the costs for grid connection, extension and refurbishment measures for both scenarios. From system operator point of view two strategies for wind park connections are possible:

The costs for grid connections of all wind parks considered in the study are assumed to be about 133 million €. The costs for grid reinforcements and extensions amount to approximately 21 million € and have always to be defrayed by the TSO. In all European countries with high wind penetration those grid reinforcement costs are shifted to the end customers via grid utilization fees. The cost sharing for grid connections between the wind park operator and the TSO depends on the strategy used. Anyway the wind park operator should pay the costs for all measures necessary between the wind park and the grid connection point.

4. POWER SYSTEM CONTROL WITH RESPECT TO WPP VARIATIONS

This section deals with power system control with respect to existing WPP variations in the region, as well as expected WPP variations in time horizon of 2020. In the first subsection general overview of WPP impact on power system operation is given. Then, detailed WPP generation data were collected for Greece, Romania, Bulgaria and Croatia in the period 2009 - 2011. Finally, expected future WPP generation is estimated based on the inputs officially prepared by the relevant ENTSO working group. Special importance is given to required reserve capacities needed for WPP balancing. Based on these analyses benefits of the regional approach to WPP integration were estimated.

4.1. GENERAL OVERVIEW

Power system operators are facing with system variability and uncertainty since the very beginning of power system operation. Demand variations on hourly, daily or seasonal level have been a fundamental characteristic of all power systems since the first consumer was connected to the first power plant. Consequently, all power systems have a relatively large range of flexible resources to manage this fluctuation. In most of the cases these flexible resources are dispatchable power plants, but demand-side management, power storage facilities, interconnections to neighboring power markets may also help a bit. The main question with WPP integration is:

Can the use of these resources be enhanced efficiently to balance additional WPP variability?

The other important question with WPP integration is:

What share of WPP penetration is possible with more effective use of *existing* flexible resources?

On the global level there are several detailed studies with these two questions[11]. A principal finding is that there is no one-size-fits-all answer to the last, very common question. As stated in IEA study, power systems differ tremendously in design, operation and consumption patterns, in the natural resources that underpin them, the markets they contain, and the transmission grids that bind them together.

[11] The most recent one is: Harnessing Variable Renewables – A Guide to Balancing Challenge, IEA, 2011

Furthermore, and as this study analysis shows, there is likely to be a wide gap between what is technically possible and what is possible at present. In other words, some systems are better able than others to manage large variable RES shares of electricity production, and direct comparison among them of variable RES deployment potential from the integration perspective is inappropriate.

Integration costs can vary dramatically from area to area as a result of differing flexible resources. Consequently, cost analysis needs to be specific to the area in question. Several studies have been conducted around the world in recent years. Most have focused on the United States and Europe, as shown on the following Figure.

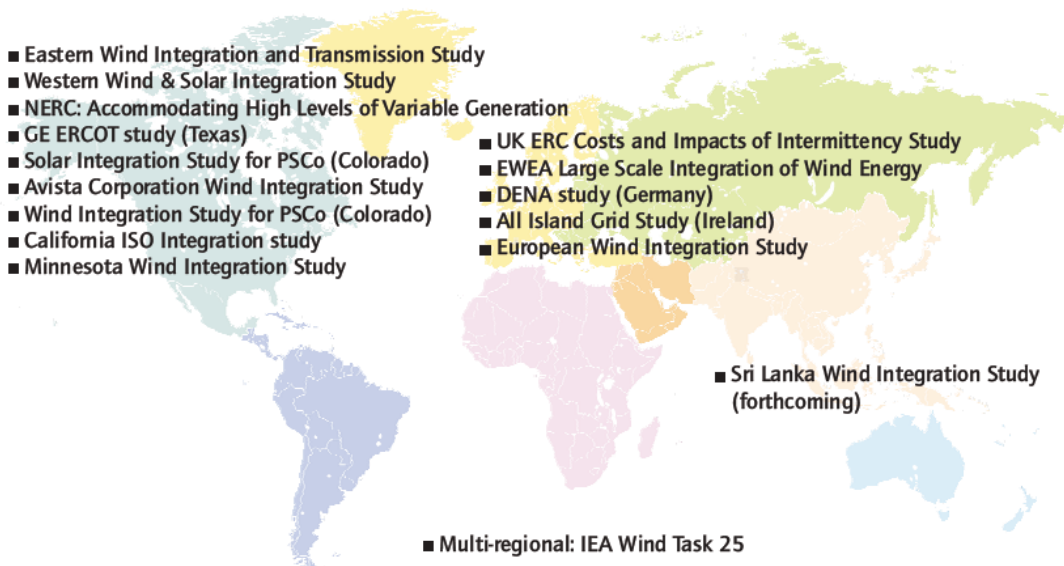


Figure 4-1 Recent studies on the WPP integration and balancing costs (Source: IEA)

To address balancing capability of existing flexible resources on the global level, the Grid Integration of Variable Renewables (GIVAR) project was launched by International Energy Agency's Renewable Energy Division. GIVAR Project has developed the Flexibility Assessment (FAST) Method that is consisting of four steps to identify the present potential for variables RES share in electricity demand (see the following Figure):

1. to assess the maximum technical ability of the four flexible resources to ramp up and down over the balancing time frame. The timeframe for balancing is considered to be 36 hours; this period will see the maximum extent of variability in most cases. Within this period, three further timeframes are assessed: 6 hours, 1 hour and 15 minutes. This is the **Technical Flexible Resource**.

2. to capture the extent to which certain attributes of the power area in question will constrain the availability of the technical resource, to yield the **Available Flexible Resource**.
3. to calculate the maximum **Flexibility Requirement** of the system, which is a combination of fluctuations in demand and variable RES output (the net load) and contingencies.
4. to bring together the requirement for flexibility and the available flexible resource to establish the **Present variable RES Penetration Potential** of the system in question.

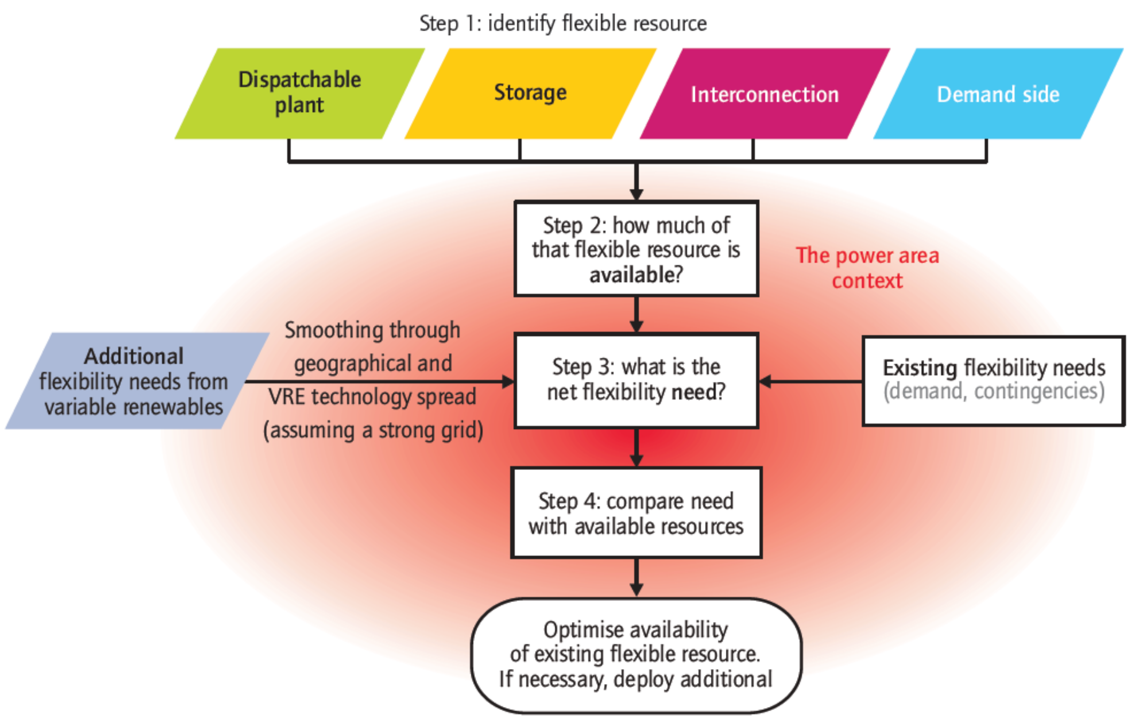


Figure 4-2 Flexibility Assessment (FAST) Method for identification of the present potential for variables RES share (Source: IEA)

Within this study the authors will try to pass through all four steps. But, its deep analysis strongly depends on available input data collected by the regional TSOs involved in this project. Having in mind that this is the first SEE regional study on this issue, it is a big challenge.

The second issue that has significant impact on WPP variations handling is wind forecasting. All of this is much easier with adequate wind forecasting system. But, wind forecasting system is still under development, still having certain errors, as shown on the following Figure for E.On power system in Germany over a twenty four hour period.

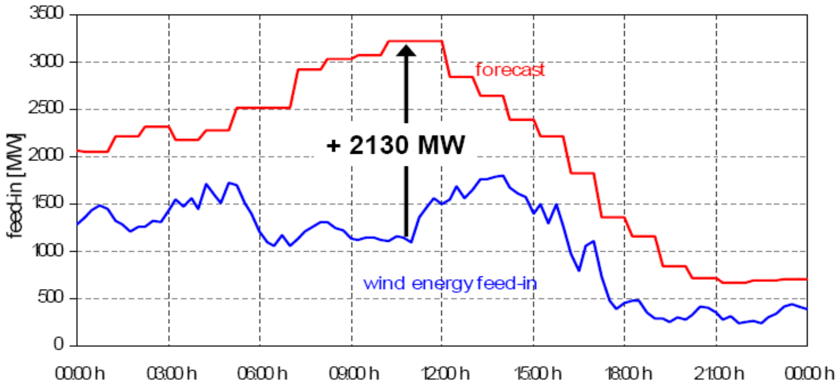


Figure 4-3 Example of wind generation compared to forecast (Source: E.On Netz)

Unfortunately, WPP generation forecasting is a relatively recent development. The experience to date shows that the overall shape of the wind production can be predicted most of the time. However, large deviations can occur both in the level and in the timing of the wind farm output. For power system operation, the uncertainty of the forecast is important because other power plant will have been scheduled on the basis of the forecast contribution from wind energy and any deviation from forecast must be made up from the available reserve.

Wind power production can vary a significantly over a 12 hour period. In extreme winds, wind turbines automatically shut down from their full rated power. Storm fronts can take several hours to pass over an area of several hundreds of kilometers. Some examples of extreme, though rare, ramp rates recorded during storms include[12]:

- Denmark: 2000 MW decrease in 6 hours (12 MW in a minute) on 8th January, 2005;
- North Germany: over 4000 MW decrease within 10 hours with an extreme negative ramp rate of 16 MW/minute on 24th December, 2004;
- Spain: 800 MW increase in 45 minutes (ramp rate of 1,067 MW/hour), and 1000 MW decrease in 1 hour and 45 minutes (ramp rate of negative 570 MW/hour); and
- Texas: loss of 1550 MW of wind capacity at the rate of approximately 600 MW/hour over a 2½ hour period on February 24, 2007.

Generally, there has been quite a dramatic improvement in the performance of WPP forecasting tools in last 10 years. The joint effects of smoothing and improved forecasting tools are reflected in the learning curves. The following Figure shows the development of the average WPP day-ahead forecasting error in Germany since 2001. These improvements have been made by using ensemble predictions based on input from different weather models in one tool and combined prediction using a combination of different prediction tools.

[12] EBRD Western Balkans Sustainable Energy Direct Financing Facility – Large Scale Wind Integration in Croatia, ECA, EIHP, KPMG, 2010

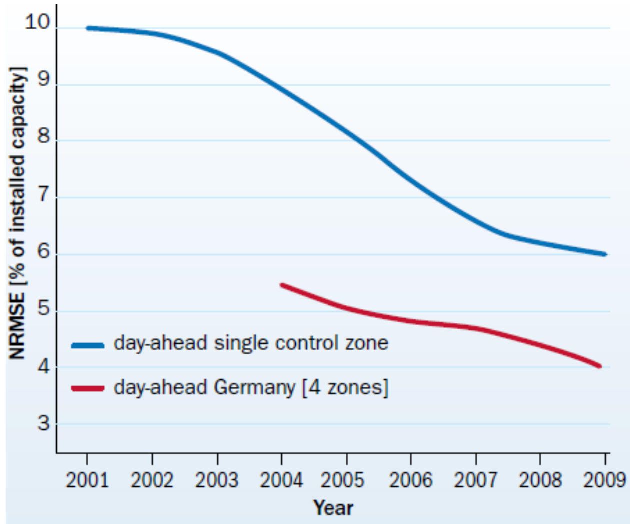


Figure 4-4 Normalized forecast error (NRMSE) in Germany in last 9 years (Source: Tambke, EWEA)

The larger the area, the better the overall prediction is, as shown on the following Figure.

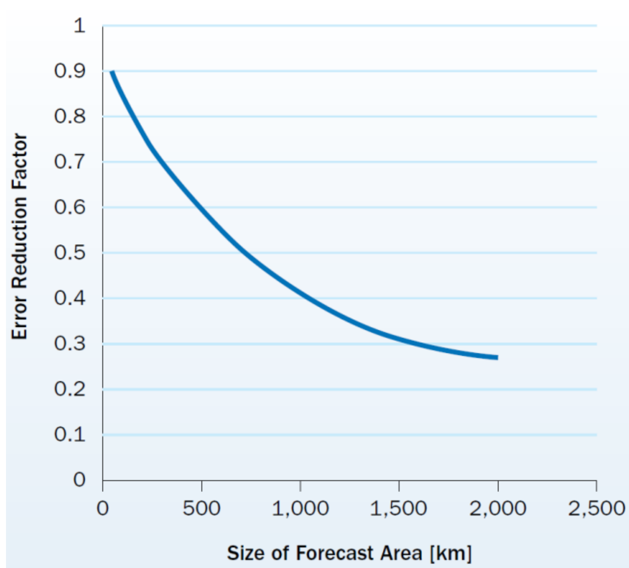


Figure 4-5 WPP forecast error reduction factor vs size of forecasted area (Source: Tambke, EWEA, 2010)

Unfortunately, most of the SEE countries are having quite small distances in between WPPs (usually few hundreds of km), so wind forecasting reduction error is not that high as in most of western European countries. Regional approach to WPP integration would help a lot in that sense.

Forecast accuracy is reduced for longer prediction horizons. Thus, reducing the time needed between scheduling supply to the market and actual delivery (gate-closure time) would dramatically reduce uncertainty. In other words, if we take larger area with larger WPP installed capacity mean absolute percentage error will drop, as shown for the case of Spain on the following Figure.

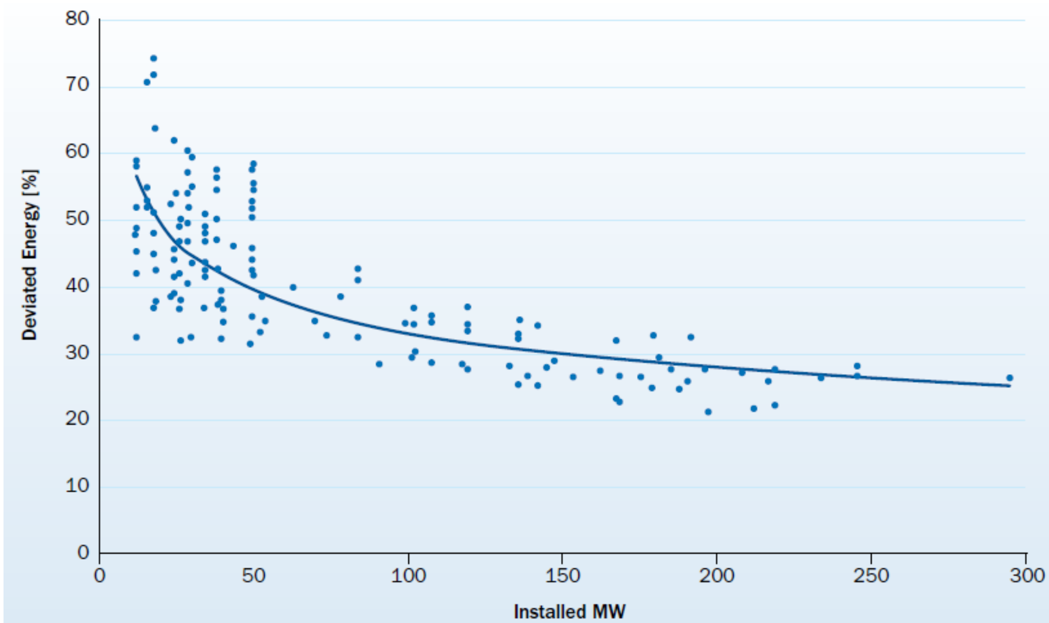


Figure 4-6 WPP deviated forecasted generation vs diversified installed capacity (Source: W2M)

4.2. CURRENT EXPERIENCE IN THE REGION

Both above mentioned aspects (systematic approach to WPP integration and WPP forecasting) are still in very early phase in SEE. Systematic approach to evaluate maximum WPP integration share was used in few countries, while there is no regional approach to expected WPP variations. Also, very few regional countries are having wind forecasting system in full operation.

On the other side, most of the WPP projects in SEE (except those in Romania and Turkey) are still having relatively small WPPs installed capacity (currently the average WPP installed capacity is 23 MW, see Figure 2-5). Based upon above mentioned national studies and data collected from the regional TSOs, there are several limitations for larger WPP integration in SEE, as shown on the following figure.

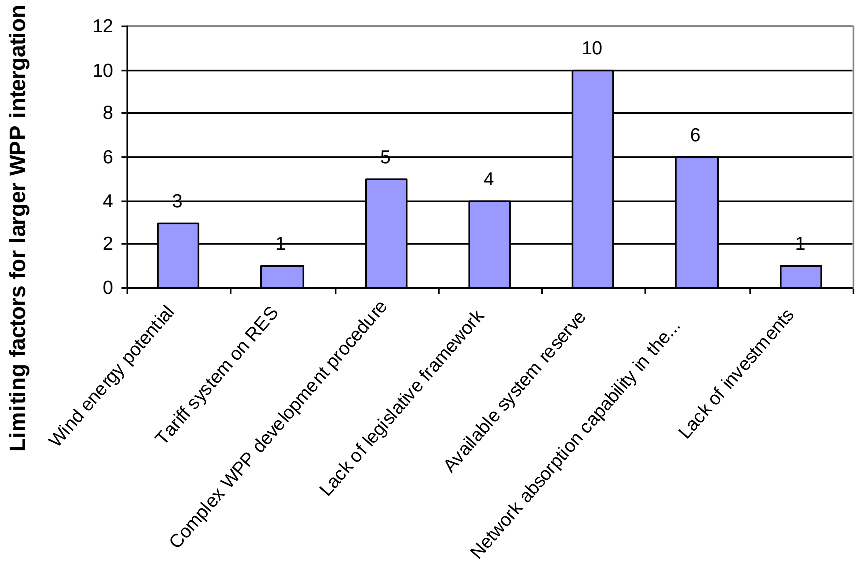
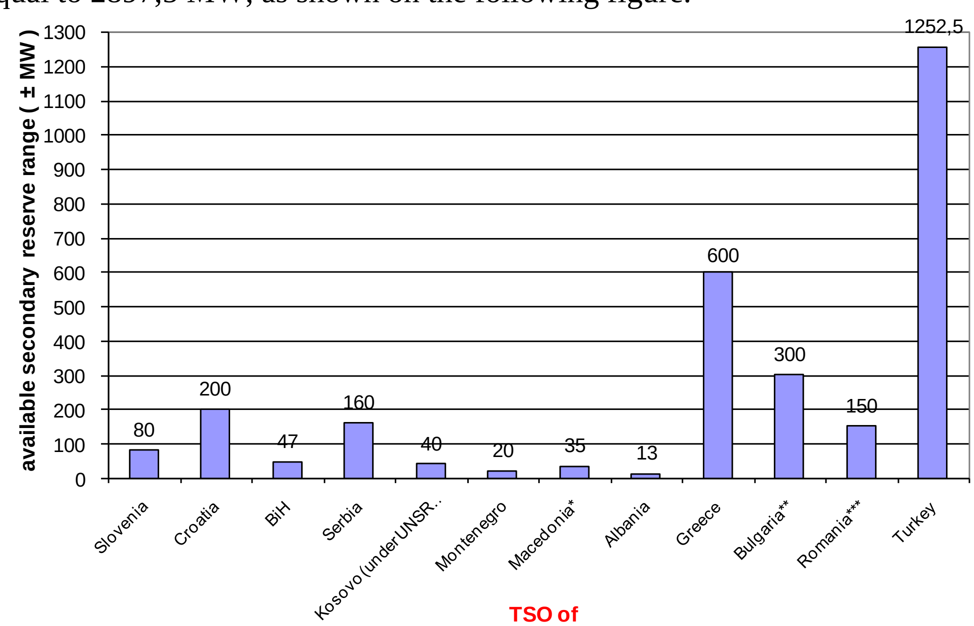


Figure 4-7 Limiting factors for larger WPP integration in SEE

Clearly, most of the TSOs (10 out of 12) declared available system reserve as one of the most important limiting factors for larger WPP integration.

Each TSO estimated available secondary reserve capacity that is available for all unbalances, including WPP fluctuations. Total sum of additionally available secondary reserve capacity in the region is equal to 2897,5 MW, as shown on the following figure.



* up to 50 MW during winter season

** from -300 MW to +500 MW

*** ±150 MW for peak-off and ±300 MW peak week day

Figure 4-8 Available secondary reserve in the region

Clearly, the main obstacle for larger WPP integration is available system reserve that needs to be upgraded or increased. The limitations for increasing available secondary control are shown on the following figure, as a number of positive TSO answers.

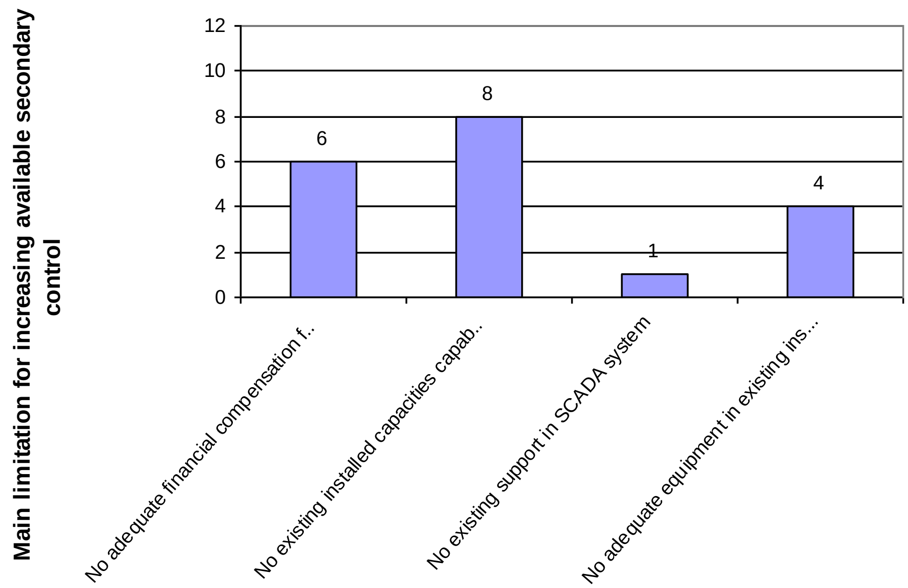


Figure 4-9 The main limitations for increasing available secondary reserve in the region

As shown in the section 2, currently in the region large WPPs are already installed in Croatia, Romania, Bulgaria, Greece and Turkey. Within this study realized WPP hourly generation data are collected from:

- Greece in the period 1.1.2009 – 31.12.2009
- Romania in the period 1.11.2010 – 23.5.2011
- Bulgaria in the period 1.5.2010 – 1.5.2011
- Croatia in the period 1.1.2011 – 1.5.2011

Input data from Turkey are not available. The following Figure shows total regional WPP generation in Croatia, Bulgaria and Romania in the period 1.1.2011 – 1.5.2011 in which simultaneous input data are available. In this period WPP installed capacity was relatively constant, so it is easier to follow the level of WPP generation variations.

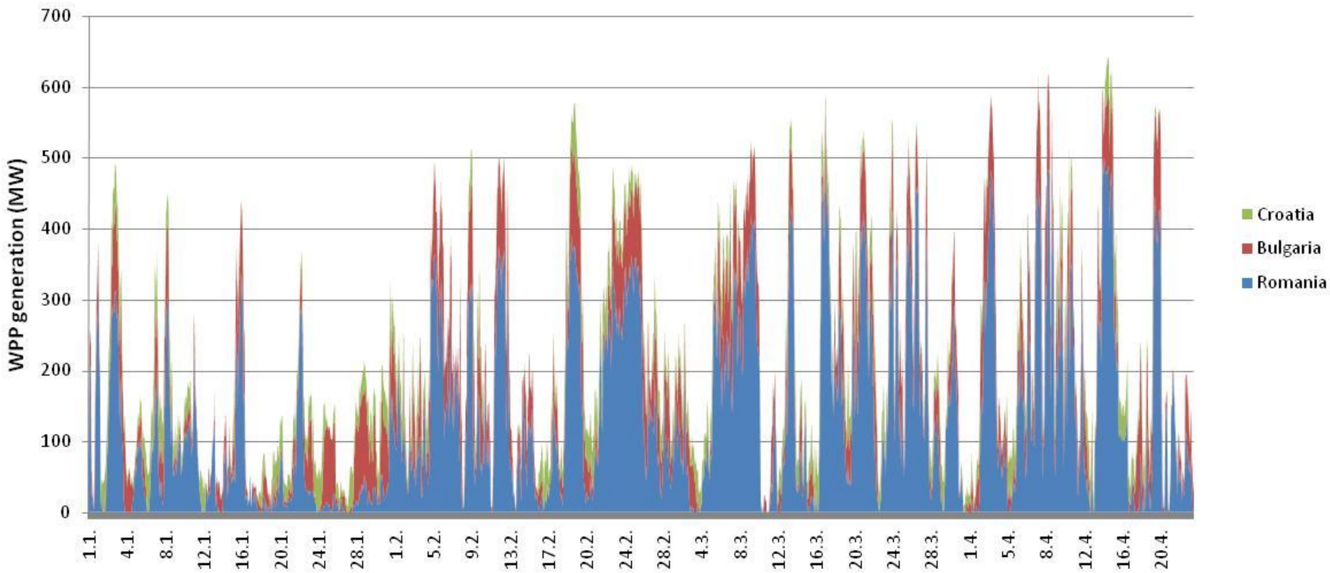


Figure 4-10 Total WPP generation in Croatia, Bulgaria and Romania in the period 1.1.2011 – 1.5.2011

Total maximum WPP generation in given timeframe was 643 MW, with the average of 208 MW and minimum of 0 MW. In four months Jan-May 2011 there were hourly periods with no wind at all in this region with more than 750 MW of WPP installed capacity at the distance of more than 1000 km.

The following subsections show each country experience with WPP generation variations in given timeframes.

4.2.1. Greece

At the beginning of 2009 in Greece there was 750 MW of installed WPPs, while at the end of 2009 there was 862 MW. In 2009 average WPP hourly generation was 207 MW, with its maximum at 642 MW and minimum of 0 MW. Equivalent full load hours were at the level of 2214 h. The following Figure shows main characteristics of WPP generation in Greece in the period 1.1.2009 – 31.12.2009.

Since we have no any inputs on eventual WPP forecasting errors, we would assume that WPP forecast error is equal to WPP generation change with respect to the previous hour (second column).

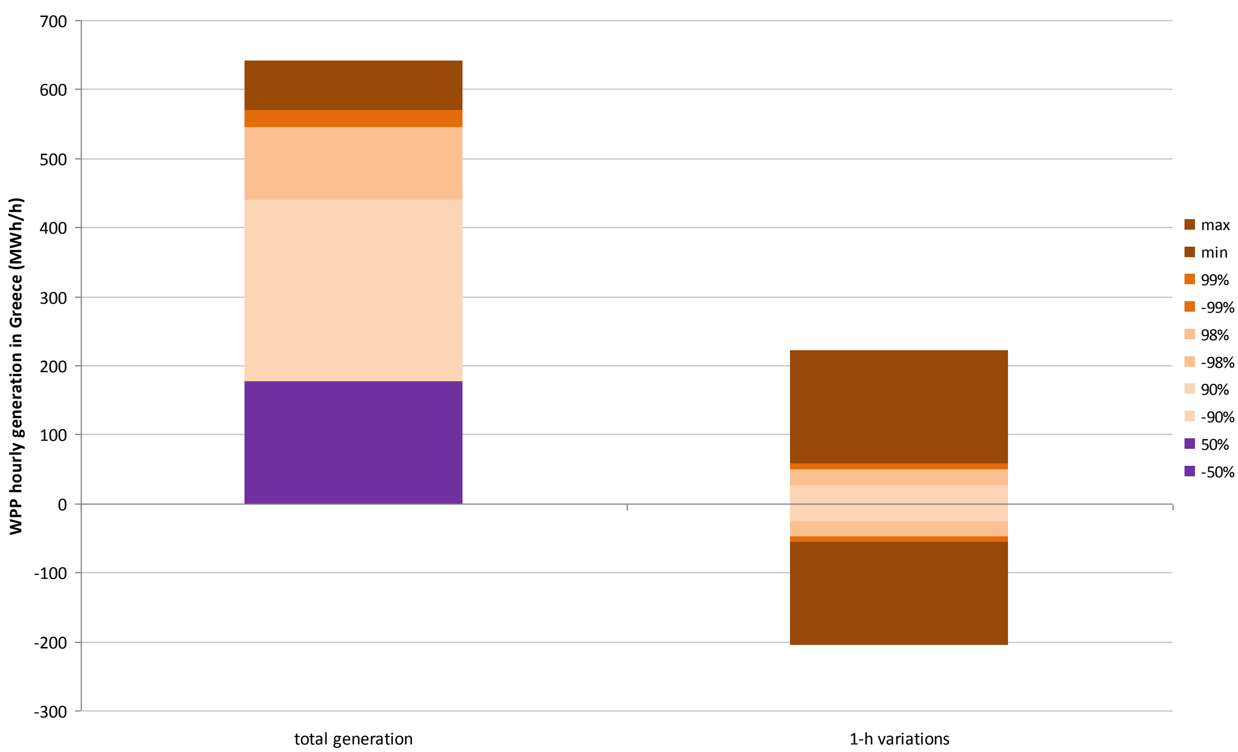


Figure 4-11 WPP generation and WPP variations in Greece in the period 1.1.2011 – 1.5.2011

In 2009 50% of the time WPP generation in Greece was up to 176 MW, while 2% of the time it was more than 546 MW. At the same time 99% of the time 1-h WPP generation variations were up to 58 MWh/h, while the largest 1-h WPP variation was 220 MWh/h. Negative WPP generation variations are quite symmetric to the positive ones.

4.2.2. Romania

In the period 1.11.2010 – 23.5.2011 in Romania total installed WPP capacity reached 564 MW. The average WPP hourly generation was 119 MW, with its maximum at 501 MW and minimum of 0 MW. Equivalent full load hours were at the level of 2100 h/year. The following Figure shows main characteristics of WPP generation in Romania in the period 1.1.2011 – 1.5.2011.

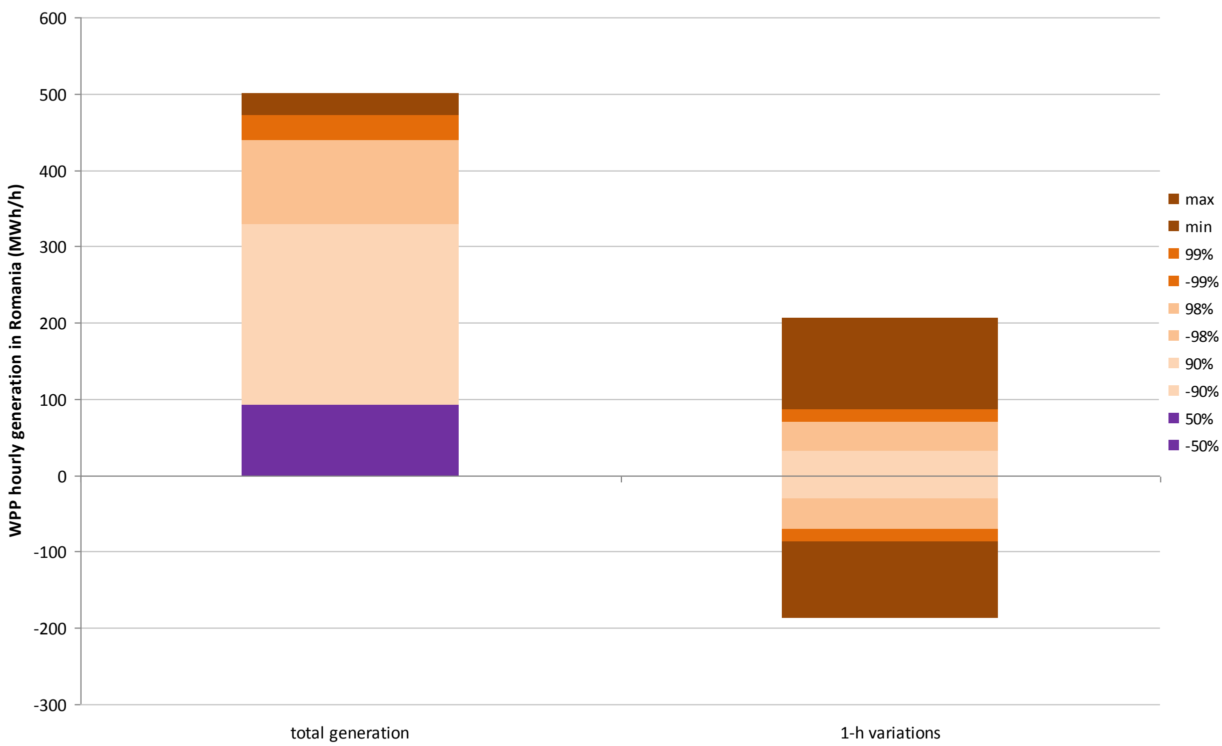


Figure 4-12 WPP generation and WPP variations in Romania in the period 1.1.2011 – 1.5.2011

In given timeframe 50% of the time WPP generation in Romania was up to 93 MW, while 2% of the time it was more than 440 MW. At the same time 99% of the time 1-h WPP generation variations were up to 86 MWh/h, while the largest 1-h WPP variation was +206 MWh/h. Negative WPP generation variations are quite symmetric to the positive ones.

4.2.3. Bulgaria

Till February 2010 there was 191 MW of installed WPP capacity connected to the transmission grid in Bulgaria. Since February there are 241 MW. In last 12 months maximum WPP hourly generation was 149 MW, minimum was 0 MW, while average was at 45 MW. Equivalent full load hours were at the level of 2000 h/year. The following Figure shows main characteristics of WPP generation in Bulgaria in the period 1.1.2011 – 1.5.2011.

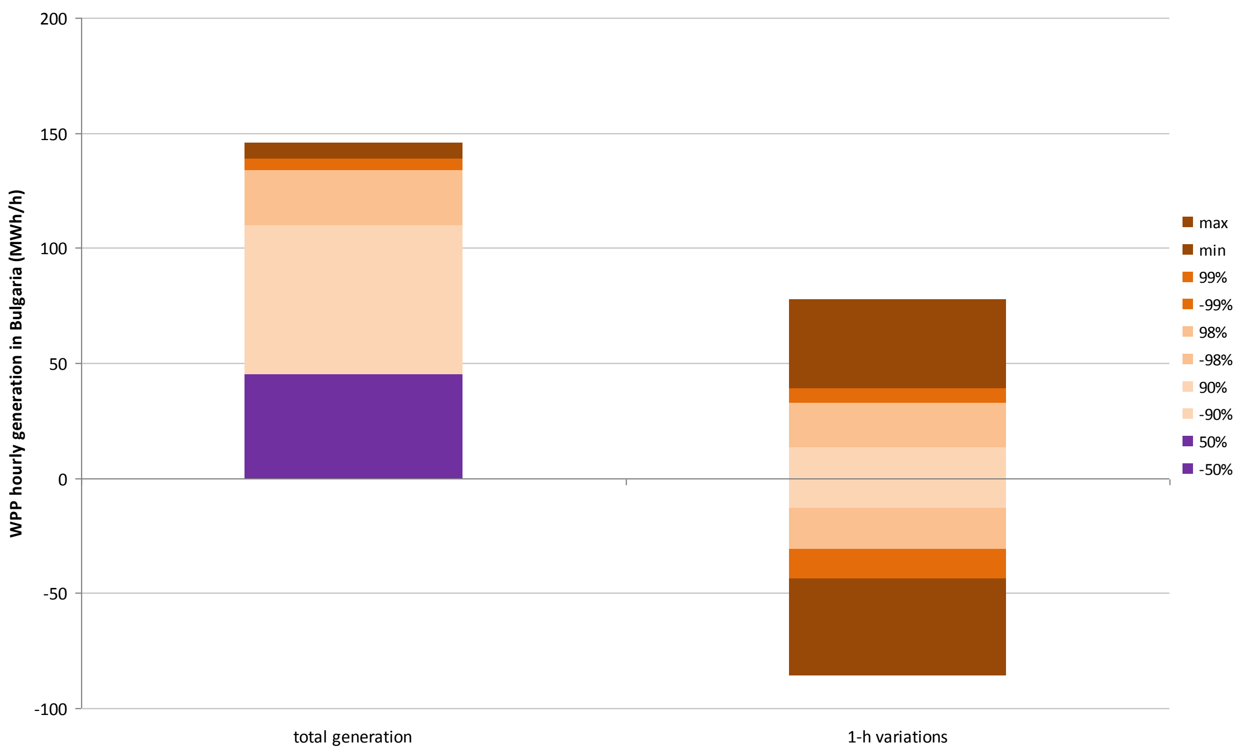


Figure 4-13 WPP generation and WPP variations in Bulgaria in the period 1.1.2011 – 1.5.2011

50% of that time WPP generation in Bulgaria was up to 45 MW, while 2% of the time it was more than 134 MW. At the same time 99% of the time 1-h WPP generation variations were up to 32 MWh/h, while the largest 1-h WPP variations were at the level of ±80 MWh/h.

4.2.4. Croatia

In 2011 in Croatia there are 78 MW of installed WPP capacity. In the period 1.1.-1.5.2011 maximum WPP hourly generation was 72 MW, minimum was 0 MW, while average was at 22,5 MW. Equivalent full load hours were at the level of 2451 h/year (2011 is extremely windy year in Croatia). The following Figure shows main characteristics of WPP generation in Croatia in the period 1.1.2011 – 1.5.2011.

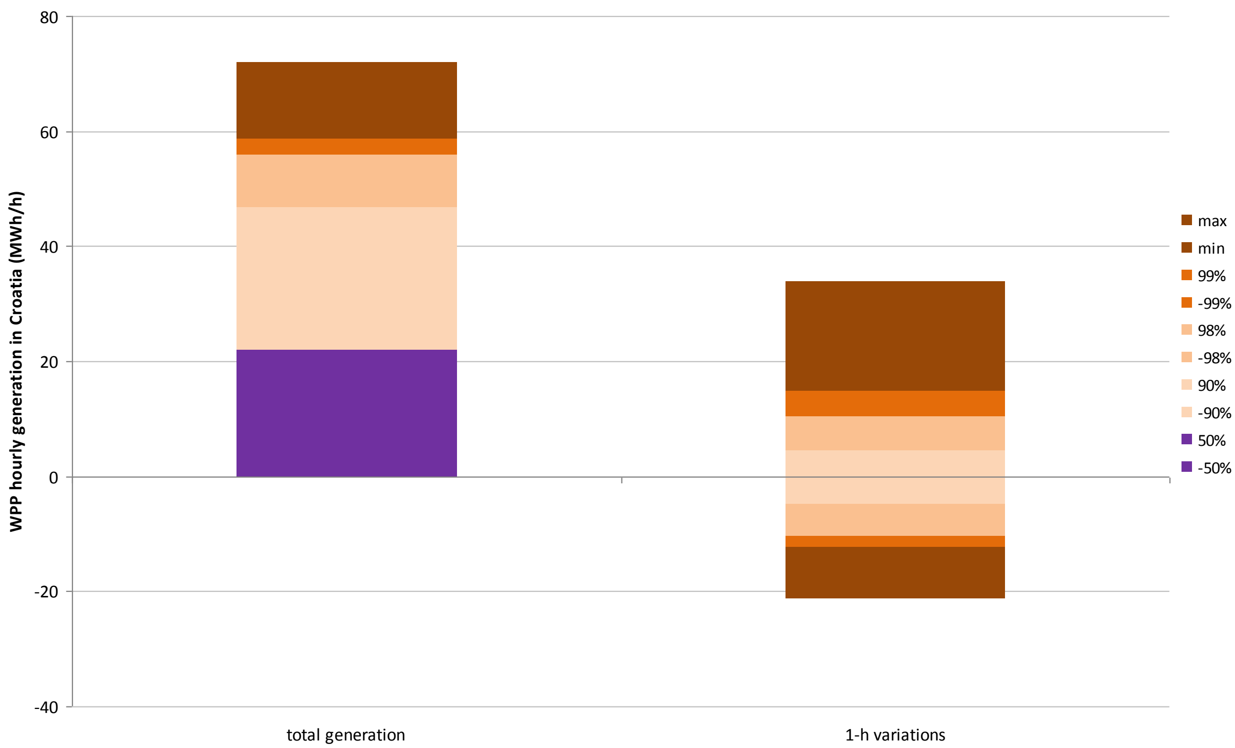


Figure 4-14 WPP generation and WPP variations in Croatia in the period 1.1.2011 – 1.5.2011

50% of that time WPP generation in Croatia was up to 22 MW, while 2% of the time it was more than 56 MW. At the same time 99% of the time 1-h WPP generation variations were up to 10 MWh/h, while the largest 1-h WPP variations were at the level of -22 MWh/h to + 34 MWh/h.

If we put all three cases (Croatia, Bulgaria and Romania) together, the results are given on the following Figure. Sum of individual maximum 1-h WPP variations is larger than 300 MWh/h.

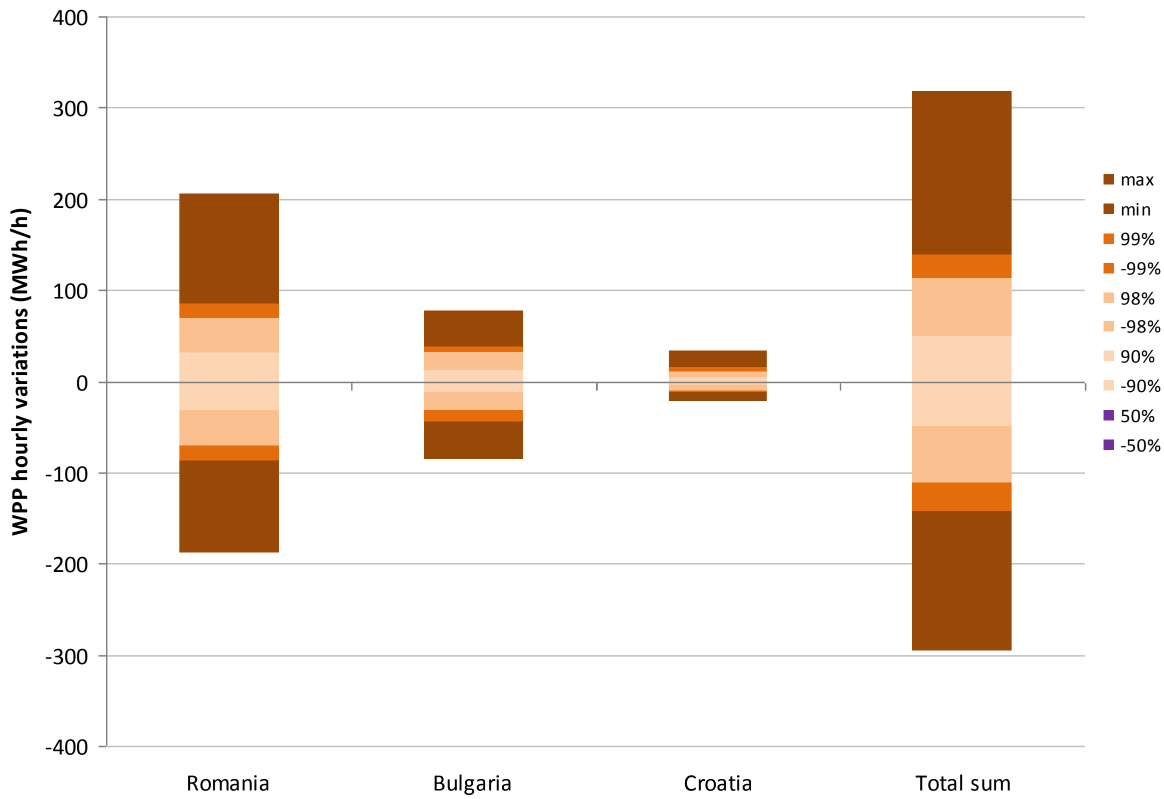


Figure 4-15 Individual and total WPP hourly variations in the period 1.1.2011 – 1.5.2011

Since the data for the same time horizon are available for Croatia, Bulgaria and Romania, it is interesting to calculate total level of generation and variations, as shown on the following Figure.

As mentioned above, maximum total simultaneous generation in these three countries was 643 MW, with the average of 208 MW. But, most of the time total generation was significantly lower. For example, 50% of the given time total generation was up to 163 MW. 2% of the time it was larger than 560 MW.

At the same time, WPP generation variations were up to 250 MWh/h, even though most of the time (99%) it was less than 98 MWh/h.

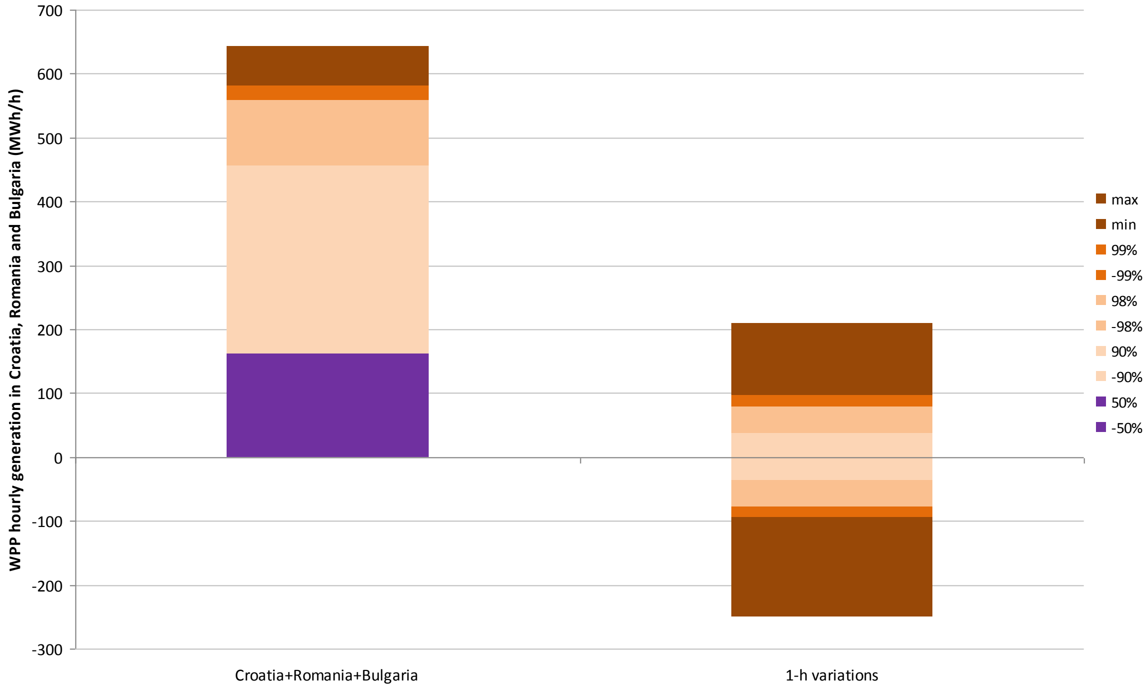


Figure 4-16 WPP generation and WPP variations in Croatia, Bulgaria and Romania in the period 1.1.2011 – 1.5.2011

The following Figure shows the comparison between individual and regional approach to WPP generation variations. Left column presents variations of total sum of all WPP generation in the region (regional approach), while right column present sum of individual WPP variations, as it is current practice.

As expected, significant reduction of WPP variations would happen if we observe all WPPs in the region as one balancing party. In this case all WPP generation variations to be balanced are in the range <-250 MWh/h, 210 MWh/h> , while individual approach would result with the variation range <-295 MWh/h, 318 MWh/h>. So, regional approach could result with significant decrease (15-35%) of system reserve needed for WPP balancing.

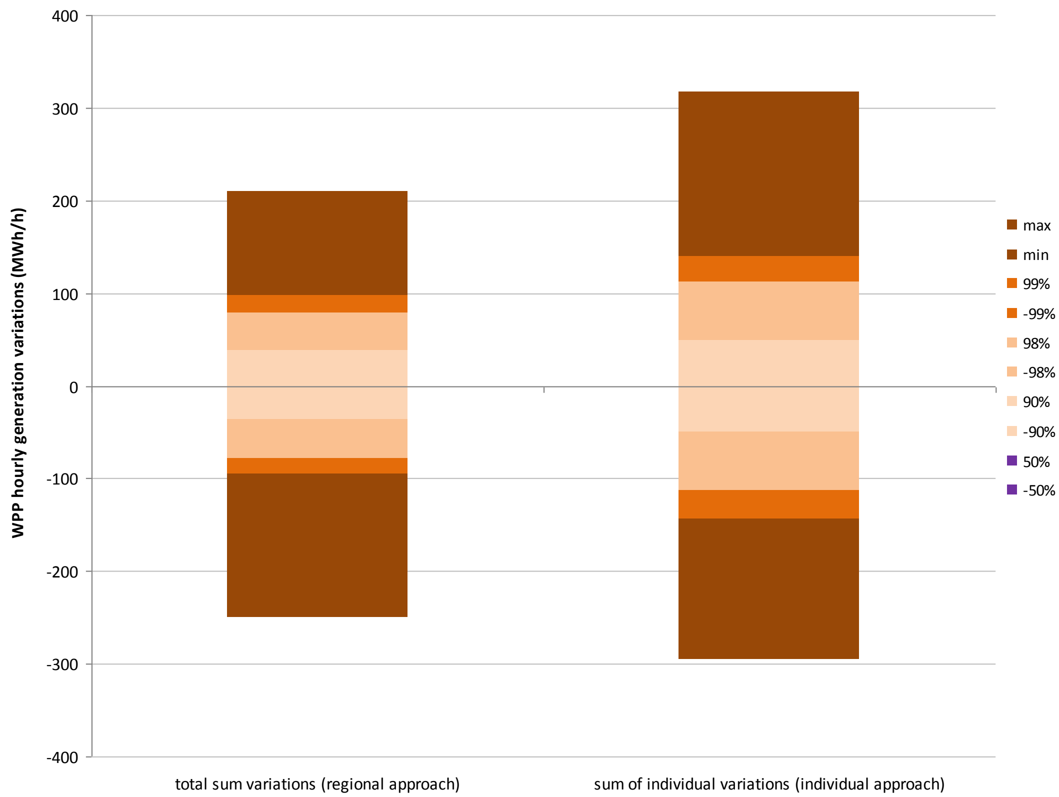


Figure 4-17 WPP output variation ranges in 2011 in the case of individual and regional approach

Finally, the following Figure shows maximum hourly variations in each country as a percentage of WPP installed capacity. Clearly, these values are in the range between 27% (Greece) and 44% (Croatia). This is expected since in Croatia WPP location diversification is rather small in comparison to other three countries.

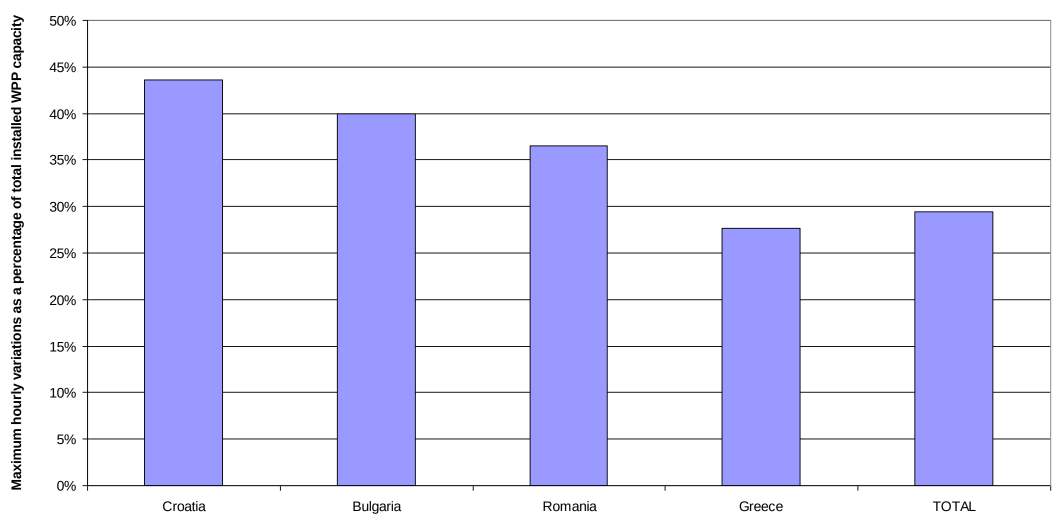


Figure 4-18 Maximum WPP hourly variations as a percentage of WPP installed capacity

4.3. EXPECTED FUTURE WPP GENERATION VARIATIONS IN THE REGION

For the purpose of this study ENTSO-E Pan-European Market Database[13] was used in accordance to formal approval of ENTSO-E Planning Data Section. Pan-European Market Database (PEMD) contains demand, supply and interconnection data for the reference scenarios of the next Ten Year Network Development Plan (TYNDP), for each of the ENTSO-E countries. The main objective of the PEMD is to provide a reference set of assumptions to be used in all Regional Groups to perform consistent market simulations. It should be underlined that the results of the analyses based on PEMD are more illustrative then quantitative, since the quantitative effect based on PEMD is quite uncertain.

This set of input data was prepared by ENTSO-E Working Group on System Adequacy and Market Modeling. Each ENTSO-E member has its data correspondent. Based on this database hourly WPP generation profiles for each country were prepared for 2020 (there are no data available for 2015, as foreseen in this study ToR).

Even though planning of WPP outputs on mid and long-term time horizon is facing large uncertainty (WPP location and size, wind turbine types, wind speed measurements, WPP reliability etc.), currently there are no better database for future WPPs in Europe, especially not in SEE.

WPP input data were collected per each country on the same harmonized way. Historical data on WPP generation (2006) were used as the reference, where available. WPP share in total generation in 2006 was used for 2020. For the 2020 scenario, a check was made whether the wind energy production, when applying the time series to the installed wind capacities, are in accordance with the wind energy production stated in the National Renewable Energy Action Plans (NREAP), if available. If the wind energy production was lower, then the production stated in the NREAP, the time series were adapted in such a way that the total energies in NREAP are met.

Countries that do not have a NREAP used strategic national documents reflecting a vision for the future or existing public top down scenarios to estimate their part of renewables. Final result of this approach is hourly WPP generation output database for 10 regional systems: Slovenia, Croatia, Bosnia and Herzegovina, Montenegro, Macedonia, Albania, Serbia+ Kosovo, Bulgaria, Romania and Greece. So, in comparison to the other parts of the study here we have missing data only for Turkey, while WPP data for Kosovo are included in the dataset for Serbia.

The following figure shows WPP installed capacity in 2010 and planned for 2020 in PEMD. Total installed WPP capacity in 2020 is expected at the level of 17068 MW, while today those countries are having around 1800 MW of WPP installed capacity (as shown on the Figure 2-5). It

[13] last available version as of 09/02/2011

means that in 10 years in SEE it is expected to increase installed WPP capacity for more than 9 times, excluding Turkey where it is expected to have by far the largest increase of WPP projects.

Clearly the largest WPP installed capacity in 2020 is expected in Greece (from 1039 MW in 2010 to 6800 MW in 2020, out of which is 300 MW planned to be off-shore), Romania (from about 500 MW to 4000 MW) and Serbia (from 0 MW to 1500 MW). The lowest level is expected in the system of Albania, Kosovo (130 MW), Macedonia (150 MW) and Montenegro (180 MW). Even though for some of the countries these values could be far above TSOs expectations (i.e. Serbia), it is important to keep in mind that the main purpose of this study is not to re-check these input data, but to evaluate regional approach to WPP integration in the region.

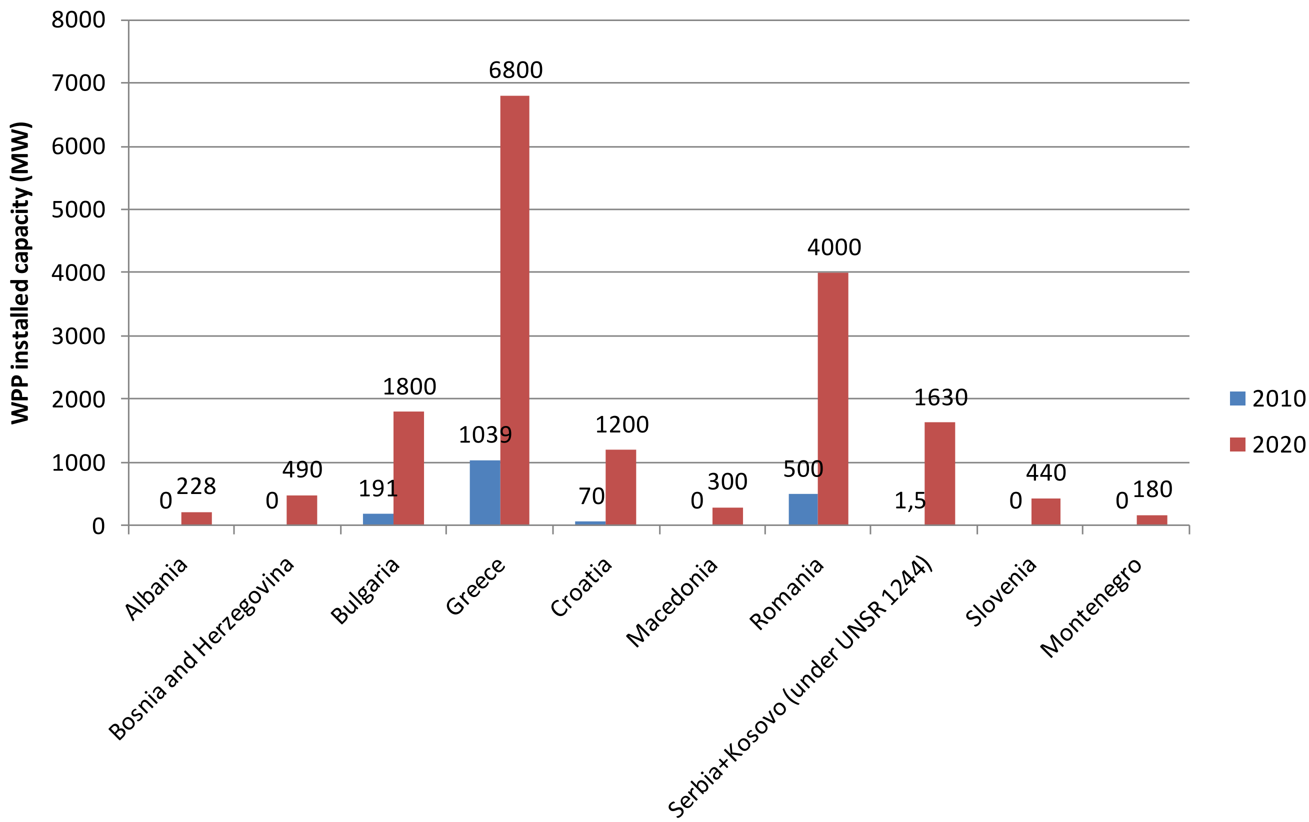


Figure 4-19 WPP installed capacity in 2010 and in 2020 (Source: TSOs and ENTSO-E PEMD)

Based on these data total WPP hourly generation in SEE in 2020 is shown on the following Figure.

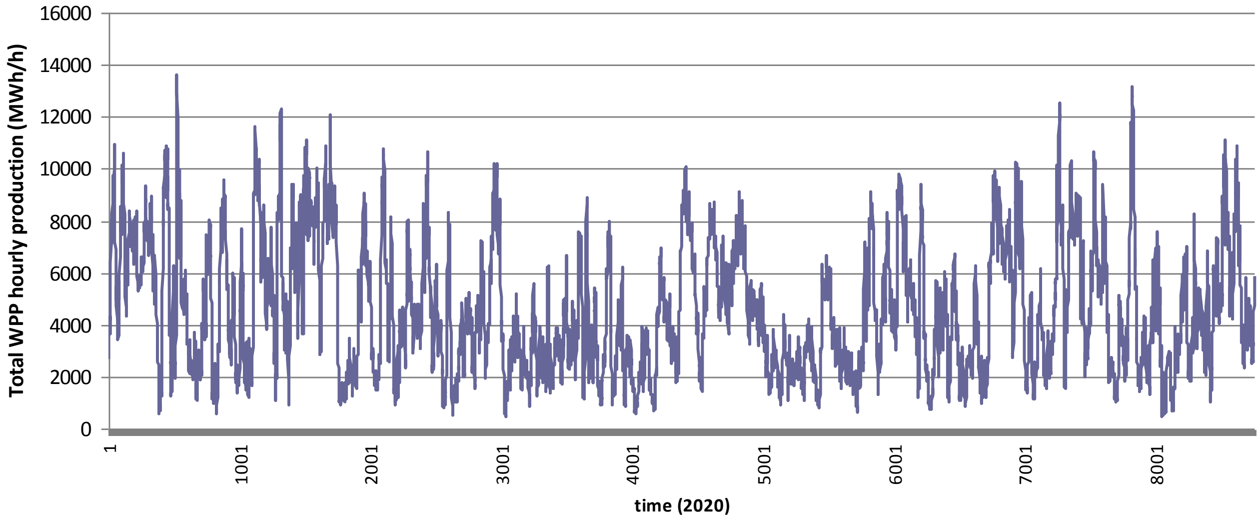


Figure 4-20 WPP hourly output in 2020 (Source: ENTSO-E PEMD)

As mentioned above, this WPP output data set is prepared for planning purposes. But, it somehow reflects wind potential in the region. The following Figure shows equivalent full load hours (FLH) for each country in 2020. The overall country FLHs are in between 1600 h/yr and 2550 h/yr, which is in the realistic and acceptable range. FLH on the regional level is 2143 h/yr. Since this is regional approach, eventual deviations from expectation on the country level are not crucial for this kind of analysis.

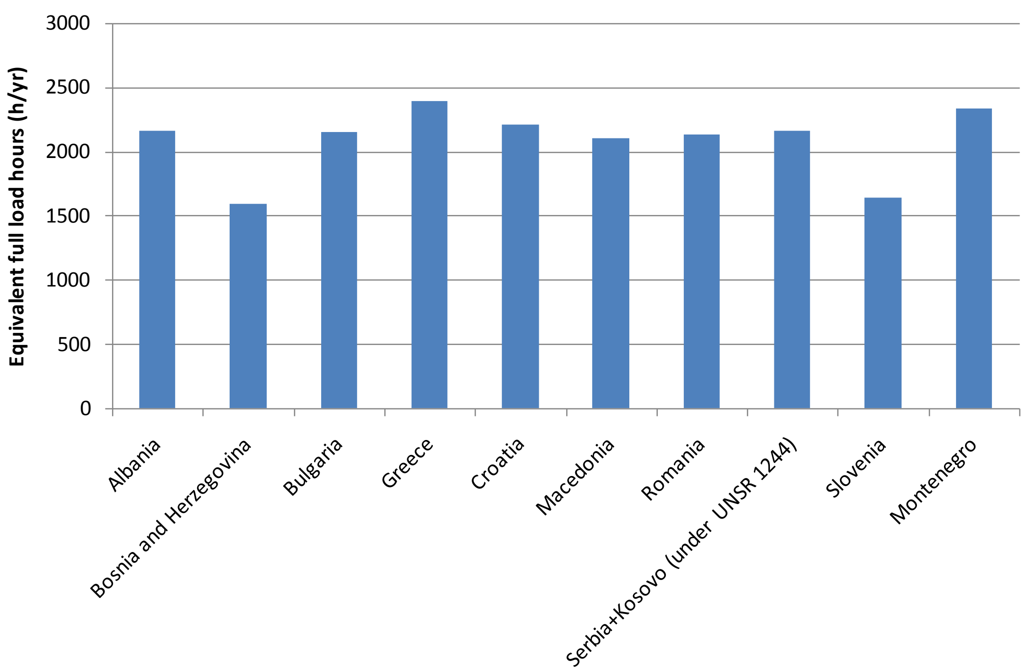


Figure 4-21 Equivalent WPP full load hours in the region in 2020

Speaking of WPP output variations, the following Figure shows that total simultaneous regional WPP generation is expected in the range between 495 MW to 12334 MW, with the average generation of 4326 MW.

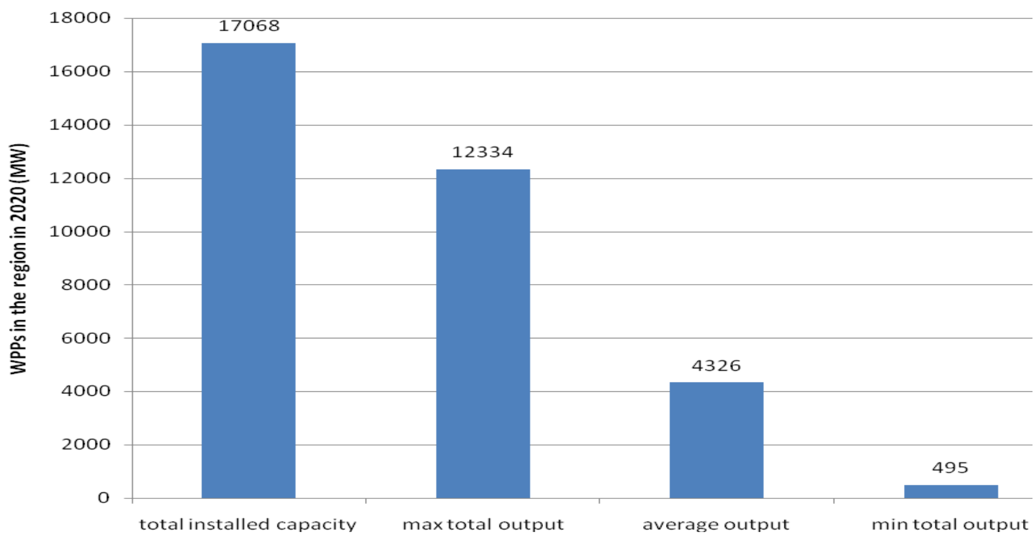


Figure 4-22 Expected WPP output characteristics in 2020

In 2020, WPP generation dynamics is expected as given on the following Figure.

Based on these values it is possible to calculate the timeframes in which certain levels of WPP generations or WPP variations are expected, as shown on the following Figure.

The first column presents range of total WPP generation in the region. In 2020 50% of the time total WPP generation in the region will be up to 3900 MW, or up to 23% of total installed capacity. 98% of the time total WPP generation in the region will be up to 9700 MW, or up to 57% of total installed capacity. Maximum hourly generation of WPPs in the region in 2020 is expected at the level of 12962 MW, as mentioned above.

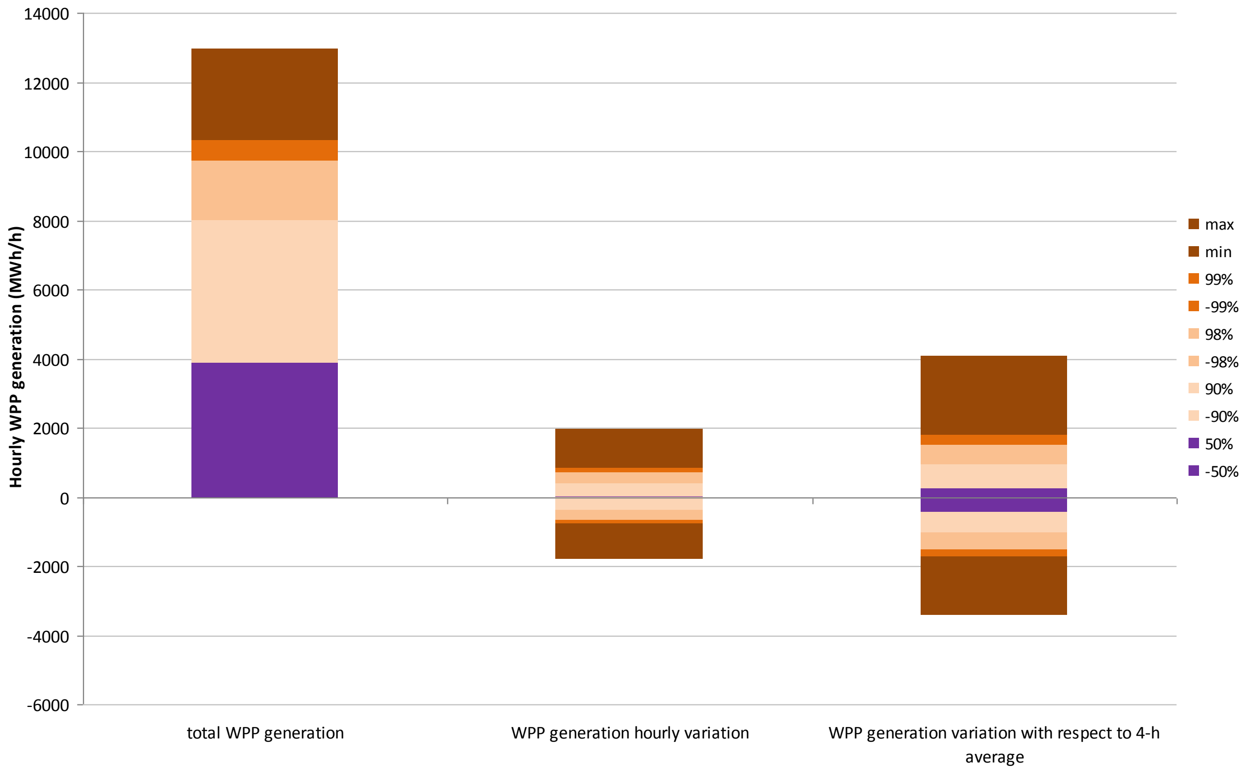


Figure 4-23 WPP output variations in 2020

The second and third column on the previous Figure present levels of expected WPP generation variations. The first issue is to define reference value from which we calculate WPP variation. Clearly, if we would have perfect wind forecasting system, there would be no unpredicted WPP variations at all. Since we have no any inputs on eventual regional WPP forecasting system, we would assume that WPP forecast error is equal to WPP generation change with respect to the previous hour (second column), or with respect to last 4-hour average (third column). In this way we get two levels of WPP variations.

WPP generation hourly variations are in the range of ±1 MW only for the 50% of the time. 99% of the time this variation is up to ±800 MWh/h, while maximum variations are very rare, going up to about ±-1900 MWh/h, or up to 11% of the total installed capacity. Key issue is that TSOs are obliged to keep system stability and balance in all system states, no matter of its probability.

WPP generation variations with respect to 4-h average are in the range of -450 MWh/h to +250 MWh/h for the 50% of the time. 99% of the time this variations are up to ±1800 MWh/h, while maximum variations are very rare, going up to -3400 MWh/h and +4100 MWh/h, or up to 32% of its total installed capacity.

4.4. IMPACT OF THE REGIONAL APPROACH TO THE SYSTEM RESERVE NEEDS

In SEE there is still no regional approach to ancillary services. It means that each TSO is responsible for its own system reserve needs and practically there are no reserve cross-border exchanges. Regional reserve needs are the sum of individual system reserves, as shown on the following Figure.

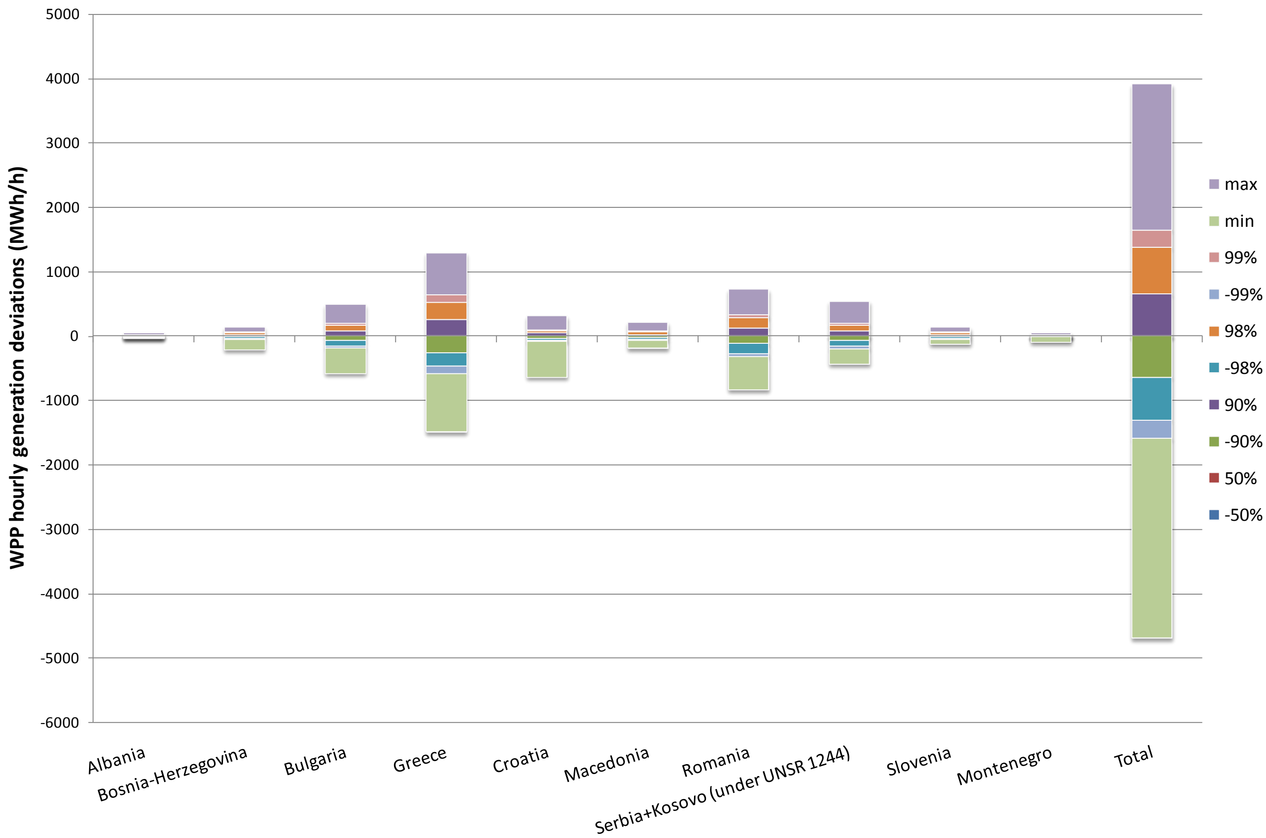
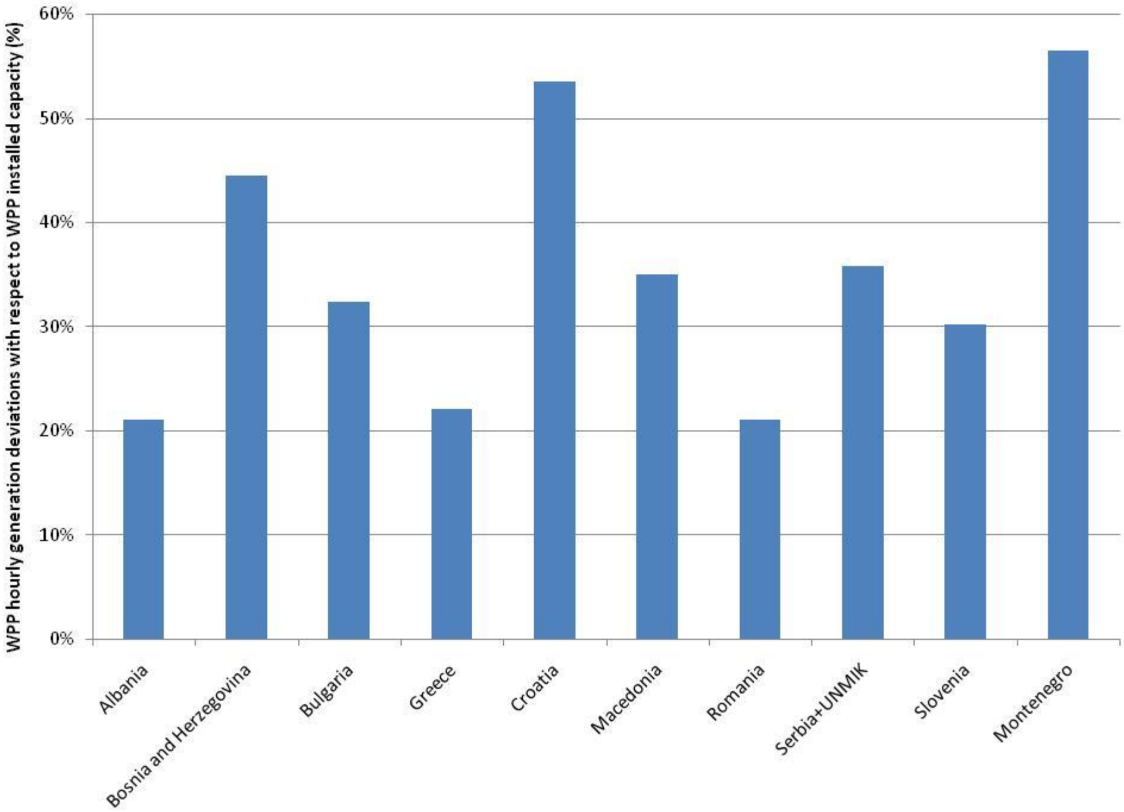


Figure 4-24 WPP output variations per each system in 2020

The largest WPP variations are expected in Greece, Serbia + Kosovo, Romania and Bulgaria, in accordance to its expected total WPP capacity. Maximum expected hourly WPP variations are in the range of 22 - 56% of WPP installed capacity per each country, while on the regional level it is 27%. Even though it strongly depends on the WPP diversification and wind characteristics, it can be concluded that in the countries with larger WPP installed capacity (Greece, Romania) relative WPP variations are lower than in small systems with low WPP diversification (Montenegro, Croatia), as given on the following Figure.



Values given on the previous Figure could be compared to the experience in EU countries, as shown in the following Table. Clearly, these WPP variations are predictable, but they cause large amount of uncertainty. The better WPP forecast is, the lower reserve is needed.

1-hour WPP generation variations in given EU countries are in the range of 16-30% of WPP installed capacity, so it is in the range of above mentioned 27% for SEE. 10-15 minutes variations are given only for three countries of different size and capacity (Germany, Portugal and Ireland), in which the range of variations is in between 6% (Germany) and 12% (Portugal and Ireland).

Table 4-1 Hourly WPP generation variations as a share of installed capacity [14]

			10-15 minutes		1 hour		4 hours		12 hours	
Region	Region size	Numbers of sites	Max decrease	Max increase	Max decrease	Max increase	Max decrease	Max increase	Max decrease	Max increase
Denmark	300x300 km^2	> 100			-23%	+20%	-62%	+53%	-74%	+79%
West-Denmark	200x200 km^2	> 100			-26%	+20%	-70%	+57%	-74%	+84%
East-Denmark	200x200 km^2	> 100			-25%	+36%	-65%	+72%	-74%	+72%
Ireland	280x480 km^2	11	-12%	+12%	-30%	+30%	-50%	+50%	-70%	+70%
Portugal	300x800 km^2	29	-12%	+12%	-16%	+13%	-34%	+23%	-52%	+43%
Germany	400x400 km^2	> 100	-6%	+6%	-17%	+12%	-40%	+27%		
Finland	400x900 km^2	30			-16%	+16%	-41%	+40%	-66%	+59%
Sweden	400x900 km^2	56			-17%	+19%	-40%	+40%		

Within this study it is evaluated how ancillary services needs would change with regional approach. The following Figure shows impact of the regional approach to the total system reserve needs. The first column presents variations of total regional sum of WPP generation, while second column presents sum of each country variations.

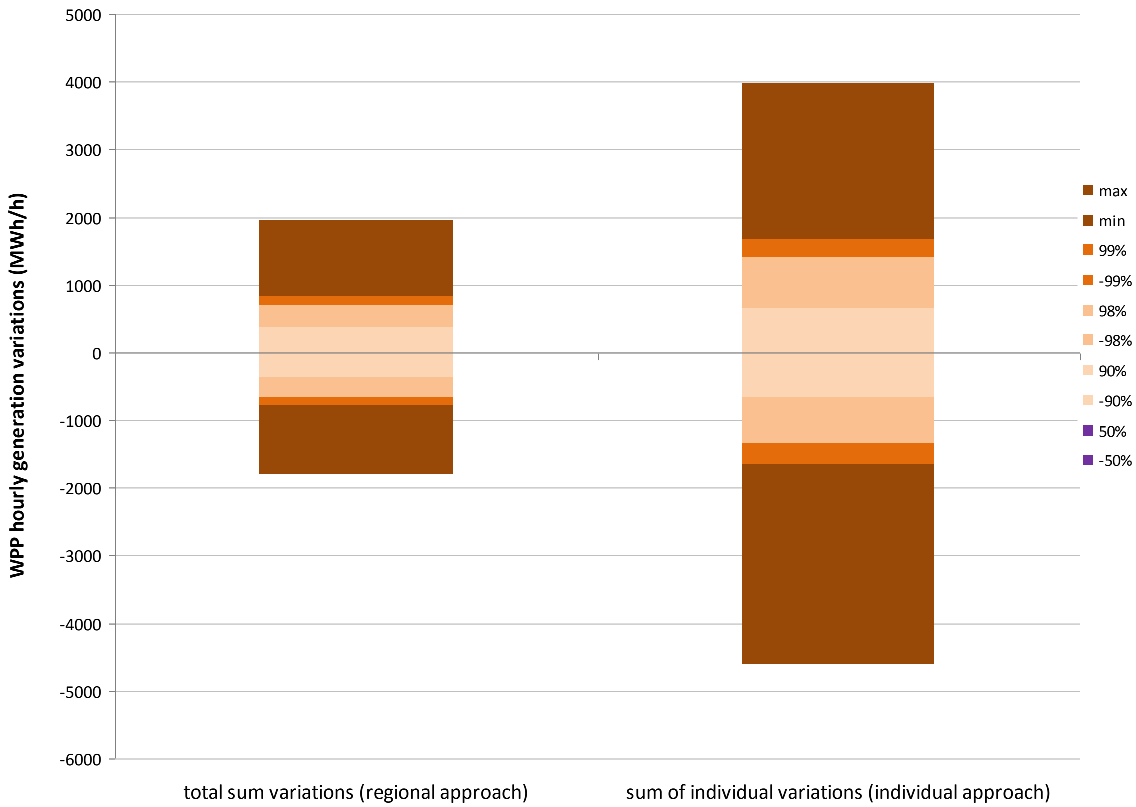


Figure 4-26 WPP output variation ranges in 2020 in the case of individual and regional approach

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14 Denmark, data 2000-2002 from http://www.energinet.dk; Ireland, Eirgrid data, 2004-2005; Germany, ISET, 2005; Finland, years 2005-2007 (Holmgren, 2008); Sweden, simulated data for 56 wind sites 1992-2001 (Axelsson et al., 2005); Por tugal, INETI; EWEA, Grid Report 2010

Maximum expected variation assumes total system reserve needs. In individual approach to the system reserve, as it is the case now, sum of maximum expected WPP variations goes up to -4600 MWh/h and +4000 MWh/h, or up to 27% of total WPP installed capacity in the region. 99% of the time these variations will be up to ±1600 MWh/h.

On the other side, regional approach significantly reduces reserve needed to balance WPP variations. Maximum variations of the total sum of regional WPP generation goes up to ±1900, or up to 11% of total WPP installed capacity in the region. It assumes 42-48% of the reserve within existing individual approach. 99% of the time these variations will be up to ±800 MWh/h.

Comparing these regional variations to the country variations, we get clear benefit of the regional approach of WPP integration: **regional approach would decrease total reserve need for -2600 MWh/h and +2000 MWh/h.** In other words, **regional approach would decrease system reserve needs for balancing WPPs to less than half of the existing individual country approach.**

5. LEGISLATIVE FRAMEWORK FOR WPP CONNECTION AND OPERATION

In this section different legislative framework aspects of WPP connection and operation and given. After general regional overview relevant country legislation is presented. Finally, recommendations for improvement and regional harmonization of WPP requirements are suggested.

5.1. INTRODUCTION

In the past, the same vertically-integrated company was responsible for operation, control, maintenance and development of whole power system, including generators access to the grid. Accordingly, technical requirements didn't have to be particularly clearly defined or equitable. After power sector deregulation and unbundling, with functional, legal and increased ownership separation of TSOs and generators, the technical requirements governing the relationship between generators and TSOs have to be more clear. The introduction of RES generation has complicated this process significantly, as these generators have characteristics which are different from the directly connected synchronous generators used in large conventional power plants. In most of the cases, these differences resulted with time delays in adoption of specific requirements for WPPs. Besides that, there are two problems with adopted grid codes: 1) diversity of national grid codes and requirements and 2) generally unclear requirements.

According to current EU legislation, Grid Codes, including the requirements for WPP connection and operation, are a national responsibility. EU Directives specify that Member States have to ensure that the criteria are developed and made public, that these rules are objective and non-discriminatory and that they ensure the interoperability of systems. But, this appears insufficient in the present situation of large scale wind integration, especially in small countries like those in SEE region. As the penetration of wind powered plants continues to grow there is an increasing need to develop a harmonised set of Grid Code requirements.

It must be noted that it is not practical to completely harmonise technical requirements straight away. In an extreme case this could lead to the implementation of the most stringent requirements from each country included. This would not be desirable, economically efficient.

Accordingly, there were several initiatives in order to harmonize WPP grid connection legislative framework. One initiative was launched in 2008 by European Wind Energy Association (EWEA)[15], while the other one was taken by ENTSO-E in 2009. In 2009, ENTSO-E agreed with ERGEG and the European Commission that it will launch a "pilot code project" with special focus on wind generation, aimed at harmonising grid code requirements for wind generators

[15] EWEA Working Group on Grid Code Requirements – Position Paper, European Grid Code Requirements for Wind Power Generation, Brussels, February 2008

throughout Europe. This is a first step towards developing network codes across Europe, which is part of the remit of ENTSO-E under the EU's continuing efforts to liberalise and harmonise the electricity market.

From one side, EWEA Working Group for Grid Code Requirements established in 2007 was consisting of wind turbine manufacturers, wind farm developers / operators, consultants, service providers and associations. They produced a position paper and gave it to EWIS Working Group for further development. The main conclusions of EWEA WG were that European Grid Code Requirements for Wind Power Generation are: frequently changing, usually available in local language only, not comprehensive and clear. Since EWEA WG concludes that an immediate complete technical harmonization is not appropriate, they proposed a two step approach:

a. A structural harmonization exercise – with the aim of establishing a Grid Code template with common definitions, parameters, units and figures, as well as a common structure.
b. A technical harmonization exercise – with the aim of adapting existing Grid Code parameters to the new Grid Code template. This will be an important starting block for work in the years to come.

On the other side, ENTSO-E working group was focused on technical requirements for connection. It means that grid access and connection costs were out of the scope. Official Consultation of Pilot Code was expected during 2011.

5.2. REGIONAL OVERVIEW

Even though the availability of Renewable Energy Sources (RES) varies within the SEE region, all countries started to develop and implement studies and Strategies on the promotion of RES. The development of these Strategies is under the responsibility of the relevant Ministries, while the National Regulatory Authorities (NRAs) are in most cases responsible to set market based incentives. In this respect the NRAs are in most countries responsible for setting the Feed-in Tariffs as well as for defining the Tariff Methodology. Usually, NRAs are responsible for issuing Secondary Legislation related to RES and for Licensing RES generation units. The Definition of RES is not fully harmonized within the region. This could be illustrated by the example of the threshold definitions for Small- and Large- Hydro Power Plants. Thus, it is very difficult to compare the various regimes for promoting RES within the region.

Among the regional countries most of them (8 out of 12) have officially defined national RES targets. But, for 4 of them (Albania, BiH, Serbia and Montenegro), it is expected to be adopted soon, as shown on the following figure (data refers to end of 2010).

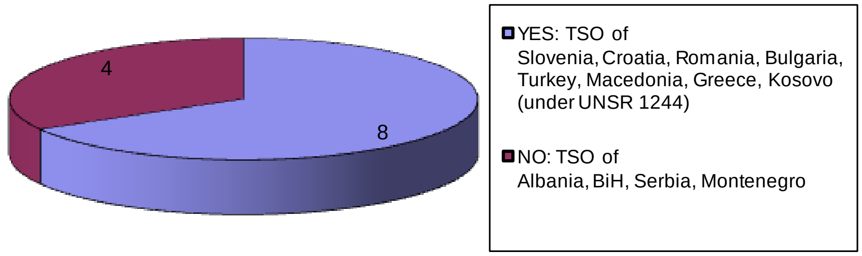


Figure 5-1 RES target officially defined

Similarly, not all of the parties adopted full RES legislative framework, as shown on the following figure.

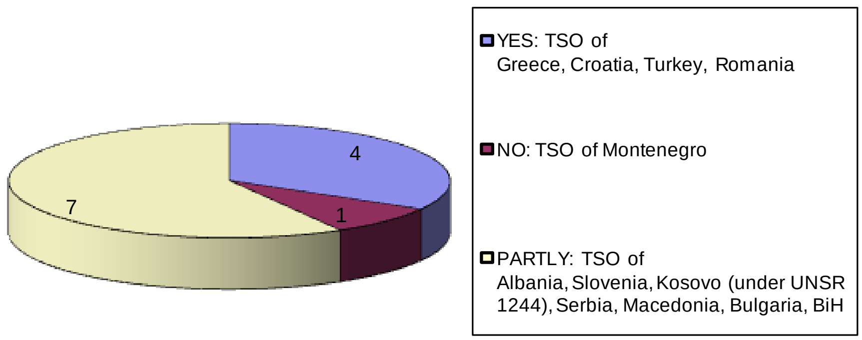


Figure 5-2 RES legislative framework fully adopted

The following table in more details shows implementation status of Directive 2001/77/EC (Source: ECRB)[16].

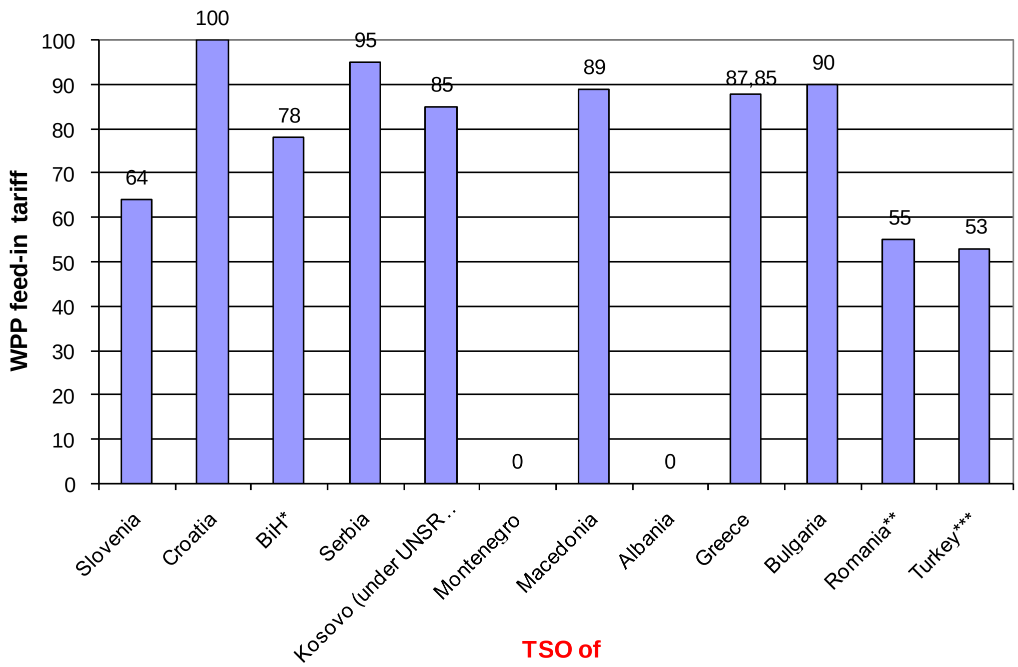
Contracting Party	Indicative targets	Support schemes	Guarantee of origin	Administrative procedures	Grid system issues
Albania	2% total power production from RES (P>100MW) 18% RESe of TPES by 2020 (new draft of RE Law)	Preferential tariffs for new SHPP (<15 MW) adopted; Feed-in tariffs to be developed for other types of RES; New RES equipment exempted from custom duties	Regulation on GO for power producers adopted in February 2007	Authorisation procedure for new capacities that are not subject to concession is in process of approval	Guaranteed grid access for all RES; TSO gives dispatching priority to privileged producers (RES<25MW, HPP<10MW, cogen<100); Grid costs covered by producers

16 Regulatory Perspectives on RES in Energy Community, N. Stefanović, ECRB EWG Chairman, Joint TSO-Utility Regulator Workshop on Integration and Cross Border Trade of RES in Regional Transmission Networks, Istanbul, March 2011

Bosnia and Herzegovina	To be set	Support schemes partially developed at entities level, not at state level	Guarantee of origin issued by Regulator in RS, in FBiH not assigned yet	Administrative procedures, regulation and codes are not proportionate to the promotion of RES	Priority access to network and obligation of purchase in FBiH adopted in 2010
Croatia	Binding 20.02% RES in GFEC by 2020; 35% RESe in power generation by 2020	Feed-in tariffs for various RES defined	Not yet adopted.	Administrative procedures, regulation and codes are not proportionate to the promotion of RES	Purchase obligation for Market Operator. Priority access for RES.Grid code limitations for wind generation due to stability requirements.
Macedonia	>20% RES in GFEC by 2020	Feed-in tariffs are introduced for wind, biomass, small hydro and photovoltaic installations	Rulebook for issuing guarantees of origin adopted	Administrative procedures, regulation and codes are not proportional to the promotion of RES	Planned to be introduced in the amendments of the Energy Law

Contracting Party	Indicative targets	Support schemes	Guarantee of origin	Administrative procedures	Grid system issues
Montenegro	New Energy Law to set indicative targets for RES Planned >20% RES of GFEC by 2020	Feed-in tariff to be introduced	No guarantee of origin mechanism for RES energy	Authorisation procedures for RES to be simplified	RES <10 MW plants have guaranteed access to the transmission and distribution networks. Grid codes for T&D are temporary
Serbia	2,2% RESe in GFEC up to 2012	Support mechanisms introduced for various RES but valid until 2012.	No guarantee of origin mechanisms for RES electricity	Guides for Investors in Renewable Energy - Administrative procedures, regulation and codes are not proportional to the promotion of RES	Priority access for RES only if offered under equal conditions. Purchase obligation for EPS. Limits for solar (5 MW) and wind (450MW) until 2012
Kosovo	7,8% RESe and RESth of TEP by 2016	Feed-in tariffs defined	The system for issuing guarantee of origin has been introduced	Administrative procedures, regulation and codes are partial proportional to the promotion of RES	Priority access for RESe and RESth (if covered by GoO). Purchase obligation for RES but priority access is not set out in the Grid Code

Since one of the most important aspects of WPP investment is feed-in tariff system, the following figure shows range of feed-in tariffs in regional systems (in accordance to TSO data).



* defined in FBiH entity only
** green certificates with min 22 – max 55 €/MWh
*** system marginal price with no less than 53 €/MWh

Figure 5-3 Feed-in tariffs in the region (end 2010)

But, while speaking of feed-in tariffs one has to be careful since support scheme may consist not only of feed-in tariff and it may depend on different project details. The following figure shows EU country profiles of support level with respect to average generation cost. Obviously, this support scheme is much higher than feed-in tariff itself.

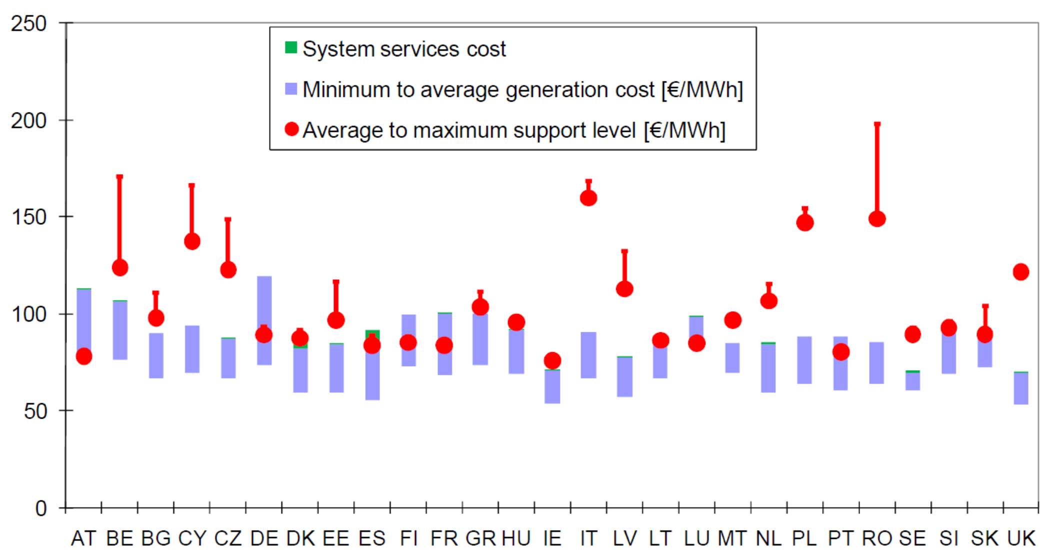


Figure 5-4 Support scheme values in EU (Source: RENEWABLE ENERGY POLICY COUNTRY PROFILES, October 2009; IEE project RE-Shaping)

Besides feed-in tariffs, one of the most important aspects of WPP integration is grid access and purchase conditions. The following table shows available relevant details in regional systems[17].

Albania	Priority access for RES <25MW, HPPs <10MW, cogeneration plants <100MW Guaranteed grid access for all RES
Bosnia-Herzegovina	No provisions made
Croatia	No priority access for RES, grid connection guaranteed for conventional power plants only (and SHPP and cogeneration) Purchase obligation for market operator ***Obstacle***: Grid code limitations on wind generation due to system stability requirements, also limitations for solar and fuel cells
Montenegro	Guaranteed priority grid access for RES <10MW to distribution grid ***Obstacle***: Grid codes for T and D are temporary
Serbia	Priority access for RES only if power offered under equal conditions Purchase obligation for RES by TSO/DSO ***Obstacle***: Priority access for privileged power producers only over other producers who offer power under equal conditions
FYR of Macedonia	MO purchase obligation for RES Priority dispatch for RES – at regulator's discretion
UNMIK	Priority access for RES_e and RES_{th} (if covered by GoOs) Purchase obligation for RES ***Obstacle***: Priority access not set out in grid code Purchase obligation for RES by TSO/DSO ***Obstacle***: Free, non-discriminatory access for RES only advantage if priority over conventional energy
Turkey	Priority access for RES based on domestic resources RES exempt from balancing obligation RES exempt from certain design and performance criteria under grid regulation

Finally, within this section technical requirements for WPP connection and operation will be reviewed per reach power system in the region. Detailed overview will be given for Bosnia and Herzegovina, Bulgaria, Croatia, Greece, Romania and Turkey.

In other regional power systems (Slovenian, Serbian, Montenegrin, Kosovo, Albanian and Macedonian) there are no specific technical requirements for WPPs. In most of these systems it is expected to amend Grid Code with these requirements soon.

5.3. ALBANIA

5.3.1. WPP grid connection procedure

[17] Study on the Implementation of the New EU Renewables Directive in the Energy Community, IPA, NTUA, 2010

Currently, in Albania there are many private (mainly foreign) companies that have applied for licenses under concession to construct power plants. Some of these applications are of large capacity, while their development plans are not clearly defined, nor its commissioning time. All WPP applicants issued the license from Albanian Regulatory Body for construction of new WPPs. Transmission System Operator (OST) gave the preliminary permission to all of them to connect to transmission system, but it is clear that not all of them will be connected. The priority of connection will be based on the principle: "first come, first serve".

5.4. BOSNIA AND HERZEGOVINA

5.4.1. WPP grid connection procedure

WPP transmission grid connection procedure was defined in "Connection Rules", adopted in 2008 (upgraded in 2010) by the State regulatory commission (SERC).

The WPP grid connection study is the same as for all other generator types and it comprises of:

a) load flow analyses;
b) voltage profile analyses;
c) short-circuit analyses;
d) dynamic simulation,
e) cost-benefit analyses.

Connection cost sharing principle in between TransCo and WPP investor is declared as "shallowish". Costs of connection to the voltage level of 110 kV and above is defined in the technical solution specified in the Project Analysis. It includes costs of preparation, including possible purchase of land, and construction of a high voltage connection transmission line, from the point in the network which is defined by the Project Analysis to the metering device, as well as the equipment of transmission line feeder bay with accompanying busbars at the facilities of the Transmission Company. The costs of connection shall also include costs of the installment of measurement and protection system as well as the installment of devices required for operation and management of the system after connecting the user's facilities to the network. The Transmission Company shall be the investor and the owner of the connection.

So far, WPP integration was not taken into account in transmission network planning.

5.4.2. Active power and frequency control

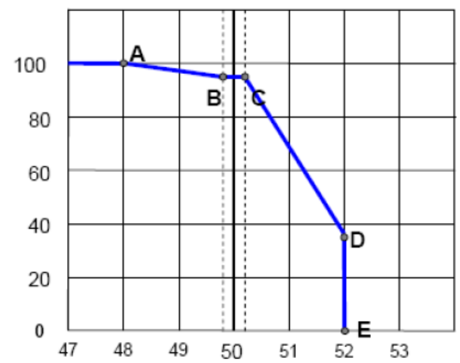
Ancillary service mechanism and balancing rules in BiH are adopted. Balancing rules and charges are defined and it works in between three dominant power companies (balancing responsible parties). Ancillary service mechanism is described in Market Rules. SERC sets Decision on ancillary services (tariffs, values…) on yearly basis.

Technical requirements for WPPs were included in the Grid Code in May 2011.

With respect to P/f regulation WPP are supposed to be capable to secure operation of each wind turbine with reduced active power if order for reduction of WPP's output power is received.

Management System of WPP must be capable to accept online request (signal) sent by ISO BiH for the change of output power of WPP and initiate adjustment for new values within the period of 10 seconds from the time the signal is first received.

System of frequency response needs to have characteristics as demonstrated in the figure bellow



Frequency (Hz)

Figure 5-5 WPP active power output / frequency requirement in BiH

ISO BiH can request change in adjustment system for active power management in real time. Change of active power of WPP caused by change of system frequency will be achieved by proportional reduction of active power output on all turbines of WPP which are available at the given period.

Also, WPP in BiH will have a capability to.

a) uninterruptedly stay in operation with normal generation output values for frequency range from 49,5 Hz to 50,5 Hz;
b) remain connected to the transmission grid for frequency range from 47,5 to 52,0 Hz in duration of 60 minutes;
c) remain in operation on the transmission grid for frequency range from 47,0 to 47,5 Hz in duration of 20 seconds requesting that in each moment system frequency be above 47,5 Hz;
d) remain connected to transmission grid at the change rate of system frequency including boarder value of 0,5 Hz per second.

The level of secondary control currently available in the system is 50 MW.

5.4.3. *Reactive power and voltage control*

Independently of the type, wind generators, in accordance with their technical characteristics WPPs must fulfill following aspects:

a) maintenance of voltage within prescribed limits
b) automatic regulation of voltage/ reactive power
c) capability to generate reactive power
d) capability to pass through the state of fault

WPP must remain connected to the transmission grid in case of decline of voltage on some phase or possibly on all phases when metering amount on block transformer is above bold black line on the diagram bellow.

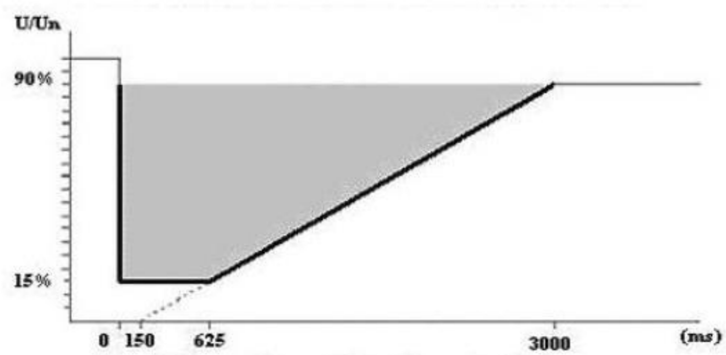


Figure 5-6 Fault ride through ability for WPPs in BiH

In order for WPP to maintain itself on the grid in case of disturbance, it must secure following functions:

a) During decline of voltage on the transmission grid at the connection point, WPP will ensure increase of reactive power proportionally to the voltage decline without exceeding prescribed wind-generator limits. Maximal generation of reactive power must be maintained at least 600 ms or until the voltage on the transmission grid returns into limits of normal operation.
b) WPP will ensure at least 90% of maximum available reactive power and with speed of increase in accordance with characteristics of regulation equipment within one second return voltage into the limits of normal operation.

5.4.4. *WPP data requirements*

In BiH there is no specific data requirement for WPPs. The same data set is taken from SCADA system for all generator types such as: active and reactive power, voltage, frequency, etc.

Also, ISO and TransCo have no any wind measurement data or wind forecasting tools available.

5.5. BULGARIA

5.5.1. WPP grid connection procedure

WPP transmission grid connection procedure in Bulgaria is divided in five main steps:

a) Application – duration 1 week;
b) Studies – 2 months;
c) Preliminary contract – 2 years;
d) Finally contract – 6 month;
e) Testing – 1 month.

The grid connection study is the specific for WPPs and it comprises of:

f) load flow analyses;
g) voltage profile analyses;
h) short-circuit analyses;
i) dynamic simulation,
j) cost-benefit analyses.

Connection cost principle is declared as “Shallow”.

Ancillary system is fully in place. In transmission planning process only WPPs under constructions are taken into account. So far, there were no WPP integration studies on the system level.

5.5.2. Active power and frequency control

In Bulgaria there is no legislative framework with specific technical requirements for WPPs in P/f control, Q/U control or fault ride-through (i.e. wind grid code). There are no balancing rules adopted. Also, ancillary service mechanism is not found appropriate for larger WPP integration.

Generally, technical requirements are the same for all generator types. The range of secondary control currently available in the system is -300 ÷ +500 MW.

5.5.3. Reactive power and voltage control

In Bulgaria only WPPs with installed capacity larger than 50 MW are obliged to regulate connection node voltage.

5.5.4. WPP data requirements

In Bulgaria there is no specific data requirement for WPPs. The same data set is taken from all generator types such as: active and reactive power, voltage level etc.

5.6. CROATIA

5.6.1. WPP grid connection procedure

Generally, in the grid connection process the network user, in this case WPP, is supposed to obtain several documents from and sign several contracts with the TSO. Generally, the connection procedure consists of the following steps:

a) Issuing of the previous consent and creation of conditions for connection to electrical network,

b) Signing a preliminary contract on connection of network users' facilities to power network,

c) Signing a contract on connection of network users' facilities to power network,

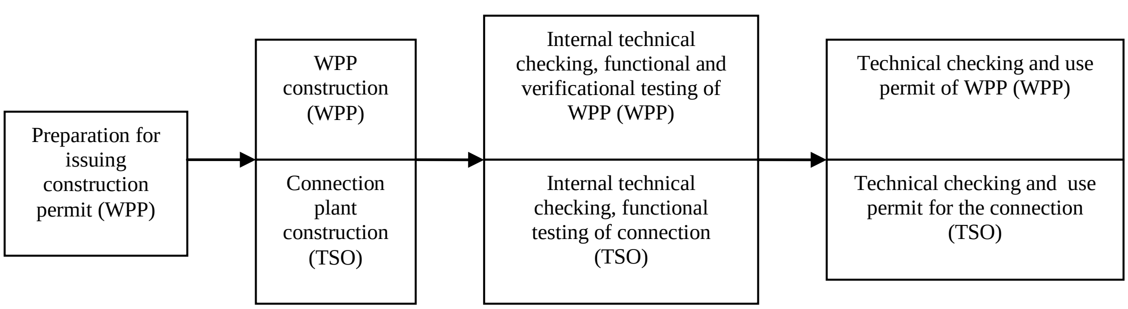
d) Signing a contract on use of a power network,

e) Issuing of the (final) consent and creation of conditions for connection to electrical network,

f) Eventually signing a contract on facility management,

g) Eventually signing a contract on ancillary services.

In total, connection procedure comprises of 64 different steps (permits, analyses, revisions, contracts, testing) that are summarized in the following Figure.



According to the existing experiences in Croatia, from the project ignition till the moment of purchasing of wind turbine it usually took 3-4 years. Turbine delivery and commissioning took additional 1-2 years, while all together it took up to 4-6 years.

The WPP grid connection study is the same as for all other generator types and it comprises of:

a) load flow analyses;
b) voltage profile analyses;
c) short-circuit analyses;
d) power quality analyses;
e) cost-benefit analyses;
f) spatial details of grid connection.

Actually, there are two WPP grid connection analyses. The first one is very preliminary for issuing preliminary energy consent. The second one is detailed elaboration on grid connection as a basis for the connection contract (cost sharing, equipment details).

Connection cost sharing principle in between TSO and WPP investor is declared as “deep” in which investor covers its connection facility while existing network reinforcements are divided proportionally in between investor and TSO.

5.6.2. Active power and frequency control

Ancillary system mechanism and balancing rules in Croatia are adopted, but need to be upgraded. Balancing rules and charges are defined but there is still no full balancing principle in place since most of the internal market in within the single balancing group. Technical requirements for WPPs were adopted as separate document in 2008.

At the moment available secondary reserve capacity in Croatia is at the level of ±200 MW.

Active power and frequency control requirements are defined as follows:

- In the case when system frequency drops below value of 47.0 Hz, WPP has to be disconnected within 0.3 seconds[18].

[18] Besides some very extreme power system conditions during the wartime in early 90’s, Croatia has never operated in isolated mode. It is even more irrelevant after UCTE reconnection in 2004.

- In the case when system frequency drops below value of 47.5 Hz, WPP has to be disconnected within 10 seconds.

- In the case when system frequency is within range from 47.5 Hz to 48.0 Hz, WPP has to remain connected to the grid for at least 10 minutes.

- In the case when system frequency is within the range from 48.0 Hz to 48.5 Hz, WPP has to remain connected to the grid for at least 20 minutes.

- In the case when system frequency is within the range from 48.5 Hz to 49.5 Hz, WPP has to remain connected to the grid for at least 60 minutes.

- In the case of appearance of system under-frequency above 49.5 Hz, WPP has to remain connected to the grid without time limitation.

- In the case of appearance of system above-frequency below 50.5 Hz, WPP has to remain connected to the grid without time limitation:

  Within the frequency range from 50.5 Hz to 51.5 Hz the WPP production has to be lowered with minimal decreasing speed of 2% of rated active power of the WPP per each 0.1 Hz of system frequency deviation above 50.5 Hz.

  No additional wind turbines should be started up if system frequency is higher than 50.5 Hz.

- In the case of system frequency within range from 50.5 Hz to 51.5 Hz, WPP has to remain connected to the grid for at least 60 minutes.

- In the cases when system frequency increased to the value above 51.5 Hz, disconnection of the WPP should be accomplished within 0.3 seconds.

- WPP must have the ability to remain connected to the grid during frequency changes (falling) of 0.07Hz/s.

- This ability does not assume the ability to retain the output power, since it depends on the wind speed.

- Each WPP has to integrate an adequate WPP frequency response controlling system in order to control its contribution to the active power management and frequency regulation.

- Given WPP frequency response controlling system must accept the reference value as stipulated by the TSO. This reference could be changed in real-time by the TSO, while controlling system settings must comply with it.

- Communication between the WPP frequency response controlling system and the operator of the particular wind turbines should be designed as to ensure the undertaking of all requested changes without delay (i.e. in 10 sec) for the purpose of achieving the desired results.

- Non-adherence to the orders from the TSO, especially with respect to the maximum WPP output power may result with temporary WPP disconnection by the TSO.

- WPP operator is responsible for the WPP’s operational security. TSO must possess the ability to impose WPP limiting output power values remotely.

- WPP frequency response controlling system is to be designed in order to allow the following parameters and ranges under normal operating conditions:

Parameters	**Normal Value**	**Minimal Value**	**Maximal Value**
Output power decreasing	5%	0%	25%
Dead band	0.1 Hz	0.0 Hz	0.5 Hz
Droop	5%	3%	20%

- Requested WPP output power decreasing should be realized within a 10 second period. WPP output active power reduction occurring within the frequency range 49.5 Hz to 47.5 Hz must be less then or equal to frequency change rate.

- WPP frequency response controlling system must allow monitoring of the output power response with respect to frequency changes as presented in the following diagram.

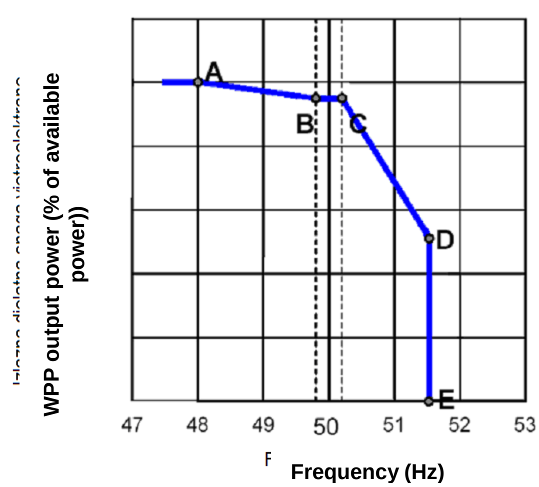


Figure 5-7 WPP active power output / frequency requirement in Croatia

The above mentioned curve relates to the whole WPP. As much as possible it should be applied in a way to keep available wind turbines loaded instead of individual activation/deactivation of additional wind turbines.

- TSO is responsible for specifying characteristic of the power response to frequency changes at least 60 working days prior to the WPP commissioning. WPP owner is responsible for applying this diagram curve.

- *It should be clearly specified why two characteristics are to be defined, what are the differences and purposes of each characteristic.*
- TSO can request the reference value change for the active power reducing in real time, while WPP operator must fulfil this request within 1 minute from the time of receiving the appropriate signal from the system operator.

- TSO can require WPP operation with the points 'A', 'B' and 'C' of the curve set at 100% of the available power. This is expected to be the most frequent case in practice.

- If the frequency increases above the level defined by the 'D' - ‘E' line, WPP should be automatically disconnected from the system by itself. WPP should be again connected to the system as soon as technically possible (when the frequency is below 50.5 Hz).

- WPP rated power designates the maximum active power injection into the system (at 50 Hz).

- WPP operator is to ensure that the rated power is not exceeded during normal system operation. The only exception can occur during the system fault when transient power increasing may be injected or in the case of generator fault which should be removed by the system protection.

- If it is not possible to maintain the WPP output power within the limit of the rated power, the WPP operator is obliged to submit request for approval of increased output power.

- The limits of WPP output power increasing/decreasing rate should be prescribed by the TSO at least 60 working days prior to the WPP commissioning.

- The maximum WPP output power increasing/decreasing rate averaged during 1-minute period is defined as 10% of the nominal WPP power per minute. The maximum output power increasing/decreasing rate averaged over 10-minutes interval is defined as 5% of the WPP rated power per 10 minutes. The maximum output power increasing/decreasing rate can be altered in real time due to limited available system active power regulation or if it is necessary due to WPP contribution in frequency regulation.

- TSO is to be informed of WPP starting-up at least 15 minutes prior to entering the operation after being stopped or after being cut-off due to the fault or after being restrained due to excessive wind speeds (>25 m/s).

- TSO informing is not required if it is not expected that the WPP will inject more than 5 MW at any given moment during the first hour after commissioning. Informing of the TSO is also not required if the WPP commissioning occurs following previous stoppage due to insufficient wind speed. Informing the TSO is also not required if the WPP is initiated within one minute from its previous deactivation.

- Under high-speed wind conditions the WPP output power should be reduced as much as possible in phases, and not simultaneously disconnecting all wind turbine generators from the system.

- WPPs are not required to ensure primary frequency control.

- The WPP operator is obliged to submit a complete WPP dynamic simulation model to the TSO within the deadline and format defined by the TSO.

Additionally, all requirements for connection and operation of the conventional power plants are given within the Grid Code, in which WPPs are not covered. The authors believe that these requirements are sufficient from the TSO perspective, while for the WPPs it is possible to fulfil it without significant additional costs. General suggestion is to clearly distinguish the responsibilities of WPP operator and TSO for different actions on the grid.

5.6.3. Reactive power and voltage control

In Croatia WPP Technical requirements' provisions on the voltage regulation and reactive power compensation are given as follows:

- WPPs must remain connected to the transmission network if the connection node voltages are within the standard operational ranges. Also, in the cases of voltage step changes up to the 10% of nominal voltage level WPPs must remain connected.

- WPP connected to the transmission network through the same transformer together with other consumer should possess ability for power factor adjustment.

- If the voltage regulation is conducted at the level of the whole WPP, the range of available power factor must not be less than the one that can be obtained using individual wind generators.

- WPP has to be able to regulate connection node voltage and to achieve specified voltage value set by the TSO, within allowed voltage limits.

- This connection node voltage value is to be set by the TSO at least 60 working days prior to WPP commissioning. Droop or voltage curve inclination can be changed depending on the system requirements. TSO has to inform the WPP operator at least two weeks in advance of the requested changes in given values. The WPP operator must confirm in a formal manner that the requested changes are applied within the deadline of two weeks from receiving formally submitted TSO notice.

- Depending on the justifiable system requirements and following connection node voltage step change TSO may request from WPP voltage control response to reach 90% of its stationary reactive power within a one second period.

- While generating active power WPP must be able to operate within the power factor range of 0.95inductive to 0.95capacitive (lead/lag capability). This requirement is imposed to the whole WPP, including block-transformers and the internal mid-voltage distribution system within the WPP.

- Each WPP must be able to sustain voltage drop at 15% of the nominal level in a period of 625 ms without grid disconnection. If the connection node voltage value drops quasi-stationary (changing slower than 5% per minute) at the level under 90% of the nominal value, grid disconnection must occur at least after 3 seconds, as shown in the following Figure.

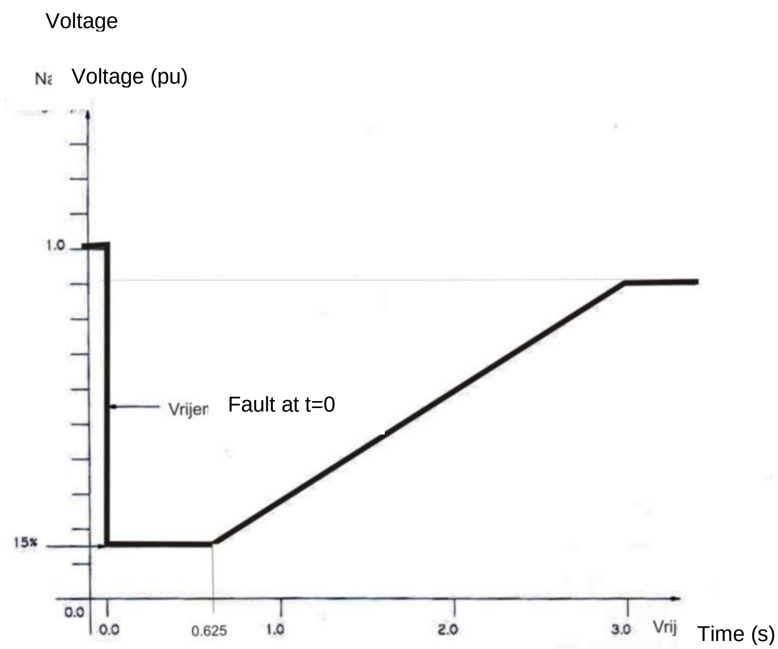


Figure 5-8 Fault ride through ability

- If the symmetric component contribution of the generator to the short-circuit current is two or more times greater than the nominal current, the following diagram must be respected (the following Figure.

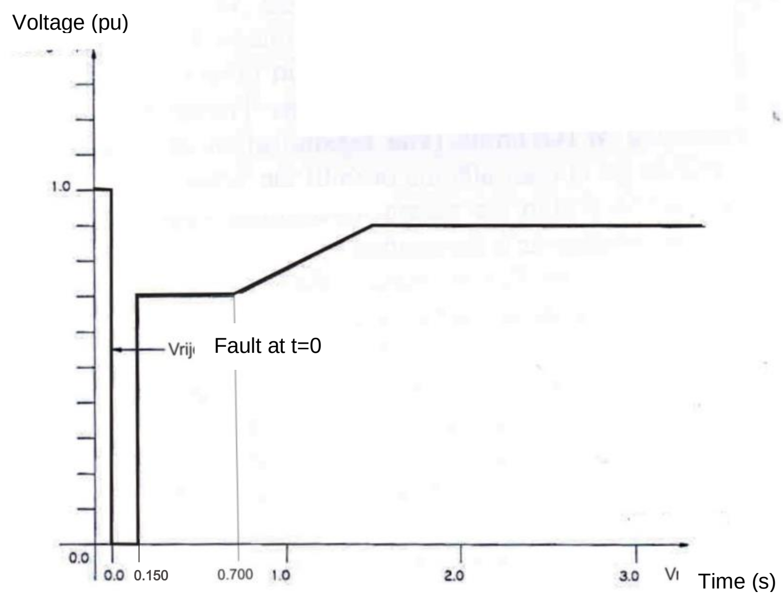


Figure 5-9 Fault ride-through ability for the WPPs significantly contributing to the short-circuit current in the connection node

5.6.4. WPP data requirements

There are large requirements for the supply of WPP technical parameters in Croatia, including the following group of data:

- Construction data (WTG type, dimensions, capacity, owner…),
- Operational data (active/reactive power output),
- Connection transformer voltages,
- Terminal voltages of the wind generators.
- WTG Behavior under of sudden voltage changes,
- WTG Behavior under conditions of system frequency changes (testing the frequency regulation
- system),
- WTG Behavior under conditions of high wind speeds and sudden wind changes,
- WPP power quality,

Currently, Croatia TSO has no wind measurement data and wind forecasting system in operation. But, wind forecaster is installed and currently in testing phase, so it is expected to be valuable operational planning tool in the near future.

5.7. GREECE

5.7.1. WPP grid connection procedure

In Greece WPP grid connection procedure consists of three main steps that lasts for maximum 4 months:

a) application - can be made after the consultation of the Regulatory Authority for Energy.

b) studies - made in advance to ensure the secure injection of power from future wind farms. The transmission capacity limits are announced every year.

c) connection consents - achieved by issuing the Connection Terms Offer (from HTSO) that describes all the necessary details of the common connection point, the legal obligations of both parts and the relevant equipment needed for the integration of a WPP to the Transmission System. After acquiring the Environmental Terms Authorization an agreement between the three parts (Producer, TSO and the Owner of the Transmission System) is signed.

After the construction of the works the wind farm is set in operation under testing mode for minimum 1 month. After the successful fulfillment of the testing period that is supervised by the TSO, the Operation License is issued by the Prefecture.

The WPP grid connection study is the same as for all other generator types and it comprises of:

a) load flow analyses;

b) voltage profile analyses;

c) stability analyses;

d) short-circuit analyses;

e) dynamic simulations;

f) power quality analyses;

g) reliability indicators;

h) fulfillment of technical requirements;

i) cost-benefit analyses.

Connection cost sharing principle in between TSO and WPP investor is declared as “shallowish” in which direct connection cost burdens the investor.

5.7.2. Active power and frequency control

Ancillary system mechanism and Balancing rules in Greece are fully in place. At the moment available secondary reserve capacity in Greece is at the level of ±600 MW.

All WPPs must dispose an active power production real-time control capability under Energy Control Centre setpoint and/ or in accordance with grid frequency, as described on the following Figure. In addition, wind power plant must have the capability to limit variation rate (increase/ decrease) of produced active power injected into the Grid Connection Point (GCP), in accordance with specified limits for maximum and minimum variation rates (±MW/min) to be defined by the Grid Operator.

In order to implement active power control as a function of grid frequency, each WPP must dispose necessary equipment (frequency response system) allowing active power production regulation as a function of grid frequency, in accordance with the figure below. Such operation shall be activated for the execution of order signal received by Energy Control Centre.

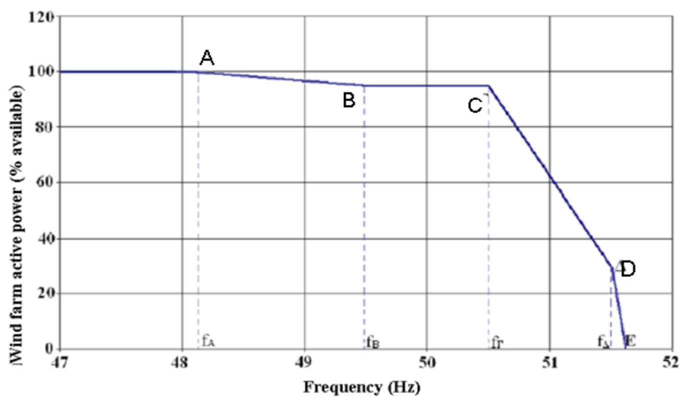


Figure 5-10 WPP active power output / frequency requirement in Greece

5.7.3. Reactive power and voltage control

In Greece WPPs must be capable to regulate their output voltage, reactive power and power factor. MV/ HV Transformer connecting wind farm to the Grid must have an on-load tap changer (OLTC). Wind farm must meet the following requirements and be approved by System Operator (TSO):

1. Wind farm must be capable to receive order by the TSO to set operating mode to:
   a) voltage regulation at grid connection point (GCP)
   b) reactive power regulation
   c) power factor (PF) regulation
   d) reactive power regulation in relation to voltage at GCP, in accordance with the voltage – reactive power regulation characteristic in the figure below

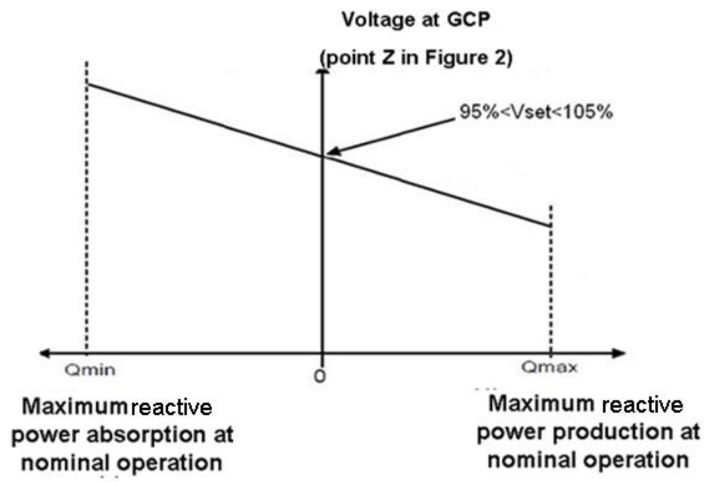


Figure 5-11 Reactive power / voltage regulation characteristic in Greece

2. Wind turbines must ensure Fault Ride Through (FRT) capability, in accordance with the figure given below.

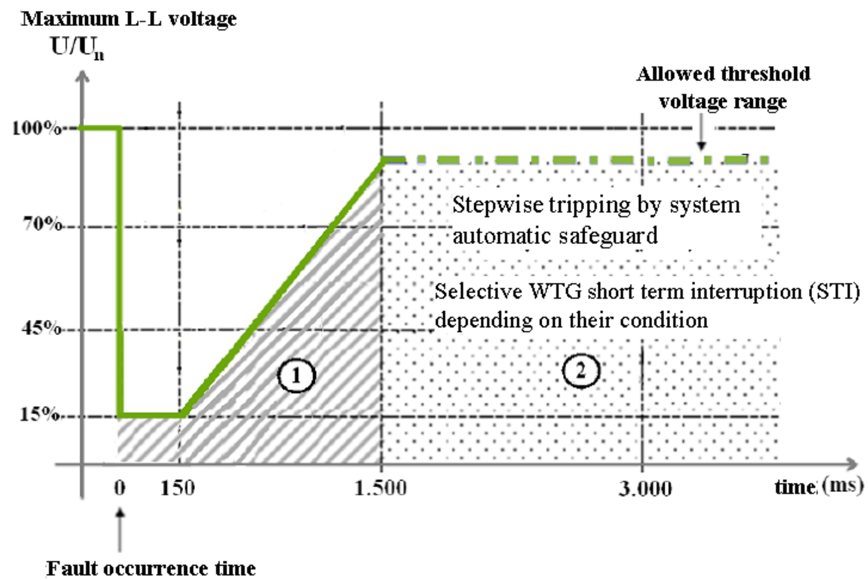


Figure 5-12 Voltage curve for wind turbines fault ride through operation in Greece

In addition, WPPs must support Grid voltage with additional reactive current during long voltage fluctuations. To achieve this, reactive power control must be activated in case of voltage dip or swell outside a ± 10% dead band around wind turbine's nominal voltage, as illustrated in the figure below.

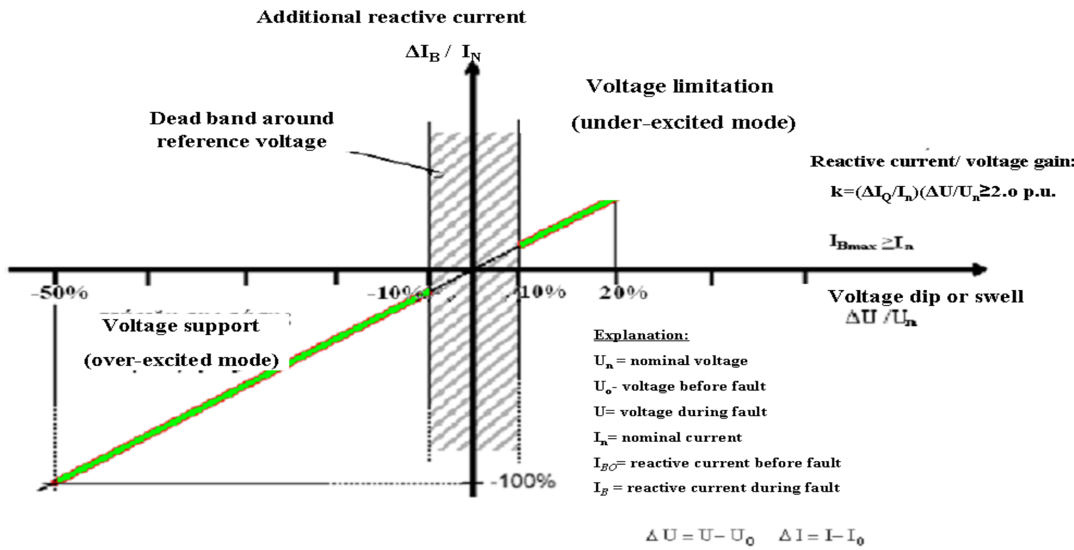


Figure 5-13 Output reactive current during long voltage fluctuations in Greece

5.7.4. WPP data requirements

Information data to be exchanged amongst RTU (installed at the MV/HV substation, WPP facilities and Substation shall be those provided for a respective remote Transmission Substation, in accordance with the provisions of applicable Technical Specification for Public Power Corporation S.A. – Transmission New Projects Department (PPC – TNPD).

In addition, WPP data exchange shall also include the following:

a) meteorological data (to be transmitted from WPPs with installed capacity of more than 10 MW deriving from meteorological mast installed on site. If WPP is located at a big region, more meteorological masts are required (their exact number shall be defined by the TSO)):

   i. wind speed
   ii. wind direction
   iii. air temperature
   iv. air pressure

b) WPP availability data:
   i. WPP production availability due to failure/ damage or scheduled service inspections (0-100%)
   ii. WTG downtime percentage due to high wind (0-100%)
   iii. WTG downtime percentage due to low wind (0-100%)

c) data on WPP (>10 MW only) contribution capability in voltage regulation:

i. currently maximum potential production (0-X MW), only for WPP larger than 10 MW,
ii. currently minimum potential production (0-X MW), only for WPP larger than 10 MW,

d) Control center instructions:
   i. One (1) digital indicator (Local/ Remote) of whether WPP is capable to automatically implement ECC instruction (Local: WPP does not accept any Energy Control Center (ECC) instruction, Remote: Wind Farm accepts all provided instructions by ECC).
   ii. One (1) digital indicator regarding the WPP Central Controller smooth operation.
   iii. Voltage regulation at Grid Connection Point (GCP) under respective setpoint transmitted at real-time by the Energy Control Centre.
   iv. Wind farm reactive power output regulation under respective setpoint transmitted at real-time by the Energy Control Centre.
   v. Wind farm power factor regulation under respective setpoint transmitted at real-time by the Energy Control Centre.
   vi. Voltage regulation at Grid Connection Point (GCP) under agreed voltage – reactive power characteristic.
   vii. Voltage regulation at Grid Connection Point (GCP) under agreed timetable and desired values.
   viii. Five (5) digital indicators corresponding to each one of the aforementioned voltage regulation modes, signaling whether they are activated or not (function is active and it is currently normally executed).
   ix. Digital indicators regarding the capability or incapability of wind farm for automatic frequency control (function is enabled and can be performed after relative ECC instruction) as follows:
   x. Wind farm active power output control as a function of Grid frequency (with droop f-P).
   xi. Wind farm reactive power output limitation under respective setpoint transmitted at real-time by the Energy Control Centre.
   xii. Two (2) digital indicators corresponding to each one of the aforementioned frequency control modes, signaling whether they are activated or not (function is active and it is currently normally executed).
   xiii. One (1) digital indicator (Local / Remote), if 20 kV capacitor blocks are available, regarding wind farm capability or incapability to automatically implement ECC or Energy Distribution Centre instructions.
   xiv. At least eight (8) digital indicators for future use.

e) RTU (or Wind Farm SCADA)/ ECC outputs:
   i. One (1) analogue signal (towards Wind Farm) defining maximum allowed value of wind farm active power production expressed in MW.
   ii. One (1) analogue signal (towards Wind Farm) defining desired voltage value at Grid Connection Point (GCP).

iii. One (1) analogue signal (towards Wind Farms) defining desired value of wind farm reactive power production expressed in MVAr.
iv. One (1) analogue signal (towards Wind Farm) defining desired value of wind farm power factor.
v. At least three (3) analogue signals for future use.
vi. One (1) digital indicator of RTU operating mode.
vii. One (1) digital indicator stating that Producer receives from ECC power production and grid connection rights, optionally.
viii. One (1) digital indicator of gradual reduction of wind farm power under ECC setpoint and automatic disconnection within 10 min.
ix. Five (5) digital indicators corresponding to each one of the aforementioned voltage regulation modes under ECC instruction.
x. Two (2) digital indicators corresponding to each one of the aforementioned frequency control modes under ECC instruction.
xi. At least four (4) digital indicators for future use.

Finally, WPPs with installed capacity of more than 10 MW are to provide online production forecast on a daily basis for following 24-hours by use of method and format complying with TSO requirements.

5.8. MONTENEGRO

5.8.1. WPP grid connection procedure

In the course of procedure for connection of the user to the transmission system, in this case for WPP, TSO prepares following documents which establish the connection requirements and required approvals and permits ensuing legal procedure in different phases of project development. Generally for all network users procedure consists of:

a) Opinion on Connection;
b) Connection approval;
c) Project documentation approval;
d) Interim connection permit for trial operation;
e) Connection contract.

The WPP grid connection study is the same as for all other generator types and it comprises of:

a) optimal PCC (point of common coupling) analyses
b) load flow analyses;
c) network security analyses;
d) voltage stability and reactive power control analyses;
e) short-circuit analyses;
f) voltage flickers analyses (power quality);
g) system reserve analyses;
h) dynamic simulations.

Connection cost sharing principle in between TSO and WPP investor is declared as "shallowish" in which direct connection cost (assets which belong to the investor till the point of ownership delimitation) to the burdens the investor.

5.8.2. Active power and frequency control

Ancillary system mechanism and balancing rules in Montenegro are fully in place. At the moment available secondary reserve capacity is at the level of ±20 MW.

Active power and frequency control requirements in Montenegro for WPPs are defined as follows:

– WPPs are not obligated to participate in primary, secondary and tertiary reserves.

– Additionally, if necessary, in the case of frequency drops, TSO can demand increase of active power production from all WPPs with such possibility, according to droop provided by TSO. So, WPPs with no possibility for increase of active power production during the frequency drops, must obtain necessary equipment only on TSO request.

– At any time WPP production has to be able to lower active power output with minimal decreasing speed of 10% per minute, without disconnection from the system.

– If the frequency of the grid is higher than 50.2 Hz, WPPs must ensure minimum decreasing speed of 40% of current activ power per Hz.

$$\Delta P = 20 P_M \frac{50.2Hz - f_m}{50Hz}$$

P_M – current active power
ΔP – decreasing of active power
f_m – current system frequency

– At frequencies between 47.5 Hz and 51.5 Hz, automatic disconnection from the transmission system due to the frequency deviation from 50 Hz is not permissible. When frequency value of 47.5 Hz or 51.5 Hz is reached, automatic disconnection must take place preferably without delay.

– In the event of frequency drops above the limit line in Figure 5-14, the active power output must not be reduced.

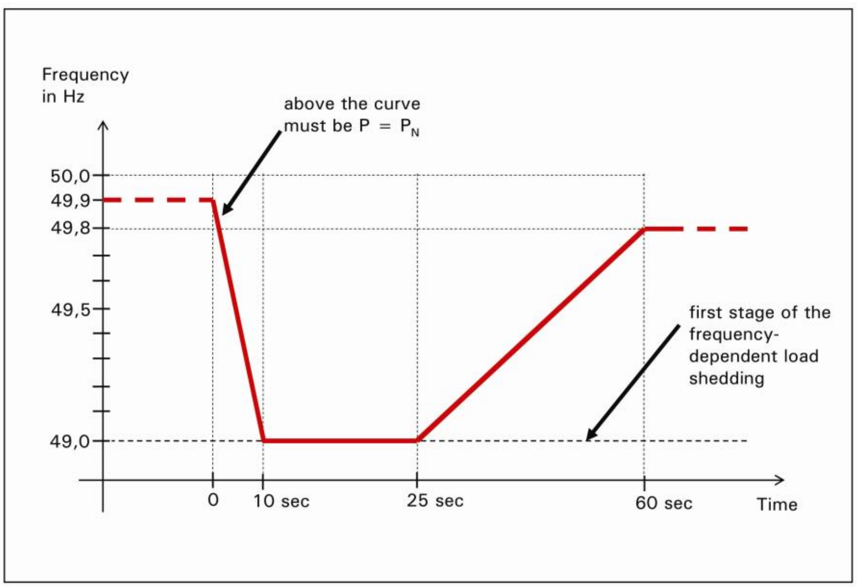


Figure 5-14 Limit line of frequency drop above which active power output must not be reduced

– Basic requirement shown in *Figure 5-15* is not related to primary and secondary control activation, but to capability of the generator unit to maintain active power output during frequency and voltage deviation for the units which are not taking part in the primary control.

- If the system frequency rises to a value of more than 50.5 Hz, TSO can demand, as an additional requirement, a reduction of the active power output as shown in *Figure 5-15*.

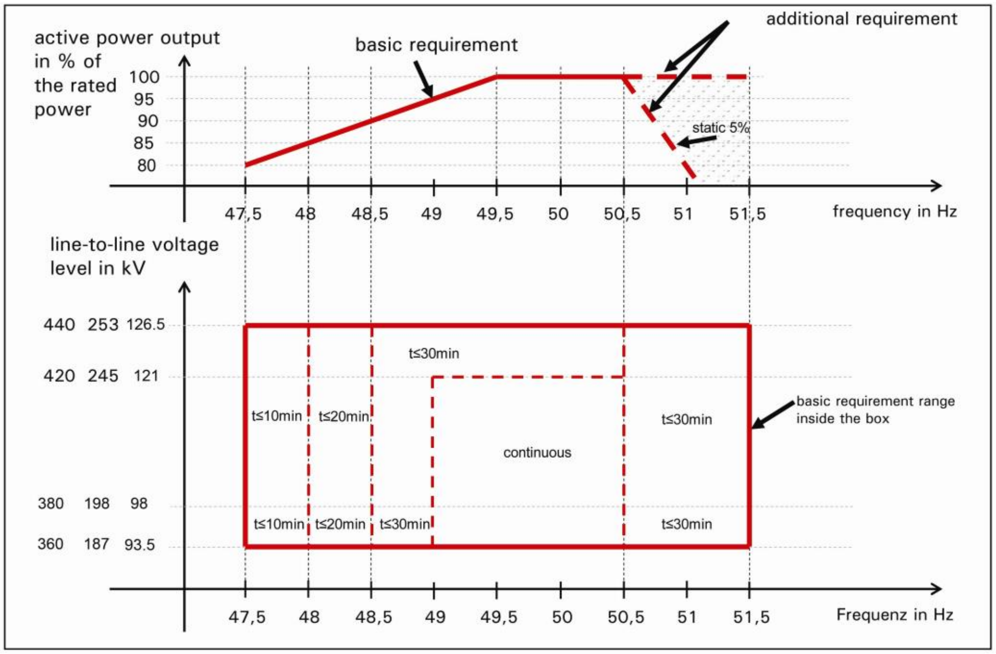


Figure 5-15 Basic requirements for active power output as a function of grid frequency and grid voltage in quasi-stationary state

WPP units are exempted from the requirement of ability for islanded operation. The operator of the WPP can offer this ability as an option.

5.8.3. *Reactive power and voltage control*

The operating point for the steady state reactive power exchange at the active power output is defined by TSO in the issued Connection approval depending on the requirements of the grid. TSO specifies one of the following three possibilities:

- power factor (cos φ);
- reactive power injection (Q in MVAr);
- voltage range (U in kV).

WPPs must meet the following requirements regarding voltage-reactive power control:

– WPP has to be able to regulate connection node voltage and to achieve specified voltage values set by TSO. Depending of working conditions, voltage limits are set in a table below.

Table 5-1 Allowed voltage limits by TSO

Voltage level	Allowed voltage limits in normal condiditons [kV]		Minimum voltage level during the system disturbances [kV]	Maximum voltage level during the system disturbances [kV]
110	99	121	93.5 – 99	121 – 126.5
220	198	242	187 - 198	242 - 253
400	380	420	360 - 380	420 - 440

WPPs must remain fully connected to the transmission grid if the connection node voltages are within the limits under normal conditions. In a case of disturbances connection time is limited for 30,60 or 180 min depending of the voltage level.

– Operation point for reactive power output must be within the solid red line. Each generation unit must fulfill, as a basic requirement, at the grid connection point the range of reactive power provision shown in *Figure 5-16*.

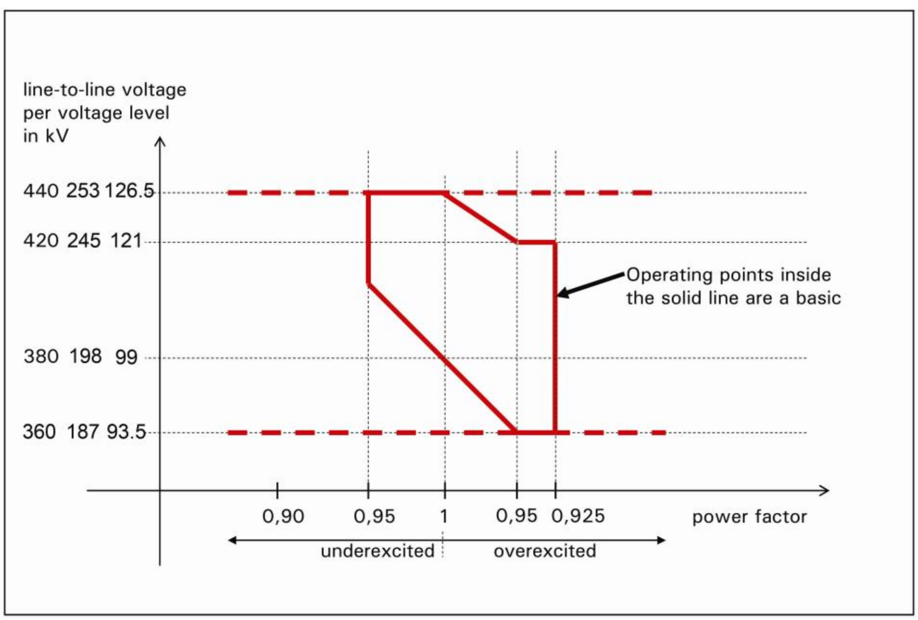


Figure 5-16 Requirements placed on the reactive power provision (U=f(Q/Pmax) of a generation unit at frequencies between 49.5 and 50.5 Hz and without limiting the active power output

As an additional requirement TSO can, in justified cases, agree an extended or different reactive power exchange.

The reactive power exchange by each generation unit with the grid must be technically configured to achieve TSO specified set-point values. Generally, it must be possible to pass, within a few minutes, through the agreed configuration range for the power factor at the rated active power output.

If necessary, equipment must be provided as an additional requirement in the power plant so that voltage and reactive power control can be carried out for all operating points within the basic requirements. In the event of faults in the grid outside the protection range of the generating plant, there must be no disconnection from the grid. A reactive current must be fed into the grid during the period of a fault. WPPs must ensure Fault Ride Through ability, in accordance with the figure bellow.

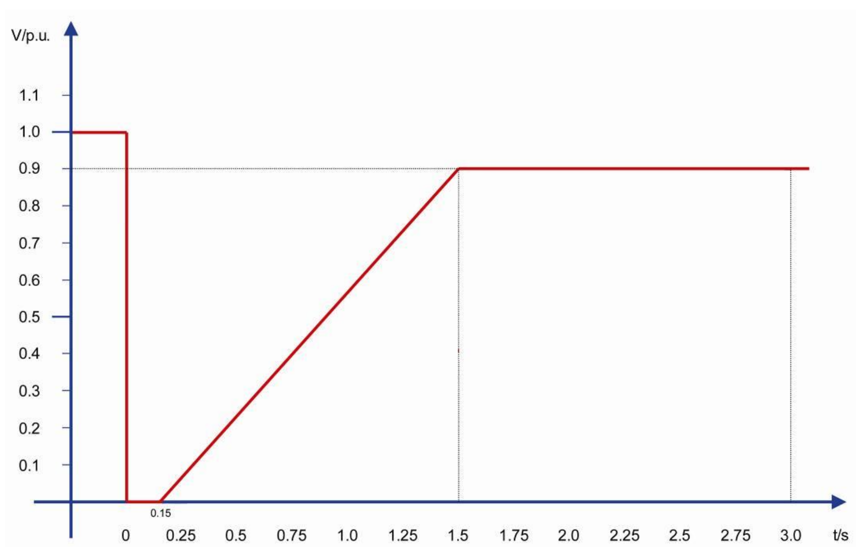


Figure 5-17 Fault ride through profile in the connection point for WPPs

The following requirements are applied above the limit line on the previous Figure.

- All generation units must stay connected to the network and must continue stable operation after the power system has been disturbed by fault.
- If, due to the network connection concept, a generation unit cannot fulfil this requirement, short time interruption (STI) of active power output is permitted with agreement from TSO while at the same time reducing the resynchronisation time and ensuring a minimum reactive power infeed during the fault. The reactive power infeed and resynchronisation must take place so that the generation unit meets, in a suitable way, the respective requirements at the grid connection point;

- if, when experiencing the fault, the individual generation unit becomes unstable or the generator (converter) protection responds short time interruption (STI) of active power is allowed by agreement with TSO. At the start of the STI, resynchronisation of the generation unit must take place within 2 seconds at the latest. The active power infeed must be increased to the original value with a gradient between 10 % and 20% of the rated generator power per second.

The following requirements are applied bellow the limit line on the previous Figure.
Short-term interruption is always allowed bellow limit line. In this case, resynchronisation time of more than 2 seconds and an active power increase following fault clearance of less than 10 % of the rated power per second are also possible but in special cases by agreement with TSO.

The generation units must support the transmission system voltage with additional reactive current during a voltage dip. In order to ensure this, the voltage control must be activated as shown in Figure 5-18, in the event of a voltage dip of more than 10 % of the effective value of the generator voltage. The voltage control must take place within 40 ms (regulator response time) after fault recognition by providing a reactive current on the low voltage side of the generator transformer amounting to at least 2 % of the rated current for each percent of the voltage dip. A reactive power output of at least 100 % of the rated current must be possible if necessary.

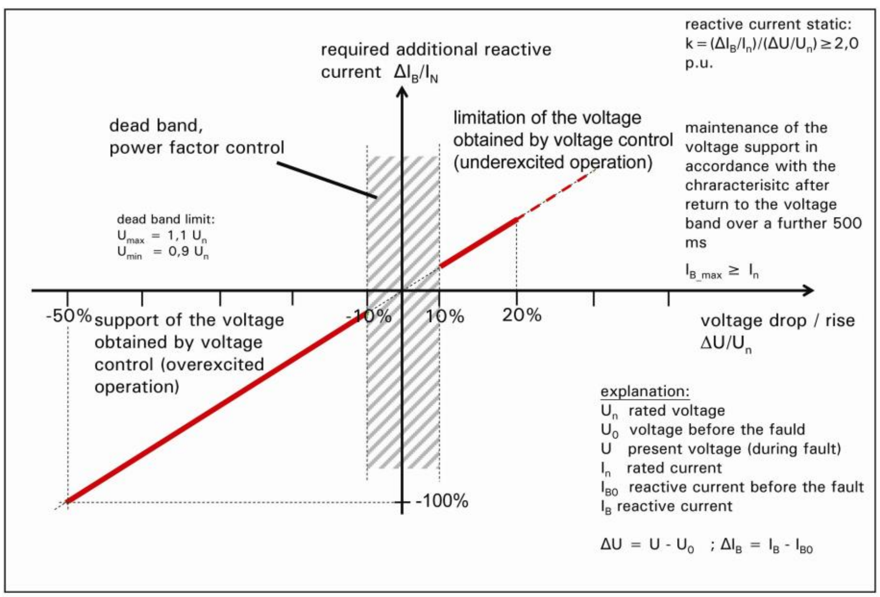


Figure 5-18 The principle of voltage control in normal operation and voltage support in case of disturbances

After the voltage returns to the permissible range, the voltage support must be maintained for a further 500 ms in accordance with the specified characteristic. The transient balancing procedures following the voltage return must be completed after 300 ms. If the generating plant's generators are too far away from the transmission system connection point, resulting in the voltage support being ineffective, TSO requires measurement of the voltage dip at the connection point and the voltage support there as a function of this measured value.

5.8.4. WPP data requirements

In Montenegro there is no specific data requirements for WPPs. Standard data sets for all production units must be provided. In addition to that, all production units must provide to the TSO detailed simulation model of the facility in appropriate format predefined by TSO which must correlate with actual response of the facility subject to static and dynamic simulations in the connection point.

5.9. ROMANIA

5.9.1. WPP grid connection procedure

In Romania WPP grid connection procedure consists of four main steps:

a) Formal application, that should include necessary documents: details about the project (identification, location, technical data), estimated commissioning date, connection study, requirement related to the land, documents from local authorities)

b) Connection study, that is performed in max. 3 months and is valid for 2 months.

c) Technical permit, that is given after 7 days from the moment all documents are sent to the TSO and it is valid for 6 months plus extra 6 months (if requested).

d) Connection contract, that is signed if the technical permit is still in force.

Within this procedure there are rules how to perform a grid solution study (Order no. 129/2009) plus additional rules (internal rules designed by Transelectrica) only for WPPs .

The WPP grid connection study comprises of:

a) load flow analyses for two cases: the next 5 and 10 years for more then 2 connection solutions;

b) stability analyses;

c) short-circuit analyses;

d) dynamic simulations;

e) power quality analyses;

f) reliability indicators;

g) fulfillment of technical requirements;

h) cost-benefit analyses,

i) indication of the most convenient solution.

It is interesting that in the process of transmission network planning WPPs are taken into account with 30% of the installed power of WPP with connection contract and technical permit.

Connection cost sharing principle in between TSO and WPP investor is declared as “shallowish” in which TSO pays if the reinforcements are in its development plans and can be done in time, otherwise the investor pays for reinforcements, but the investment is recovered from the grid operator afterwards. If the identified reinforcement is 60-100% for a particular investor, than investor shares the costs.

5.9.2. Active power and frequency control

Additional technical requirements for WPPs are the part of the technical code. These requirements were approved by ANRE (regulatory authority) in 2009 (Order no. 51).

Ancillary system mechanism and Balancing rules in Romania are fully in place. The main balancing principles are as follows:

a) balancing market has been developed according to the Commercial Code,
b) all the available capacity should be notified, there is a price cap principle,
c) day ahead schedule, intra-day schedule, hourly based notification, the system allows notifications at 15-min intervals,
d) Scheduling Management System is in place,
e) BRP – balancing responsible parties (consumption/production responsible parties) are introduced.

At the moment available secondary reserve capacity in Romania varies in between ±150 MW for peak-off and ±300 MW for peak week day.

At the moment it is estimated that tertiary reserves are not enough for the amount of WPP applications.

Speaking of active power and frequency regulation WPPs larger than 10 MW (dispatchable WPPs with more than 10 MW at the connection point) should be able to:

a) operate continuously for frequencies within the range 47.5 ÷ 52 Hz;
b) remain connected to the electric grid for frequencies within the range 47,0 ÷ 47,5 Hz for at least 20 seconds;
c) stay connected to the electric grid for frequency variation speed up to 0,5 Hz/second;
d) operate continuously to a voltage in the connection point within 0,90 ÷ 1,10 Un;

Wind generating unit must remain connected:

a) in frequencies range of 49,5 ÷ 47,5 Hz. When frequency decreases below 49,5 Hz it's allowed a linear cut of the available power proportional with frequency departure;

b) at frequency fluctuation with a speed within 0,5 Hz/s and/or voltage fluctuation within 0,90 ÷ 1,10Un;

Operation at abnormal voltages or frequencies shall not result in reducing the available active power of wind generating unit for more than 20%.

WPPs (> 10 MW) must be equipped with an automatic controller system of the active power according with the frequency value (automatic controller f/P). It will act according to a response curve frequency / active power exemplified in the following figure, where Pd is the available active power. The coordinates of the points A, B, C, D and E depend on the frequency value of the active power that the plant can produce and on the reference (threshold) value whereupon the active power is limited, within ranges: A (50-47 Hz), B (50-47 Hz), C (50-52 Hz), DE (50-52 Hz). The position points must be set according to the network operator's quests with a maximum error of ±10 mHz. The measurement error of the frequency should not exceed ± 10 mHz.

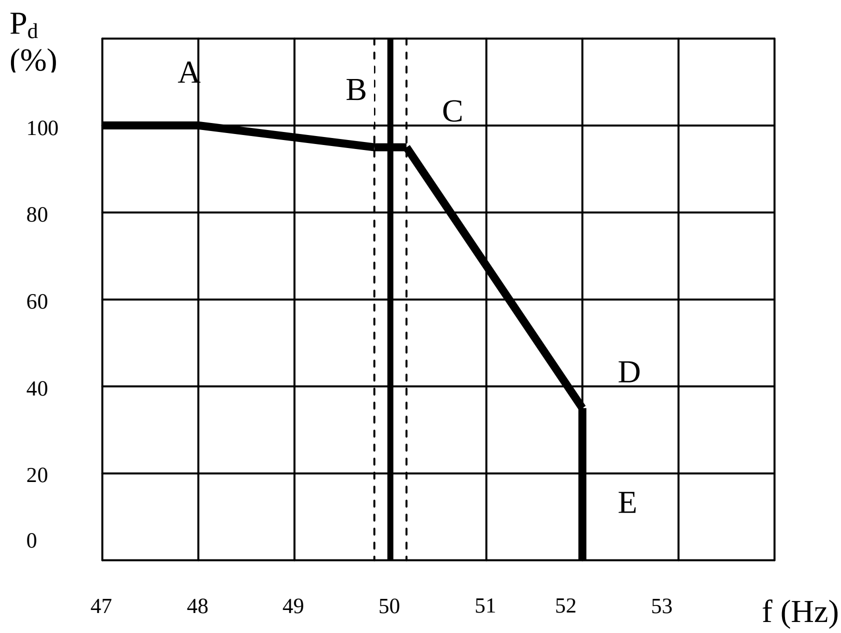


Figure 5-19 WPP active power output / frequency requirement in Romania

The change of the generated active power due to the variations of frequency will be achieved, if possible, by the proportionally change of the active power generated by each group of WPPs, and not by starting and stopping the groups. The response speed of each wind turbine in operation must be at least 60% of nominal power per minute (MW/min).

If the frequency reaches a value higher than the corresponding segment „D – E" on the characteristic curve shown above, it is allowed for the WPP to be disconnected. Conditions for resuming operation are determined by TSO.

For frequency variation in the National Power System, WPP must be able to:

a) ensure the decrease of the active power with at least 40% of installed power / Hz to the increase of frequency over 50,2 Hz;
b) ensure the increase of the active power to the maximum limit of the available active power at decreasing frequency under 49,8 Hz.

5.9.3. Reactive power and voltage control

For values of the voltage in the connection point in the admissible voltage range, the reactive power produced/ absorbed by a WPP must be able to be continuously adjusted to a power factor situated in the range 0,95 capacitive and 0,95 inductive.

WPP must be able to provide automatic voltage- reactive power control in PCC *(= common connection point)* in any of the following modes:

a) voltage control;
b) reactive power control exchanged with the Power System;
c) power factor control.

The detailed conditions regarding voltage and reactive power control are established by the network operator through the technical permit for connection. The response speed of the voltage control system must be at a minimum of 95% of the available reactive power per second.

In normal operation of the grid, WPP must not cause rapid voltage variations grater than ± 5 % of the nominal voltage in the connection point.

Wind turbine must remain in operation at the occurrence of the voltage gaps and voltage variations, on one or all phases, at the connection point, like those given on the following figure.

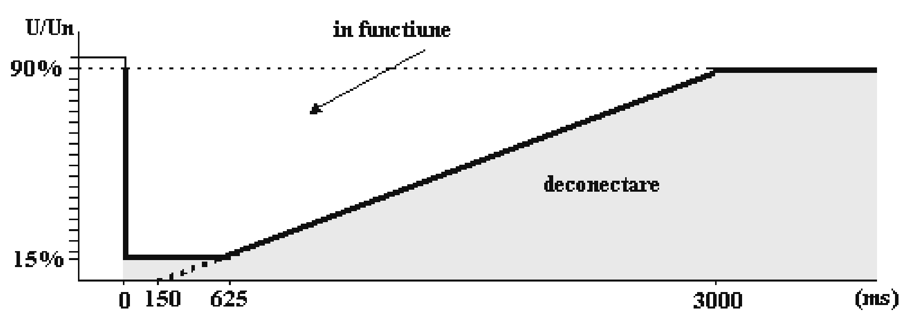


Figure 5-20 Voltage curve for wind turbines fault ride through operation in Romania

During voltage gaps WPP must produce active power appropriate to the residual voltage level and maximize the reactive current injected without exceeding the operational limits of WPP. WPP must be able to generate the maximum reactive current for at least 3 seconds.

Since restoring voltage power of the electrical grid in proper operating parameters WPP must produce all available active power in the shortest time possible, with the variation gradient of the load with at least 20% of the installed power per second (MW/sec).

5.9.4. WPP data requirements

All WPPs larger than 10 MW are obliged to send:

a) active and reactive power output,
b) voltage level,
c) frequency,
d) the position of commuting equipment,
e) produced energy,
f) P/f regulation (yes/no),
g) wind speed and direction,
h) air pressure,
i) sir temperature,

for medium (1-3 days) and short-term (4-24 hours) periods.

Besides these data requirements it is important to note that WPP design conditions and requirements are standardized, as well as wind turbine energy quality characteristics.

Currently, Romanian TSO has no wind measurement data and wind forecasting in operation. But, it is expected soon since the terms of reference for wind forecasting tools has been defined.

5.10. SERBIA

5.10.1. WPP grid connection procedure

Serbian grid code will be adopted at the end of 2011. In Serbia grid connection procedure for connection of users to the transmission system, in this case for WPP, consists of several approvals and permits, issued by TSO:

a) TSO opinion for conditions and possibilities for connection of a new power plant to the transmission system;
b) technical requirements for construction of a power plant and connection to the transmission system;
c) optimal connection conditions analyses;
d) connection contract;
e) connection approval.

Production units are connected to the transmission network in accordance with the Connection contract and the Connection approval.

The WPP network Connection study is the same as for all other generator types and it comprises of:

a) network security analyses;
b) short-circuit analyses;
c) stability analyses.

Connection cost sharing principle in between TSO and WPP investor is declared as "shallowish" in which direct connection cost (assets which belong to the investor till the point of ownership delimitation) burdens the investor.

5.10.2. *Active power and frequency control*

Ancillary system mechanism and balancing rules in Serbia are fully in place. At the moment available secondary reserve capacity is at the level of ±170 MW. In case of the WPPs balancing entity is the power plant.

Active power and frequency control requirements are defined as follows:

- During the voltage and frequency deviations in the transmission networks within the steady state, generator units must be capable to produce active power P that meets the values in the *Table 5-2* if it's connected to the 110 kV and 220 kV voltage level, or *Table 5-3* in case of the 400 kV voltage level.

Table 5-2 Active power production for generators connected to the 110 kV or 220 kV networks

U \ f	47,5 – 48,5 Hz	48,5 – 49,5 Hz	49,5 – 51,5 Hz
$0{,}9U_{nom}$ - U_{max}	$P > 0{,}95P_{nom}$	$P > 0{,}975P_{nom}$	$P = P_{nom}$
$0{,}85U_{nom}$ - $0{,}9U_{nom}$	$P > 0{,}875P_{nom}$	$P > 0{,}875P_{nom}$	$P > 0{,}875P_{nom}$

Table 5-3 Active power production for generators connected to the 400 kV networks

U \ f	47,5 – 48,5 Hz	48,5 – 49,5 Hz	49,5 – 51,5 Hz
$0{,}95U_{nom}$ - U_{max}	$P > 0{,}95P_{nom}$	$P > 0{,}975P_{nom}$	$P = P_{nom}$
$0{,}9U_{nom}$ - $0{,}95U_{nom}$	$P > 0{,}875P_{nom}$	$P > 0{,}875P_{nom}$	$P > 0{,}875P_{nom}$

U – operational voltage in the transmission network connection point;
f – operational frequency in the transmission network;
P_{nom} – nominal active power of a generator;
U_{nom} – nominal voltage of the transmission network in the connection point;
U_{max} – maximal operational voltage in the transmission network, specified by the Grid Code.

Specified active power decrease does not relate to the influence of the primary and the secondary regulation.

- WPP must be capable to decrease active power generation with minimal decreasing speed of 25% per minute of total installed power.
- Every generation unit with the active power generation greater or equal to 50 MW except CHPP, must be capable for the primary regulation.
- Every generation unit with active power generation less than 50 MW, can be used for the primary regulation depending of the agreement with the TSO (EMS).
- Every generation unit must be capable to work with a decreased active power generation. The minimum value of production which guarantees the stable operation of WPP i.e. the technical minimum must be at least 80% of the nominal power.
- Production facility must be capable to operate permanently in frequency limits of 49.5 – 50.5 Hz.
- If the frequency is outside the prescribed range, production facility has to stay connected to the transmission network for the period of time depending of the frequency deviation value:
    a) for the interval of $47{,}5\ Hz \leq f \leq 48{,}5\ Hz$, minimum 30 minutes;
    b) for the interval of $48{,}5\ Hz \leq f \leq 49{,}0\ Hz$, minimum 90 minutes;
    c) for the interval of $49{,}0\ Hz < f \leq 51\ Hz$, permanently;
    d) for the interval of $51\ Hz < f \leq 51{,}5\ Hz$, minimum 30 minutes.
- Generation unit must be capable to remain connected to the transmission network for the frequency change rate up to ±2 Hz/s. For frequency change rates greater than ±2 Hz/s disconnection of generation unit from the network is allowed after 1.25 seconds.

5.10.3. Reactive power and voltage control

WPPs must meet the following requirements regarding the voltage-reactive power control:

- Power plant must remain connected to the transmission grid if the connection node voltages are within the ranges gives as follows.
    a) 400 kV voltage level: between 380 kV and 420 kV;
    b) 220 kV voltage level: between 200 kV and 240 kV;
    c) 110 kV voltage level: between 99 kV and 121 kV.
- If the voltage level is outside the prescribed range, power plant has to stay connected to the transmission grid for the period of time depending of the voltage deviation value:

  a) for connection point to 400 kV:
    - for the interval of $85\%U_{nom} < U_m \leq 95\%U_{nom}$, minimum 60 minutes;
    - for the interval of 95%Unom < Um ≤ 105%Unom, permanently;
    - for the interval of $105\%U_{nom} < U_m \leq 110\%U_{nom}$, minimum 60 minutes;

  б) for connection point to 110 kV or 220 kV:
    - for the interval of $85\%U_{nom} < U_m \leq 90\%U_{nom}$, minimum 60 minutes;
    - for the interval of $90\%U_{nom} < U_m \leq 111.5\%U_{nom}$, permanently;
    - for the interval of $111.5\%U_{nom} < U_m \leq 115\%U_{nom}$, minimum 60 minutes.
- During the quasi-stationary state if the voltage value in the point of connection is out of the limits, generation unit can be automatically disconnected.
- WPP unit must be capable to perform the voltage regulation within the marked area in *Figure 5-21*, but only for the range:

$$0{,}95 \text{ capacitive} \leq \cos\varphi \leq 0{,}95 \text{ inductive}.$$

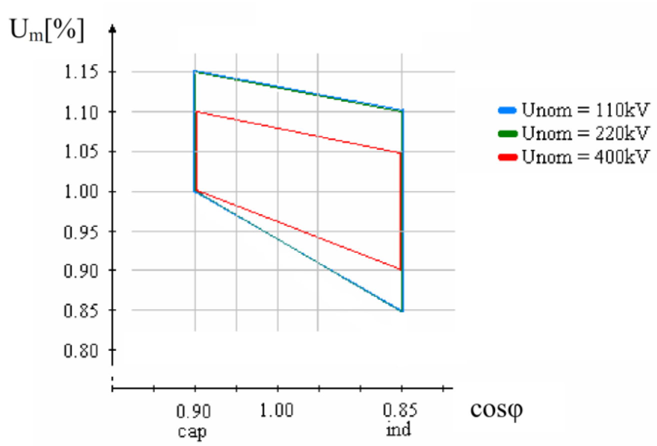


Figure 5-21 Requirements for production of reactive power (U=f(Q/Pmax) of a generation unit at frequencies between 49.5 and 50.5 Hz and without limiting the active power output

U_{nom} – nominal voltage of the transmission network at the connection point;

U_m – voltage value in the transmission network at the connection point;

cosφ – power factor at the connection point.

- Voltage regulation droop coefficient at the transmission grid busbars ($\Delta U_m/\Delta Q_{el}$) where the WPP is connected must be controllable within the range -1.5% to -6% with dead band adjustable for the range 0-1%U_{nom}.
- In case voltage drops bellow the normal operating voltages, generation unit must be capable to increase excitation current for amount not less than 2% for every percent of voltage decrease beyond the normal operating range, and maximally 160%. Increasing of the excitation current must begin at the least 20 ms after voltage drop and last for minimum 500 ms after voltage returns to normal operation range, but to not exceed 10 s from beginning of a voltage drop.
- In the case of voltage drops in the transmission grid during the short circuits, power plant has to stay connected to the transmission network according to the following conditions.
    a) if the voltage level at the connection point is equal to 0 V, power plant must remain connected at least 0.15 s;
    b) if the voltage level at the connection point is 90% of the nominal value, power plant must remain connected at least 1.5 s;
    c) if the voltage level at the connection point greater than 90% of the nominal value, power plant remains in operation until the fault end.
    d) for voltage values between 0 and 90% of the nominal value, time is determined by linear interpolation in accordance with *Figure 5-22.*

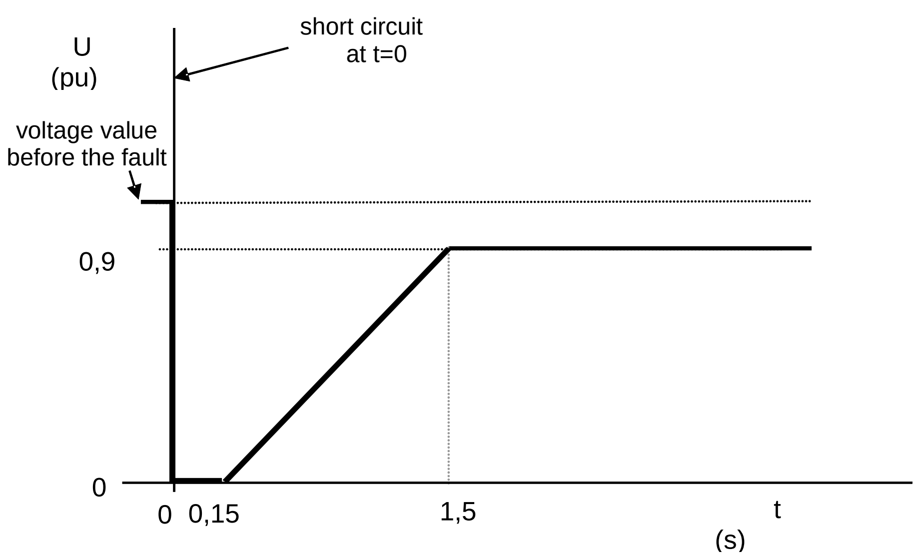


Figure 5-22 Fault ride through profile in the connection point for WPPs in Serbia

- In the case of the voltage increase in the transmission grid, power plant has to stay connected to the transmission network according to the following conditions.

a) for the period of 50 ms, power plant have to stay connected to the transmission network if the voltage value in connection point is less or equal to 120% of a nominal value;

b) for the period of time between 50 ms and 1000 ms, power plant have to stay connected to the transmission grid for voltage value less or equal to the value determined by linear interpolation, in accordance with *Figure 5-23* (U_{max} is a permanent operational voltage defined by the grid code)

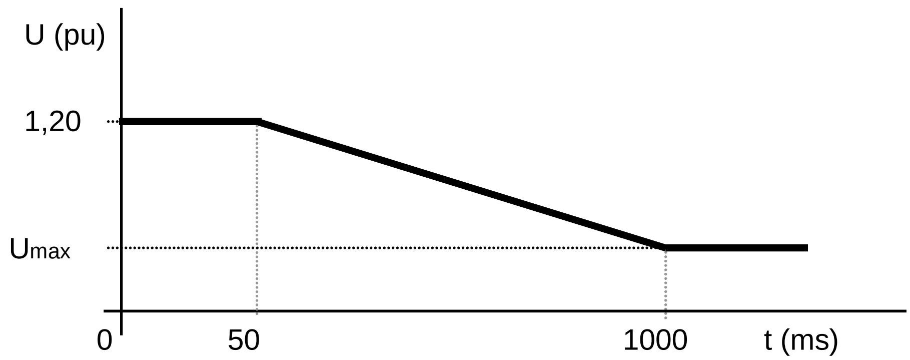


Figure 5-23 Grid voltage requirements in Serbia

5.10.4. WPP data requirements

In Serbia alongside the standard data sets for all production units that must be provided there are some specific data requirements for WPPs.

- WPP must provide to the TSO the following additional real time data:
  a) the number of wind generation units in operation;
  b) the number of wind generation units out of operation due to high wind speed;
  c) the number of wind generation units out of operation due to low wind speed.
- WPP must be equipped with the technical system to submit the following weather data to TSO in real time:
  a) wind speed at the altitude of the wind generators, for the range of 0-50 m/s;
  b) wind direction;
  c) wind temperature, for the range of -40 -60 ºC
  d) atmospheric pressure, for the range of 735-1060 mbar.
- TSO publishes on it's official web page production forecast for WPPs for day D on hour level, until 3pm by previous day D-1.

5.11. TURKEY

5.11.1. WPP grid connection procedure

In Turkey WPP grid connection procedure is done in four main steps:

a) WPP applications are to be sent to EMRA (Turkish Regulatory Agency),
b) After EMRA's approval applications are forwarded to TEIAS for studying connection opportunities,
c) After TEIAS gives its comment concerning the availability, EMRA issues WPP license,
d) Based on the license the connection agreement is signed with TEIAS.

The WPP grid connection study mainly comprises of:

a) load flow analyses,
b) voltage profile analyses,
c) short-circuit and contingency studies.

Restriction criteria for WPP connection is short circuit power level at the WPP connection node. Ratio between WPP installed capacity and short circuit apparent power at the connection node should be up to 5%.

Connection cost sharing principle is defined as "shallow". If the investor pays for connection then the TSO will pay it back to the investor. Otherwise, TSO will put required investment connection in it's yearly investment plan and these procedures takes approximately 3 years for bidding and construction.

During transmission network planning in Turkey all WPPs under development, under construction and with location/construct permit are taken into account.

5.11.2. Active power and frequency control

Ancillary system mechanism and balancing mechanism in Turkey are fully in place. But, despite large WPP penetration, WPPs are not included in ancillary service mechanism. At the moment available secondary reserve capacity in Turkey is at the level of ±1252.5 MW.

WPP's connection to the system is regulated within specific grid code.

P/f control requirements for WPPs in Turkish system are defined as follows:

a) If the frequency of the grid is higher than 50.2 Hz, there will be no permission for additional WPP's connection to the grid.
b) Wind turbines will be able to generate all of it's available capacity on the condition that the grid frequency is between 47.5-50.3 Hz.
c) In the condition that the grid frequency is higher than 50.3 Hz, the curve in P/f diagram will be followed and for each 100 mHz frequency increase, generation shedding will be applied with the rate of 5% of it's available capacity.

5.11.3. Reactive power and voltage control

Similarly to the other countries, WPPs must be able to operate within black solid lines of the specified diagram in wind Grid Code (Diagram E.18.2.1).

Fault ride through is also regulated in accordance to the specified diagram. In the case of fault the following principle is respected:

a) if the voltage stays in the region numbered 1, active power of the wind turbine should be increased with the rate of 20% of its nominal power per second and it should reach its max. active power value which can be generated as soon as the fault cleared away,

b) if the voltage stays in the region numbered 2, active power of the wind turbine should be increased with the rate of 5% of its nominal power per second and it should reach its max. active power value which can be generated as soon as the fault cleared away.

5.11.4. WPP data requirements

Set of WPP data requirement is defined in Wind Grid Code (section E.18.7).

The wind forecast system has been developed by Turkish State Meteorological Service which is available to provide information about the wind forecasts for different heights and for 48 hours with 4 km resolution all around Turkey. The trial tests are going on in order to improve the system.

5.12. OVERVIEW OF LEGISLATIVE FRAMEWORKS

This subsection gives overview of the above mentioned national legislative frameworks for WPP integration. For easier comparison the following Table shows connection procedure, cost sharing principle, ancillary service mechanism, available secondary reserves and specific technical and data requirements for WPP in the regional countries.

Table 5-4 Regional overview of legislative frameworks and procedures for WPPs

	Albania	BiH	Bulgaria	Croatia	Greece	Macedonia	Montenegro	Romania	Serbia	Kosovo*	Slovenia	Turkey
Connection procedure	N/A	✓	✓	✓	✓	N/A	✓	✓	✓	N/A	✓	✓
Connection study	N/A	✓	✓	✓	✓	N/A	✓	✓	✓	N/A	✓	✓
Optimal connection point analysis	N/A	✗	✗	✗	✗	N/A	✓	✓	✓	N/A	✓	✗
Load flow analysis	N/A	✓	✓	✓	✓	N/A	✓	✓	✓	N/A	✓	✓
Voltage profile analysis	N/A	✓	✓	✓	✓	N/A	✓	✗	✗	N/A	✓	✓
Short-circuit analyses	N/A	✓	✓	✓	✓	N/A	✓	✓	✓	N/A	✓	✓
Power quality	N/A	✗	✗	✓	✓	N/A	✓	✓	✗	N/A	✓	✗
Stability analysis	N/A	✗	✗	✗	✓	N/A	✗	✓	✓	N/A	✓	✗
Dynamic simulation	N/A	✓	✓	✗	✓	N/A	✓	✓	✗	N/A	✓	✗
Cost-benefit analysis	N/A	✓	✓	✓	✓	N/A	✗	✓	✗	N/A	✗	✗
Realiability indicators	N/A	✗	✗	✗	✓	N/A	✗	✓	✗	N/A	✓	✗
Spatial details of grid connection	N/A	✗	✗	✓	✗	N/A	✗	✗	✗	N/A	✓	✗
Cost sharing principle	N/A	shallowish	shallow	deep	shallowish	N/A	shallowish	shallowish	shallowish	N/A	shallow	shallow
Ancillary service	N/A	✓	✓ 1	✓ 2	✓	N/A	✓	✓	✓	N/A	✓ 4	✓ 4
Available secondary reserve [MW]	N/A	50	-300:+500	±200	±600	N/A	±20	±150/±300	±170	N/A	±80	±1252.5
Specific technical requirements in Grid Code	N/A	✓	✗	✓	✓	N/A	✓	✓	✓	N/A	✓	✓
P/f regulation	N/A	✓	✗	✓	✓	N/A	✓	✓	✓	N/A	✓	✓
Voltage/reactive power control	N/A	✓	✗	✓	✓	N/A	✓	✓	✓	N/A	✓	✓
FRT	N/A	✓	✗	✓	✓	N/A	✓	✓	✓	N/A	✓	✓
WPP specific data requirements	N/A	✗	✗	✓	✓	N/A	✗	✓	✓	N/A	✓	✓
Wind measurment data	N/A	✗	✗	✗	✓	N/A	✗	✗	✓	N/A	✗	N/A
Wind forecasting tools	N/A	✗	✗	✓ 3	✓	N/A	✗	✗	✗	N/A	✗	✓

*This designation is without prejudice to positions on status, and is in line with UNSCR 1244 and ICJ Advisory opinion on the Kosovo declaration of independence.
1 - Not appropriate for larger WPP integration
2 - Need to be upgraded
3 - Wind forecaster in testing phase
4 - WPPs not included in ancillary service mechanism

In most of the regional countries the connection procedure is defined (data not available for Albania, Macedonia, Kosovo). Most of the countries use very similar connection procedure, including connection study with load flow, voltage profile, short circuit and cost-benefit calculation. In some countries additional analyses are taken with respect to power quality, dynamic simulation and reliability indicators.

Connection cost sharing principle is mainly "shallowish" in the region, with exception of Croatia that has "deep" connection cost sharing model.

In all regional countries with data available, technical and data requirements for WPPs are defined.

It is interesting to compare fault ride through requirements across the region, as given on the following Figure.

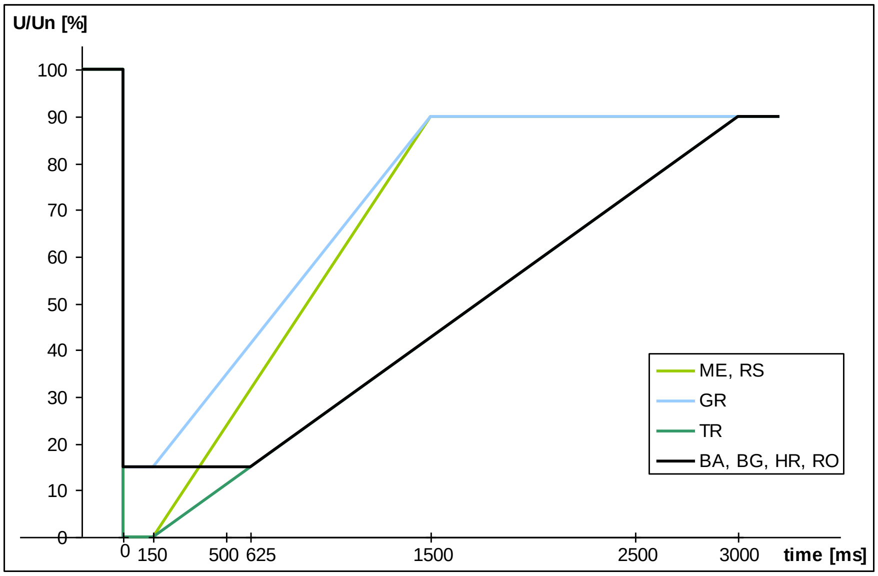


Figure 5-24 WPP fault-ride through requirements in the regional power systems

5.13. RECOMMENDATIONS FOR WIND GRID CODE REQUIREMENTS

This subsection gives the list of general recommendations for regional wind grid code requirements, mostly based on relevant international experience. Some regional countries already adopted most of these requirements, while some of them are about to do it soon, in accordance to national wind integration studies mentioned above. Nevertheless, every TSO is obliged to respect its Grid Code requirements and international obligations, so these recommendations should not be taken as obligatory, but as a step toward regional harmonization and easier WPP integration and secure system operation with large share of WPPs.

All generators connecting to the transmission system are required to comply with the National Grid Codes. As mentioned above, since Wind Turbine Generators (WTG) do not have the same characteristics as conventional synchronous generators, it is appropriate to include a set of Grid Code provisions specifically for controllable wind farms, besides those applicable generally for all generators. These specific recommendations refer to:

1) general WPP requirements
2) operation requirements
3) P/f requirements
4) Q/U requirements
5) Fault ride through requirements
6) Data exchange requirements

5.13.1. General WPP requirements

The authors recommend to use the following list of general requirements for WPPs:

c) All Wind Turbine Generators (WTGs) connecting to the Transmission System are required to be controllable i.e. to have the possibility to regulate the active power according to the frequency deviation.
d) Dynamic simulation model of the WPP should be submitted to the TSO in required format.
e) Active power ramping control must be possible. It must be possible to limit the ramping speed of active power production from the wind turbine in upwards direction. There is no requirement for ramping down control due to rapid wind speed decays, but it must be possible to limit the ramping down rate to 10% of rated power per minute, when the maximum power output limit is reduced by a control action.
f) If the stability of the system is endangered and the problem cannot be solved by other control activities, the TSO is empowered to reduce the active power output of WPPs connected to the system. WPPs have to be able to reduce active power in accordance to the value defined by the TSO.
g) WPPs should be able to follow a defined set-point value for voltage or for power factor or for reactive power injection at the wind farms' connection points.
h) WPPs must be able to continue operation during and after defined disturbances on the transmission network in line with required fault ride through capability).
i) WPPs should be designed such that the wind turbines within the wind farm do not all stop simultaneously as a result of high wind speeds with a phased reduction of wind farm output being achieved over a 30 minute period.
j) WPPs must be controllable from remote locations by telecommunication. Control functions and operational measurements must be made available to the TSO upon request.

5.13.2. Operation requirements

It is also recommended that WPPs are to be capable to operate continuously at normal rated output at:

a) power system frequencies in the range from 49 Hz to 51 Hz;
b) transmission system voltage measured at the HV terminals of the grid connected transformer in the range from 0.95 to 1.05 pu (for 400 kV) and 0.9 to 1.1 of the rated network voltage (for connection nodes at voltage levels lower then 400 kV; it is expected that most of WPPs will be connected to 110 kV).

ENTSO-E recommendations specify that automatic disconnection is not allowed in the range 47.5 - 51.5 Hz. Moreover, in the frequency range of 47.7 - 48.5 Hz and 51 - 51.5 Hz WPPs should remain connected at least for 30 minutes, while in the range of 48.5 - 49 Hz at least for 90 minutes.

Similarly, in the connection node voltage of 0.8 - 0.85 in 220 and 110 kV network, WPP should stay connected for at least 30 minutes, in the range 0.85 - 0.9 for at least 180 minutes, in the range 0.9 - 1.115 it should remain constantly connected and in the range 1.115 - 1.15 for at least 60 minutes.

A designated responsible WPP operator should be contactable by the TSO at all times to discuss operational matters without undue delay and in any event within 15 minutes. Following a request from the TSO, the responsible operator should be present at the Wind Farm’s connection point without undue delay and in any the event within one hour and will be capable of taking any required appropriate actions. The responsible operator must be contactable 24 hours a day, 365 days a year.

If Active Power Control, Frequency Response or Voltage Regulation facilities for the Wind Farm become unavailable, the responsible WPP operator should contact and inform the TSO without undue delay.

5.13.3. Active power control and frequency requirements

WPPs will install Control Systems to allow performing of active power control and frequency response functions. WPP Control System will be capable of operating each WTG at a reduced level or of switching off some WTGs if the WPP's active power output has been restricted by the TSO. The Control System will be capable of receiving an on-line active power control set-point sent by the TSO and will be able to reach the requested set-point within 15 minutes of receipt of the signal from the TSO. The rate of change of output to achieve the requested set-point should be no less than 10% of the current WPP’s active power output per minute.

As given above, WPPs should have the capability to remain connected for at least for 30 minutes in the frequency range of 47.7 - 48.5 Hz and 51 - 51.5 Hz, while in the range of 48.5 - 49 Hz for at least for 90 minutes.

The frequency response system will have a frequency dead-band in the range 47.5 to 50.5 Hz, where no change in the WPP’s active power output will be required. If the system frequency exceeds 50.5 Hz the Frequency Response System will act to ramp down the WPP's active power output with a ramp rate of at least 40% of the current WPP's active power output per Hz. No additional WTG will be switched on until the system frequency is below 50.5 Hz.

If the system frequency is at a level above 51.5 Hz or below 47.5 Hz, the TSO accepts that WPP may disconnect. Any WTG which has disconnected will be brought back on load as fast as technically feasible provided that the system frequency has fallen below 50.5 Hz.

5.13.4. Reactive power control and voltage requirements

Assuming the nominal voltage at the connection point a Wind Farm should be able to ensure a power factor at the connection point in the range from i.e. 0.95 lagging (under-excited) to 0.95 leading (over-excited), or in accordance to required U-Q/Pmax diagram.

In the event of under-voltages at the connection point which are within the continuous voltage operating range defined by the Grid Code (from 100% to 95% of the rated voltage), a Wind Farm has to be able to operate with the power factor in the range with the upper bound of 0.95-overexcited and the lower bound which changes linearly from 0.95-underexcited at 100% of the rated voltages to 1 at 95% of the rated voltage.

In the event of over-voltages at the connection point which are within the continuous voltage operating range defined by the Grid Code (from 100% to 105% of the rated voltage), a Wind Farm has to be able to operate with the power factor in the range with lower bound of 0.95-underexcited and upper bound which changes linearly from 1 at 105% of the rated voltage to 0.95-overexcited at 100% of the rated voltages at the higher voltage side of the grid connected transformer.

WPPs will provide grid connected transformers with on-load tap-changing facilities at all their transmission network connection points. Relevant performance of the tap-changing facility of the grid connected transformer will be specified by the TSO within the grid connection approval.

WPPs will have a continuously acting voltage regulation system with similar response characteristics to a conventional automatic voltage regulator. The voltage regulation system will be capable of receiving a set-point for the voltage at the connection point from the TSO. The voltage regulation system will act to regulate the voltage at this point by continuous adjustment of the Wind Farm's reactive power output, within the required range of the power factor. A voltage change to the set-point will be implemented by the Wind Farm within 20 seconds of receipt of the appropriate signal from the TSO.

5.13.5. Fault ride through requirements

In the event of transmission system voltage dips specified below on any or all phases (where the transmission system voltage is measured at the high voltage terminals of the grid connected transformer) i.e. in the event of any voltage drop below 0.9 of the rated voltage, a WPP will remain connected to the transmission system for at least the following specified period of time:

a) 0.150 seconds if the voltage at the connection point drops to 0% of the rated voltage (in accordance to the very last ENTSO-E recommendations).
b) Required time interval increases linearly to 1.5 seconds with changes of voltage at the connection point from 0% to 90% of the nominal voltage.

In addition to remaining connected to the transmission system during voltage dips, WPPs will have the technical capability to provide the following functions:

a) During a transmission system voltage dip WPPs are required to stop drawing reactive power within 100 ms after a voltage drop;
b) 40 ms after a voltage drop WPPs will start injecting reactive power. The maximal reactive power that should be reached corresponds to 2% of the rated reactive current per each percent of the voltage dip). The maximal reactive power will be reached at least 150 ms after the voltage drop. The injection of the maximum reactive power should continue for at least 350 ms or until the transmission system voltage recovers to within the normal operational range, whichever is the sooner;
c) Following the transmission system voltage recovering to the continuous operating range (±10% around the rated voltage) WPPs will restore to the pre-fault operating regime with a restoration rate of 20% of the active power output before the voltage dip per second (reaching 100% in 5 seconds after voltage recovery).

In the event of more severe voltage dips (out of the above specified limits), the TSO accepts that WPPs may disconnect. Any Wind Farm which has disconnected due to a voltage dip will be brought back on load as fast as technically feasible.

Finally, the following figure presents fault-ride through requirements for the regional countries, as well as recommendation for its harmonization.

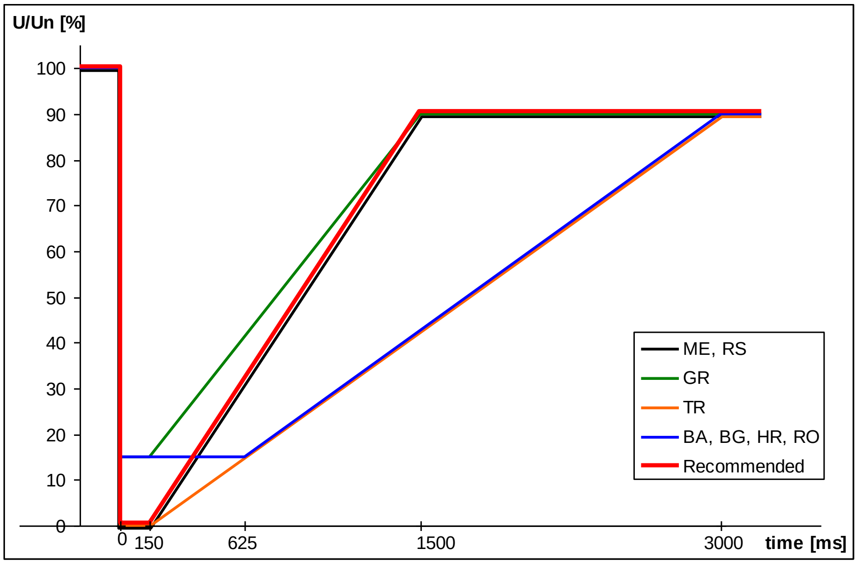


Figure 5-25 Fault-ride through requirements for the regional countries, as well as recommendation for its harmonization

5.13.6. Provision of Operational Data

Responsible WPP operators should submit their operation schedules to the TSO on hourly basis for a day ahead in a format and timescale as specified by the TSO.

Each Wind Farm will make the following signals regarding its operational status available to the TSO using the designated telecommunication interface:

a) Active power output (MW) at the higher voltage side of the grid connected transformer;
b) Reactive power output/demand (±MVAr) at the higher voltage side of the grid connected transformer;
c) Voltage (in kV) at the higher voltage side of the grid connected transformer;
d) Grid connected transformer tap positions;
e) Voltage regulation set-point (in kV);
f) On/off status indications for all available reactive power devices exceeding 2 MVAr;

Meteorological data signals that will be metered at a dedicated meteorological mast located at the Wind Farm's site and provided to the TSO are as follows:

g) Wind speed;
h) Wind direction;
i) Air temperature;
j) Air pressure.

Where signals required to be provided by the Wind Farm become unavailable or do not comply with applicable standards due to failure of the Wind Farm's technical equipment or any other reason under the control of the Wind Farm, the responsible operator of the WPPs shall, acting in accordance with the best professional practice, restore or correct the signals and/or indications as soon as possible.

6. STEADY-STATE ANALYSIS WITH WPP LARGE SCALE INTEGRATION

6.1. PREREQUISITES AND ASSUMPTIONS

PSS/E RTSM (Regional Transmission System Model) which was created by SECI Project Group on the Regional Transmission System Planning, sponsored by USAID, has been used as starting model for the analyses. With a participation of all power system utilities and planners from South East Europe, the Project Group finalized the PSS/E Regional Transmission System Model for 2015 and 2020 used as starting model. The Regional Transmission System Model also comprises models of Greece, Turkey, Slovenia, Burstyn Island (Ukraine), Italy, Hungary and Austria, with aim to have adequate network representation for all types of network analyses. High voltage transmission network of 750 kV, 400 kV, 220 kV, 150 kV (existing in Greece and Turkey), and 110 kV voltage levels is implemented in the model.

In order to make model suitable for this analysis Regional Transmission System Models for 2015 and 2020 were updated according to the most recent national wind power development plans and best knowledge of the TSOs which includes connection points of the planned Wind power plants and their installed power.

Analyses on the PSS/E RTSM should provide insight to transmission network adequacy under different wind power penetration across the analyzed region. Special attention on analysis of overloadings and voltage profile in the region should be given with respect to different wind power scenarios. Possible network congestions and significance of new interconnections and internal lines under different future wind power penetration should be identified.

All system states in which branches are loaded beyond thermal limit (overloaded), by full topology or (n-1) contingency analyses are treated as "insecure states" and referenced as such in the present study.

Voltages are also monitored in full topology as well as in (n-1) contingency cases, but voltages out of limits are not treated as limiting factor, because usually such problems have local characters. Voltage level limits are presented in the Table 6-1. These limits are used in load flow calculations as well as in contingency analysis.

Table 6-1 Defined limits for voltage levels

	Defined voltage levels											
	750 kV		400 kV		220 kV		150 kV		110 kV		Generator	
	min	max	min	max	min	max	min	max	min	max	min	max
kV	712	787	380	420	198	242	135	165	99	121		
p.u.	0,95	1,05	0,95	1,05	0,90	1,10	0,90	1,10	0,90	1,10	0,95	1,05

These limits are defined according to the operational and planning standards used in the monitored region, and they are used for full topology and "n-1" analyses. Although wider voltage limits are allowed in emergency conditions for some voltage levels, these are not taken into consideration.

The list of contingencies included internal branches in systems of Albania, B&H, Bulgaria, Croatia, Macedonia, Montenegro, Romania, Serbia, northern Greece and European part of Turkey as well as tie-lines between these countries. Voltage levels of these branches are as follows:

- all interconnection lines 400, 220 and 110 kV;
- all internal lines 400 and 220 kV;
- all transformers 400/220 kV.

In case of parallel branches, outage of one branch is considered. All branches which are included in list of outages are also monitored.
Internal lines 110 kV as well as transformers 400/110 and 220/110 kV were considered as of local importance, so they were not monitored.

It should be emphasized that models of Italy and Slovenia, especially the ones for year 2020, have not been updated recently. Because of that, these models can’t be treated as reliable, so problems detected in these networks as well as in tie-lines between these networks should not be taken at face value. The problems on the tie-lines between Slovenia and Italy can be a result of the limited range which is covered in the model (not the whole ENTSO-E grid). Italy has high imports and all the power from SEE region is delivered to Italy only through Slovenia and DC links in Greece and Montenegro. Although the pressure of high power flows trough Slovenia towards Italy is expected in the future, the results of this study for loadings of the elements in Slovenian network and Slovenia-Italian border are much higher as if the whole ENTSO-E model was used, therefore the results are not sufficiently credible.

Current thermal limits are used as rated limits for lines and transformers. These limits are established on the basis of a temperature to which conductor is heated by current above which either the conductor material would start being softened or the clearance from conductor to ground would drop beyond permitted limits. In these analyses, conductor current must not reach limits imposed by thermal limit defined for conductors material and cross-section according to the IEC standard (50) 466: 1995 – International Electrotechnical Vocabulary - Chapter 466: Overhead Lines.
For some lines in the models, current limits are defined by other equipment (mostly by measurement transformers) or protection settings. Such limits were imposed by owner TSO with explanation that such limiting equipments were not included in plants for replacement (upgrade).
For transformers, installed rated MVA power is used as thermal limit. Every branch with current above its thermal limit is treated as overloaded.

According to the geographic location of modeled WPPs and wind patterns across the South East Europe four wind regions are identified (Figure 6-1):

- Adriatic – Slovenia, Croatia, Montenegro, Albania, Bosnia and Herzegovina
- Aegean – Greece, Macedonia, South-West Turkey
- Black Sea – North Turkey, East Romania, East Bulgaria
- Continental – Serbia, Kosovo, West Romania, West Bulgaria

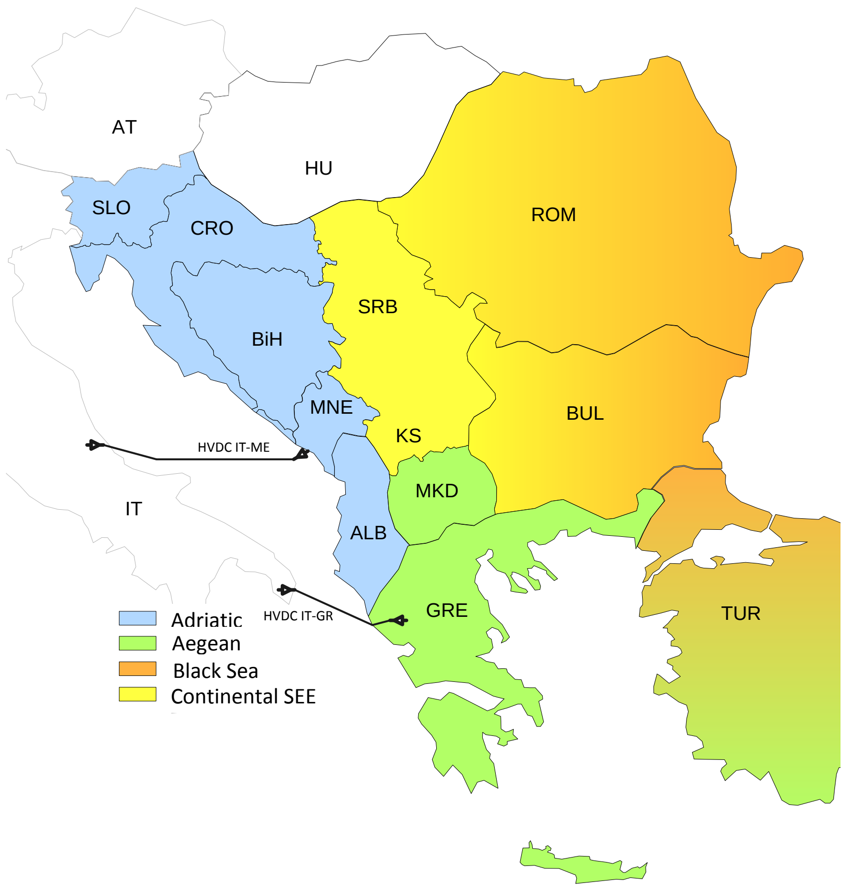


Figure 6-1 Defined Wind regions in South East Europe

It is assumed that countries and part of the countries which belong to one particular Wind region will have the similar wind pattern and therewith the wind power plants in respective wind region will have similar wind power output. This assumption serves as a basis for definition of the wind power scenarios in order to analyze different wind patterns i.e. wind power outputs across the SEE and their impact on regional transmission system.

In addition to Base Case scenario the total number of analyzed scenarios was set to 8. Only winter maximum regimes have been analyzed as they are regarded as the most critical ones on transmission system loading. There are two scenarios related to the planning time frame, i.e. years 2015 and 2020 have been analyzed.

Three levels of wind penetration were used in calculations:

- Low wind penetration (with unity factor of 10% - each WPP unit in region is engaged by 10% of its installed power)
- Medium wind penetration (with unity factor of 35% - each WPP unit in region is engaged by 35% of its installed power)
- High wind penetration (with unity factor of 70% - each WPP unit in region is engaged by 70% of its installed power)

Base case models have been adjusted presuming medium wind penetration. This means that engagement of all WPPs in analyzed region is 35% of installed power, so engagement of other generation units in the region is changed in order to keep the same country totals.

Four exchange scenarios which differ in the level of wind power plant injection in defined regions have been analyzed. Exchange scenarios were created on the assumption that one or two adjacent wind regions would have high wind penetration while the other wind region would have low wind penetration. The last scenario assumes high wind penetration in all wind regions.

The following exchange scenarios will be analyzed related to the level of wind power output in defined wind regions (Figure 6-2):

1. Adriatic + Aegean (Max) → Black Sea (Min)
    - *High wind in Adriatic and Aegean region, 70% of installed wind capacity in operation*
    - *Low wind in Black Sea region, 10% of installed capacity in operation*

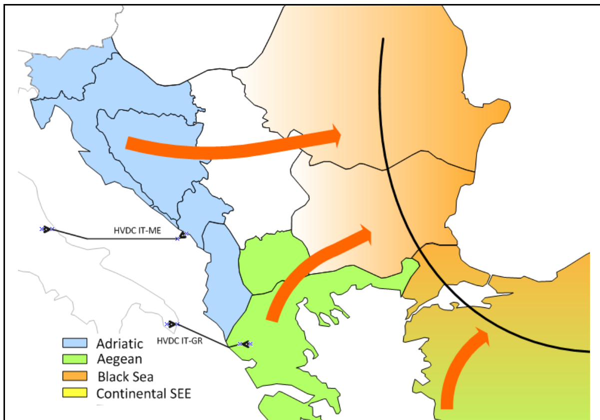
2. Aegean + Black Sea (Max) → Adriatic (Min)
    - *High wind in Black Sea and Aegean region, 70% of installed wind capacity in operation*
    - *Low wind in Adriatic region, 10% of installed capacity in operation*

3. Continental SEE + Black Sea (Max) → Adriatic (Min)
    - *High wind in Black Sea and Continental SEE region, 70% of installed wind capacity in operation*
    - *Low wind in Adriatic region, 10% of installed capacity in operation*

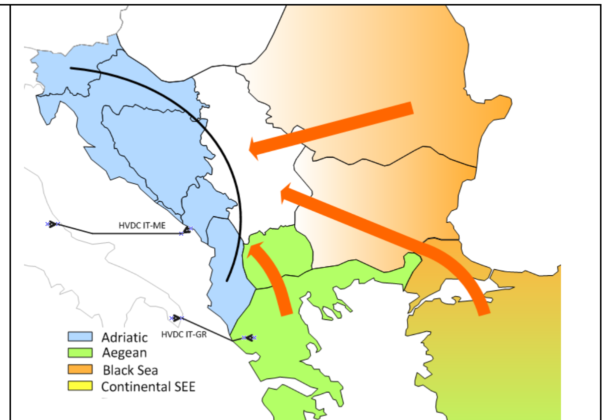
4. Adriatic + Aegean + Black Sea + Continental SEE (Max) → rest of ENTSO-E
    - *High wind in the whole SEE, 70% of installed wind capacity in operation*

In the first three scenarios, according to the wind power output Base case exchanges of respective countries are changed thus creating the power exchange from one Wind region to another while all undistributed excessive or shortage of power is balanced by changing the exchange with the rest of ENTSO-E interconnection. This practically means that rest of ENTSO-E interconnection is playing role of secondary control which “covers” all deficit or surplus in analyzed region.
In practice, high wind power penetration should be followed by decrease output of conventional power plants (especially thermal power plants in order to decrease CO_2 emission). This decrease

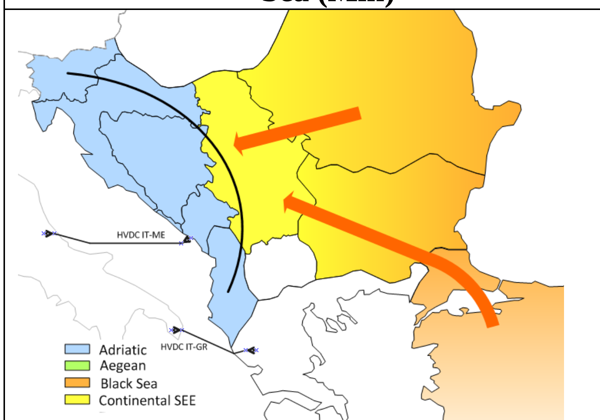
in conventional power plant output should be realized in order to maintain country totals or to minimize change of country totals. The idea that ENTSO-E plays role of secondary control is to make the worst case scenario for analysis.



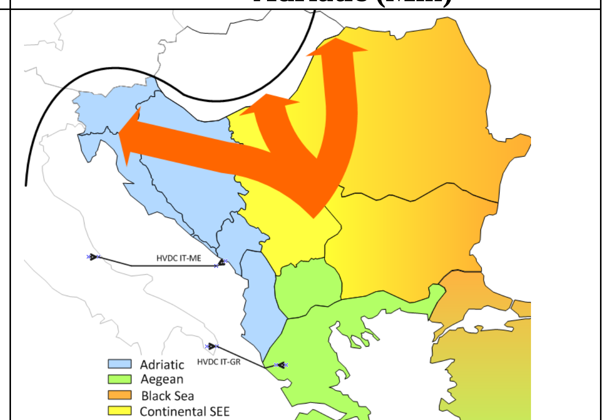
1. Adriatic + Aegean (Max) → Black Sea (Min)



2. Aegean + Black Sea (Max) → Adriatic (Min)



3. Continental SEE + Black Sea (Max) → Adriatic (Min)



4. All Wind regions (Max) → rest ENTSO-E

Figure 6-2 Exchange scenarios between defined wind regions related to level of wind power output

Overview of analyzed exchange scenarios (engagement of WPPs and totals for analyzed region is shown in following tables, Table *6-2* for year 2015 and Table 6-3 for year 2020.

It should be noted that engagement of WPPs in Greece and Turkey was limited in high wind penetration scenarios in 2020. The reason for this is significant amount of planned WPPs in these two countries. Concerning high wind penetration in these two countries, with presumption already described in this chapter, means significant power transfer through analyzed region, which can cause numeric instability of calculation (problems with convergence). So, in order to avoid such problems WPP outputs in these countries are limited by country total.

Table 6-2 WPP generation and totals in 2015 for analyzed scenarios

Country	Region	Base case			Adriatic+Aegean (MAX) & Black Sea (MIN)			Aegean+Black Sea (MAX) & Adriatic (MIN)			Black Sea+Continental (MAX) & Adriatic (MIN)			All regions (MAX)		
		WPP Generation [MW]	Country total: *WPP Generation [MW]*	Country total: Balance (Export) [MW]	WPP Generation [MW]	Country total: *WPP Generation [MW]*	Country total: Balance (Export) [MW]	WPP Generation [MW]	Country total: *WPP Generation [MW]*	Country total: Balance (Export) [MW]	WPP Generation [MW]	Country total: *WPP Generation [MW]*	Country total: Balance (Export) [MW]	WPP Generation [MW]	Country total: *WPP Generation [MW]*	Country total: Balance (Export) [MW]
Albania	Adriatic	18	18	-300	35	35	-283	5	5	-313	5	5	-313	35	35	-283
B&H	Adriatic	30	30	488	60	60	518	9	9	467	9	9	467	60	60	518
Bulgaria	Black Sea	210	210	1000	60	60	850	420	420	1210	420	420	1210	420	420	1210
	Continental	0			0			0			0			0		
Croatia	Adriatic	123	123	-435	246	246	-312	35	35	-523	35	35	-523	246	246	-312
Greece	Aegean	875	875	-350	1750	1750	525	1750	1750	525	875	875	-350	1750	1750	525
Macedonia	Aegean	26	26	-200	53	53	-174	53	53	-174	26	26	-200	53	53	-174
Montenegro	Adriatic	41	41	20	83	83	61	12	12	-10	12	12	-10	83	83	61
Romania	Black Sea	662	662	1000	189	189	527	1324	1324	1662	1324	1324	1662	1324	1324	1662
	Continental	0			0			0			0			0		
Serbia (with UNMIK)	Continental	242	242	-200	242	242	-200	242	242	-200	484	484	42	484	484	42
Slovenia	Adriatic	35	35	824	70	70	859	10	10	799	10	10	799	70	70	859
Turkey	Aegean	78	204	-800	157	193	-812	157	409	-596	78	330	-674	157	409	-596
	Black Sea	126			36			252			252			252		
Total	**Adriatic**	**247**			**494**			**71**			**71**			**494**		
	Aegean	**980**			**1959**			**1959**			**980**			**1959**		
	Black Sea	**998**			**285**			**1996**			**1996**			**1996**		
	Continental	**242**			**242**			**242**			**484**			**484**		
Total	**SEE**	**2467**		**1047**	**2981**		**1561**	**4268**		**2848**	**3531**		**2111**	**4934**		**3514**

- maximum wind penetration (70% of capacity)
- minimum wind penetration (10% of cqpacity)

Table 6-3 WPP generation and totals in 2020 for analyzed scenarios

Country	Region	Base case			Adriatic+Aegean (MAX) & Black Sea (MIN)			Aegean+Black Sea (MAX) & Adriatic (MIN)			Black Sea+Continental (MAX) & Adriatic (MIN)			All regions (MAX)		
		WPP Generation [MW]	Country total: *WPP Generation [MW]*	Country total: Balance (Export) [MW]	WPP Generation [MW]	Country total: *WPP Generation [MW]*	Country total: Balance (Export) [MW]	WPP Generation [MW]	Country total: *WPP Generation [MW]*	Country total: Balance (Export) [MW]	WPP Generation [MW]	Country total: *WPP Generation [MW]*	Country total: Balance (Export) [MW]	WPP Generation [MW]	Country total: *WPP Generation [MW]*	Country total: Balance (Export) [MW]
Albania	Adriatic	80	80	0	160	160	80	23	23	-57	23	23	-57	160	160	80
B&H	Adriatic	134	134	750	269	269	884	38	38	654	38	38	654	269	269	884
Bulgaria	Black Sea	475	525	1000	136	186	661	951	1000	1475	951	1050	1525	951	1050	1525
	Continental	50			50			50			99			99		
Croatia	Adriatic	443	443	-1000	885	885	-557	126	126	-1316	126	126	-1316	885	885	-557
Greece	Aegean	2310	2310	0	3000	3000	690	3000	3000	690	2310	2310	0	3000	3000	690
Macedonia	Aegean	53	53	-100	105	105	-48	105	105	-48	53	53	-100	105	105	-48
Montenegro	Adriatic	41	41	550	83	83	591	12	12	521	12	12	521	83	83	591
Romania	Black Sea	1056	1274	1500	302	520	746	2112	2330	2556	2112	2548	2774	2112	2548	2774
	Continental	218			218			218			437			437		
Serbia (with UNMIK)	Continental	568	568	750	568	568	750	568	568	750	1137	1137	1318	1137	1137	1318
Slovenia	Adriatic	140	140	1415	280	280	1555	40	40	1315	40	40	1315	280	280	1555
Turkey	Aegean	2714	6146	-800	5427	6408	-538	3250	7200	254	2714	7214	267	3250	7200	254
	Black Sea	3433			981			3950			4500			3950		
Total	**Adriatic**	**838**			**1676**			**239**			**239**			**1676**		
	Aegean	**5076**			**8532**			**6355**			**5076**			**6355**		
	Black Sea	**4964**			**1418**			**7012**			**7562**			**7012**		
	Continental	**837**			**837**			**837**			**1673**			**1673**		
Total	**SEE**	**11715**		**4065**	**12463**		**4814**	**14443**		**6794**	**14551**		**6901**	**16717**		**9067**

- maximum wind penetration (70% of capacity)
- minimum wind penetration (10% of cqpacity)
- maximum wind penetration limited by country total

6.2. Winter MAXIMUM 2015

6.2.1. Base case scenario

In this subchapter, steady state analyses are presented for the following power system operation regime:

- load level: winter maximum load in 2015
- wind penetration in Adriatic region: medium (35%)
- wind penetration in Aegean region: medium (35%)
- wind penetration in Black Sea region: medium (35%)

- wind penetration in Continental region: medium (35%)

Generation, Load, Exchange programs

Table 6-4 shows production, demand and exchange programs and other basic information about the areas (countries) of the analyzed region. The same data for two zones in Serbia (Kosovo (under UNSR 1244) zone and EMS zone) are given in Table 6-5. For each area, the first line in the table represents the active power (MW) and the second line the reactive power (MVar).

Table 6-4 Area summary of analyzed region

X-- AREA --X	FROM GENERATION	TO LOAD AT AREA BUSES	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	1276.7	1536.5	0.0	0.0	0.0	0.0	40.2	-300.0	-300.0	-300.0
AL	420.8	555.2	-108.1	0.0	0.0	603.0	388.5	188.2	188.2	
20	8807.2	7603.7	0.0	0.0	14.6	0.0	188.8	1000.0	1000.0	1000.0
BG	3149.7	3045.8	194.6	0.0	123.7	3152.1	2573.0	364.7	364.7	
30	3145.7	2603.2	0.0	0.0	0.0	0.0	54.5	488.0	488.0	488.0
BA	690.0	714.5	0.0	0.0	0.0	906.0	612.6	268.9	268.9	
40	3107.2	3483.0	0.0	0.0	0.0	0.0	59.2	-435.0	-435.0	-435.0
HR	351.4	1074.2	0.0	0.0	0.0	1405.3	715.4	-32.9	-32.9	
50	12305.2	12371.1	0.0	0.0	0.0	0.0	284.1	-350.0	-350.0	-350.0
GR	1652.1	4654.6	170.4	0.0	23.7	6431.0	3343.6	-109.2	-109.2	
60	1553.7	1731.0	0.0	0.0	0.2	0.0	22.5	-200.0	-200.0	-200.0
MK	377.8	529.7	0.0	0.0	2.5	448.7	263.4	31.0	31.0	
70	10193.0	8937.9	0.0	0.0	81.5	0.0	173.6	1000.0	1000.0	1000.0
RO	268.4	2731.1	0.0	0.0	237.5	4690.3	2040.0	-49.9	-49.9	
75	3408.2	2514.0	0.0	0.0	8.8	0.0	61.3	824.1	824.1	824.0
SI	1025.1	811.0	0.0	0.0	53.6	600.7	875.7	-114.5	-114.5	
80	54586.2	54622.0	0.0	0.0	0.0	0.0	764.2	-800.0	-800.0	-800.0
TR	4505.6	7792.0	1176.2	0.0	0.0	17243.5	12866.9	-86.0	-86.0	
90	7217.9	7240.5	0.0	0.0	11.4	0.0	166.0	-200.0	-200.0	-200.0
RS	1903.4	2389.5	0.0	0.0	66.6	1851.8	1924.9	-625.8	-625.8	
91	927.9	877.5	0.5	0.0	2.2	0.0	27.7	20.0	20.0	20.0
ME	139.3	318.4	-33.0	0.0	16.2	283.0	235.7	-115.0	-115.0	

COLUMN	106529.0	103520.5	0.5	0.0	118.8	0.0	1842.1	1047.1	1047.1
1047.0									
TOTALS	14483.5	24615.9	1400.1	0.0	523.8	37615.5	25839.7	-280.6	-280.6

Table 6-5 Zone summary in Serbia

X-- ZONE --X	FROM GENE-RATION	TO LOAD AT ZONE BUSES	TO BUS SHUNT	TO GNE BUS DEVICES	TO LINE SHUNT	FROM CHARGING	TO LOSSES	-NET INTERCHANGE- TO TIE LINES	TO TIES + LOADS
90	6415.4	6111.4	0.0	0.0	9.8	0.0	143.3	150.9	150.9
EPS	1462.5	2011.1	0.0	0.0	57.9	1592.2	1676.1	-690.4	-690.4
901	802.5	1129.1	0.0	0.0	1.6	0.0	22.7	-350.9	-350.9
KOS	440.9	378.4	0.0	0.0	8.6	259.6	248.8	64.6	64.6
COLUMN	7217.9	7240.5	0.0	0.0	11.4	0.0	166.0	-200.0	-200.0
TOTALS	1903.4	2389.5	0.0	0.0	66.6	1851.8	1924.9	-625.8	-625.8

Element loadings

Figure 6-3 shows histogram of branch loadings in the transmission grid of analyzed region. All lines 220 kV, 400 kV and 750 kV in these countries are taken into consideration as well as transformers 750/400 kV and 400/220 kV. Power network on 110 kV and 150 kV voltage level is not analyzed in details in this Study since they are considered as of local importance. It can be noticed that all but two observed elements are loaded below 80% of their thermal limits.

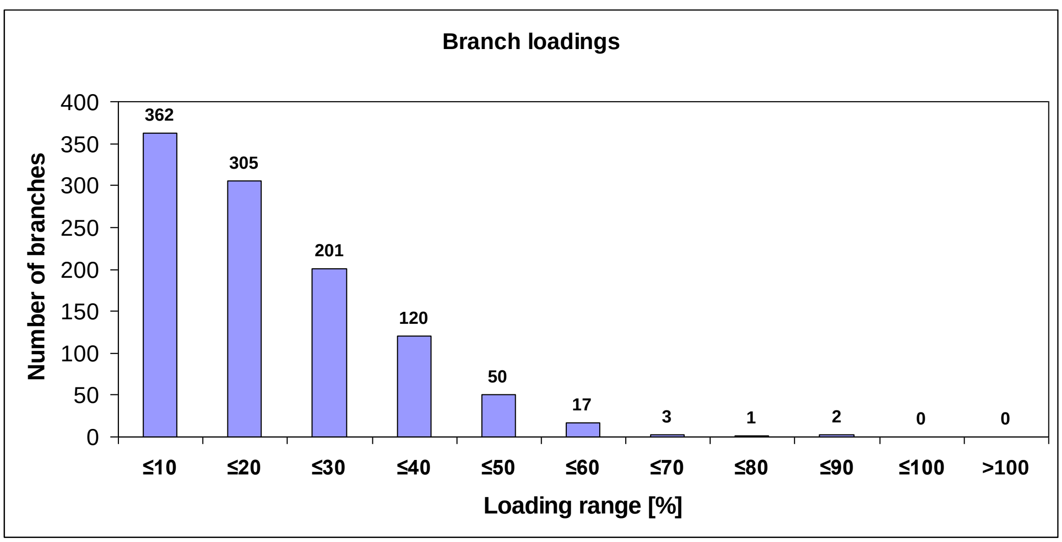


Figure 6-3 Branch loadings in analyzed region

List of transmission lines and transformers in monitored grid which are loaded more than 80% of their thermal limits is given in Table 6-6.

Table 6-6 Branches loaded over 80% of their thermal limits

FRMBUS,	FROMBUSEXNAME,	TOBUS,	TOBUSEXNAME,	CKT,	STS,	MW,	MVAR,	MVA,	%I,
31410,	LDIVAC1 400.00,	31411,	LDIVAC1P 400.00,	1 ,	1,	517.79,	114.79,	530.37,	89.04
31410,	LDIVAC1 400.00,	31411,	LDIVAC1P 400.00,	2 ,	1,	517.79,	114.79,	530.37,	89.04

Total 2 items

There are only two elements loaded more then 80% of their thermal limits. These elements are phase-shift transformers in Slovenia, which are installed on 400 kV tie-line Divaca (SI) – Redipuglia (IT). Although the pressure of high power flows trough Slovenia towards Italy is expected in the future, the results are not sufficiently credible due to the causes listed in Chapter 6.1.

Voltage profile

Figure 6-4 shows histogram of busbar voltages in 220 kV and 400 kV network of analyzed region. It can be noticed that the voltages of all monitored buses are within the permitted limits in normal operating conditions. Voltages in the most of the 220 kV buses are slightly above nominal values, but still within the limits. In other words, there are no voltages out of limits in the area of interest.

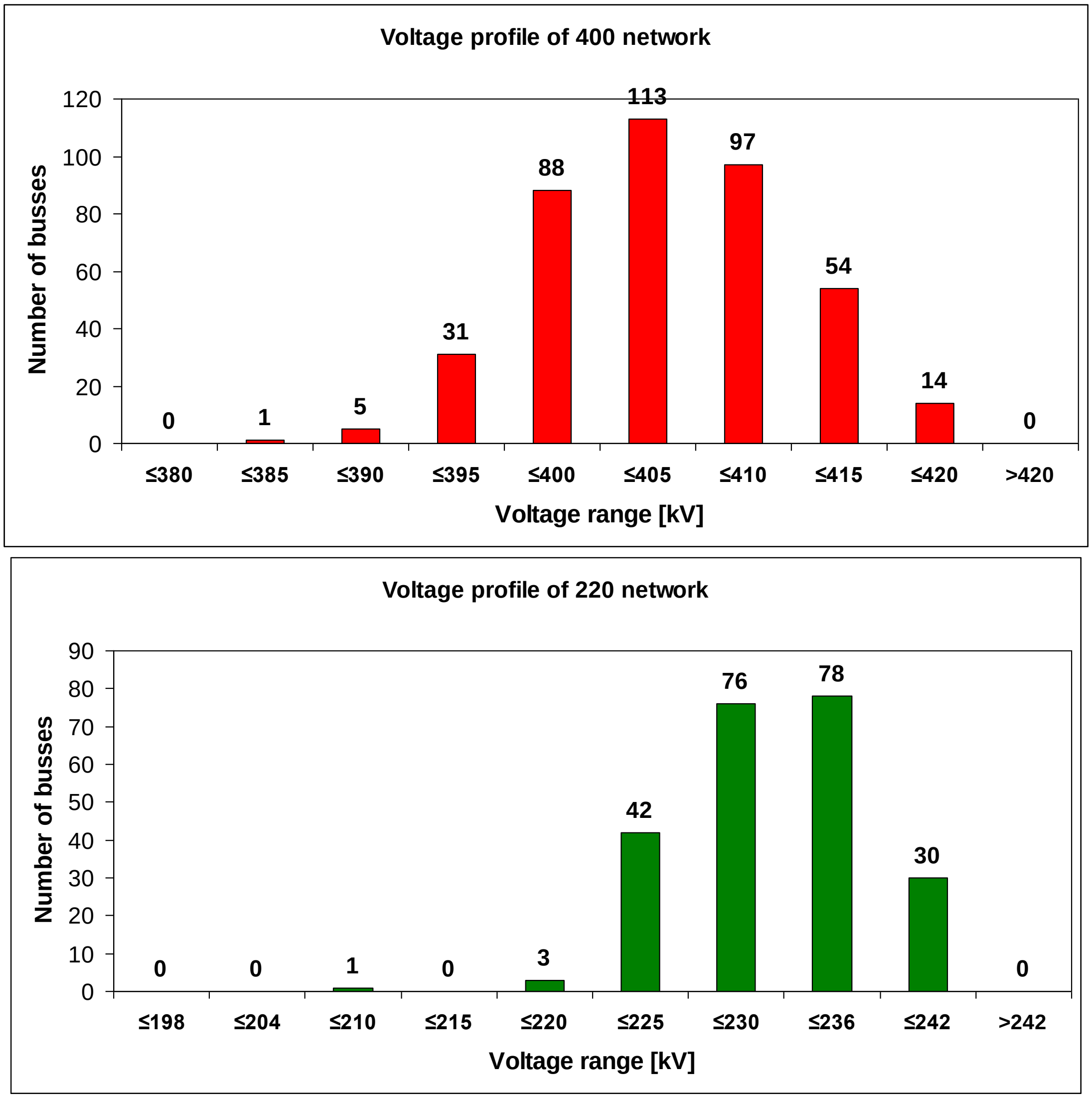


Figure 6-4 Voltage profile of 400 and 220 kV network in analyzed region

Security (n-1) Assessment

Results of contingency (n-1) analysis for the observed regime are presented in Table 6-7. Monitored branches are given with their bus number and bus name used in the PSS/E models. For easier illustration of critical elements geographical positions of critical elements are shown in Figure 6-5.

Table 6-7 Results of security (n-1) analysis

<----------------- MONITORED BRANCH		-----------------	----------------->	CONTINGENCY	RATING	FLOW	%
31210 LDIVAC2	220.00	156*XPA_DI21	220.00 1	SINGLE 205	365.8	462.4	125.9
31210 LDIVAC2	220.00	156*XPA_DI21	220.00 1	SINGLE 206	365.8	462.4	125.9
28058 RCRAIO2B	220.00	28060*RISALN2A	220.00 1	SINGLE 507	304.8	322.9	101.2
28057 RCRAIO2A	220.00	28060*RISALN2A	220.00 1	SINGLE 509	304.8	322.5	101.1
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 1	SINGLE 731	600.0	620.5	103.4

```
 31410*LDIVAC1     400.00  31411 LDIVAC1P    400.00 2  SINGLE 731      600.0    620.5    103.4
 31210 LDIVAC2     220.00    156*XPA_DI21    220.00 1  SINGLE 734      365.8    642.1    178.9


CONTINGENCY LEGEND:
LABEL          EVENTS
SINGLE 205  : OPEN LINE FROM BUS 31410 [LDIVAC1     400.00] TO BUS 31411 [LDIVAC1P    400.00] CKT
1
SINGLE 206  : OPEN LINE FROM BUS 31410 [LDIVAC1     400.00] TO BUS 31411 [LDIVAC1P    400.00] CKT
2
SINGLE 507  : OPEN LINE FROM BUS 28057 [RCRAIO2A    220.00] TO BUS 28060 [RISALN2A    220.00] CKT
1
SINGLE 509  : OPEN LINE FROM BUS 28058 [RCRAIO2B    220.00] TO BUS 28060 [RISALN2A    220.00] CKT
1
SINGLE 731  : OPEN LINE FROM BUS 31210 [LDIVAC2     220.00] TO BUS 156 [XPA_DI21    220.00] CKT 1
SINGLE 734  : OPEN LINE FROM BUS 31411 [LDIVAC1P    400.00] TO BUS 80 [XRE_DI11    400.00] CKT 1
```

It can be seen that there are four critical branches which are overloaded:

Phase-shift transformers in SS Divaca, which are installed on 400 kV tie-line Divaca (SI) – Redipuglia (IT), are overloaded of around 3% in case of outage of tie-line 220 kV Divaca (SI) – Padriciano (IT). The main purpose of installation of these two transformers is to limit flows to Italy. Tie-line 220 kV Divaca (SI) – Padriciano (IT) is overloaded around 79% in case of outage of tie-line 400 kV Divaca (SI) – Redipuglia (IT). Although the pressure of high power flows trough Slovenia towards Italy is expected in the future, the results related to problems in Slovenia are not sufficiently credible due to the causes listed in Chapter 6.1.

There are two parallel lines 220 kV Craiova – Isalnita in Romania which are also critical. Outage of one of them causes overload of the other one by 1%.

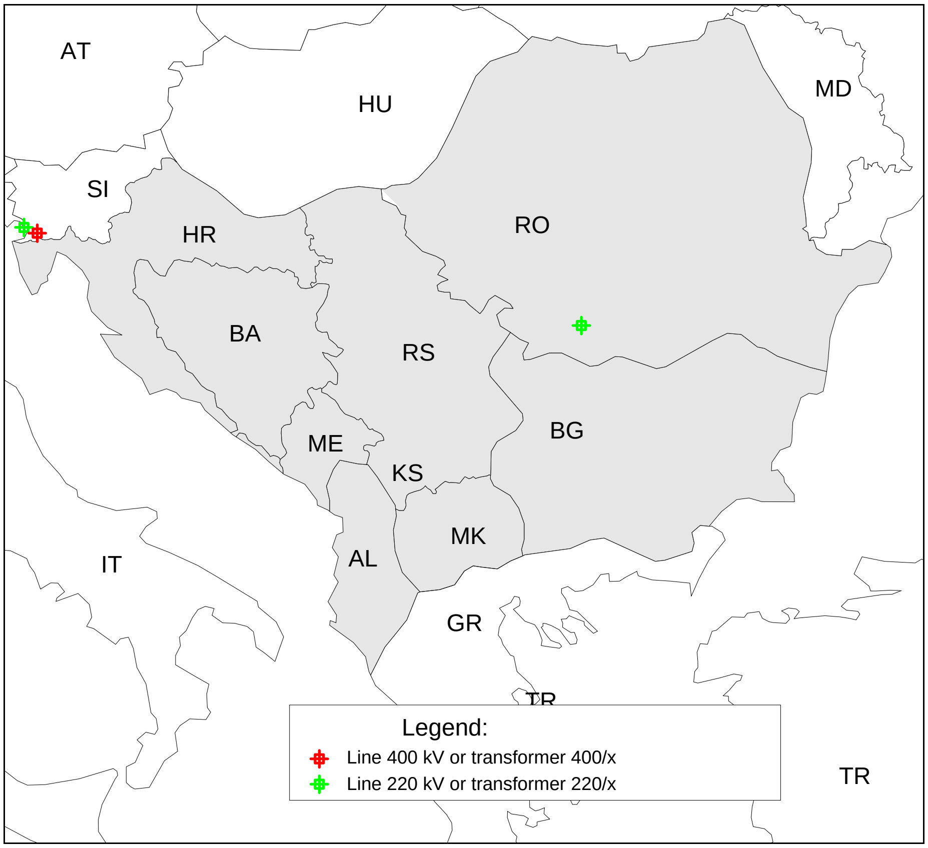


Figure 6-5 Geographical positions of critical elements

All other scenarios in 2015 that follow in the Study will be compared with these results. In that way it will be easy to clarify which changes and problems in the network are caused by each analyzed wind scenario.

6.2.2. Wind scenario 1: Adriatic + Aegean (Max) → Black Sea (Min)

In this subchapter, steady state analyses are presented for the following power system operation regime:

- load level: winter maximum load in 2015
- wind penetration in Adriatic region: high (70%)
- wind penetration in Aegean region: high (70%)
- wind penetration in Black Sea region: low (10%)
- wind penetration in Continental region: medium (35%)

Basic information about areas (countries) of the analyzed region and aggregated physical exchanges among analyzed countries are given in Appendix (Table 9-1 and Table 9-2).

Histogram of branch loadings with comparison against branch loadings in base case is given in Appendix (Figure 9-1). List of transmission lines and transformers in monitored grid which are loaded more than 80% of their thermal limits is also given in Appendix (Table 9-3). There are only three elements loaded above 80% of their thermal limits. Phase-shift transformers in Slovenia, which are installed on 400 kV tie-line Divaca (SI) – Redipuglia (IT) are loaded around 96% of their thermal limits. Tie line 220 kV Divaca (SI) – Padriciano (IT) is loaded 83% of it thermal limit. Increase of loading of these branches is result of increase of power transfer from the analyzed region to the rest of ENTSO-E, since ENTSO-E is taking all region's surplus, especially because of surplus in Adriatic region.

The most significant changes in power flows in the area of SEE are shown in Appendix (Table 9-4). The main paths for transfer output power from WPPs with high wind penetration could be detected from these tables.

These changes in power flows have influence on power losses. The changes are shown in Figure 6-6. Significant decrease of losses can be noticed in Bulgaria, Turkey and Serbia and increase in Romania and Croatia.

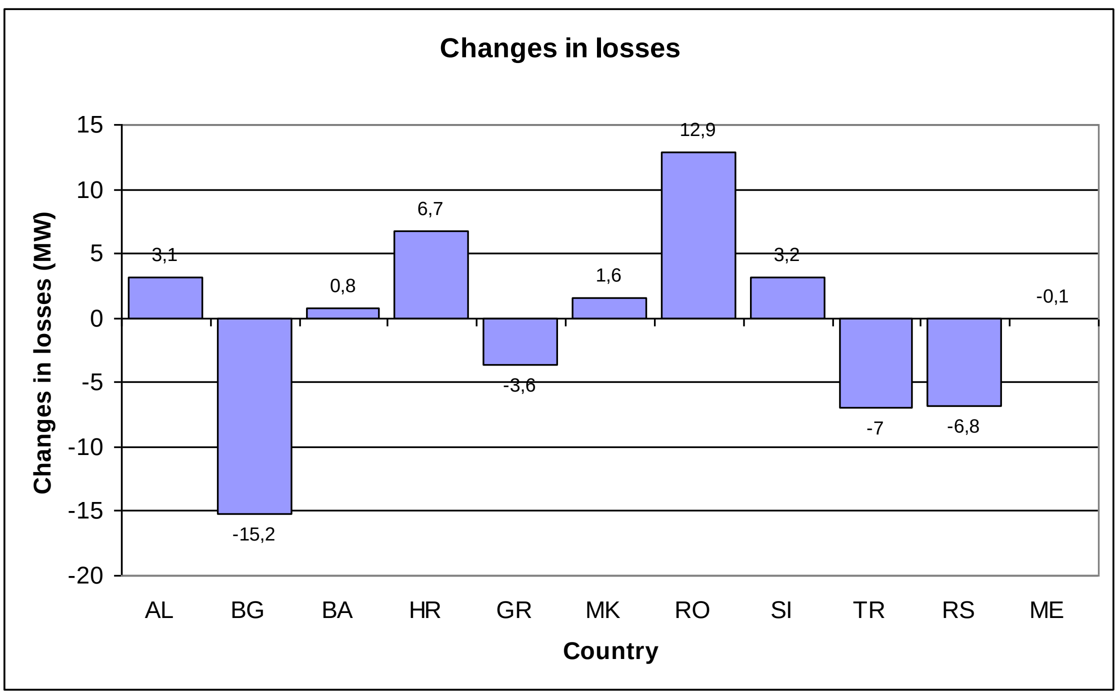


Figure 6-6 Changes in power losses in analyzed region

Histogram of busbar voltages in 220 kV and 400 kV network of analyzed region with comparison against base case is given in Appendix (Figure 9-2). It can be noticed that the voltages of all monitored buses are within the permitted limits in normal operating conditions, without significant changes in comparison against base case.

List of overloaded branches as result from contingency (n-1) analysis for the observed regime is presented in Table 6-8. and geographical positions of critical elements are shown on Figure 6-7.

Table 6-8 Results of security (n-1) analysis

<----------------- MONITORED BRANCH			----------------->	CONTINGENCY	RATING	FLOW	%
31210 LDIVAC2	220.00	156*XPA_DI21	220.00 1	SINGLE 205	365.8	492.8	135.0
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 2	SINGLE 205	600.0	619.5	103.3
31210 LDIVAC2	220.00	156*XPA_DI21	220.00 1	SINGLE 206	365.8	492.8	135.0
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 1	SINGLE 206	600.0	619.5	103.3
28058 RCRAIO2B	220.00	28060*RISALN2A	220.00 1	SINGLE 507	304.8	326.0	102.3
28057 RCRAIO2A	220.00	28060*RISALN2A	220.00 1	SINGLE 509	304.8	325.8	102.2
31210 LDIVAC2	220.00	156*XPA_DI21	220.00 1	SINGLE 734	365.8	692.9	195.5
31210 LDIVAC2	220.00	156*XPA_DI21	220.00 1	SINGLE 746	365.8	470.6	129.2

CONTINGENCY LEGEND:

LABEL	EVENTS
SINGLE 205	: OPEN LINE FROM BUS 31410 [LDIVAC1 400.00] TO BUS 31411 [LDIVAC1P 400.00] CKT 1
SINGLE 206	: OPEN LINE FROM BUS 31410 [LDIVAC1 400.00] TO BUS 31411 [LDIVAC1P 400.00] CKT 2
SINGLE 507	: OPEN LINE FROM BUS 28057 [RCRAIO2A 220.00] TO BUS 28060 [RISALN2A 220.00] CKT 1
SINGLE 509	: OPEN LINE FROM BUS 28058 [RCRAIO2B 220.00] TO BUS 28060 [RISALN2A 220.00] CKT 1
SINGLE 734	: OPEN LINE FROM BUS 31411 [LDIVAC1P 400.00] TO BUS 80 [XRE_DI11 400.00] CKT 1
SINGLE 746	: OPEN LINE FROM BUS 36017 [0LASTV11 400.00] TO BUS 701 [XIT_ME1M 400.00] CKT D1

In comparison against base case it can be seen that in case of outage one of the phase shift transformers in Divaca, which are installed on tie-line 400 kV Divaca (SI) – Redipuglia (IT), the other one is overloaded by 3%. Reason for this is increase export from region to the rest of ENTSO-E, especially because of increase totals in Adriatic region.

In addition, outage of HVDC line between Italy and Montenegro causes overload of tie-line 220 kV Divaca (SI) – Padriciano (IT) by 29%. The main reason for this overload is great import of Italy. This problem can be solved by proper dispatch actions. Also, this tie-line is more overloaded in case of outage of one phase-shift transformers in SS Divaca, which are installed on 400 kV tie-line Divaca (SI) – Redipuglia (IT) as well as in case of outage of tie-line 400 kV Divaca (SI) – Redipuglia (IT).

Also, in comparison against base case, phase shift transformers in Divaca, which are installed on tie-line 400 kV Divaca (SI) – Redipuglia (IT), are not overloaded in case of outage of tie-line 220 kV Divaca (SI) – Padriciano (IT).

There are two more critical elements in Romania. Outage of one of parallel lines 220 kV Craiova – Isalnita causes overload of the other one by 3%.

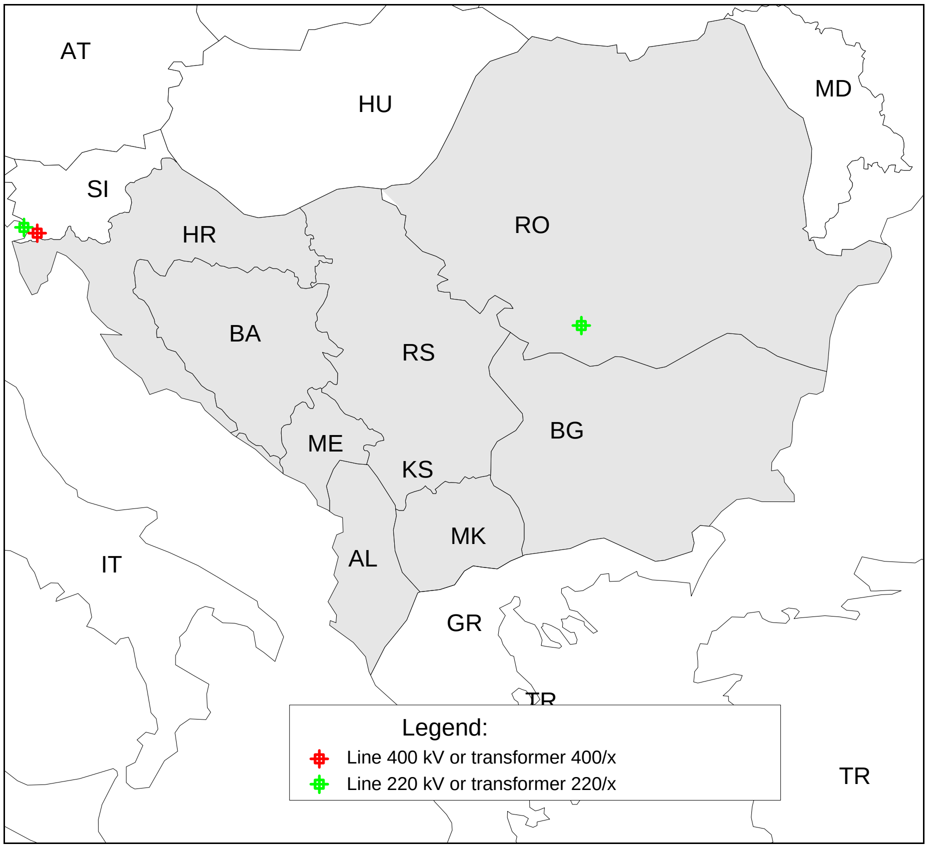


Figure 6-7 Geographical positions of critical elements

6.2.3. Wind scenario 2: Aegean + Black Sea (Max) → Adriatic (Min)

In this subchapter, steady state analyses are presented for the following power system operation regime:

- load level: winter maximum load in 2015
- wind penetration in Adriatic region: low (10%)
- wind penetration in Aegean region: high (70%)
- wind penetration in Black Sea region: high (70%)
- wind penetration in Continental region: medium (35%)

Basic information about areas (countries) of the analyzed region and aggregated physical exchanges among analyzed countries are given in Appendix (Table 9-5 and Table 9-6).

Histogram of branch loadings with comparison against branch loadings in base case is given in Appendix (Table 9-3) List of transmission lines and transformers in monitored grid which are loaded more than 80% of their thermal limits is also given in Appendix (Table 9-7). There is only one branch, loaded more then 80% of it thermal limits. Tie-line 220 kV Divaca (SI) –

Padriciano (IT) is overloaded by 32%. On the other hand, loading of phase-shift transformers in Slovenia, which are installed on 400 kV tie-line Divaca (SI) – Redipuglia (IT) was decreased. This is result of deficit in Adriatic region, so power transfer from the analyzed region to the rest of ENTSO-E flows through northern network of 400 kV voltage level. Because of great import of Italy, part of the power transfer flows through 220 kV network from Austria to Slovenia and then to Italy.

The most significant changes in power flows in the area of SEE are shown in Appendix (Table 9-8). The main paths for transfer output power from WPPs with high wind penetration could be detected from these tables.

These changes in power flows have influence on power losses. The changes are shown in Figure 6-8. Significant increase of losses can be noticed in Romania, Serbia and Croatia.

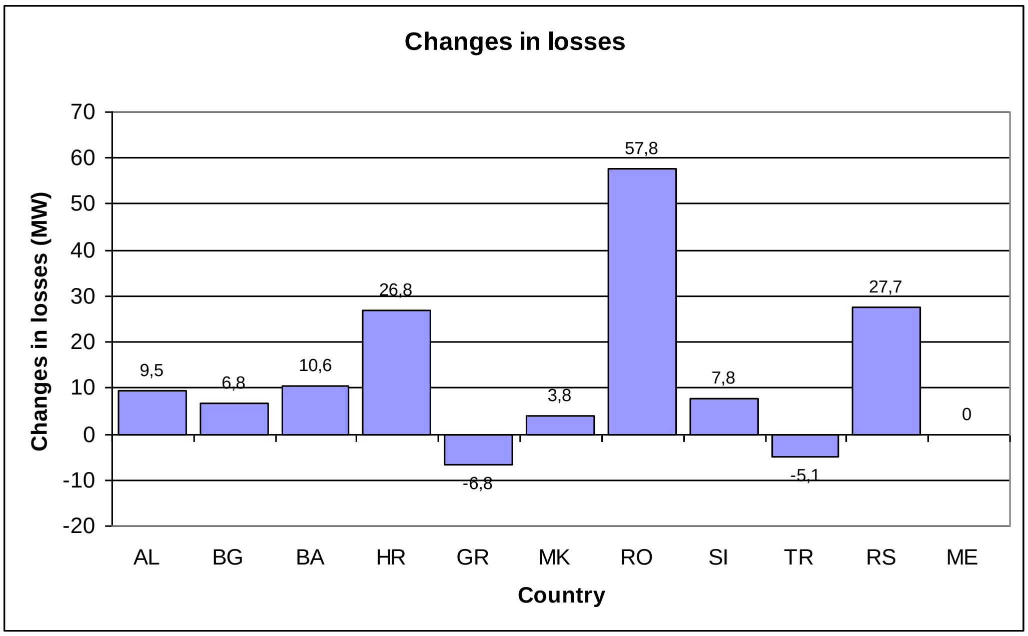


Figure 6-8 Changes in power losses in analyzed region

Histogram of busbar voltages in 220 kV and 400 kV network of analyzed region with comparison against base case is given in Appendix (Figure 9-4). Voltages of all monitored buses are within the permitted limits in normal operating conditions. It can be noticed that the number of buses with voltages above nominal value is decreased.

List of overloaded branches as result from contingency (n-1) analysis for the observed regime is presented in Table 6-9. and geographical positions of critical elements are shown on Figure 6-9.

Table 6-9 Results of security (n-1) analysis

<----------------- MONITORED BRANCH			---------------->	CONTINGENCY	RATING	FLOW	%
31210 LDIVAC2	220.00	156*XPA_DI21	220.00 1	BASE CASE	365.8	480.0	132.4
153*XPE_DI21	220.00	20126 HPEHLI21	220.00 1	SINGLE 21	362.0	401.4	109.9
153 XPE_DI21	220.00	31210*LDIVAC2	220.00 1	SINGLE 21	365.8	390.6	108.8

```
   153*XPE_DI21    220.00  20126 HPEHLI21    220.00 1  SINGLE 22       362.0    401.5    109.9
   153 XPE_DI21    220.00  31210*LDIVAC2     220.00 1  SINGLE 22       365.8    390.5    108.8
 31410*LDIVAC1     400.00  31411 LDIVAC1P    400.00 2  SINGLE 205      600.0    731.4    121.9
 31410*LDIVAC1     400.00  31411 LDIVAC1P    400.00 1  SINGLE 206      600.0    731.4    121.9
 28052*RRESIT2A    220.00  28071 RTIMIS2     220.00 2  SINGLE 501      333.4    393.7    112.7
 28052*RRESIT2A    220.00  28071 RTIMIS2     220.00 1  SINGLE 502      333.4    393.7    112.7
 28058 RCRAIO2B    220.00  28060*RISALN2A    220.00 1  SINGLE 507      304.8    324.1    101.7
 28057 RCRAIO2A    220.00  28060*RISALN2A    220.00 1  SINGLE 509      304.8    323.7    101.6
 31410*LDIVAC1     400.00  31411 LDIVAC1P    400.00 1  SINGLE 731      600.0    606.1    101.0
 31410*LDIVAC1     400.00  31411 LDIVAC1P    400.00 2  SINGLE 731      600.0    606.1    101.0

CONTINGENCY LEGEND:
LABEL         EVENTS
SINGLE 21   : OPEN LINE FROM BUS 71 [XME_DI11    400.00] TO BUS 20097 [HMELIN11    400.00] CKT 1
SINGLE 22   : OPEN LINE FROM BUS 71 [XME_DI11    400.00] TO BUS 31410 [LDIVAC1     400.00] CKT 1
SINGLE 205  : OPEN LINE FROM BUS 31410 [LDIVAC1     400.00] TO BUS 31411 [LDIVAC1P    400.00] CKT
1
SINGLE 206  : OPEN LINE FROM BUS 31410 [LDIVAC1     400.00] TO BUS 31411 [LDIVAC1P    400.00] CKT
2
SINGLE 501  : OPEN LINE FROM BUS 28052 [RRESIT2A    220.00] TO BUS 28071 [RTIMIS2     220.00] CKT
1
SINGLE 502  : OPEN LINE FROM BUS 28052 [RRESIT2A    220.00] TO BUS 28071 [RTIMIS2     220.00] CKT
2
SINGLE 507  : OPEN LINE FROM BUS 28057 [RCRAIO2A    220.00] TO BUS 28060 [RISALN2A    220.00] CKT
1
SINGLE 509  : OPEN LINE FROM BUS 28058 [RCRAIO2B    220.00] TO BUS 28060 [RISALN2A    220.00] CKT
1
SINGLE 731  : OPEN LINE FROM BUS 31210 [LDIVAC2     220.00] TO BUS 156 [XPA_DI21    220.00] CKT 1
```

In comparison against base case it can be seen that tie-line 220 kV Divaca (SI) – Padriciano (IT) is critical element, because it is overloaded by 32,4% even in case without any outage.

Also, in comparison against base case it can be seen that in case of outage one of the phase shift transformers in Divaca, which are installed on tie-line 400 kV Divaca (SI) – Redipuglia (IT), the other one is overloaded by 22%.

Also there is one more critical element, in comparison against base case. Tie-line 220 kV Pehlin (HR) – Divaca (SI) is overloaded by 10% in case of outage of tie-line 400 kV Meline (HR) – Divaca (SI).

There are four more critical elements in Romania. Outage of one of parallel lines 220 kV Resita – Timisoara causes overload of the other one by 13%. Outage of one of parallel lines 220 kV Craiova – Isalnita causes overload of the other one by 2%.

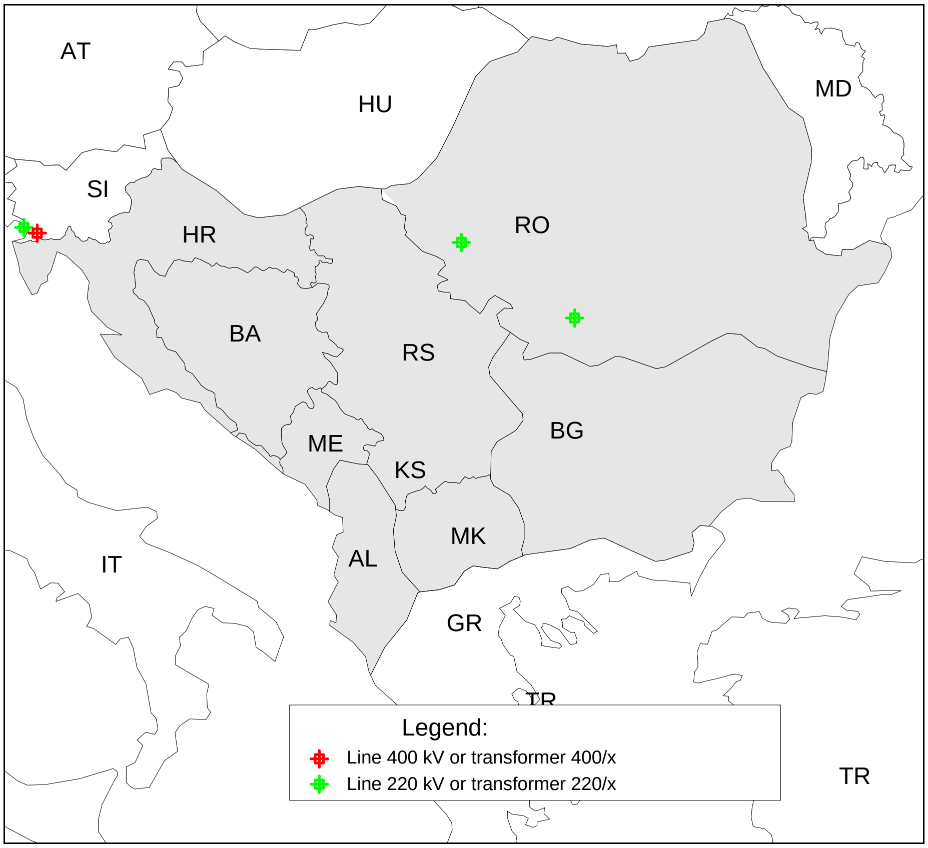


Figure 6-9 Geographical positions of critical elements

6.2.4. Wind scenario 3: Continental SEE + Black Sea (Max) → Adriatic (Min)

In this subchapter, steady state analyses are presented for the following power system operation regime:

- load level: winter maximum load in 2015
- wind penetration in Adriatic region: low (10%)
- wind penetration in Aegean region: medium (35%)
- wind penetration in Black Sea region: high (70%)
- wind penetration in Continental region: high (70%)

Basic information about areas (countries) of the analyzed region and aggregated physical exchanges among analyzed countries are given in Appendix (Table 9-9 and Table 9-10).

Histogram of branch loadings with comparison against branch loadings in base case is given in Appendix (Figure 9-5). List of transmission lines and transformers in monitored grid which are loaded more than 80% of their thermal limits is also given in Appendix (Table 9-11). There are three branches which are loaded more then 80% of their thermal limits and two of them are overloaded. Loading of phase-shift transformers in Slovenia, which are installed on 400 kV tie-line Divaca (SI) – Redipuglia (IT) was increased, which is result of increase of export from the region. Although the pressure of high power flows trough Slovenia towards Italy is expected in the future, the results related to Slovenian grid are not sufficiently credible due to the causes listed in Chapter 6.1.

The most significant changes in power flows in the area of SEE are shown in Appendix (Table 9-12). The main paths for transfer output power from WPPs with high wind penetration could be detected from these tables.

These changes in power flows have influence on power losses. The changes are shown in Figure 6-10. Significant increase of losses can be noticed in Romania, Bulgaria, Serbia and Croatia.

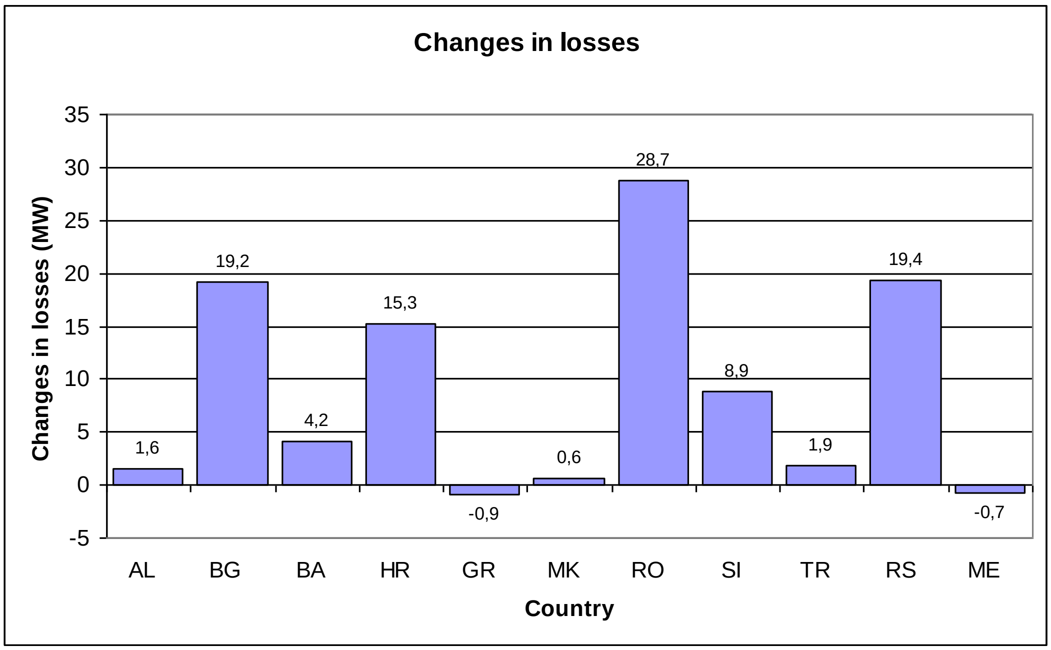


Figure 6-10 Changes in power losses in analyzed region

Histogram of busbar voltages in 220 kV and 400 kV network of analyzed region with comparison against base case is given in Appendix (Figure 9-6). Voltages of all monitored buses are within the permitted limits in normal operating conditions. It can be noticed that the number of buses with voltages above nominal value is decreased.

List of overloaded branches as result from contingency (n-1) analysis for the observed regime is presented in Table 6-10. and geographical positions of critical elements are shown on Figure 6-11.

Table 6-10 Results of security (n-1) analysis

<----------------- MONITORED BRANCH			----------------->	CONTINGENCY	RATING	FLOW	%
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 1	SINGLE 7	600.0	601.1	100.2
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 2	SINGLE 7	600.0	601.1	100.2
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 1	SINGLE 8	600.0	601.1	100.2
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 2	SINGLE 8	600.0	601.1	100.2
31210*LDIVAC2	220.00	156 XPA_DI21	220.00 1	SINGLE 21	365.8	364.2	100.6
31210*LDIVAC2	220.00	156 XPA_DI21	220.00 1	SINGLE 22	365.8	364.4	100.7
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 1	SINGLE 195	600.0	603.0	100.5
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 2	SINGLE 195	600.0	603.0	100.5
31210 LDIVAC2	220.00	156*XPA_DI21	220.00 1	SINGLE 205	365.8	510.4	140.6
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 2	SINGLE 205	600.0	665.0	110.8
31210 LDIVAC2	220.00	156*XPA_DI21	220.00 1	SINGLE 206	365.8	510.4	140.6
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 1	SINGLE 206	600.0	665.0	110.8
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 1	SINGLE 208	600.0	601.8	100.3
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 2	SINGLE 208	600.0	601.8	100.3
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 1	SINGLE 211	600.0	602.7	100.4
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 2	SINGLE 211	600.0	602.7	100.4
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 1	SINGLE 229	600.0	601.6	100.3
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 2	SINGLE 229	600.0	601.6	100.3
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 1	SINGLE 243	600.0	601.1	100.2
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 2	SINGLE 243	600.0	601.1	100.2
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 1	SINGLE 286	600.0	601.0	100.2
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 2	SINGLE 286	600.0	601.0	100.2
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 1	SINGLE 294	600.0	601.2	100.2
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 2	SINGLE 294	600.0	601.2	100.2
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 1	SINGLE 295	600.0	601.0	100.2
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 2	SINGLE 295	600.0	601.0	100.2
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 1	SINGLE 331	600.0	612.3	102.1
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 2	SINGLE 331	600.0	612.3	102.1
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 1	SINGLE 332	600.0	612.4	102.1
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 2	SINGLE 332	600.0	612.4	102.1
28058 RCRAIO2B	220.00	28060*RISALN2A	220.00 1	SINGLE 507	304.8	322.5	101.2
28057 RCRAIO2A	220.00	28060*RISALN2A	220.00 1	SINGLE 509	304.8	322.1	101.0
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 1	SINGLE 570	600.0	601.5	100.2
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 2	SINGLE 570	600.0	601.5	100.2
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 1	SINGLE 571	600.0	603.5	100.6
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 2	SINGLE 571	600.0	603.5	100.6
31210 LDIVAC2	220.00	156*XPA_DI21	220.00 1	SINGLE 575	365.8	457.8	125.3
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 1	SINGLE 731	600.0	701.7	116.9
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 2	SINGLE 731	600.0	701.7	116.9
31210 LDIVAC2	220.00	156*XPA_DI21	220.00 1	SINGLE 734	365.8	736.1	206.0
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 1	SINGLE 737	600.0	608.2	101.4
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 2	SINGLE 737	600.0	608.2	101.4
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 1	SINGLE 740	600.0	602.8	100.5
31410*LDIVAC1	400.00	31411 LDIVAC1P	400.00 2	SINGLE 740	600.0	602.8	100.5
31210 LDIVAC2	220.00	156*XPA_DI21	220.00 1	SINGLE 746	365.8	504.2	138.6

CONTINGENCY LEGEND:

LABEL	EVENTS
SINGLE 7	: OPEN LINE FROM BUS 13 [XTR_PG11 400.00] TO BUS 14405 [WTREBI1 400.00] CKT 1
SINGLE 8	: OPEN LINE FROM BUS 13 [XTR_PG11 400.00] TO BUS 36017 [0LASTV11 400.00] CKT A
SINGLE 21	: OPEN LINE FROM BUS 71 [XME_DI11 400.00] TO BUS 20097 [HMELIN11 400.00] CKT 1
SINGLE 22	: OPEN LINE FROM BUS 71 [XME_DI11 400.00] TO BUS 31410 [LDIVAC1 400.00] CKT 1
SINGLE 195	: OPEN LINE FROM BUS 28034 [RSIBIU1 400.00] TO BUS 28036 [RIERNU1 400.00] CKT 1
SINGLE 205	: OPEN LINE FROM BUS 31410 [LDIVAC1 400.00] TO BUS 31411 [LDIVAC1P 400.00] CKT 1
SINGLE 206	: OPEN LINE FROM BUS 31410 [LDIVAC1 400.00] TO BUS 31411 [LDIVAC1P 400.00] CKT 2
SINGLE 208	: OPEN LINE FROM BUS 31415 [LKRSKO1 400.00] TO BUS 31435 [LCIRKO11 400.00] CKT 1
SINGLE 211	: OPEN LINE FROM BUS 31420 [LMARIB1 400.00] TO BUS 31450 [LKOZJK1 400.00] CKT 1
SINGLE 229	: OPEN LINE FROM BUS 34025 [JNSAD31 400.00] TO BUS 34078 [JSRBOB1 400.00] CKT A

```
SINGLE 243  : OPEN LINE FROM BUS 34050 [JSUBO31     400.00] TO BUS 34078 [JSRBOB1     400.00] CKT
A
SINGLE 286  : OPEN LINE FROM BUS 24018 [MGONYU11    400.00] TO BUS 24019 [MGYOR 11    400.00] CKT
1
SINGLE 294  : OPEN LINE FROM BUS 24024 [MLITR 11    400.00] TO BUS 24033 [MPAKS 11    400.00] CKT
1
SINGLE 295  : OPEN LINE FROM BUS 24025 [MMART 11    400.00] TO BUS 24033 [MPAKS 11    400.00] CKT
1
SINGLE 331  : OPEN LINE FROM BUS 153 [XPE_DI21    220.00] TO BUS 20126 [HPEHLI21    220.00] CKT 1
SINGLE 332  : OPEN LINE FROM BUS 153 [XPE_DI21    220.00] TO BUS 31210 [LDIVAC2     220.00] CKT 1
SINGLE 507  : OPEN LINE FROM BUS 28057 [RCRAIO2A    220.00] TO BUS 28060 [RISALN2A    220.00] CKT
1
SINGLE 509  : OPEN LINE FROM BUS 28058 [RCRAIO2B    220.00] TO BUS 28060 [RISALN2A    220.00] CKT
1
SINGLE 570  : OPEN LINE FROM BUS 31205 [LBERIC2     220.00] TO BUS 31215 [LKLECE2     220.00] CKT
1
SINGLE 571  : OPEN LINE FROM BUS 31210 [LDIVAC2     220.00] TO BUS 31215 [LKLECE2     220.00] CKT
1
SINGLE 575  : OPEN LINE FROM BUS 34105 [JBGD1721    220.00] TO BUS 34110 [JBGD8 21    220.00] CKT
1
SINGLE 731  : OPEN LINE FROM BUS 31210 [LDIVAC2     220.00] TO BUS 156 [XPA_DI21    220.00] CKT 1
SINGLE 734  : OPEN LINE FROM BUS 31411 [LDIVAC1P    400.00] TO BUS 80 [XRE_DI11    400.00] CKT 1
SINGLE 737  : OPEN LINE FROM BUS 31420 [LMARIB1     400.00] TO BUS 9 [XKA_MA11    400.00] CKT 1
SINGLE 740  : OPEN LINE FROM BUS 31450 [LKOZJK1     400.00] TO BUS 10 [XKA_MA12    400.00] CKT 1
SINGLE 746  : OPEN LINE FROM BUS 36017 [0LASTV11    400.00] TO BUS 701 [XIT_ME1M    400.00] CKT
D1
```

In comparison against base case it can be seen that there are 18 more outages which cause overload of phase-shift transformers in SS Divaca, which are installed on 400 kV tie-line Divaca (SI) – Redipuglia (IT). Although the pressure of high power flows through Slovenia towards Italy is expected in the future, the results related to Slovenia are not sufficiently credible due to the causes listed in Chapter 6.1.

There are two more critical elements in Romania. Outage of one of parallel lines 220 kV Craiova – Isalnita causes overload of the other one by 1%.

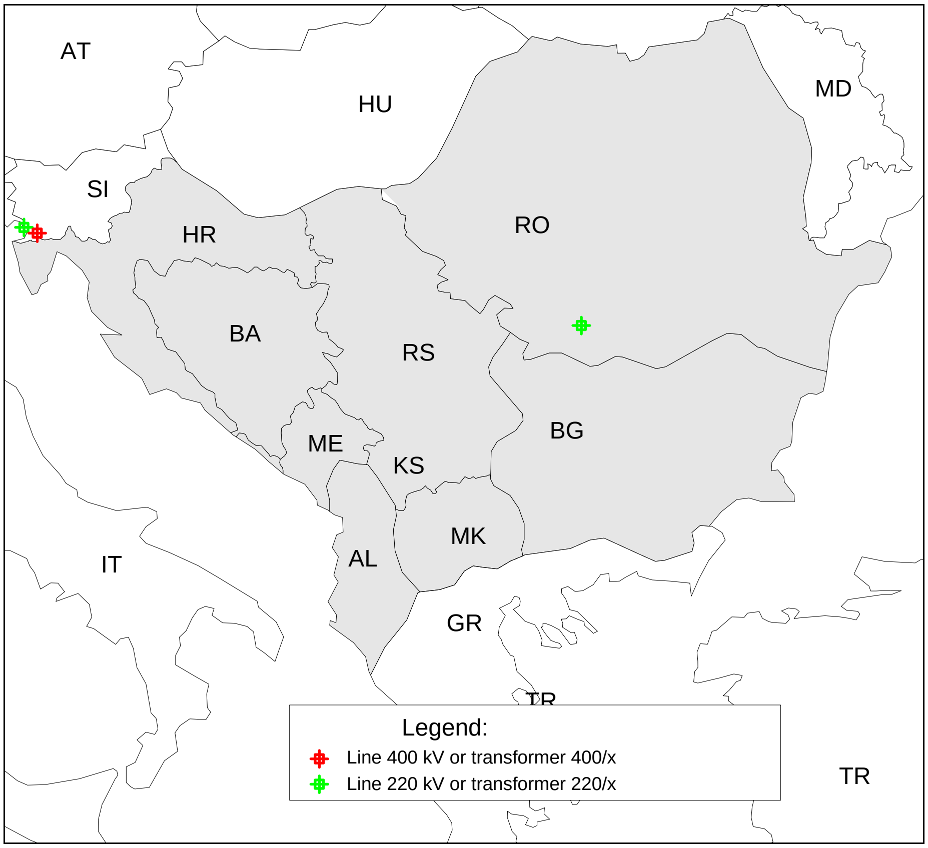


Figure 6-11 Geographical positions of critical elements

6.2.5. Wind scenario 4: All regions (Max) → rest of ENTSO-E

In this subchapter, steady state analyses are presented for the following power system operation regime:

- load level: winter maximum load in 2015
- wind penetration in Adriatic region: high (70%)
- wind penetration in Aegean region: high (70%)
- wind penetration in Black Sea region: high (70%)
- wind penetration in Continental region: high (70%)

Basic information about areas (countries) of the analyzed region and aggregated physical exchanges among analyzed countries are given in Appendix (Table 9-13 and Table 9-14)

Histogram of branch loadings with comparison against branch loadings in base case is given in Appendix (Figure 9-7). List of transmission lines and transformers in monitored grid which are loaded more than 80% of their thermal limits is also given in Appendix (Table 9-15). There are three branches loaded more than 80% of their thermal limits. Phase-shift transformers in

Slovenia, which are installed on 400 kV tie-line Divaca (SI) – Redipuglia (IT) are loaded 90% of their thermal limits. Tie-line 220 kV Divaca (SI) – Padriciano (IT) is overloaded by 48% as result of great import of Italy. Also, it can be seen that there are 14 more branches which are loaded more than 60% of their thermal limits.

The most significant changes in power flows in the area of SEE are shown in Appendix (Table 9-16). The main paths for transfer output power from WPPs with high wind penetration could be detected from these tables.

These changes in power flows have influence on power losses. The changes are shown in Figure 6-12. Significant increase of losses can be noticed in Romania, Croatia and Serbia.

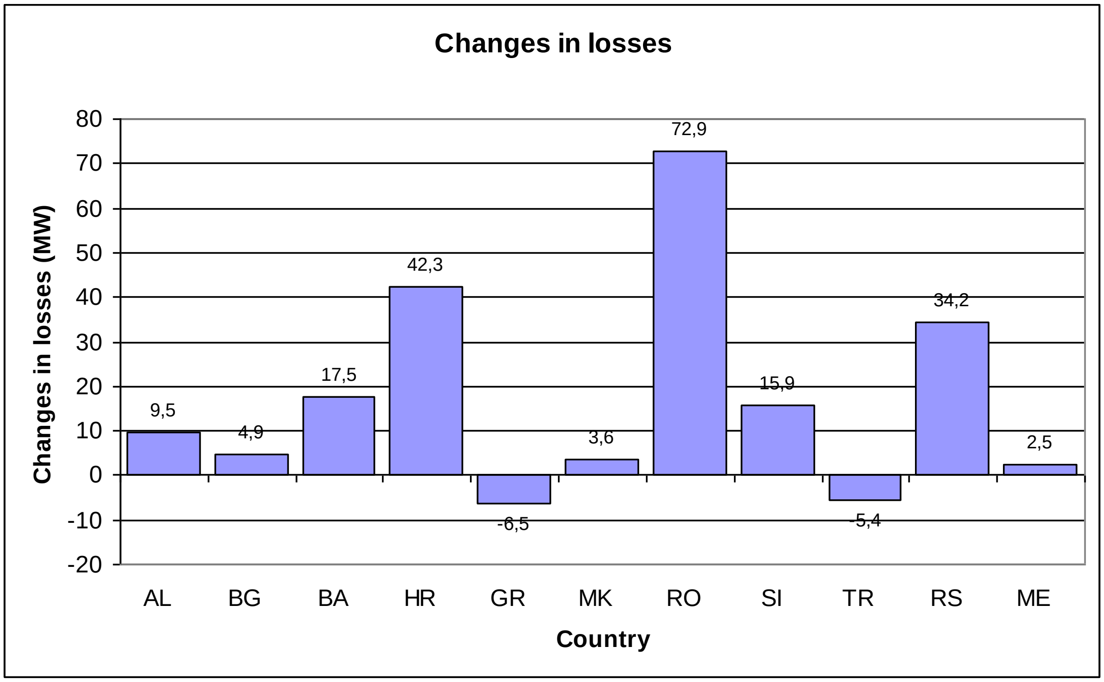


Figure 6-12 Changes in power losses in analyzed region

Histogram of busbar voltages in 220 kV and 400 kV network of analyzed region with comparison against base case is given in Appendix (Figure 9-8). Voltages of all monitored buses are within the permitted limits in normal operating conditions. It can be noticed that the number of buses with voltages above nominal value is decreased.

List of overloaded branches as result from contingency (n-1) analysis for the observed regime is presented in
Table *6-11*. and geographical positions of critical elements are shown on Figure 6-13.

Table 6-11 Results of security (n-1) analysis

<----------------- MONITORED BRANCH ----------------->					CONTINGENCY	RATING	FLOW	%
31210 LDIVAC2	220.00	156*XPA_DI21	220.00	1	BASE CASE	365.8	528.3	148.0
153*XPE_DI21	220.00	20126 HPEHLI21	220.00	1	SINGLE 21	362.0	444.6	123.9

```
   153*XPE_DI21    220.00  31210 LDIVAC2     220.00 1  SINGLE 21       365.8    444.6    122.6
   153*XPE_DI21    220.00  20126 HPEHLI21    220.00 1  SINGLE 22       362.0    444.6    123.9
   153*XPE_DI21    220.00  31210 LDIVAC2     220.00 1  SINGLE 22       365.8    444.6    122.6
 28036*RIERNU1     400.00  28087 RIERNU2     220.00 1  SINGLE 196      400.0    419.6    104.9
 31410*LDIVAC1     400.00  31411 LDIVAC1P    400.00 2  SINGLE 205      600.0    866.3    144.4
 31410*LDIVAC1     400.00  31411 LDIVAC1P    400.00 1  SINGLE 206      600.0    866.3    144.4
 28052*RRESIT2A    220.00  28071 RTIMIS2     220.00 2  SINGLE 501      333.4    419.6    120.5
 28052*RRESIT2A    220.00  28071 RTIMIS2     220.00 1  SINGLE 502      333.4    419.6    120.5
 28058 RCRAIO2B    220.00  28060*RISALN2A    220.00 1  SINGLE 507      304.8    324.9    102.0
 28057 RCRAIO2A    220.00  28060*RISALN2A    220.00 1  SINGLE 509      304.8    324.5    101.9
 31410*LDIVAC1     400.00  31411 LDIVAC1P    400.00 1  SINGLE 731      600.0    700.7    120.4
 31410*LDIVAC1     400.00  31411 LDIVAC1P    400.00 2  SINGLE 731      600.0    700.7    120.4
   153*XPE_DI21    220.00  20126 HPEHLI21    220.00 1  SINGLE 734      362.0    380.3    103.8
   153*XPE_DI21    220.00  31210 LDIVAC2     220.00 1  SINGLE 734      365.8    355.7    103.2
 31210 LDIVAC2     220.00    156*XPA_DI21    220.00 1  SINGLE 734      365.8    877.7    254.5

CONTINGENCY LEGEND:
LABEL         EVENTS
SINGLE 21    : OPEN LINE FROM BUS 71 [XME_DI11    400.00] TO BUS 20097 [HMELIN11    400.00] CKT 1
SINGLE 22    : OPEN LINE FROM BUS 71 [XME_DI11    400.00] TO BUS 31410 [LDIVAC1     400.00] CKT 1
SINGLE 196   : OPEN LINE FROM BUS 28036 [RIERNU1     400.00] TO BUS 28037 [RGADAL1     400.00] CKT
1
SINGLE 205   : OPEN LINE FROM BUS 31410 [LDIVAC1     400.00] TO BUS 31411 [LDIVAC1P    400.00] CKT
1
SINGLE 206   : OPEN LINE FROM BUS 31410 [LDIVAC1     400.00] TO BUS 31411 [LDIVAC1P    400.00] CKT
2
SINGLE 501   : OPEN LINE FROM BUS 28052 [RRESIT2A    220.00] TO BUS 28071 [RTIMIS2     220.00] CKT
1
SINGLE 502   : OPEN LINE FROM BUS 28052 [RRESIT2A    220.00] TO BUS 28071 [RTIMIS2     220.00] CKT
2
SINGLE 507   : OPEN LINE FROM BUS 28057 [RCRAIO2A    220.00] TO BUS 28060 [RISALN2A    220.00] CKT
1
SINGLE 509   : OPEN LINE FROM BUS 28058 [RCRAIO2B    220.00] TO BUS 28060 [RISALN2A    220.00] CKT
1
SINGLE 731   : OPEN LINE FROM BUS 31210 [LDIVAC2     220.00] TO BUS 156 [XPA_DI21    220.00] CKT 1
SINGLE 734   : OPEN LINE FROM BUS 31411 [LDIVAC1P    400.00] TO BUS 80 [XRE_DI11    400.00] CKT 1
```

Although the pressure of high power flows through Slovenia towards Italy is expected in the future, the results related to Slovenian grid, especially in area of Divaca, are not sufficiently credible due to the causes listed in Chapter 6.1.

There are five more critical elements in Romania. Transformer 400/220 kV in Iernut is overloaded by 5% in case of outage of 400 kV line Iernut – Gadalin. Outage of one of parallel lines 220 kV Resita – Timisoara causes overload of the other one by 20%. Outage of one of parallel lines 220 kV Craiova – Isalnita causes overload of the other one by 2%.

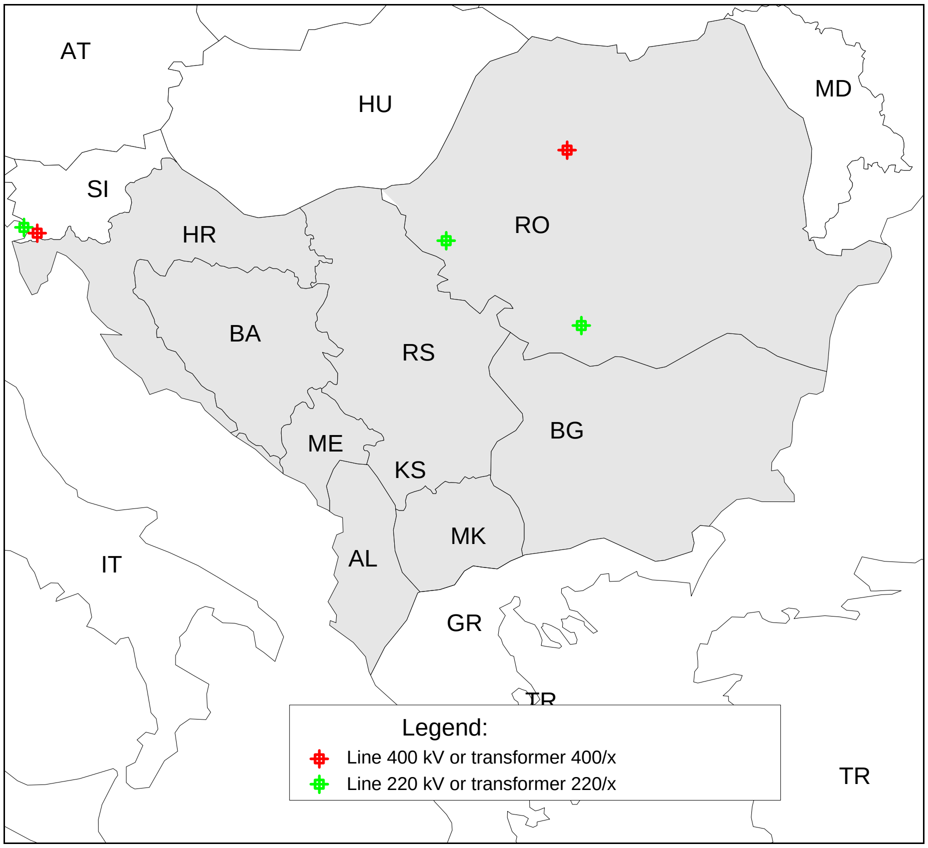


Figure 6-13 Geographical positions of critical elements

6.3. Winter MAXIMUM 2020

6.3.1. Base case scenario

In this subchapter, steady state analyses are presented for the following power system operation regime:

- load level: winter maximum load in 2020
- wind penetration in Adriatic region: medium (35%)
- wind penetration in Aegean region: medium (35%)
- wind penetration in Black Sea region: medium (35%)
- wind penetration in Continental region: medium (35%)

Generation, Load, Exchange programs

Table 6-12 shows production, demand and exchange programs and other basic information about the areas (countries) of the analyzed region. The same data for two zones in Serbia (Kosovo (under UNSR 1244) zone and EMS zone) are given in Table 6-13. For each area, the first line in the table represents the active power (MW) and the second line the reactive power (MVar).

Table 6-12 Area summary of analyzed region

X-- AREA --X	FROM GENE-RATION	TO LOAD AT AREA BUSES	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	1820.1	1765.2	0.0	0.0	0.0	0.0	54.9	0.0	0.0	0.0
AL	480.3	636.1	-105.5	0.0	0.0	586.6	479.7	56.6	56.6	
20	9618.3	8393.4	0.0	0.0	15.5	0.0	209.4	1000.0	1000.0	1000.0
BG	3632.8	3343.1	231.1	0.0	182.4	3315.4	2902.2	289.3	289.3	
30	3507.4	2662.5	0.0	0.0	0.6	0.0	94.3	750.0	750.0	750.0
BA	652.2	207.8	0.0	0.0	1.3	972.9	931.0	485.0	485.0	
40	3572.0	4436.2	0.0	0.0	0.0	0.0	135.9	-1000.1	-1000.1	-1000.0
HR	608.0	1114.4	0.0	0.0	0.0	1600.2	1310.2	-216.5	-216.5	
50	13746.6	13426.0	0.0	0.0	0.0	0.0	320.6	0.0	0.0	0.0
GR	2464.7	5067.4	203.7	0.0	23.2	6690.6	3860.5	0.5	0.5	
60	1902.7	1974.4	0.0	0.0	0.2	0.0	28.1	-100.0	-100.0	-100.0
MK	507.3	609.6	0.0	0.0	2.5	470.6	331.7	34.1	34.1	
70	12035.9	10176.3	0.0	0.0	90.3	0.0	269.3	1500.0	1500.0	1500.0
RO	2003.1	3213.2	1404.7	0.0	271.2	5547.3	3038.8	-377.6	-377.6	
75	4487.4	2887.0	0.0	0.0	10.0	0.0	175.5	1414.9	1414.9	1415.0
SI	1956.7	863.0	0.0	0.0	62.2	870.3	2034.2	-132.4	-132.4	
80	77447.9	77342.9	0.0	0.0	0.0	0.0	905.0	-800.0	-800.0	-800.0
TR	6492.3	11034.0	999.1	0.0	0.0	22794.0	17465.0	-211.8	-211.8	
90	8836.2	7867.4	0.0	0.0	12.8	0.0	206.0	750.0	750.0	750.0
RS	2433.7	2621.5	0.0	0.0	81.4	2082.5	2386.9	-573.6	-573.6	
91	1610.6	1022.9	0.5	0.0	3.6	0.0	33.6	550.0	550.0	550.0
ME	303.1	365.1	-32.9	0.0	21.3	417.8	379.3	-11.9	-11.9	
COLUMN	138585.3	131954.3	0.5	0.0	132.9	0.0	2432.7	4064.8	4064.8	4065.0
TOTALS	21534.1	29075.2	2700.1	0.0	645.5	45348.1	35119.5	-658.2	-658.2	

Table 6-13 Zone summary in Serbia

X-- ZONE --X	FROM GENE-RATION	TO LOAD AT ZONE BUSES	TO BUS SHUNT	TO GNE BUS DEVICES	TO LINE SHUNT	FROM CHARGING	TO LOSSES	-NET INTERCHANGE- TO TIE LINES	TO TIES + LOADS
90	7438.7	6544.7	0.0	0.0	10.5	0.0	176.7	706.8	706.8
EPS	1855.9	2167.2	0.0	0.0	68.3	1789.2	2033.0	-623.4	-623.4
901	1397.5	1322.7	0.0	0.0	2.3	0.0	29.3	43.2	43.2
KOS	577.8	454.3	0.0	0.0	13.1	293.3	354.0	49.8	49.8
COLUMN	8836.2	7867.4	0.0	0.0	12.8	0.0	206.0	750.0	750.0

TOTALS	2433.7	2621.5	0.0	0.0	81.4	2082.5	2386.9	-573.6	-573.6

Element loadings

Figure 6-14 shows histogram of branch loadings in the transmission grid of analyzed region. All lines 220 kV, 400 kV and 750 kV in these countries are taken into consideration as well as transformers 750/400 kV and 400/220 kV. Power network on 110 kV and 150 kV voltage level is not analyzed in details in this Study since they are considered as of local importance. It can be noticed that all but four observed elements are loaded below 80% of their thermal limits.

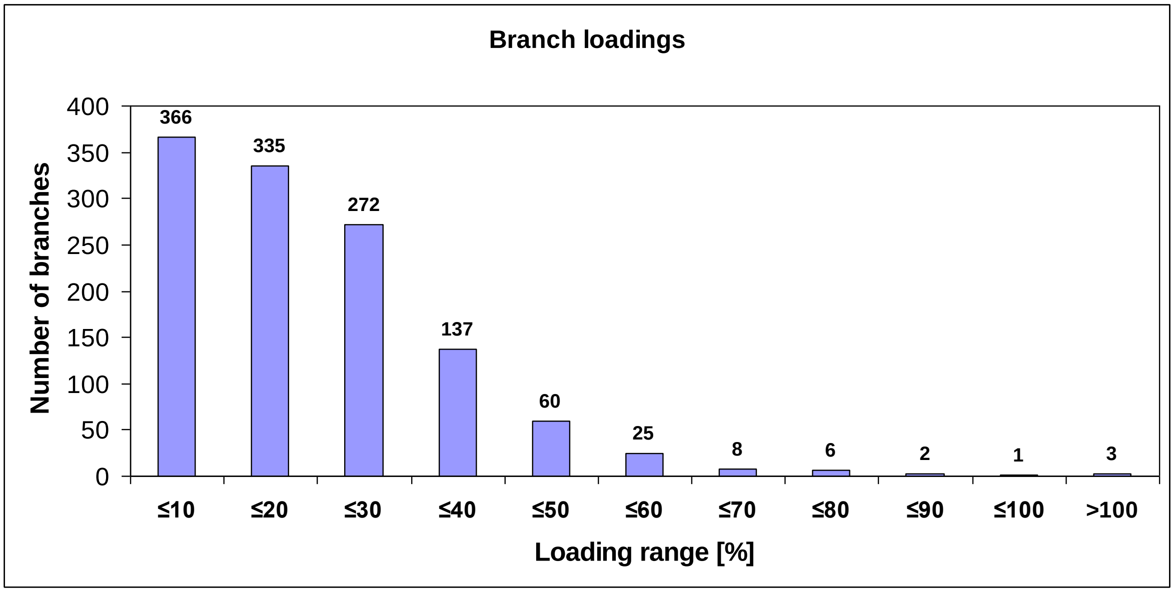


Figure 6-14 Branch loadings in analyzed region

List of transmission lines and transformers in monitored grid which are loaded more than 80% of their thermal limits is given in Table 6-14.

Table 6-14 Branches loaded over 80% of their thermal limits

FRMBUS,	FROMBUSEXNAME,	TOBUS,	TOBUSEXNAME,	CKT,	STS,	MW,	MVAR,	MVA,	%I
12474,	VMI 1 400.00,	12274,	VMI 2 220.00,	1 ,	1,	538.72,	160.16,	562.02,	86.56
31405,	LOKROG1 400.00,	503,	XUD_OK11 400.00,	1 ,	1,	1215.25,	199.13,	1231.46,	96.41
31405,	LOKROG1 400.00,	31438,	LHAVCE1 400.00,	1 ,	1,	1076.02,	142.30,	1085.39,	84.98
31430,	LBERIC1 400.00,	31405,	LOKROG1 400.00,	1 ,	1,	1187.47,	265.34,	1216.75,	111.58 *
31430,	LBERIC1 400.00,	31405,	LOKROG1 400.00,	2 ,	1,	1187.47,	265.34,	1216.75,	111.58 *
31438,	LHAVCE1 400.00,	504,	XUD_AV11 400.00,	1 ,	1,	1291.61,	99.40,	1295.43,	103.71 *
Total 6 items									

There are six elements loaded more than 80% of their thermal limits. Three of them are overloaded lines in Slovenia. Although the pressure of high power flows through Slovenia towards Italy is expected in the future, the results are not sufficiently credible due to the causes listed in Chapter 6.1.

Voltage profile

Figure 6-15 shows histogram of busbar voltages in 220 kV and 400 kV network of analyzed region. It can be noticed that the voltages of almost all monitored buses are within the permitted limits in normal operating conditions. Voltages in the most of the 220 kV buses are slightly above nominal values, but still within the limits. There are two 400 kV nodes with voltages out of limits. Voltage in 400 kV bus bars of HPP Avce, in Slovenia, is slightly below limits (376 kV) and voltage in 400 kV bus bars of NPP Belene, in Bulgaria, is slightly above limits (420.7 kV). Since these nodes are placed in power plants, the problem can be solved by changing reference point of excitation systems, so these out of limit voltages should not be treated as problem.
Although the pressure of high power flows through Slovenia towards Italy is expected in the future, the results related to problems in Slovenian grid are not sufficiently credible due to the causes listed in Chapter 6.1.

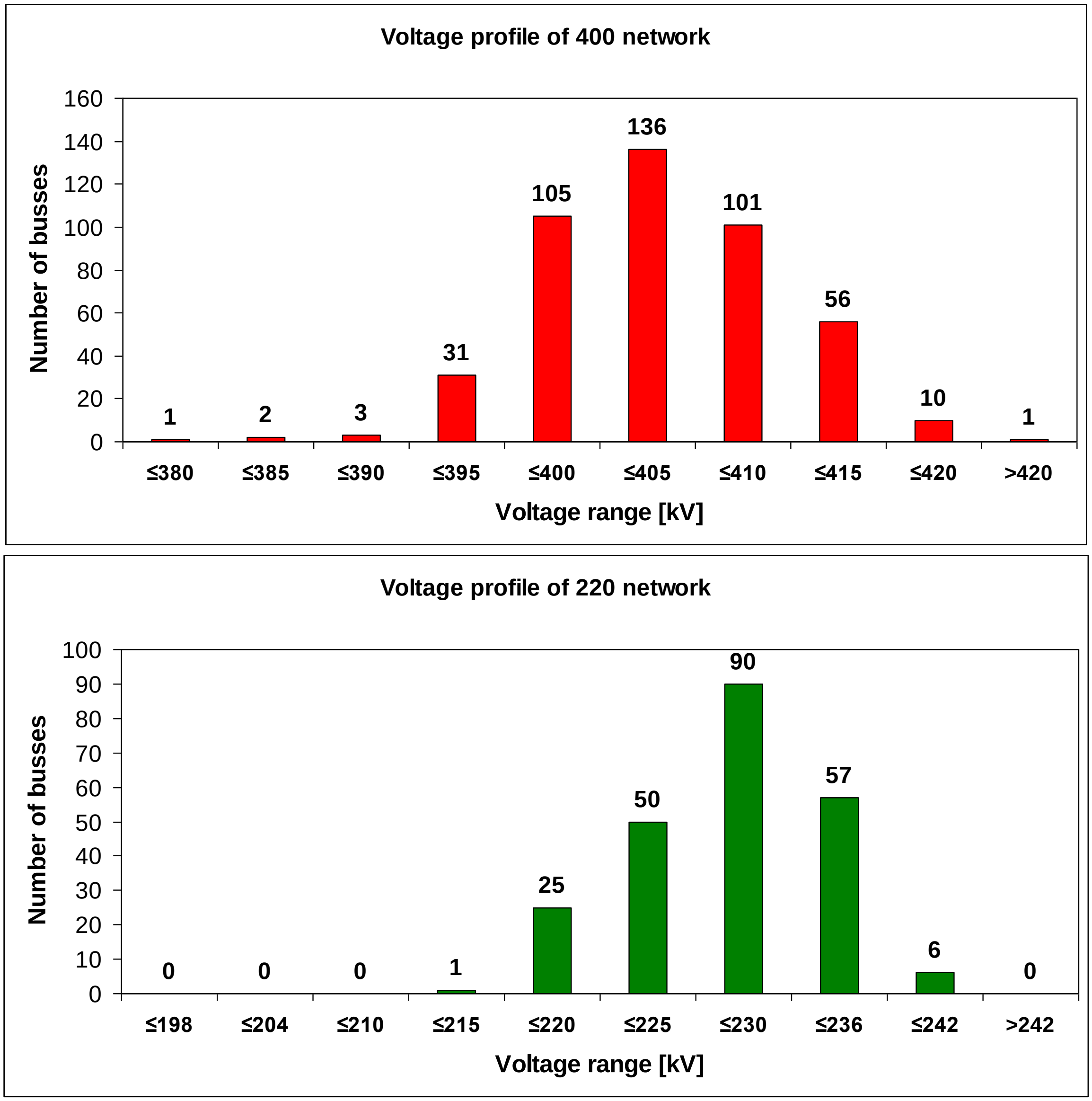


Figure 6-15 Voltage profile of 400 and 220 kV network in analyzed region

Security (n-1) Assessment

Results of contingency (n-1) analysis for the observed regime are presented in Table 6-15. Monitored branches are given with their bus number and bus name used in the PSS/E models. For easier illustration of critical elements geographical positions of critical elements are shown in Figure 6-16.

Table 6-15 Results of security (n-1) analysis

```
<----------------- MONITORED BRANCH -----------------> CONTINGENCY    RATING     FLOW       %
 31405*LOKROG1     400.00  31430 LBERIC1     400.00 1  BASE CASE      1108.5   1191.4    111.9
 31405*LOKROG1     400.00  31430 LBERIC1     400.00 2  BASE CASE      1108.5   1191.4    111.9
 31438 LHAVCE1     400.00    504*XUD_AV11    400.00 1  BASE CASE      1330.2   1274.2    103.7
 20059*HESENJ      220.00  20096 HMELIN21    220.00 1  SINGLE 152      297.0    354.3    113.7
 20502*HBRINJ11    400.00  20010 HBRINJ21    220.00 1  SINGLE 152      400.0    451.7    112.9
 31405 LOKROG1     400.00    503*XUD_OK11    400.00 1  SINGLE 264     1330.2   1572.1    129.6
 20103*HMRACL21    220.00  20168 HTE_SI21    220.00 2  SINGLE 553      297.0    317.8    105.1
 28052*RRESIT2A    220.00  28071 RTIMIS2     220.00 2  SINGLE 582      333.4    362.3    104.7
 28052*RRESIT2A    220.00  28071 RTIMIS2     220.00 1  SINGLE 583      333.4    362.3    104.7
 31405 LOKROG1     400.00  31438*LHAVCE1     400.00 1  SINGLE 816     1330.2   1562.8    126.8
 31405 LOKROG1     400.00    503*XUD_OK11    400.00 1  SINGLE 818     1330.2   1241.6    102.7
 31405 LOKROG1     400.00    503*XUD_OK11    400.00 1  SINGLE 824     1330.2   1683.2    139.5
 31405 LOKROG1     400.00    503*XUD_OK11    400.00 1  SINGLE 832     1330.2   1232.8    102.7

CONTINGENCY LEGEND:
LABEL          EVENTS
SINGLE 152   : OPEN LINE FROM BUS 20097 [HMELIN11    400.00] TO BUS 20502 [HBRINJ11    400.00] CKT
1
SINGLE 264   : OPEN LINE FROM BUS 31405 [LOKROG1     400.00] TO BUS 31438 [LHAVCE1     400.00] CKT
1
SINGLE 553   : OPEN LINE FROM BUS 20103 [HMRACL21    220.00] TO BUS 20168 [HTE_SI21    220.00] CKT
1
SINGLE 582   : OPEN LINE FROM BUS 28052 [RRESIT2A    220.00] TO BUS 28071 [RTIMIS2     220.00] CKT
1
SINGLE 583   : OPEN LINE FROM BUS 28052 [RRESIT2A    220.00] TO BUS 28071 [RTIMIS2     220.00] CKT
2
SINGLE 816   : OPEN LINE FROM BUS 31405 [LOKROG1     400.00] TO BUS 503 [XUD_OK11    400.00] CKT 1
SINGLE 818   : OPEN LINE FROM BUS 31411 [LDIVAC1P    400.00] TO BUS 80 [XRE_DI11    400.00] CKT 1
SINGLE 821   : OPEN LINE FROM BUS 31420 [LMARIB1     400.00] TO BUS 9 [XKA_MA11    400.00] CKT 1
SINGLE 824   : OPEN LINE FROM BUS 31438 [LHAVCE1     400.00] TO BUS 504 [XUD_AV11    400.00] CKT 1
SINGLE 832   : OPEN LINE FROM BUS 36017 [0LASTV11    400.00] TO BUS 701 [XIT_ME1M    400.00] CKT
D1
```

It can be seen that there are three critical branches in Slovenia which are overloaded in base case. Although the pressure of high power flows through Slovenia towards Italy is expected in the future, the results related to problems in Slovenia are not sufficiently credible due to the causes listed in Chapter 6.1.

There are three critical elements in Croatia. Transformer 400/220 kV in SS Brinje in overloaded by 13% in case of outage line 400 kV Meline – Brinje. This outage also causes overload of line 220 kV HPP Senj – Meline by 4%. In addition one line 220 kV TPP Sisak – Mraclin is overloaded by 5% in case of outage of the its parallel line, but not vice versa. The reason is because these two lines have different electrical parameters (different cross section of conductors as well as different lengths).

There are two critical elements in Romania. Outage of one of parallel lines 220 kV Resita – Timisoara causes overload of the other one by 5%.

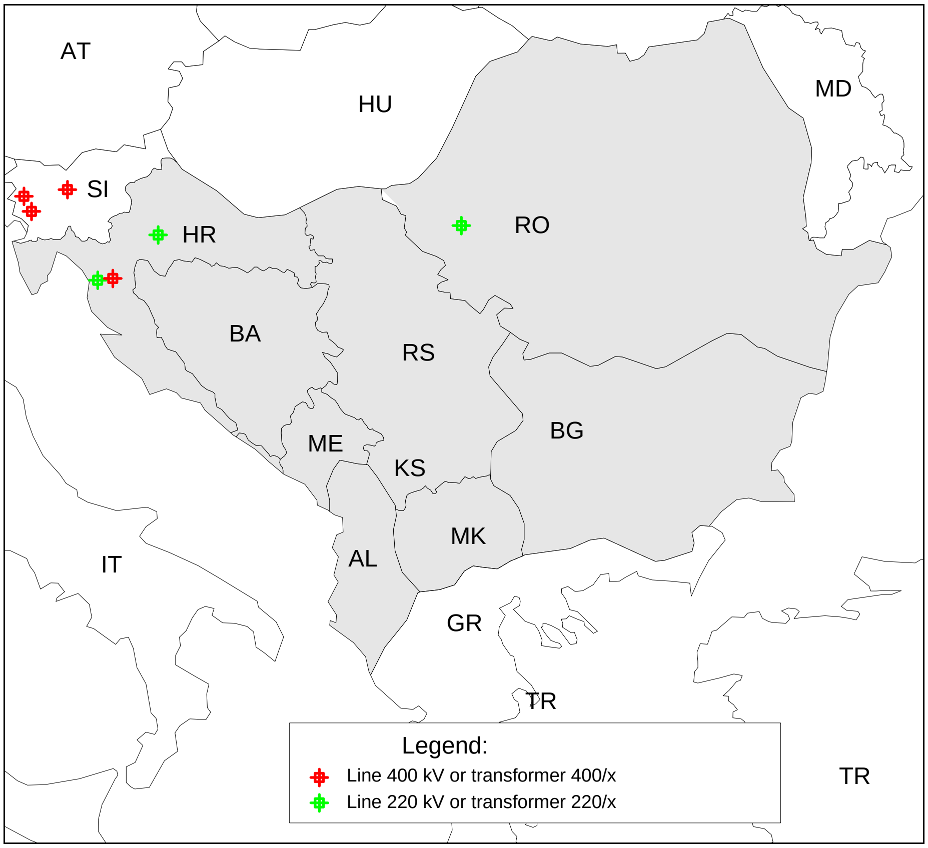


Figure 6-16 Geographical positions of critical elements

All other scenarios in 2020 that follow in the Study will be compared against these results. In that way it will be easy to clarify which changes and problems in the network are caused by each analyzed wind scenario.

6.3.2. Wind scenario 1: Adriatic + Aegean (Max) → Black Sea (Min)

In this subchapter, steady state analyses are presented for the following power system operation regime:

- load level: winter maximum load in 2020
- wind penetration in Adriatic region: high (70%)
- wind penetration in Aegean region: high (70%)
- wind penetration in Black Sea region: low (10%)
- wind penetration in Continental region: medium (35%)

Basic information about areas (countries) of the analyzed region and aggregated physical exchanges among analyzed countries are given in Appendix (Table 9-17 and Table 9-18)

Histogram of branch loadings with comparison against branch loadings in base case is given in Appendix (Figure 9-9). List of transmission lines and transformers in monitored grid which are loaded more than 80% of their thermal limits is also given in Appendix (Table 9-19). Although the pressure of high power flows through Slovenia towards Italy is expected in the future, the results are not sufficiently credible due to the causes listed in Chapter 6.1.

The most significant changes in power flows in the area of SEE are shown in Appendix (Table 9-20). The main paths for transfer output power from WPPs with high wind penetration could be detected from these tables.

These changes in power flows have influence on power losses. The changes are shown in Figure 6-17. Significant increase of losses can be noticed in Turkey, Croatia, Slovenia and B&H and decrease of losses in Bulgaria and Greece.

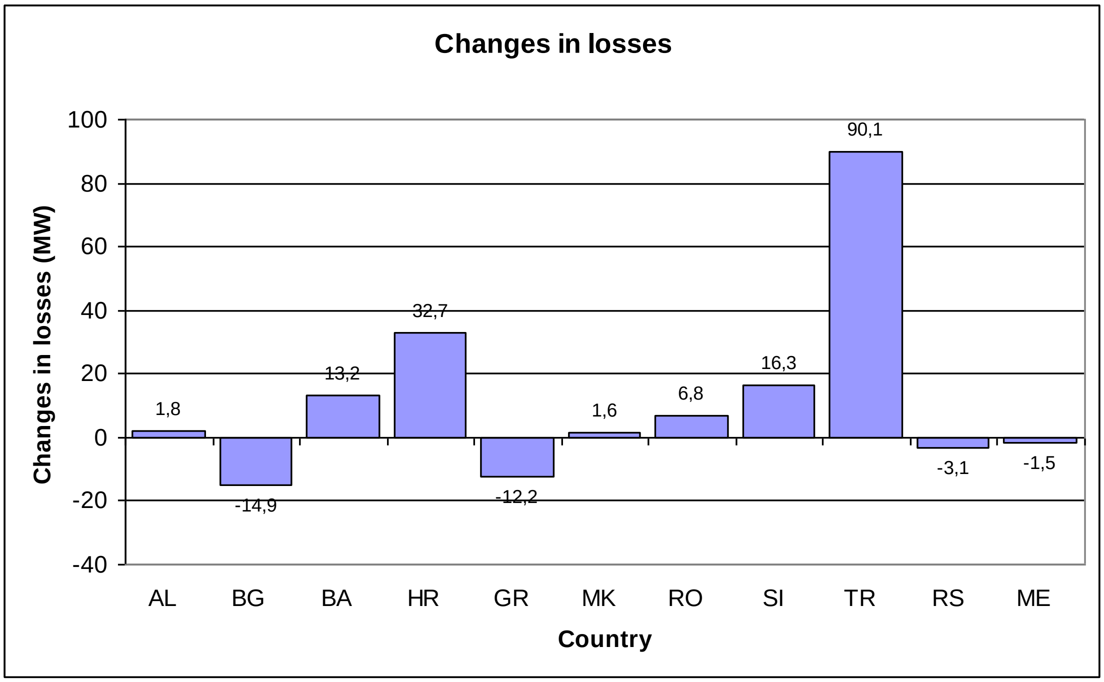


Figure 6-17 Changes in power losses in analyzed region

Histogram of busbar voltages in 220 kV and 400 kV network of analyzed region with comparison against base case is given in Appendix (Figure 9-10). In comparison against base case it can be noticed one more node of 400 kV level with voltage bellow limit. This is node on phase-shift transformer in SS Divaca, which is installed on tie-line 400 kV Divaca (SI) – Redipuglia (IT), with voltage 378 kV. The main reason for this low voltage is significant export to Italy through this tie-line as well as low voltage profile in neighboring nodes in Slovenia. This should be treated as local problem. For all other monitored nodes it can be seen that voltages are slightly decreased.

List of overloaded branches as result from contingency (n-1) analysis for the observed regime is presented in Table 6-16. and geographical positions of critical elements are shown on Figure 6-18.

Table 6-16 Results of security (n-1) analysis

<----------------- MONITORED BRANCH			----------------->	CONTINGENCY	RATING	FLOW	%
31405*LOKROG1	400.00	31430 LBERIC1	400.00 1	BASE CASE	1108.5	1197.3	113.7
31405*LOKROG1	400.00	31430 LBERIC1	400.00 2	BASE CASE	1108.5	1197.3	113.7
31438 LHAVCE1	400.00	504*XUD_AV11	400.00 1	BASE CASE	1330.2	1292.4	106.5
20103 HMRACL21	220.00	20168*HTE_SI21	220.00 2	SINGLE 145	297.0	307.3	102.5
20010*HBRINJ21	220.00	20059 HESENJ	220.00 1	SINGLE 152	297.0	381.6	124.9
20059*HESENJ	220.00	20096 HMELIN21	220.00 1	SINGLE 152	297.0	436.2	142.5
20103*HMRACL21	220.00	20168 HTE SI21	220.00 2	SINGLE 152	297.0	304.9	103.5
20502*HBRINJ11	400.00	20010 HBRINJ21	220.00 1	SINGLE 152	400.0	571.5	142.9
31405 LOKROG1	400.00	503*XUD_OK11	400.00 1	SINGLE 264	1330.2	1582.4	132.3
31405 LOKROG1	400.00	503*XUD_OK11	400.00 1	SINGLE 265	1330.2	1223.6	101.5
31405 LOKROG1	400.00	503*XUD_OK11	400.00 1	SINGLE 266	1330.2	1223.6	101.5
20103 HMRACL21	220.00	20168*HTE_SI21	220.00 2	SINGLE 553	297.0	372.6	122.7
20103 HMRACL21	220.00	20168*HTE_SI21	220.00 1	SINGLE 554	297.0	315.8	103.7
28052*RRESIT2A	220.00	28071 RTIMIS2	220.00 2	SINGLE 582	333.4	392.5	113.6
28052*RRESIT2A	220.00	28071 RTIMIS2	220.00 1	SINGLE 583	333.4	392.5	113.6
28036*RIERNU1	400.00	28087 RIERNU2	220.00 1	SINGLE 758	400.0	407.0	101.8
31405 LOKROG1	400.00	503*XUD_OK11	400.00 1	SINGLE 814	1330.2	1210.9	100.1
31405 LOKROG1	400.00	31438*LHAVCE1	400.00 1	SINGLE 816	1330.2	1564.7	128.8
31405 LOKROG1	400.00	503*XUD_OK11	400.00 1	SINGLE 818	1330.2	1295.7	109.2
31405 LOKROG1	400.00	503*XUD_OK11	400.00 1	SINGLE 824	1330.2	1698.5	142.8
20103 HMRACL21	220.00	20168*HTE_SI21	220.00 2	SINGLE 832	297.0	308.0	103.7
31405 LOKROG1	400.00	503*XUD_OK11	400.00 1	SINGLE 832	1330.2	1241.0	105.0

CONTINGENCY LEGEND:

LABEL	EVENTS
SINGLE 145	: OPEN LINE FROM BUS 20037 [HERNES11 400.00] TO BUS 20203 [HZERJA11 400.00] CKT 1
SINGLE 152	: OPEN LINE FROM BUS 20097 [HMELIN11 400.00] TO BUS 20502 [HBRINJ11 400.00] CKT 1
SINGLE 264	: OPEN LINE FROM BUS 31405 [LOKROG1 400.00] TO BUS 31438 [LHAVCE1 400.00] CKT 1
SINGLE 265	: OPEN LINE FROM BUS 31410 [LDIVAC1 400.00] TO BUS 31411 [LDIVAC1P 400.00] CKT 1
SINGLE 266	: OPEN LINE FROM BUS 31410 [LDIVAC1 400.00] TO BUS 31411 [LDIVAC1P 400.00] CKT 2
SINGLE 553	: OPEN LINE FROM BUS 20103 [HMRACL21 220.00] TO BUS 20168 [HTE SI21 220.00] CKT 1
SINGLE 554	: OPEN LINE FROM BUS 20103 [HMRACL21 220.00] TO BUS 20168 [HTE SI21 220.00] CKT 2
SINGLE 582	: OPEN LINE FROM BUS 28052 [RRESIT2A 220.00] TO BUS 28071 [RTIMIS2 220.00] CKT 1
SINGLE 583	: OPEN LINE FROM BUS 28052 [RRESIT2A 220.00] TO BUS 28071 [RTIMIS2 220.00] CKT 2
SINGLE 758	: OPEN LINE FROM BUS 28039 [RROSIO1 400.00] TO BUS 28094 [RROSIO2 220.00] CKT 1
SINGLE 814	: OPEN LINE FROM BUS 31210 [LDIVAC2 220.00] TO BUS 156 [XPA_DI21 220.00] CKT 1
SINGLE 816	: OPEN LINE FROM BUS 31405 [LOKROG1 400.00] TO BUS 503 [XUD_OK11 400.00] CKT 1
SINGLE 818	: OPEN LINE FROM BUS 31411 [LDIVAC1P 400.00] TO BUS 80 [XRE_DI11 400.00] CKT 1
SINGLE 824	: OPEN LINE FROM BUS 31438 [LHAVCE1 400.00] TO BUS 504 [XUD_AV11 400.00] CKT 1
SINGLE 832	: OPEN LINE FROM BUS 36017 [0LASTV11 400.00] TO BUS 701 [XIT_ME1M 400.00] CKT D1

In Croatia, in comparison against base case, it can be seen that line 220 kV TPP Sisak – Mraclin appears as critical in 4 more outages, with overload up to 23%. Also, one additional critical line appears. Line 220 kV HPP Senj – Brinje is overloaded by 43% in case of outage of line 400 kV Meline – Brinje.

In Romania, in comparison against base case, it can be seen one more critical element. Transformer 400/220 kV in SS Iernut is overloaded by 2% in case of outage of transformer 400/220 kV in SS Rosiori.

Also, in comparison against base case, it can be seen that tie-line 400 kV Okroglo (SI) – Udine (IT) appears as critical in case of 3 more outages, with overload up to 43%.

Although the pressure of high power flows through Slovenia towards Italy is expected in the future, the results are not sufficiently credible due to the causes listed in Chapter 6.1.

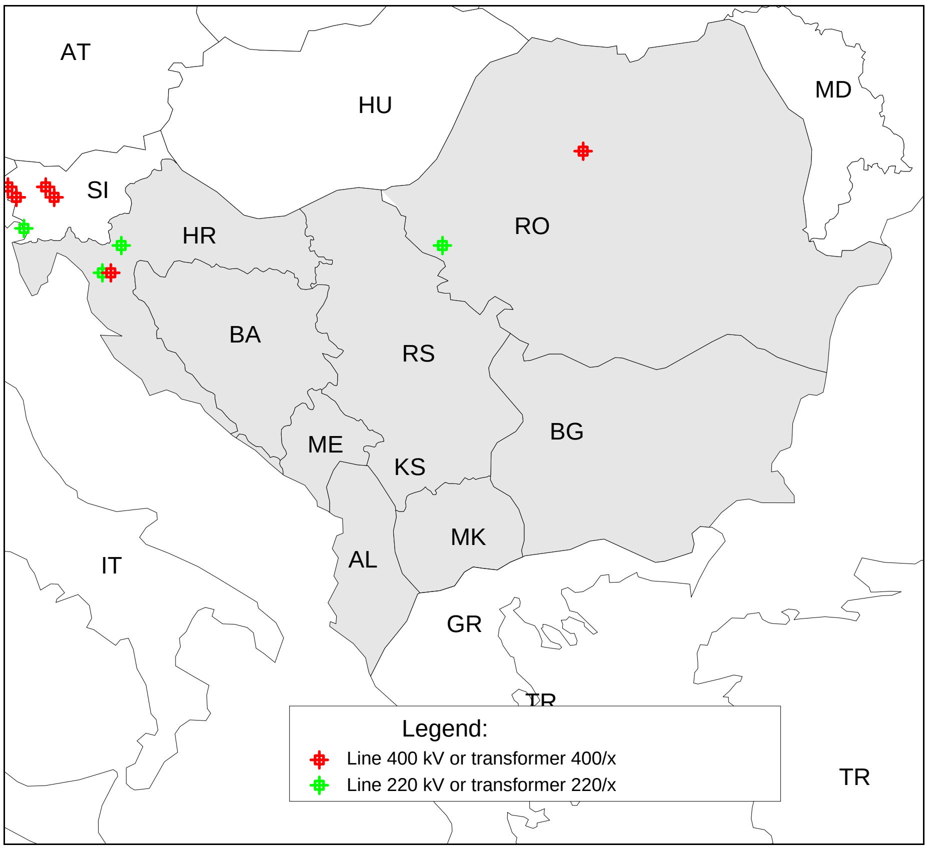


Figure 6-18 Geographical positions of critical elements

6.3.3. *Wind scenario 2: Aegean + Black Sea (Max) → Adriatic (Min)*

In this subchapter, steady state analyses are presented for the following power system operation regime:

- load level: winter maximum load in 2020
- wind penetration in Adriatic region: low (10%)
- wind penetration in Aegean region: high (70%)
- wind penetration in Black Sea region: high (70%)
- wind penetration in Continental region: medium (35%)

Basic information about areas (countries) of the analyzed region and aggregated physical exchanges among analyzed countries are given in Appendix (Table 9-21 and Table 9-22).

Histogram of branch loadings with comparison against branch loadings in base case is given in Appendix (Figure 9-11). List of transmission lines and transformers in monitored grid which are loaded more than 80% of their thermal limits is also given in Appendix (Table 9-23). There are 29 branches loaded more than 80% of their thermal limits. In comparison against base case there are three more branches which are overloaded. Line 220 kV TPP Sisak – Mraclin, in Croatia, is overloaded by 7%. In Serbia, line 400 kV Mladost – Sremska Mitrovica is overloaded by 13%. The third overloaded element is 400 kV tie-line Okroglo (SI) – Udine (IT), which is overloaded by 3%. The main reason for these six overloaded branches is significant amount of surplus in the region (more than 2700 MW) which is exported to the rest of ENTSO-E, including Italy.

The most significant changes in power flows in the area of SEE are shown in Appendix (Table 9-24). The main paths for transfer output power from WPPs with high wind penetration could be detected from these tables.

These changes in power flows have influence on power losses. The changes are shown in Figure 6-19. It can be seen that active power losses are increased in all countries. The most significant increase of losses can be noticed in Romania, Croatia, Serbia and B&H.

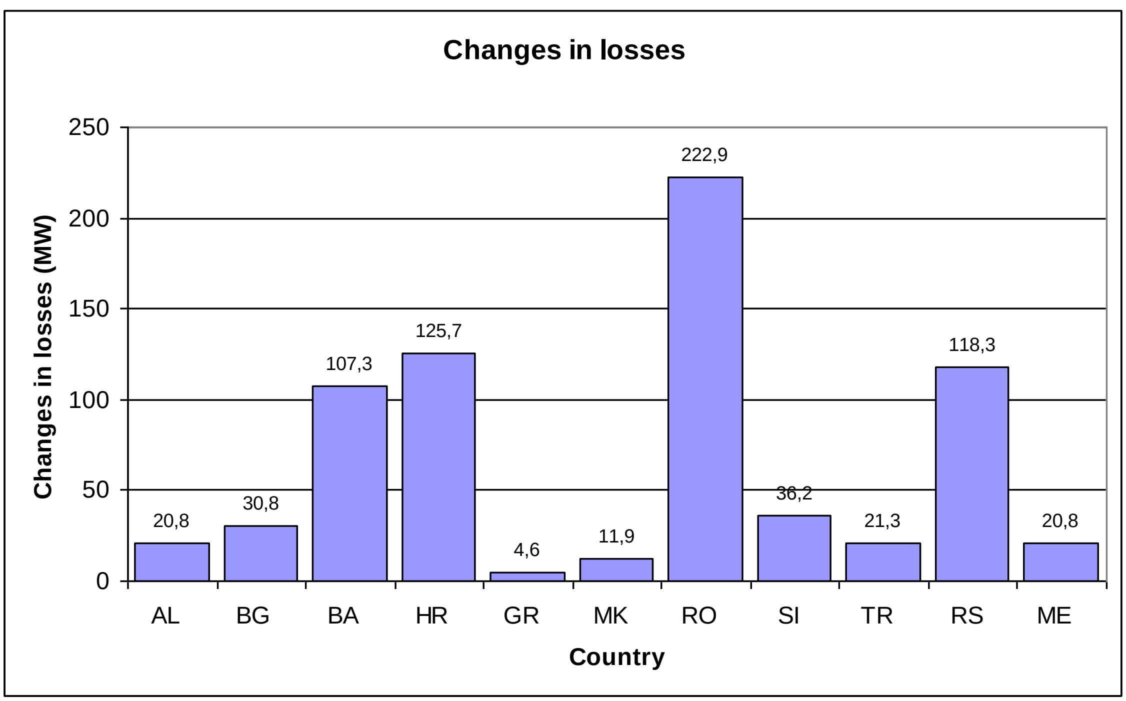


Figure 6-19 Changes in power losses in analyzed region

Histogram of busbar voltages in 220 kV and 400 kV network of analyzed region with comparison against base case is given in Appendix (Figure 9-12). In comparison against base case it can be noticed 10 more nodes of 400 kV level with voltage bellow limits, 4 in Romania, 3 in Serbia and 3 in Slovenia. The main reason for these low voltages is significantly increased export from Romania (more then 1000 MW of additional export) as well as transit of significant part of export from Bulgaria and Turkey through Serbia. For all other monitored nodes it can be seen that voltage profile generally is decreased.

List of critical outages and critical elements, modified report from contingency (n-1) analysis for the observed regime is presented in Table 6-17. and geographical positions of critical elements are shown on Figure 6-20. In the table for each critical element only results for the most critical outages are shown (i.e. outages which cause the greatest overload) and the last column in the table shows total number of critical outages for each element (number of outages which cause overloads).

Table 6-17 Results of security (n-1) analysis

<----------------- MONITORED	BRANCH	----------------->		WORST CASE (THE GREATEST OVERLOAD) CONTINGENCY	RATING	FLOW	%	NO.CRIT. OUTAGES
20103 HMRACL21	220.00	20168*HTE SI21	220.00 2	BASE CASE	297.0	311.3	106.5	
31405 LOKROG1	400.00	503*XUD_OK11	400.00 1	BASE CASE	1330.2	1227.0	103.4	
31405*LOKROG1	400.00	31430 LBERIC1	400.00 1	BASE CASE	1108.5	1232.3	119.8	
31405*LOKROG1	400.00	31430 LBERIC1	400.00 2	BASE CASE	1108.5	1232.3	119.8	
31438*LHAVCE1	400.00	504 XUD_AV11	400.00 1	BASE CASE	1330.2	1334.8	110.8	
34040 JRPMLA1	400.00	34045*JSMIT21	400.00 1	BASE CASE	1330.2	1453.5	112.6	
88 XKO_PO21	220.00	10016*AKOPLI2	220.00 1	SINGLE 68	278.2	389.3	141.5	11
10005 AKOMAN2	220.00	10006*AVDEJA2	220.00 1	SINGLE 68	325.4	380.9	116.4	36
88*XKO_PO21	220.00	36015 0PODG121	220.00 1	SINGLE 68	274.4	387.4	143.3	14
10006*AVDEJA2	220.00	10016 AKOPLI2	220.00 1	SINGLE 69	278.2	411.7	147.0	74
12474*VMI 1	400.00	12274 VMI 2	220.00 1	SINGLE 98	630.0	631.1	100.2	1
71*XME_DI11	400.00	31410 LDIVAC1	400.00 1	SINGLE 149	1108.5	1125.1	106.8	24
111 XPR_MR21	220.00	14201*WPRIJ22	220.00 1	SINGLE 152	316.0	358.0	118.2	7
111*XPR_MR21	220.00	20168 HTE SI21	220.00 2	SINGLE 152	297.0	352.4	125.6	8
20010*HBRINJ21	220.00	20059 HESENJ	220.00 1	SINGLE 152	297.0	482.6	165.5	1
20502*HBRINJ11	400.00	20010 HBRINJ21	220.00 1	SINGLE 152	400.0	686.6	171.6	1
20059*HESENJ	220.00	20096 HMELIN21	220.00 1	SINGLE 152	297.0	508.2	174.0	1
28064*RBARU 2	220.00	28065 RHAJD 2	220.00 1	SINGLE 191	333.4	346.4	104.6	2
28063*RPAROS2	220.00	28064 RBARU 2	220.00 1	SINGLE 191	304.8	313.6	103.5	2
28062*RTG.JI2	220.00	28063 RPAROS2	220.00 1	SINGLE 191	304.8	338.9	109.7	3
28045 RURECH2	220.00	28062*RTG.JI2	220.00 1	SINGLE 191	304.8	326.7	105.7	3

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 28002*RURECH1      400.00  28045 RURECH2     220.00 1  SINGLE 194      400.0    450.8    112.7
101
 28008*RARAD 1      400.00  29007 RARAD2      220.00 1  SINGLE 198      400.0    447.5    111.9
1
 28037*RGADAL1      400.00  28039 RROSIO1     400.00 1  SINGLE 198     1204.0   1147.1    100.9
1
 28047*RP.D.F2A    220.00  28052 RRESIT2A    220.00 1  SINGLE 203      333.4    385.8    110.5
4
 28036*RIERNU1      400.00  28087 RIERNU2     220.00 1  SINGLE 249      400.0    505.3    126.3
6
 34035*JPANC21      400.00  34075 JBGD201     400.00 A  SINGLE 312     1144.5   1140.3    102.6
1
   116 XTR_PE21     220.00  36027*0HPERU21    220.00 1  SINGLE 326      274.4    292.0    106.2
1
 20103 HMRACL21     220.00  20168*HTE SI21    220.00 1  SINGLE 554      297.0    381.3    129.9
1
 28052 RRESIT2A     220.00  28071*RTIMIS2     220.00 2  SINGLE 582      333.4    469.9    150.1
33
 28052 RRESIT2A     220.00  28071*RTIMIS2     220.00 1  SINGLE 583      333.4    469.9    150.1
33
 28065*RHAJD 2      220.00  28068 RMINTI2B    220.00 1  SINGLE 596      333.4    350.2    104.3
1
 28065*RHAJD 2      220.00  28066 RPESTI2     220.00 1  SINGLE 597      304.8    356.0    115.5
1
 28071*RTIMIS2      220.00  29007 RARAD2      220.00 1  SINGLE 604      333.4    371.2    116.2
3
 28070 RSACALZ2     220.00  28071*RTIMIS2     220.00 1  SINGLE 605      333.4    337.2    105.3
1
 16402*WTUZL41      400.00  16211 WTUZL42     220.00 2  SINGLE 725      400.0    457.8    114.4
2
 16402*WTUZL41      400.00  16211 WTUZL42     220.00 1  SINGLE 726      400.0    457.8    114.4
2
 28083 RSTEJA2      220.00  28084*RGHEOR2     220.00 1  SINGLE 757      304.8    276.3    107.5
1
 31405 LOKROG1      400.00  31438*LHAVCE1     400.00 1  SINGLE 816     1330.2   1612.1    136.2
3
    71*XME_DI11     400.00  20097 HMELIN11    400.00 1  SINGLE 832     1300.0   1224.4    103.9
1
 20097 HMELIN11     400.00  20502*HBRINJ11    400.00 1  SINGLE 832     1316.0   1368.0    113.6
2


CONTINGENCY LEGEND:
LABEL         EVENTS
SINGLE 68   : OPEN LINE FROM BUS 220 [XKA_PG11    400.00] TO BUS 10143 [ALEZHA1     400.00] CKT 1
SINGLE 69   : OPEN LINE FROM BUS 220 [XKA_PG11    400.00] TO BUS 36005 [0PODG211    400.00] CKT 1
SINGLE 98   : OPEN LINE FROM BUS 12434 [VZLATI1     400.00] TO BUS 12480 [VPLOVD1     400.00] CKT
1
SINGLE 145  : OPEN LINE FROM BUS 20037 [HERNES11    400.00] TO BUS 20203 [HZERJA11    400.00] CKT
1
SINGLE 149  : OPEN LINE FROM BUS 20097 [HMELIN11    400.00] TO BUS 20177 [HTUMBR11    400.00] CKT
1
SINGLE 152  : OPEN LINE FROM BUS 20097 [HMELIN11    400.00] TO BUS 20502 [HBRINJ11    400.00] CKT
1
SINGLE 191  : OPEN LINE FROM BUS 28001 [RTANTA1     400.00] TO BUS 28034 [RSIBIU1     400.00] CKT
1
SINGLE 194  : OPEN LINE FROM BUS 28002 [RURECH1     400.00] TO BUS 28004 [RP.D.F1     400.00] CKT
1
SINGLE 198  : OPEN LINE FROM BUS 28003 [RMINTI1A    400.00] TO BUS 28008 [RARAD 1     400.00] CKT
1
SINGLE 203  : OPEN LINE FROM BUS 28004 [RP.D.F1     400.00] TO BUS 28018 [RRESIT1A    400.00] CKT
1
SINGLE 249  : OPEN LINE FROM BUS 28037 [RGADAL1     400.00] TO BUS 28039 [RROSIO1     400.00] CKT
1
SINGLE 312  : OPEN LINE FROM BUS 34055 [JTDRMN1     400.00] TO BUS 34083 [JSMED311    400.00] CKT
A
SINGLE 326  : OPEN LINE FROM BUS 36005 [0PODG211    400.00] TO BUS 36017 [0LASTV11    400.00] CKT
A
```

```
SINGLE 554  : OPEN LINE FROM BUS 20103 [HMRACL21    220.00] TO BUS 20168 [HTE SI21    220.00] CKT
2
SINGLE 582  : OPEN LINE FROM BUS 28052 [RRESIT2A    220.00] TO BUS 28071 [RTIMIS2     220.00] CKT
1
SINGLE 583  : OPEN LINE FROM BUS 28052 [RRESIT2A    220.00] TO BUS 28071 [RTIMIS2     220.00] CKT
2
SINGLE 596  : OPEN LINE FROM BUS 28065 [RHAJD 2     220.00] TO BUS 28066 [RPESTI2     220.00] CKT
1
SINGLE 597  : OPEN LINE FROM BUS 28065 [RHAJD 2     220.00] TO BUS 28068 [RMINTI2B    220.00] CKT
1
SINGLE 604  : OPEN LINE FROM BUS 28070 [RSACALZ2    220.00] TO BUS 29007 [RARAD2      220.00] CKT
1
SINGLE 605  : OPEN LINE FROM BUS 28071 [RTIMIS2     220.00] TO BUS 29007 [RARAD2      220.00] CKT
1
SINGLE 725  : OPEN LINE FROM BUS 16402 [WTUZL41     400.00] TO BUS 16211 [WTUZL42     220.00] CKT
1
SINGLE 726  : OPEN LINE FROM BUS 16402 [WTUZL41     400.00] TO BUS 16211 [WTUZL42     220.00] CKT
2
SINGLE 757  : OPEN LINE FROM BUS 28036 [RIERNU1     400.00] TO BUS 28087 [RIERNU2     220.00] CKT
1
SINGLE 816  : OPEN LINE FROM BUS 31405 [LOKROG1     400.00] TO BUS 503 [XUD_OK11    400.00] CKT 1
SINGLE 832  : OPEN LINE FROM BUS 36017 [0LASTV11    400.00] TO BUS 701 [XIT_ME1M    400.00] CKT
D1
```

In comparison against base case it can be seen that there are several more critical elements and outages. There are 14 more critical elements in Romania, three more critical elements in Croatia, two more critical elements in Albania, two more critical elements in Serbia, one more critical element in Bulgaria and B&H.

Also, .there are four tie-lines which appear as critical elements in comparison against base case. One of them is 400 kV tie-line Meline (HR) – Divaca (SI) and others are 220 kV tie-lines Koplic (AL) – Podgorica (ME), Trebinje (BA) – HPP Perucica (ME) and Prijedor (BA) – TPP Sisak (HR).

It also should be noted that tie-line 400 kV Meline (HR) – Divaca (SI) appears overloaded only on Slovenian side of the tie-line as well as tie-line 220 kV Trebinje (BA) – HPP Perucica (ME) which appears as overloaded only on Montenegrin side of the tie-line. The reason for this is different protection settings on these tie-lines and such problems can be solved by adjusting limits on both sides of these tie-lines.

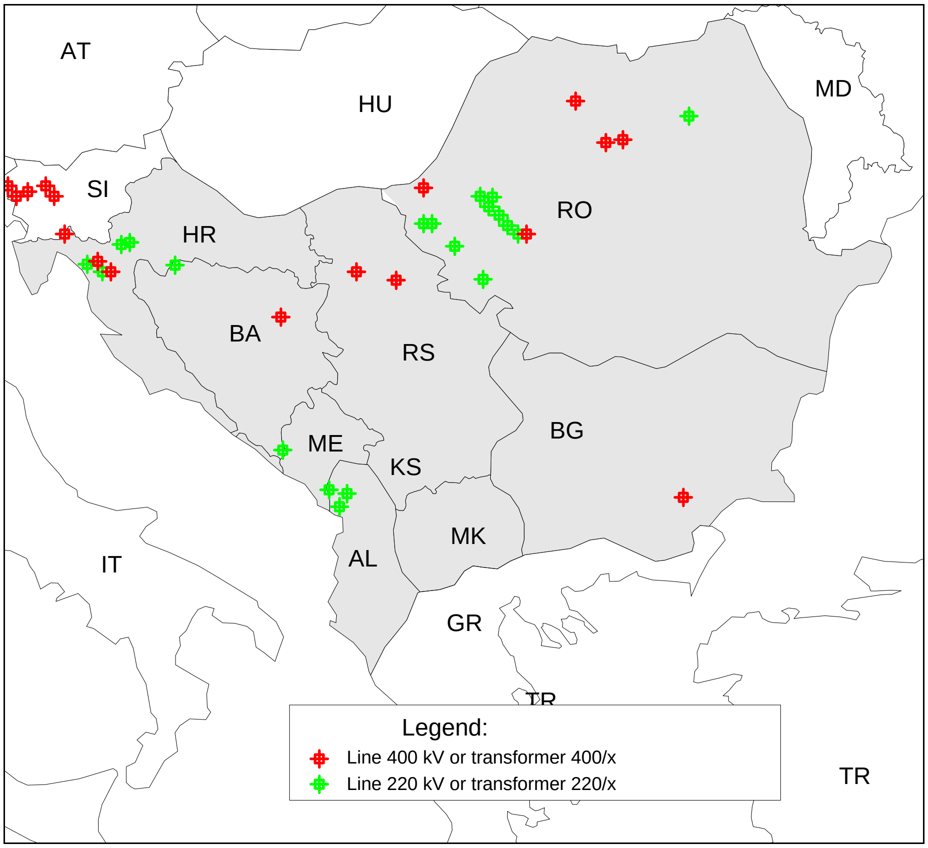


Figure 6-20 Geographical positions of critical elements

6.3.4. Wind scenario 3: Continental SEE + Black Sea (Max) → Adriatic (Min)

In this subchapter, steady state analyses are presented for the following power system operation regime:

- load level: winter maximum load in 2020
- wind penetration in Adriatic region: low (10%)
- wind penetration in Aegean region: medium (35%)
- wind penetration in Black Sea region: high (70%)
- wind penetration in Continental region: high (70%)

Basic information about areas (countries) of the analyzed region and aggregated physical exchanges among analyzed countries are given in Appendix (Table 9-25 and Table 9-26).

Histogram of branch loadings with comparison against branch loadings in base case is given in Appendix (Figure 9-13). List of transmission lines and transformers in monitored grid which are loaded more than 80% of their thermal limits is also given in Appendix (Table 9-27). There are 21 more branches loaded more than 80% of their thermal limits, including 6 more overloaded branches. Additional overloads can be found in Croatia (line 220 kV TPP Sisak – Mraclin is overloaded by 10%), in Romania (parallel lines 220 kV Resita – Timisoara are overloaded by 3%) and in Serbia (line 400 kV Mladost – Sremska Mitrovica is overloaded by 19%). Also, tie-line 400 kV Meline (HR) – Divaca (SI) is overloaded by 4% and tie-line 400 kV Okroglo (SI) – Udine (IT) is overloaded by 9%. The main reason for these six overloaded branches is significant amount of surplus in the region (more than 2800 MW) which is exported to the rest of ENTSO-E, including Italy.

The most significant changes in power flows in the area of SEE are shown in Appendix (Table 9-28). The main paths for transfer output power from WPPs with high wind penetration could be detected from these tables.

These changes in power flows have influence on power losses. The changes are shown in Figure 6-21. Significant increase of losses can be noticed in Romania, Croatia, Serbia and BIH.

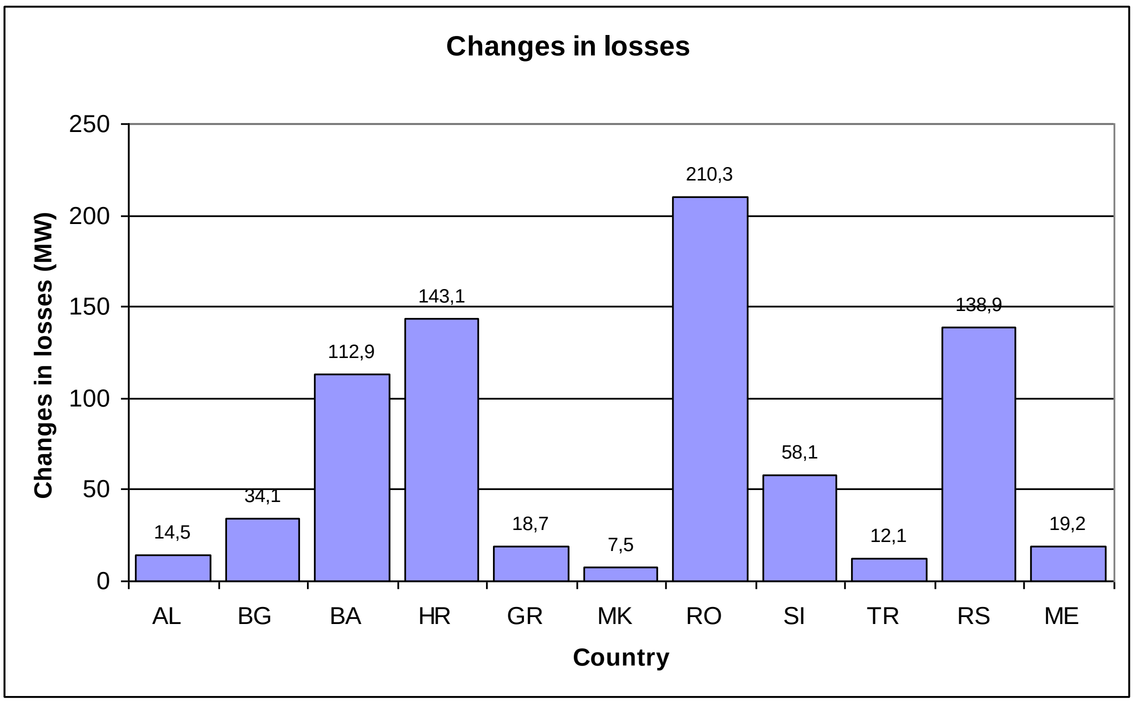


Figure 6-21 Changes in power losses in analyzed region

Histogram of busbar voltages in 220 kV and 400 kV network of analyzed region with comparison against base case is given in Appendix (Figure 9-14). In comparison against base case it can be noticed 12 more nodes of 400 kV level with voltage bellow limits, 4 in Romania, 3 in Serbia and 5 in Slovenia. The main reason for these low voltages is significantly increased export from Romania (more than 1200 MW of additional export) and Serbia as well as transit of significant part of export from Bulgaria and Turkey through Serbia. For all other monitored nodes it can be seen that voltage profile generally is decreased.

List of overloaded branches as result from contingency (n-1) analysis for the observed regime is presented in Table 6-18 and geographical positions of critical elements are shown on Figure 6-22.

Table 6-18 Results of security (n-1) analysis

<----------------- MONITORED		BRANCH	----------------->	WORST CASE (THE GREATEST OVERLOAD) CONTINGENCY	RATING	FLOW	%	NO.CRIT. OUTAGES
71 XME_DI11	400.00	31410*LDIVAC1	400.00 1	BASE CASE	1108.5	1072.9	103.6	
31438*LHAVCE1	400.00	504 XUD_AV11	400.00 1	BASE CASE	1330.2	1377.8	116.9	
31405*LOKROG1	400.00	31430 LBERIC1	400.00 1	BASE CASE	1108.5	1275.5	126.4	
31405*LOKROG1	400.00	31430 LBERIC1	400.00 2	BASE CASE	1108.5	1275.5	126.4	
31405 LOKROG1	400.00	503*XUD_OK11	400.00 1	BASE CASE	1330.2	1268.7	109.4	
28052 RRESIT2A	220.00	28071*RTIMIS2	220.00 2	BASE CASE	333.4	326.0	102.9	
28052 RRESIT2A	220.00	28071*RTIMIS2	220.00 1	BASE CASE	333.4	326.0	102.9	
34040 JRPMLA1	400.00	34045*JSMIT21	400.00 1	BASE CASE	1330.2	1519.5	118.6	
28002*RURECH1	400.00	28045 RURECH2	220.00 1	BASE CASE	400.0	404.7	101.2	
153 XPE_DI21	220.00	31210*LDIVAC2	220.00 1	SINGLE 22	365.8	370.2	108.3	2
153*XPE_DI21	220.00	20126 HPEHLI21	220.00 1	SINGLE 22	362.0	381.0	109.4	2
88*XKO_PO21	220.00	36015 0PODG121	220.00 1	SINGLE 68	274.4	348.3	128.2	10
10006*AVDEJA2	220.00	10016 AKOPLI2	220.00 1	SINGLE 69	278.2	371.1	132.1	9
111 XPR_MR21	220.00	14201*WPRIJ22	220.00 1	SINGLE 152	316.0	366.6	122.9	7
111*XPR_MR21	220.00	20168 HTE SI21	220.00 2	SINGLE 152	297.0	359.9	130.7	17
20059*HESENJ	220.00	20096 HMELIN21	220.00 1	SINGLE 152	297.0	528.6	184.2	1
20010*HBRINJ21	220.00	20059 HESENJ	220.00 1	SINGLE 152	297.0	504.0	175.7	1
20502*HBRINJ11	400.00	20010 HBRINJ21	220.00 1	SINGLE 152	400.0	713.8	178.4	1
28063*RPAROS2	220.00	28064 RBARU 2	220.00 1	SINGLE 191	304.8	313.6	103.5	2
28062*RTG.JI2	220.00	28063 RPAROS2	220.00 1	SINGLE 191	304.8	339.3	109.8	7
28064*RBARU 2	220.00	28065 RHAJD 2	220.00 1	SINGLE 191	333.4	346.4	104.7	2
28045 RURECH2	220.00	28062*RTG.JI2	220.00 1	SINGLE 191	304.8	328.1	106.1	3
28008*RARAD 1	400.00	29007 RARAD2	220.00 1	SINGLE 198	400.0	465.0	116.2	3
28036*RIERNU1	400.00	28087 RIERNU2	220.00 1	SINGLE 247	400.0	451.4	112.8	6
14406*WVISEG1	400.00	16402 WTUZL41	400.00 1	SINGLE 307	1330.0	1367.7	106.2	1
34025 JNSAD31	400.00	34078*JSRBOB1	400.00 A	SINGLE 307	1330.2	1191.1	102.7	1
115*XSA_PI21	220.00	36025 0HPIVA21	220.00 1	SINGLE 307	381.1	391.1	102.0	2
34035*JPANC21	400.00	34075 JBGD201	400.00 A	SINGLE 312	1144.5	1311.1	118.5	2
116 XTR_PE21	220.00	36027*0HPERU21	220.00 1	SINGLE 326	274.4	280.7	101.8	1
10005 AKOMAN2	220.00	10006*AVDEJA2	220.00 1	SINGLE 418	325.4	371.3	112.7	16
20103 HMRACL21	220.00	20168*HTE SI21	220.00 1	SINGLE 554	297.0	389.6	134.1	3
28065*RHAJD 2	220.00	28068 RMINTI2B	220.00 1	SINGLE 596	333.4	351.2	104.7	1
28065*RHAJD 2	220.00	28066 RPESTI2	220.00 1	SINGLE 597	304.8	356.5	115.8	1

```
 28071*RTIMIS2      220.00  29007 RARAD2       220.00 1  SINGLE 604       333.4    393.8    124.1
9
 28070*RSACALZ2     220.00  29007 RARAD2       220.00 1  SINGLE 605       333.4    330.4    105.1
1
 28070 RSACALZ2     220.00  28071*RTIMIS2      220.00 1  SINGLE 605       333.4    354.4    111.3
1
 16402*WTUZL41      400.00  16211 WTUZL42      220.00 2  SINGLE 725       400.0    464.8    116.2
2
 16402*WTUZL41      400.00  16211 WTUZL42      220.00 1  SINGLE 726       400.0    464.8    116.2
2
 28083 RSTEJA2      220.00  28084*RGHEOR2      220.00 1  SINGLE 757       304.8    274.5    106.4
1
 31405 LOKROG1      400.00  31438*LHAVCE1      400.00 1  SINGLE 816      1330.2   1662.3    144.1
5
    71*XME_DI11     400.00  20097 HMELIN11     400.00 1  SINGLE 832      1300.0   1243.2    101.4
1
 20097 HMELIN11     400.00  20502*HBRINJ11     400.00 1  SINGLE 832      1316.0   1336.8    107.5
2


CONTINGENCY LEGEND:
LABEL         EVENTS
SINGLE 22   : OPEN LINE FROM BUS 71 [XME_DI11    400.00] TO BUS 31410 [LDIVAC1     400.00] CKT 1
SINGLE 68   : OPEN LINE FROM BUS 220 [XKA_PG11    400.00] TO BUS 10143 [ALEZHA1     400.00] CKT 1
SINGLE 69   : OPEN LINE FROM BUS 220 [XKA_PG11    400.00] TO BUS 36005 [0PODG211    400.00] CKT 1
SINGLE 145  : OPEN LINE FROM BUS 20037 [HERNES11    400.00] TO BUS 20203 [HZERJA11    400.00] CKT
1
SINGLE 152  : OPEN LINE FROM BUS 20097 [HMELIN11    400.00] TO BUS 20502 [HBRINJ11    400.00] CKT
1
SINGLE 191  : OPEN LINE FROM BUS 28001 [RTANTA1     400.00] TO BUS 28034 [RSIBIU1     400.00] CKT
1
SINGLE 198  : OPEN LINE FROM BUS 28003 [RMINTI1A    400.00] TO BUS 28008 [RARAD 1     400.00] CKT
1
SINGLE 247  : OPEN LINE FROM BUS 28036 [RIERNU1     400.00] TO BUS 28037 [RGADAL1     400.00] CKT
1
SINGLE 307  : OPEN LINE FROM BUS 34040 [JRPMLA1     400.00] TO BUS 34045 [JSMIT21     400.00] CKT
1
SINGLE 312  : OPEN LINE FROM BUS 34055 [JTDRMN1     400.00] TO BUS 34083 [JSMED311    400.00] CKT
A
SINGLE 326  : OPEN LINE FROM BUS 36005 [0PODG211    400.00] TO BUS 36017 [0LASTV11    400.00] CKT
A
SINGLE 418  : OPEN LINE FROM BUS 10005 [AKOMAN2     220.00] TO BUS 10140 [AKOLAC2     220.00] CKT
1
SINGLE 554  : OPEN LINE FROM BUS 20103 [HMRACL21    220.00] TO BUS 20168 [HTE SI21    220.00] CKT
2
SINGLE 596  : OPEN LINE FROM BUS 28065 [RHAJD 2     220.00] TO BUS 28066 [RPESTI2     220.00] CKT
1
SINGLE 597  : OPEN LINE FROM BUS 28065 [RHAJD 2     220.00] TO BUS 28068 [RMINTI2B    220.00] CKT
1
SINGLE 604  : OPEN LINE FROM BUS 28070 [RSACALZ2    220.00] TO BUS 29007 [RARAD2      220.00] CKT
1
SINGLE 605  : OPEN LINE FROM BUS 28071 [RTIMIS2     220.00] TO BUS 29007 [RARAD2      220.00] CKT
1
SINGLE 725  : OPEN LINE FROM BUS 16402 [WTUZL41     400.00] TO BUS 16211 [WTUZL42     220.00] CKT
1
SINGLE 726  : OPEN LINE FROM BUS 16402 [WTUZL41     400.00] TO BUS 16211 [WTUZL42     220.00] CKT
2
SINGLE 757  : OPEN LINE FROM BUS 28036 [RIERNU1     400.00] TO BUS 28087 [RIERNU2     220.00] CKT
1
SINGLE 816  : OPEN LINE FROM BUS 31405 [LOKROG1     400.00] TO BUS 503 [XUD_OK11    400.00] CKT 1
SINGLE 832  : OPEN LINE FROM BUS 36017 [0LASTV11     400.00] TO BUS 701 [XIT_ME1M    400.00] CKT
D1
```

In comparison against base case it can be seen that there are several more critical elements and outages. There are 13 more critical elements in Romania, three more critical elements in Serbia, two more critical elements in Croatia, two more critical elements in Albania, two more critical elements in B&H.

Also, .there are six tie-lines which appear as critical elements in comparison against base case. One of them is 400 kV tie-line Meline (HR) – Divaca (SI) and others are 220 kV tie-lines Koplic (AL) – Podgorica (ME), Trebinje (BA) – HPP Perucica (ME), Sarajevi (BA) – HPP Piva (ME), Prijedor (BA) – TPP Sisak (HR) and Pehlin (HR) – Divaca (SI).
It also should be noted that tie-line 400 kV Meline (HR) – Divaca (SI) appears overloaded only on Slovenian side of the tie-line as well as tie-lines 220 kV Trebinje (BA) – HPP Perucica (ME), Sarajevo (BA) – HPP Piva (ME) and Koplic (AL) – Podgorica (ME) which appear as overloaded only on Montenegrin side of the tie-line. The reason for this is different protection settings on these tie-lines and such problems can be solved by adjusting limits on both sides of these tie-lines.

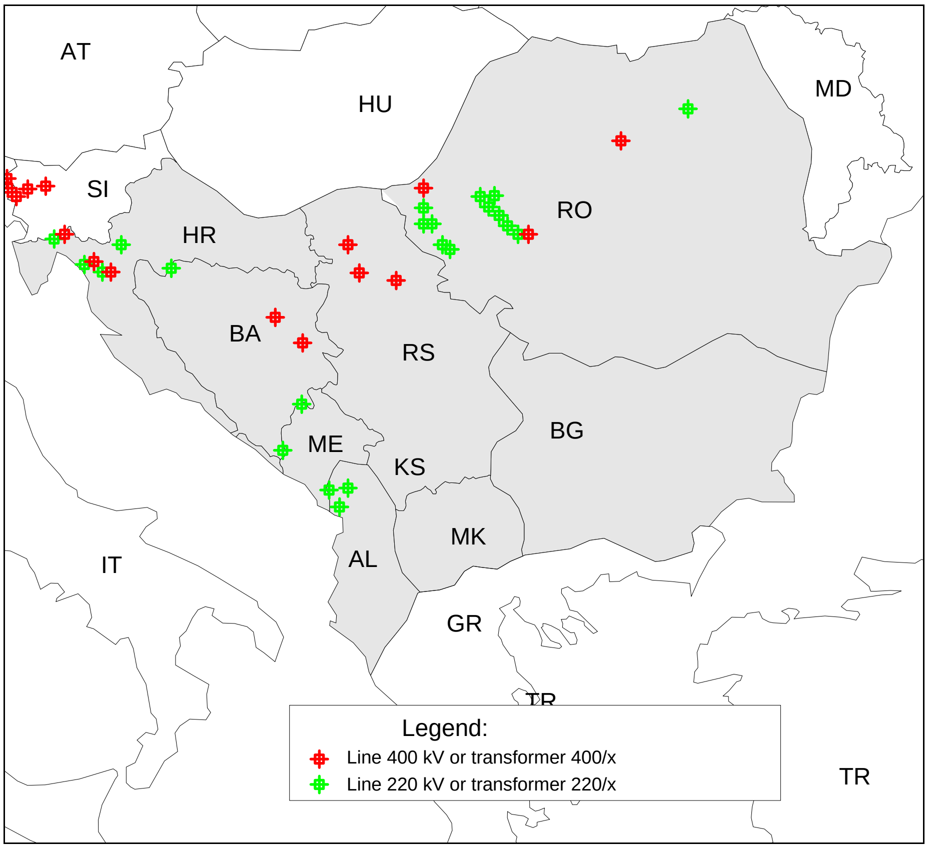


Figure 6-22 Geographical positions of critical elements

6.3.5. Wind scenario 4: All regions (Max) → rest of ENTSO-E

In this subchapter, steady state analyses are presented for the following power system operation regime:

- load level: winter maximum load in 2020
- wind penetration in Adriatic region: high (70%)
- wind penetration in Aegean region: high (70%)
- wind penetration in Black Sea region: high (70%)
- wind penetration in Continental region: high (70%)

Basic information about areas (countries) of the analyzed region and aggregated physical exchanges among analyzed countries are given in Appendix (Table 9-29 and Table 9-30).

Histogram of branch loadings with comparison against branch loadings in base case is given in Appendix (Figure 9-15). List of transmission lines and transformers in monitored grid which are loaded more than 80% of their thermal limits is also given in Appendix (Table 9-31). There are 40 more branches loaded more than 80% of their thermal limits, including 22 more overloaded branches. Additional overloads can be found in Croatia (line 400 kV Meline – Brinje is overloaded by 25% and line 220 kV TPP Sisak – Mraclin is overloaded by 35%), in Romania (seven lines 220 kV which are overloaded up to 21% and two transformers 400/220 kV which are overloaded up to 15%), in Albania (two lines 220 kV which are overloaded up to 7%), in Serbia (line 400 kV Mladost – Sremska Mitrovica is overloaded by 32%). Also, tie-line 220 kV Koplic (AL) – Podgorica (ME) is overloaded by 3% and tie-line Prijedor (BA) – TPP Sisak (HR) is overloaded by 34%. The main reason for these 25 overloaded branches is significant amount of surplus in the region (around 5000 MW) which is exported to the rest of ENTSO-E, including Italy. Although the pressure of high power flows through Slovenia towards Italy is expected in the future, the results related to Slovenian grid are not sufficiently credible due to the causes listed in Chapter 6.1.

The most significant changes in power flows in the area of SEE are shown in Appendix (Table 9-32). The main paths for transfer output power from WPPs with high wind penetration could be detected from these tables.

These changes in power flows have influence on power losses. The changes are shown in Figure 6-23. Significant increase of losses can be noticed in Romania, Croatia, Serbia, B&H and Slovenia.

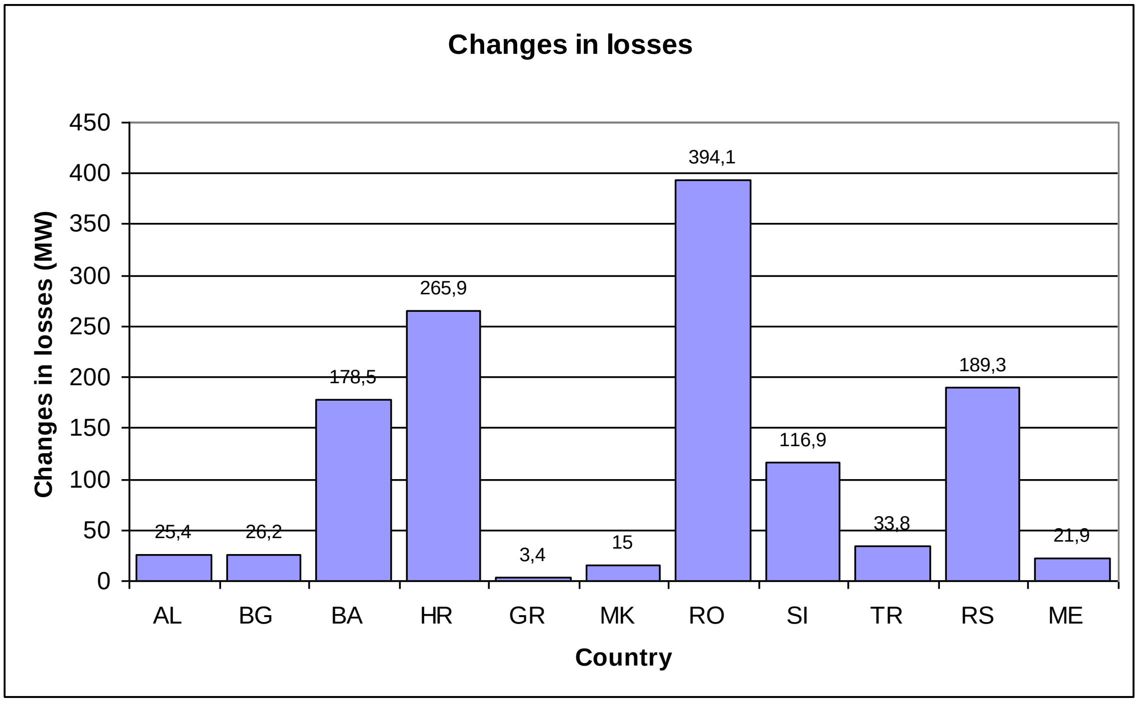


Figure 6-23 Changes in power losses in analyzed region

Histogram of busbar voltages in 220 kV and 400 kV network of analyzed region with comparison against base case is given in Appendix (Figure 9-16). In comparison against base case it can be noticed 12 more nodes of 400 kV level with voltage bellow limits, 6 in Romania, 3 in Serbia, 3 in Croatia and 5 in Slovenia. The main reason for these low voltages is significantly increased export from the region (around 5000 MW of additional export) as well as transit of significant part of export through Serbia, Croatia and Slovenia. For all other monitored nodes it can be seen that voltage profile generally is decreased.

Geographical positions of overloaded elements are shown on Figure 6-24.

Since there are 25 overloaded branches in case without any contingency in system, it doesn't have sense to perform security (n-1) analysis, so further analysis can be avoided.

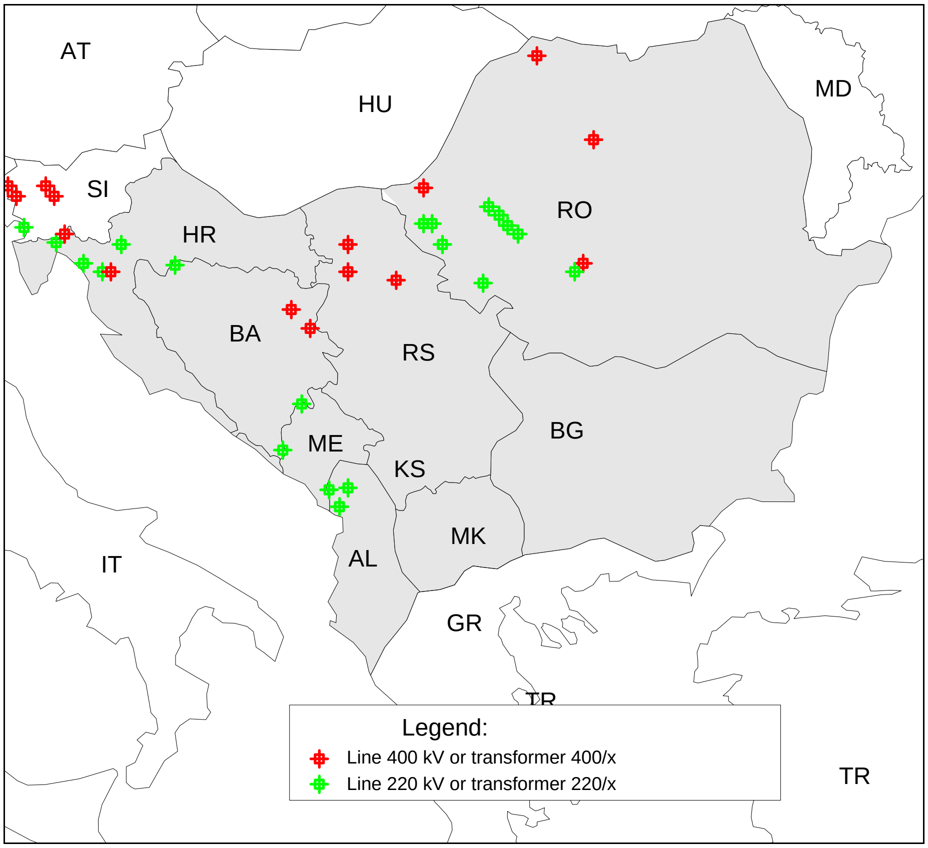


Figure 6-24 Geographical positions of critical elements

7. CONCLUSION

This Study is continuation of SECI Transmission System Planning Project activities in last 10 years. Transmission planners were faced to different uncertainties, even before introduction of market conditions in power system. Introduction of market environment makes transmission planning more difficult. Locations and capacities of new power plants, their biding behavior, existence of the present ones in the future, consumer's reaction on instantaneous electricity price (price elasticity), electricity and power trading, hydrological conditions, branches and generators availability, regulatory aspects etc., are hard to be predicted even for the purpose of short-term planning. Network development based on deterministic power flow analyses of several possible system conditions will not give the clear picture of future transmission system operating conditions and transmission system investments will not be satisfactory evaluated, especially concerning a risk that is caused due to some uncertainties. WPPs introduce additional level of uncertainty.

This study on wind power is right in the heart of the regional transmission future, both from a regional energy security and climate change policy perspective.

The most valuable inputs for this study analysis were given by 12 regional TSO, member of the SECI TSP working group. Detailed questionnaire was used to collect more than 320 inputs from the system operation perspective with respect current and expected WPP development level, existing and expected WPP integration problems as well as connection and operational requirements and procedures.

The study consists of 7 sections. After introductory section, in the Section 2 current status of WPP integration in SEE is given. In late 2010 there were 131 WPPs in operation in SEE with total installed capacity of more than 3100 MW (including 1300 MW in Turkey). In 2020 it is expected to have about 17000 MW (without Turkey), with currently more than 1700 WPP projects under development. All countries are having WPP integration plans till 2020. Based upon national WPP integration studies and data collected from the regional TSOs, there are several limitations for larger WPP integration in SEE. Most of the TSOs (10 out of 12) declared available system reserve as one of the most significant limiting factors for larger WPP integration. Each TSO estimated currently available secondary reserve capacity that is available for WPP regulation purposes only. Total sum of additionally available secondary reserve capacity in the region is about 2900 MW, which is fairly insufficient for WPP integration targets. Other WPP integration limitations refer to network absorption capability, complex WPP development procedure and lack of legislative framework. So, the key issue for larger WPP integration is to reduce the need for secondary reserve capacity in the region.

In Section 3 the most important findings of existing national WPP integration studies were presented. Since this study is dealing with regional approach to WPP integration, it is of utmost importance to keep in mind country specifics and development plans, especially WPP integration targets and abilities.

Section 4 deals with power system control with respect to existing WPP variations in the region (in 2011), as well as expected WPP variations in time horizon of 2020. Detailed WPP generation data were collected for Greece, Romania, Bulgaria and Croatia in the period 2009 - 2011. For 2020 time horizon expected future WPP generation is estimated based on the inputs officially prepared by the relevant ENTSO working group. Special importance is given to required reserve capacities needed for WPP balancing. Based on these analyses benefits of the regional approach to WPP integration were evaluated.

Small regional countries are characterized by the small WPP geographical dispersion, meaning large WPP generation variations. Maximum expected hourly WPP variations in each country is expected to be in the range of 22 - 56% of its WPP installed capacity (in EU countries this range is 16-30%) At the SEE regional level total WPP variations are expected to be around 27% in 2020. So, regional approach would definitely significantly reduce power reserve needed to balance WPP variations and respective costs. Among other detailed analysis results, the most important study finding is that regional approach would decrease total reserve need for -2 600 MW and +2 000 MW. In other words, regional approach would decrease system reserve needs for balancing WPPs to less than half of the existing individual country approach. It would deliberate more than 2000 MW of generation capacity in the region for market activities instead of keeping it for ancillary service activities. This could significantly impact generation investment needs and country balances in the future.

Regional approach to balancing wind power will cost the region significantly less than if each country pursues wind power capacity regulation independently. These results will certainly open a discussion on the importance of a regional balancing market and some of the challenges associated with it, such as common regional wind forecasting, harmonized ancillary service mechanisms and costs, harmonized wind grid codes etc.

Section 5 of the Study gives overview of the national legislative frameworks for WPP integration, including connection procedure, cost sharing principle, ancillary service mechanism, available secondary reserves and specific technical and data requirements for WPP in the regional countries.

In most of the regional countries the connection procedure is fully defined. Most of the countries use very similar connection procedure, including connection study with load flow, voltage profile, short circuit and cost-benefit calculation. In some countries additional analyses are taken with respect to power quality, dynamic simulation and reliability indicators.

Connection cost sharing principle is mainly "shallowish" in the region, with exception of Croatia that has "deep" connection cost sharing model. In most of the regional countries technical and data requirements for WPPs are defined.

Finally, the list of general recommendations for regional wind grid code requirements is suggested, including:

a) general WPP requirements
b) operation requirements
c) P/f requirements
d) Q/U requirements

e) Fault ride through requirements

f) Data exchange requirements

Steady-state analysis given in the Section 6 included 2015 and 2020 as target years. For each of the target years winter regime was selected as the most critical, since transmission grid in winter regime is much more loaded then in any other period of the year. Area of interest has been divided in four regions, according to geographical and climate positions and different wind penetration scenarios within these regions have been analyzed.

In all analyzed cases all undistributed excessive or shortage of power in SEE is balanced by changing the exchange with the rest of ENTSO-E interconnection. This practically means that rest of ENTSO-E interconnection is playing role of secondary control which "covers" all deficit/surplus in analyzed region. In practice, high wind power penetration should be followed by decrease output of conventional power plants (especially thermal power plants in order to decrease CO2 emission). This decrease in conventional power plant output should be realized in order to maintain country totals or to minimize change of country totals. The idea that ENTSO-E plays role of secondary control is to make the worst case scenario for analysis.

Although the pressure of high power flows trough Slovenia towards Italy is expected in the future, the results related to problems in Slovenian grid, as well as problems on border between Slovenia and Italy, are not sufficiently credible due to the causes listed in Chapter 6.1.

Generally, in year 2015 there are only few critical elements in Romania. Most of the problems are not significant (small overloads of branches) so such problems can be solved by proper dispatch actions. Parallel lines 220 kV Resita – Timisoara in some cases have overloads of 20% and these problems can be solved by changing topology of the transmission grid in case of high wind penetration, especially in area of Black Sea or area of continental SEE.

One of the most important conclusions is that there are no detected problems with tie-lines in region of SECI countries.

Situation in year 2020 is little bit complicated in comparison against year 2015. First of all, as already mentioned, models of Slovenia and Italy are not fully reliable and this can lead to inaccurate conclusions when detecting problems within these two countries as well as in transmission grid in neighborhood of Slovenia.

Some problems are detected in Croatia in base case, near border with Slovenia. Since models of Slovenia are not reliable these results should lead to conclusion that more detailed analysis of possible problems in this area is required. Problems detected in Croatia are related to North Adriatic region and should be analyzed internally in Croatian transmission development plan.

There are a lot of problems detected in local transmission grids, especially in Romania. These problems are result of very high wind penetration in region of SEE, followed by significant export to the rest of ENTSO-E. This great export as result of high wind penetration is not realistic, but authors of the Study wanted to analyze the worst case scenarios in order to check adequacy of the transmission grid.

Concerning interconnection lines, all detected problems are related to tie-lines of 220 kV voltage level. Problems are detected on 220 kV tie lines Albania – Montenegro – B&H as well as in tie-line Prijedor (BA) – TPP Sisak (HR). Some overloads of tie-lines from Montenegro appear only on Montenegrin side, as result of different protection settings on these tie-lines, and can be solved by adjusting of protection settings on both sides of these tie-lines.

There are several critical elements in Romania, mostly related to 220 kV voltage level. These problems are results of high wind penetration in region of Black Sea. The most critical are parallel lines 220 kV Resita – Timisoara with overloads up to 20%. These lines appear as critical even in base case. In addition, TSO of Romania has plans for upgrade 220 kV path near Serbian border (Portille de Fier – Resita – Timisoara – Sacalaz – Arad) to 400 kV voltage level, so this overloads should be solved.

There are few overloads detected problems in B&H and Serbia, as result of transit of significant part of power produced in WPPs. The most critical element in Serbia is line 400 kV Mladost – Sremska Mitrovica which is overloaded in some wind scenarios even in case without outages, as result of transit in case of high wind penetration in Black Sea region.

It should be noted that, because of very ambitious plans in area of WPP development, especially in regions of Black Sea and Aegean Sea, scenarios in year 2020 includes very high export from the region of SEE to ENTSO-E. Because of that, maximum wind penetration in these regions is followed by great export from SEE to ENTSO-E (this export is greater than export in scenario 2015 with maximum wind penetration in whole SEE). In addition, it is not realistic to expect that whole surplus, resulted from high wind penetration, will be taken by the rest of the ENTSO-E. This presumption was made in order to achieve the worst case scenarios. Also, unity factor of 70% for all WPPs in the SEE is presumed ambitiously, trying to achieve the worst case scenario.

Having in mind that there were no detected significant problems in year 2015, even in case of maximum wind penetration in whole SEE, and that it is not realistic to expect so great export from SEE to ENTSO-E, as considered in the worst case scenarios in 2020, it can be concluded generally, that significant problems in regional transmission network should not be expected.

Finally, this study is the first step toward regional approach to WPP integration in SEE. It clarifies that the regional approach to WPP integration would decrease total WPP integration costs and reserve need for more than 2000 MW. This could significantly impact generation investment needs, country balances and regional market development in the future. Focused on the challenging regional transmission future, both from a regional energy security and climate change policy perspective, these results should open a discussion on the importance of a common regional forecasting, planning and operation of the power system in new environment.

8. REFERENCES

[1] Regional Balkans Infrastructure Study (REBIS) – Electricity and Generation Investment Study (GIS); the World Bank, 2004

[2] Evaluation of investments in transmission network to sustain generation and market development in SEE; EIHP, EKC, 2007

[3] Transmission Network Investment Criteria; EIHP, EKC, 2007

[4] Memorandum of Understanding on the Regional Electricity Market in South East Europe and its Integration into the European Union Internal Electricity Market ("The Athens Memorandum – 2002"), 25 November 2002

[5] Memorandum of Understanding on the Regional Energy Market in South East Europe and its Integration into the European Community Internal Energy Market – The Athens Memorandum – 2003, 8 December 2003

[6] Treaty Establishing the Energy Community, 2005

[7] Regional Electricity Interconnection Study; EIHP, EKC, 2002

[8] EBRD framework project “Western Balkans Sustainable Energy Direct Financing Facility”

9. APPENDIX: STEADY-STATE ANALYSIS RESULTS

9.1. Winter MAXIMUM 2015, Scenario 1 (Adriatic + Aegean (Max) → Black Sea (Min))

Table 9-1 Area summary of analyzed region

X-- AREA --X	FROM GENE- RATION	TO LOAD AT AREA BUSES	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	1296.8	1536.5	0.0	0.0	0.0	0.0	43.3	-283.0	-283.0	-283.0
AL	415.3	555.2	-108.2	0.0	0.0	603.7	417.4	154.6	154.6	
20	8642.0	7603.7	0.0	0.0	14.6	0.0	173.6	850.0	850.0	850.0
BG	3088.4	3045.8	194.3	0.0	124.0	3161.4	2429.0	456.7	456.7	
30	3176.5	2603.2	0.0	0.0	0.0	0.0	55.3	518.0	518.0	518.0
BA	700.7	714.5	0.0	0.0	0.0	907.0	617.8	275.4	275.4	
40	3236.9	3483.0	0.0	0.0	0.0	0.0	65.9	-311.9	-311.9	-312.0
HR	377.8	1074.2	0.0	0.0	0.0	1401.7	760.4	-55.1	-55.1	
50	13176.6	12371.1	0.0	0.0	0.0	0.0	280.5	525.0	525.0	525.0
GR	1405.0	4654.6	170.9	0.0	23.7	6444.8	3195.6	-195.0	-195.0	
60	1581.3	1731.0	0.0	0.0	0.2	0.0	24.1	-174.0	-174.0	-174.0
MK	372.4	529.7	0.0	0.0	2.5	449.8	279.3	10.8	10.8	
70	9732.4	8937.9	0.0	0.0	81.0	0.0	186.5	527.0	527.0	527.0
RO	386.8	2731.1	0.0	0.0	236.2	4660.5	2174.6	-94.5	-94.5	
75	3446.3	2514.0	0.0	0.0	8.8	0.0	64.5	859.1	859.1	859.0
SI	1068.6	811.0	0.0	0.0	53.4	598.0	937.9	-135.7	-135.7	
80	54567.2	54622.0	0.0	0.0	0.0	0.0	757.2	-812.0	-812.0	-812.0
TR	4432.2	7792.0	1176.4	0.0	0.0	17245.8	12790.2	-80.5	-80.5	
90	7211.2	7240.5	0.0	0.0	11.5	0.0	159.2	-200.0	-200.0	-200.0
RS	1859.4	2389.5	0.0	0.0	66.7	1855.9	1858.9	-599.7	-599.7	
91	968.8	877.5	0.5	0.0	2.2	0.0	27.6	61.0	61.0	61.0
ME	130.5	318.4	-33.2	0.0	16.3	284.3	222.6	-109.3	-109.3	
COLUMN	107036.1	103520.5	0.5	0.0	118.3	0.0	1837.7	1559.1	1559.1	1559.0
TOTALS	14237.0	24615.9	1400.2	0.0	522.7	37613.0	25683.7	-372.5	-372.5	

Table 9-2 Zone summary in Serbia

X-- ZONE --X	FROM GENE- RATION	TO LOAD AT ZONE BUSES	TO BUS SHUNT	TO GNE BUS DEVICES	TO LINE SHUNT	FROM CHARGING	TO LOSSES	-NET INTERCHANGE- TO TIE LINES	TO TIES + LOADS
90	6408.7	6111.4	0.0	0.0	9.8	0.0	137.2	150.3	150.3
EMS	1434.7	2011.1	0.0	0.0	58.0	1595.4	1617.2	-656.2	-656.2
901	802.5	1129.1	0.0	0.0	1.6	0.0	22.0	-350.3	-350.3
KOSTT	424.7	378.4	0.0	0.0	8.7	260.5	241.7	56.5	56.5

COLUMN	7211.2	7240.5	0.0	0.0	11.5	0.0	159.2	-200.0	-200.0
TOTALS	1859.4	2389.5	0.0	0.0	66.7	1855.9	1858.9	-599.7	-599.7

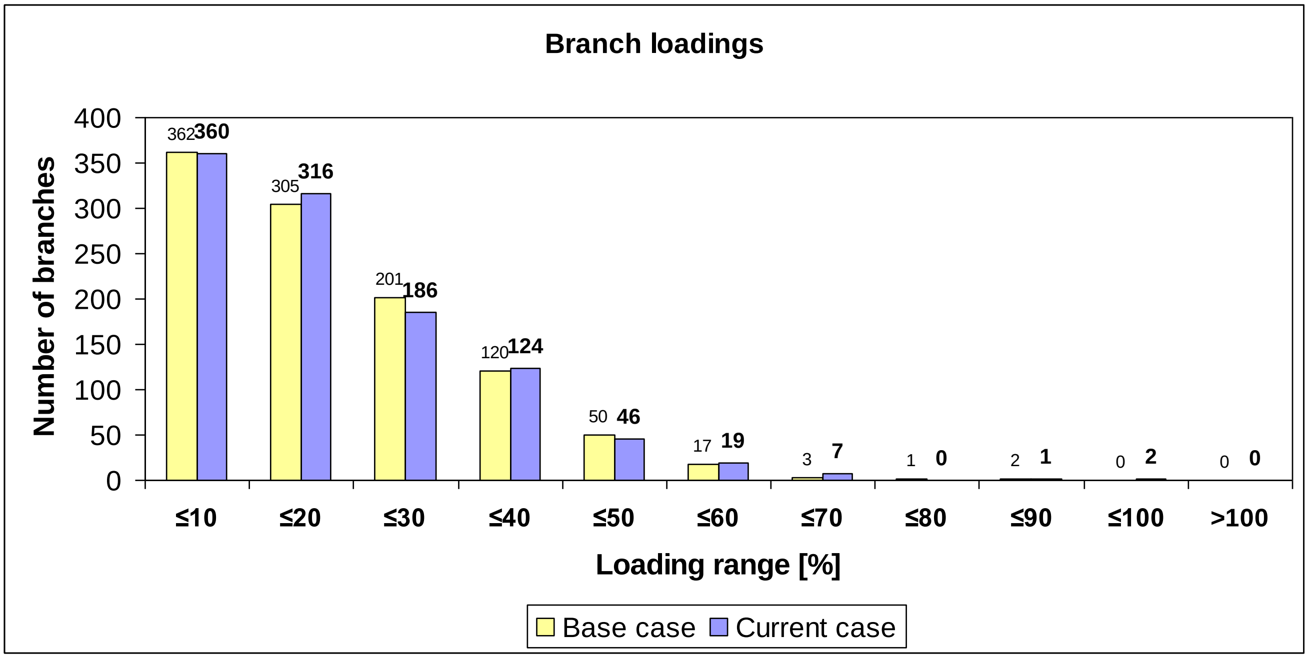


Figure 9-1 Branch loadings in analyzed region

Table 9-3 Branches loaded over 80% of their thermal limits

FRMBUS,	FROMBUSEXNAME,	TOBUS,	TOBUSEXNAME,	CKT,	STS,	MW,	MVAR,	MVA,	%I
31210,	LDIVAC2 220.00,	156,	XPA_DI21 220.00,	1 ,	1,	307.17,	-7.20,	307.26,	83.00
31410,	LDIVAC1 400.00,	31411,	LDIVAC1P 400.00,	1 ,	1,	558.20,	121.91,	571.36,	96.45
31410,	LDIVAC1 400.00,	31411,	LDIVAC1P 400.00,	2 ,	1,	558.20,	121.91,	571.36,	96.45

Total 3 items

Table 9-4 Significant changes of branch flows in comparison against base case scenario

					IN WORKING CASE		IN Winter MAX 2015 - Base Case			
X------- FROM BUS	--------X	X-------- TO BUS	---------X	CKT	MW	MVAR	MW	MVAR	DELTA MW	%
2 [XZE_KA11	400.00]	10020 [AZEMLA1	400.00]	1	303.8	-12.6	179.9	-2.9	-123.9	40.8
20 [XBG_TH11	400.00]	12433 [VBLAGO1	400.00]	1	-56.8	-12.3	-257.6	15.3	-200.8	353.4
21 [XDO_MG11	400.00]	12461 [VDOBRU1	400.00]	1	72.0	-7.2	174.9	-6.9	102.9	143.1
21 [XDO_MG11	400.00]	28974 [RMEDGI1	400.00]	1	-72.0	7.2	-174.9	6.9	-102.9	143.1
69 [XTH_DU11	400.00]	26022 [YDUBRO1	400.00]	1	31.2	-43.5	-93.8	-27.8	-125.0	400.3
79 [XSA_SU11	400.00]	24039 [MSAFA 11	400.00]	1	-71.0	-139.1	-168.4	-128.1	-97.4	137.2
79 [XSA_SU11	400.00]	34050 [JSUBO31	400.00]	1	71.0	139.1	168.4	128.1	97.4	137.2
81 [XSK_KB11	400.00]	26111 [YSK 5 1	400.00]	1	-31.9	40.6	82.0	27.0	113.9	357.1
81 [XSK_KB11	400.00]	34072 [JUROS21	400.00]	1	31.9	-40.6	-82.0	-27.0	-113.9	357.1
85 [XPF_DJ11	400.00]	28004 [RP.D.F1	400.00]	1	-108.6	-127.5	-216.9	-142.9	-108.3	99.7
85 [XPF_DJ11	400.00]	34010 [JHDJE11	400.00]	1	108.6	127.5	216.9	142.9	108.3	99.7
181 [XSV_MG11	400.00]	12460 [VVARNA1	400.00]	1	79.0	-16.8	203.0	-15.5	124.0	157.0
181 [XSV_MG11	400.00]	28974 [RMEDGI1	400.00]	1	-79.0	16.8	-203.0	15.5	-124.0	157.0
198 [XMI_HA11	400.00]	12471 [VMI3 11	400.00]	1	-523.4	-55.2	-630.7	-46.5	-107.3	20.5
206 [XFL_BI11	400.00]	26005 [YBITOL1	400.00]	1	326.7	22.3	100.5	40.0	-226.1	69.2
207 [XCM_ST11	400.00]	12432 [VCMOGI1	400.00]	1	-132.7	2.9	-263.9	19.1	-131.2	98.9

207	[XCM_ST11	400.00]	26112	[YSTIP 1	400.00]	1	132.7	-2.9	263.9	-19.1	131.2	98.9
208	[XST_NI11	400.00]	26112	[YSTIP 1	400.00]	1	-49.9	-28.5	40.6	-38.9	90.5	181.2
208	[XST_NI11	400.00]	34084	[JVRAN31	400.00]	1	49.9	28.5	-40.6	38.9	-90.5	181.2
10010	[AELBS21	400.00]	10014	[ATIRA21	400.00]	1	213.8	63.2	87.7	80.8	-126.1	59.0
10010	[AELBS21	400.00]	10020	[AZEMLA1	400.00]	1	-204.6	-41.3	-90.6	-57.2	113.9	55.7
12431	[VSOFIW1	400.00]	12432	[VCMOGI1	400.00]	1	247.8	-8.1	365.0	-12.2	117.3	47.3
12431	[VSOFIW1	400.00]	12432	[VCMOGI1	400.00]	2	247.8	-8.1	365.0	-12.2	117.3	47.3
12432	[VCMOGI1	400.00]	12433	[VBLAGO1	400.00]	1	126.4	-6.9	219.5	-10.9	93.2	73.7
12432	[VCMOGI1	400.00]	12433	[VBLAGO1	400.00]	2	126.4	-6.9	219.5	-10.9	93.2	73.7
12450	[VCAREV1	400.00]	12460	[VVARNA1	400.00]	1	149.5	25.3	34.4	26.6	-115.1	77.0
12460	[VVARNA1	400.00]	12470	[VBURGA1	400.00]	1	-85.5	-58.0	67.3	-65.6	152.8	178.6
12470	[VBURGA1	400.00]	12474	[VMI 1	400.00]	1	-191.2	-93.0	-97.8	-97.5	93.4	48.9
26022	[YDUBRO1	400.00]	26112	[YSTIP 1	400.00]	1	31.4	-23.3	-169.2	11.8	-200.7	638.1
26064	[YSK 41	400.00]	26111	[YSK 5 1	400.00]	1	123.7	38.9	20.3	49.8	-103.4	83.6
28024	[RGUTIN1	400.00]	28031	[RBRASO1	400.00]	1	-165.6	-23.0	-71.8	-29.3	93.8	56.6
28028	[RRAHMAN 1	400.00]	28974	[RMEDGI1	400.00]	1	-116.9	-24.3	20.0	-19.6	136.9	117.1
34005	[JBOR 21	400.00]	34010	[JHDJE11	400.00]	1	-609.9	-14.5	-704.2	-17.8	-94.2	15.5
34005	[JBOR 21	400.00]	34020	[JNIS2 1	400.00]	1	559.8	-3.5	655.8	0.2	96.0	17.1
34020	[JNIS2 1	400.00]	34070	[JTKOSB2	400.00]	1	90.3	-76.3	185.7	-89.1	95.3	105.5
34070	[JTKOSB2	400.00]	34072	[JUROS21	400.00]	1	-31.9	2.3	82.1	-10.4	114.0	357.6
36001	[0RIBAR11	400.00]	36012	[0MAOCE11	400.00]	1	-299.2	-31.7	-398.9	-21.2	-99.7	33.3
36010	[0PLJE211	400.00]	36012	[0MAOCE11	400.00]	1	300.1	11.4	400.5	9.0	100.4	33.5

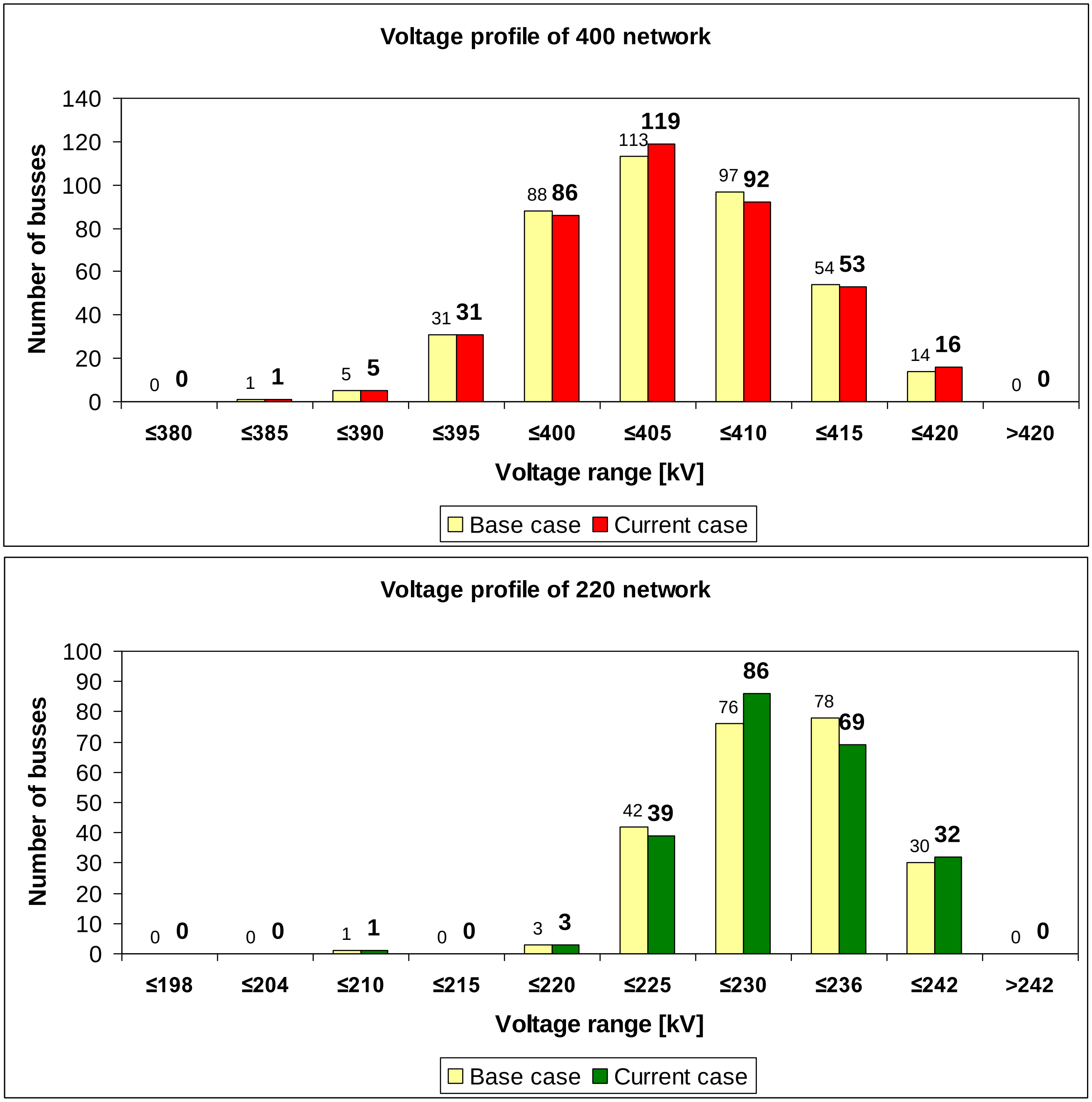


Figure 9-2 Voltage profile of 400 and 220 kV network in analyzed region

9.2. Winter MAXIMUM 2015, Scenario 2 (Aegean + Black Sea (Max) → Adriatic (Min))

Table 9-5 Area summary of analyzed region

FROM	TO LOAD		TO				-NET INTERCHANGE-		
GENE-	AT AREA	TO BUS	GNE BUS	TO LINE	FROM	TO	TO TIE	TO TIES	DESIRED

X-- AREA --X	RATION	BUSES	SHUNT	DEVICES	SHUNT	CHARGING	LOSSES	LINES	+ LOADS	NET INT
10	1273.2	1536.5	0.0	0.0	0.0	0.0	49.7	-313.0	-313.0	-313.0
AL	437.4	555.2	-107.0	0.0	0.0	597.1	495.0	91.4	91.4	
20	9023.9	7603.7	0.0	0.0	14.6	0.0	195.6	1210.0	1210.0	1210.0
BG	3172.6	3045.8	193.7	0.0	123.4	3147.9	2572.7	384.8	384.8	
30	3135.3	2603.2	0.0	0.0	0.0	0.0	65.1	467.0	467.0	467.0
BA	803.9	714.5	0.0	0.0	0.0	898.0	694.3	293.2	293.2	
40	3045.9	3483.0	0.0	0.0	0.0	0.0	86.0	-523.1	-523.1	-523.0
HR	518.9	1074.2	0.0	0.0	0.0	1385.6	919.8	-89.5	-89.5	
50	13173.4	12371.1	0.0	0.0	0.0	0.0	277.3	525.0	525.0	525.0
GR	1452.0	4654.6	171.0	0.0	23.7	6441.0	3160.6	-116.9	-116.9	
60	1583.5	1731.0	0.0	0.0	0.2	0.0	26.3	-174.0	-174.0	-174.0
MK	402.7	529.7	0.0	0.0	2.5	447.1	304.9	12.8	12.8	
70	10911.5	8937.9	0.0	0.0	80.2	0.0	231.4	1662.0	1662.0	1662.0
RO	530.1	2731.1	0.0	0.0	233.8	4615.4	2504.1	-323.5	-323.5	
75	3390.8	2514.0	0.0	0.0	8.7	0.0	69.1	798.9	798.9	799.0
SI	1185.5	811.0	0.0	0.0	52.9	592.7	891.5	22.7	22.7	
80	54785.1	54622.0	0.0	0.0	0.0	0.0	759.1	-596.0	-596.0	-596.0
TR	4437.4	7792.0	1176.1	0.0	0.0	17243.3	12807.5	-94.9	-94.9	
90	7245.5	7240.5	0.0	0.0	11.4	0.0	193.7	-200.0	-200.0	-200.0
RS	2243.3	2389.5	0.0	0.0	66.1	1836.5	2202.6	-578.4	-578.4	
91	897.9	877.5	0.5	0.0	2.2	0.0	27.7	-10.0	-10.0	-10.0
ME	150.8	318.4	-33.0	0.0	16.2	281.7	245.8	-114.8	-114.8	
COLUMN	108466.1	103520.5	0.5	0.0	117.2	0.0	1981.0	2846.9	2846.9	2847.0
TOTALS	15334.6	24615.9	1400.8	0.0	518.6	37486.3	26798.6	-513.2	-513.2	

Table 9-6 Zone summary in Serbia

	FROM	TO LOAD		TO				-NET INTERCHANGE-	
	GENE-	AT ZONE	TO BUS	GNE BUS	TO LINE	FROM	TO	TO TIE	TO TIES
X-- ZONE --X	RATION	BUSES	SHUNT	DEVICES	SHUNT	CHARGING	LOSSES	LINES	+ LOADS
90	6433.0	6111.4	0.0	0.0	9.8	0.0	169.1	142.8	142.8
EMS	1779.9	2011.1	0.0	0.0	57.5	1578.3	1932.3	-642.7	-642.7
901	812.5	1129.1	0.0	0.0	1.6	0.0	24.6	-342.8	-342.8
KOSTT	463.4	378.4	0.0	0.0	8.6	258.2	270.3	64.3	64.3
COLUMN	7245.5	7240.5	0.0	0.0	11.4	0.0	193.7	-200.0	-200.0
TOTALS	2243.3	2389.5	0.0	0.0	66.1	1836.5	2202.6	-578.4	-578.4

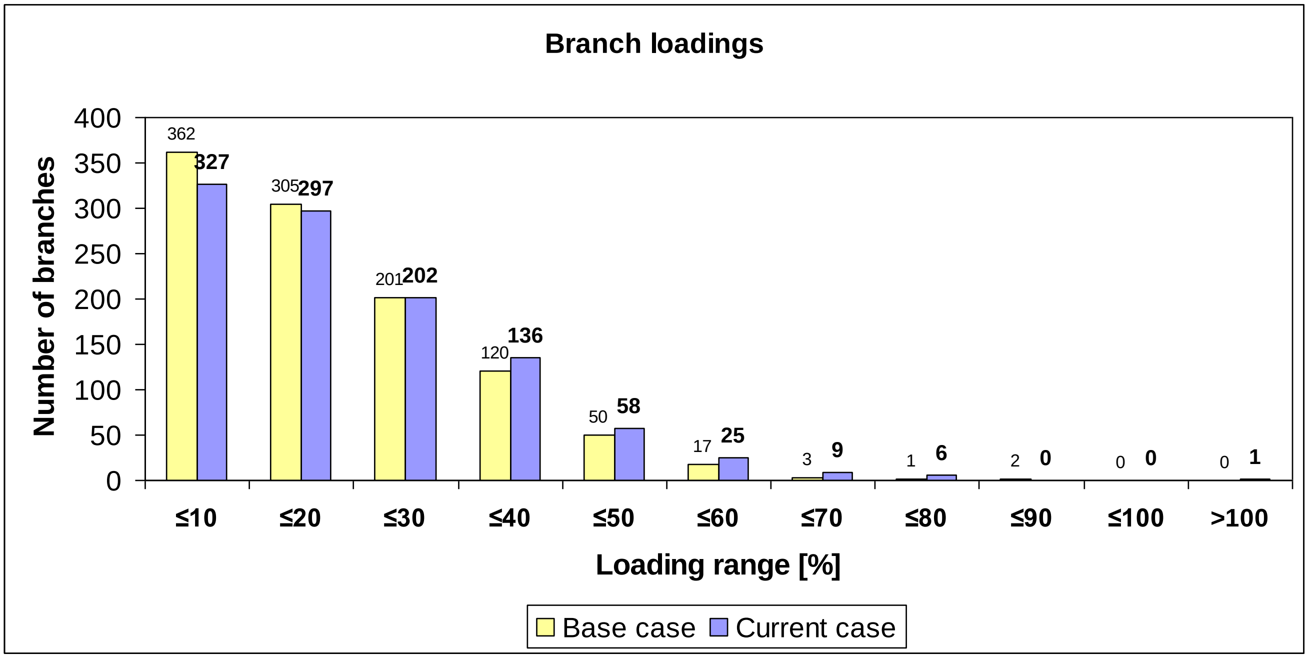


Figure 9-3 Branch loadings in analyzed region

Table 9-7 Branches loaded over 80% of their thermal limits

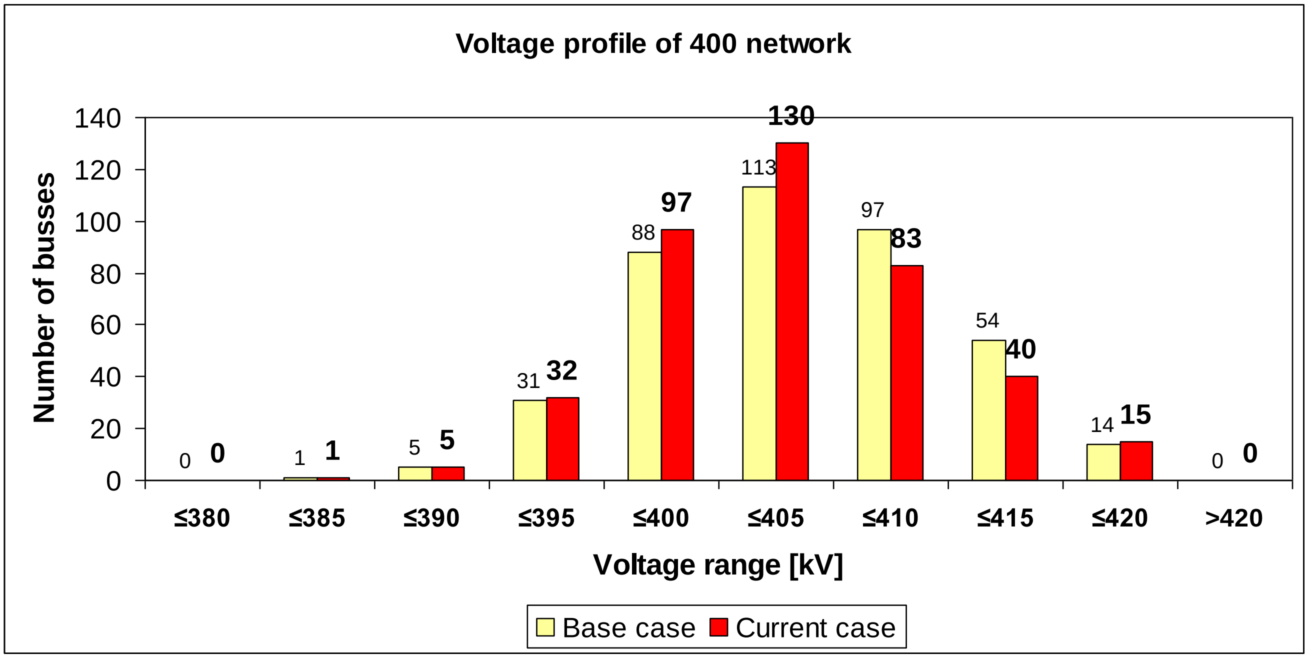
FRMBUS,	FROMBUSEXNAME,	TOBUS,	TOBUSEXNAME,	CKT,	STS,	MW,	MVAR,	MVA,	%I
31210,	LDIVAC2 220.00,	156,	XPA_DI21 220.00,	1 ,	1,	483.23,	12.86,	483.40,	132.36 *

Total 1 items

Table 9-8 Significant changes of branch flows in comparison against base case scenario

X------- FROM BUS		--------X	X-------- TO BUS		---------X	CKT	IN WORKING CASE MW	MVAR	IN Winter MAX 2015 - Base Case MW	MVAR	DELTA MW	%
2	[XZE_KA11	400.00]	10020	[AZEMLA1	400.00]	1	409.4	-9.7	179.9	-2.9	-229.5	56.1
13	[XTR_PG11	400.00]	14405	[WTREBI1	400.00]	1	-131.7	-99.5	-353.8	-59.7	-222.1	168.7
13	[XTR_PG11	400.00]	36017	[0LASTV11	400.00]	A	131.7	99.5	353.8	59.7	222.1	168.7
24	[XSO_NI11	400.00]	12431	[VSOFIW1	400.00]	1	-566.8	-41.7	-294.4	-52.4	272.4	48.1
24	[XSO_NI11	400.00]	34020	[JNIS2 1	400.00]	1	566.8	41.7	294.4	52.4	-272.4	48.1
74	[XER_SM11	400.00]	20037	[HERNES11	400.00]	1	428.3	-104.3	153.6	-87.1	-274.7	64.1
74	[XER_SM11	400.00]	34045	[JSMIT21	400.00]	1	-428.3	104.3	-153.6	87.1	274.7	64.1
79	[XSA_SU11	400.00]	24039	[MSAFA 11	400.00]	1	79.3	-149.1	-168.4	-128.1	-247.7	312.3
79	[XSA_SU11	400.00]	34050	[JSUBO31	400.00]	1	-79.3	149.1	168.4	128.1	247.7	312.3
81	[XSK_KB11	400.00]	26111	[YSK 5 1	400.00]	1	-157.7	46.5	82.0	27.0	239.8	152.0
81	[XSK_KB11	400.00]	34072	[JUROS21	400.00]	1	157.7	-46.5	-82.0	-27.0	-239.8	152.0
84	[XRO_MU11	400.00]	28039	[RROSIO1	400.00]	1	-120.9	74.2	298.2	-15.4	419.1	346.6
184	[XRI_PE11	400.00]	34086	[JPEC 31	400.00]	1	-175.2	38.4	63.0	16.5	238.2	136.0
184	[XRI_PE11	400.00]	36001	[0RIBAR11	400.00]	1	175.2	-38.4	-63.0	-16.5	-238.2	136.0
206	[XFL_BI11	400.00]	26005	[YBITOL1	400.00]	1	427.2	29.1	100.5	40.0	-326.7	76.5
219	[XNA_BE11	400.00]	24004	[MBEKO 11	400.00]	1	292.0	-46.8	89.5	-1.5	-202.4	69.3
219	[XNA_BE11	400.00]	28009	[RNADAB1	400.00]	1	-292.0	46.8	-89.5	1.5	202.4	69.3
220	[XKA_PG11	400.00]	10014	[ATIRA21	400.00]	1	-273.0	-18.1	-23.8	-57.4	249.2	91.3
220	[XKA_PG11	400.00]	36005	[0PODG211	400.00]	1	273.0	18.1	23.8	57.4	-249.2	91.3
10010	[AELBS21	400.00]	10014	[ATIRA21	400.00]	1	367.7	51.8	87.7	80.8	-279.9	76.1
10010	[AELBS21	400.00]	10020	[AZEMLA1	400.00]	1	-298.4	-33.0	-90.6	-57.2	207.7	69.6
24001	[MAISA 11	400.00]	24048	[MSZOL 11	400.00]	1	8.8	20.1	265.7	-25.2	256.9	999.9
24004	[MBEKO 11	400.00]	24048	[MSZOL 11	400.00]	1	157.5	-61.0	-100.6	-7.8	-258.1	163.9
24019	[MGYOR 11	400.00]	24024	[MLITR 11	400.00]	1	-190.2	35.2	26.7	-3.3	216.8	114.0
24024	[MLITR 11	400.00]	24033	[MPAKS 11	400.00]	1	-544.8	23.3	-329.4	-3.0	215.4	39.5
24033	[MPAKS 11	400.00]	24039	[MSAFA 11	400.00]	1	-41.0	99.0	262.6	35.9	303.5	741.0

26064	[YSK 41	400.00]	26111	[YSK 5 1	400.00]	1	236.0	32.1	20.3	49.8	-215.7	91.4
28003	[RMINTI1A	400.00]	28008	[RARAD 1	400.00]	1	418.0	-71.9	174.8	-58.0	-243.2	58.2
28008	[RARAD 1	400.00]	28009	[RNADAB1	400.00]	1	334.7	-96.1	104.0	-48.7	-230.7	68.9
28024	[RGUTIN1	400.00]	28031	[RBRASO1	400.00]	1	136.9	-38.1	-71.8	-29.3	-208.7	152.5
28031	[RBRASO1	400.00]	28034	[RSIBIU1	400.00]	1	245.7	-63.6	-52.4	-73.9	-298.1	121.3
28034	[RSIBIU1	400.00]	28036	[RIERNU1	400.00]	1	611.1	-3.8	322.8	-8.7	-288.3	47.2
28036	[RIERNU1	400.00]	28037	[RGADAL1	400.00]	1	352.1	-87.7	65.3	-46.7	-286.8	81.5
28037	[RGADAL1	400.00]	28039	[RROSIO1	400.00]	1	250.8	-108.1	-34.5	-56.4	-285.3	113.8
28973	[RCERNA1	400.00]	28974	[RMEDGI1	400.00]	1	331.0	-47.4	539.1	-51.1	208.0	62.8
34010	[JHDJE11	400.00]	34055	[JTDRMN1	400.00]	1	610.4	13.4	402.9	-17.5	-207.5	34.0
34015	[JKRAG21	400.00]	34079	[JJAGO41	400.00]	1	-179.1	-6.6	50.4	-32.3	229.5	128.1
34015	[JKRAG21	400.00]	34088	[JTKOLB1	400.00]	1	-63.3	-124.5	-287.8	-100.7	-224.5	354.5
34020	[JNIS2 1	400.00]	34079	[JJAGO41	400.00]	1	336.2	12.1	81.9	20.2	-254.3	75.6
34025	[JNSAD31	400.00]	34078	[JSRBOB1	400.00]	A	506.7	-22.1	302.2	-36.6	-204.5	40.4
34030	[JOBREN11	400.00]	34040	[JRPMLA1	400.00]	2	102.2	-141.6	-180.1	-142.3	-282.3	276.2
34031	[JOBREN12	400.00]	34040	[JRPMLA1	400.00]	1	103.0	-142.9	-181.8	-143.4	-284.8	276.5
34031	[JOBREN12	400.00]	34088	[JTKOLB1	400.00]	1	63.6	63.5	289.8	58.8	226.2	355.5
34040	[JRPMLA1	400.00]	34045	[JSMIT21	400.00]	1	792.5	-69.3	420.5	-97.0	-371.9	46.9
34050	[JSUBO31	400.00]	34078	[JSRBOB1	400.00]	A	-380.3	70.5	-157.5	55.8	222.7	58.6
34070	[JTKOSB2	400.00]	34072	[JUROS21	400.00]	1	-157.4	12.1	82.1	-10.4	239.5	152.2
34070	[JTKOSB2	400.00]	34086	[JPEC 31	400.00]	1	324.5	-5.8	90.7	6.7	-233.8	72.1
36005	[0PODG211	400.00]	36017	[0LASTV11	400.00]	A	447.3	-36.1	225.2	-8.0	-222.1	49.6



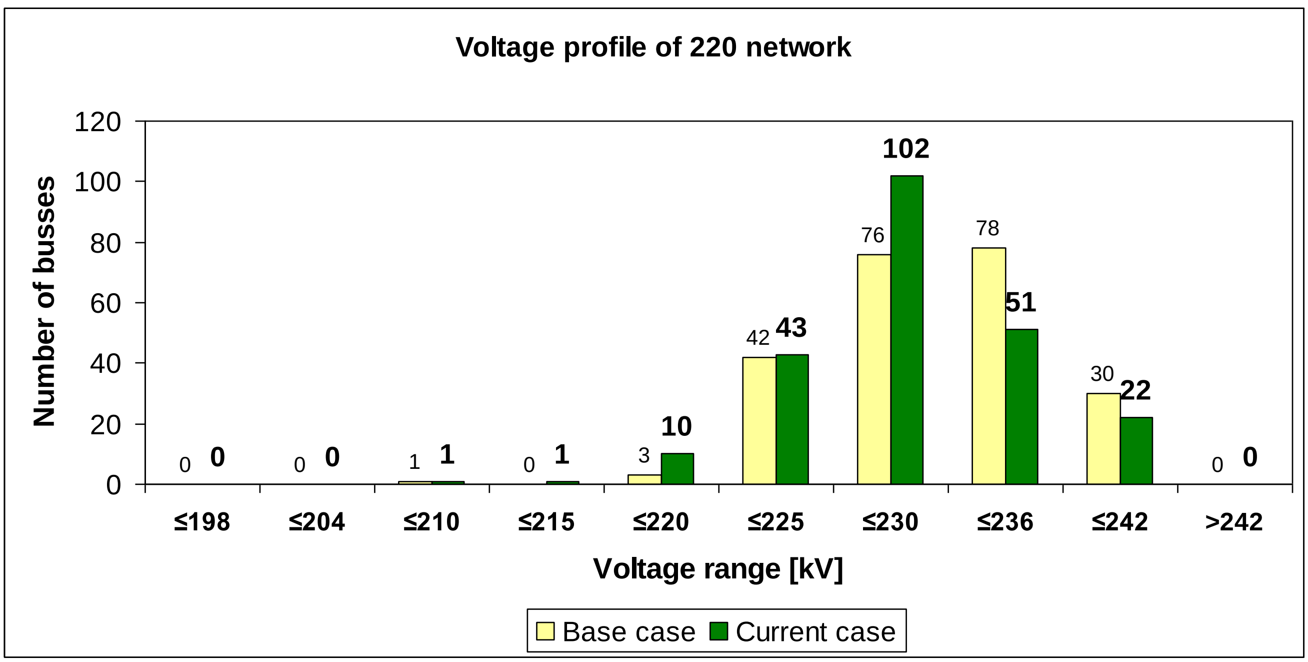


Figure 9-4 Voltage profile of 400 and 220 kV network in analyzed region

9.3. Winter MAXIMUM 2015, Scenario 3 (Continental SEE + Black Sea (Max) → Adriatic (Min))

Table 9-9 Area summary of analyzed region

FROM	TO LOAD	TO	-NET INTERCHANGE-

X-- AREA --X	GENE- RATION	AT AREA BUSES	TO BUS SHUNT	GNE BUS DEVICES	TO LINE SHUNT	FROM CHARGING	TO LOSSES	TO TIE LINES	TO TIES + LOADS	DESIRED NET INT
10	1265.3	1536.5	0.0	0.0	0.0	0.0	41.8	-313.0	-313.0	-313.0
AL	424.9	555.2	-107.8	0.0	0.0	601.1	411.8	166.9	166.9	
20	9036.3	7603.7	0.0	0.0	14.5	0.0	208.0	1210.0	1210.0	1210.0
BG	3237.0	3045.8	193.5	0.0	123.2	3139.6	2710.2	303.9	303.9	
30	3128.8	2603.2	0.0	0.0	0.0	0.0	58.7	467.0	467.0	467.0
BA	756.1	714.5	0.0	0.0	0.0	902.1	652.8	290.9	290.9	
40	3034.5	3483.0	0.0	0.0	0.0	0.0	74.5	-523.0	-523.0	-523.0
HR	466.9	1074.2	0.0	0.0	0.0	1391.4	840.0	-55.9	-55.9	
50	12304.3	12371.1	0.0	0.0	0.0	0.0	283.2	-350.0	-350.0	-350.0
GR	1679.0	4654.6	170.5	0.0	23.7	6428.7	3332.4	-73.5	-73.5	
60	1554.3	1731.0	0.0	0.0	0.2	0.0	23.1	-200.0	-200.0	-200.0
MK	390.2	529.7	0.0	0.0	2.5	447.5	270.1	35.5	35.5	
70	10883.2	8937.9	0.0	0.0	81.0	0.0	202.3	1662.0	1662.0	1662.0
RO	375.9	2731.1	0.0	0.0	235.9	4659.2	2250.1	-182.1	-182.1	
75	3391.9	2514.0	0.0	0.0	8.7	0.0	70.2	798.9	798.9	799.0
SI	1143.4	811.0	0.0	0.0	53.0	593.9	1005.5	-132.3	-132.3	
80	54714.1	54622.0	0.0	0.0	0.0	0.0	766.1	-674.0	-674.0	-674.0
TR	4519.2	7792.0	1176.0	0.0	0.0	17241.8	12885.4	-92.5	-92.5	
90	7479.3	7240.5	0.0	0.0	11.4	0.0	185.4	42.0	42.0	42.0
RS	2102.5	2389.5	0.0	0.0	66.3	1841.8	2125.9	-637.4	-637.4	
91	897.3	877.5	0.5	0.0	2.2	0.0	27.0	-10.0	-10.0	-10.0
ME	144.0	318.4	-33.1	0.0	16.2	282.6	239.2	-114.2	-114.2	
COLUMN	107689.4	103520.5	0.5	0.0	118.0	0.0	1940.5	2109.9	2109.9	2110.0
TOTALS	15239.2	24615.9	1399.2	0.0	520.8	37529.6	26723.4	-490.6	-490.6	

Table 9-10 Zone summary in Serbia

	FROM	TO LOAD		TO				-NET INTERCHANGE-	
X-- ZONE --X	GENE- RATION	AT ZONE BUSES	TO BUS SHUNT	GNE BUS DEVICES	TO LINE SHUNT	FROM CHARGING	TO LOSSES	TO TIE LINES	TO TIES + LOADS
90	6666.3	6111.4	0.0	0.0	9.8	0.0	161.5	383.7	383.7
EMS	1650.2	2011.1	0.0	0.0	57.7	1583.2	1866.4	-701.7	-701.7
901	813.0	1129.1	0.0	0.0	1.6	0.0	24.0	-341.7	-341.7
KOSTT	452.3	378.4	0.0	0.0	8.6	258.6	259.5	64.3	64.3
COLUMN	7479.3	7240.5	0.0	0.0	11.4	0.0	185.4	42.0	42.0
TOTALS	2102.5	2389.5	0.0	0.0	66.3	1841.8	2125.9	-637.4	-637.4

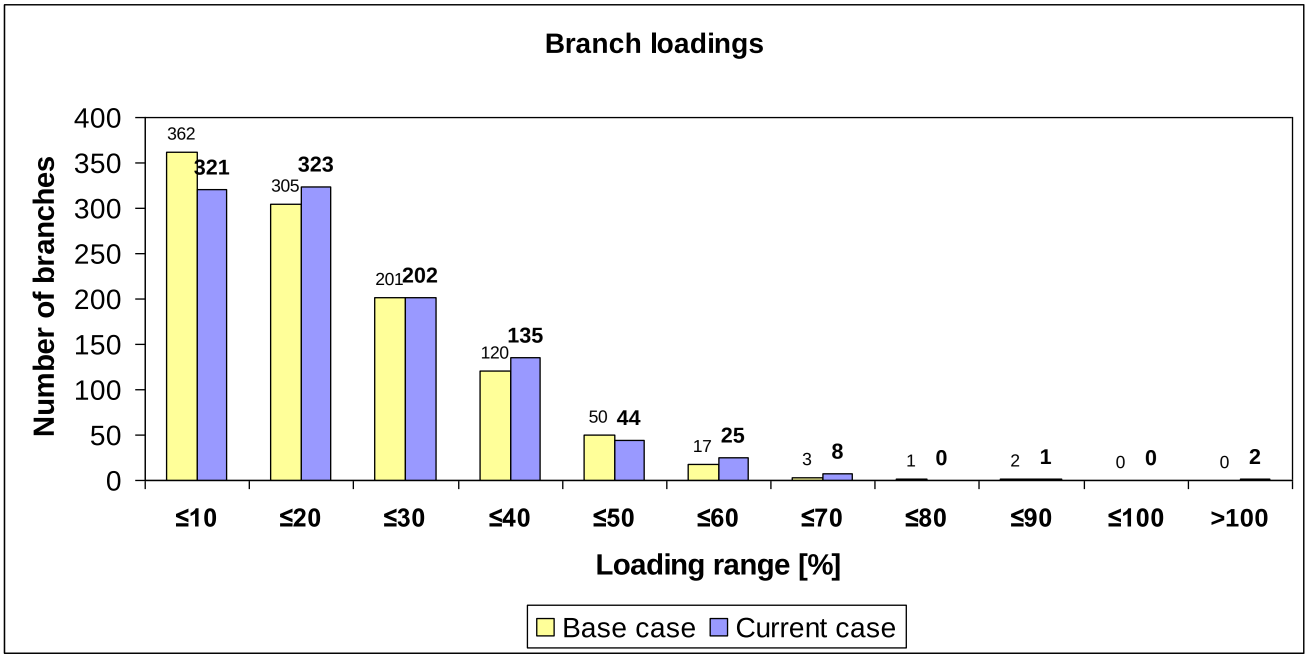


Figure 9-5 Branch loadings in analyzed region

Table 9-11 Branches loaded over 80% of their thermal limits

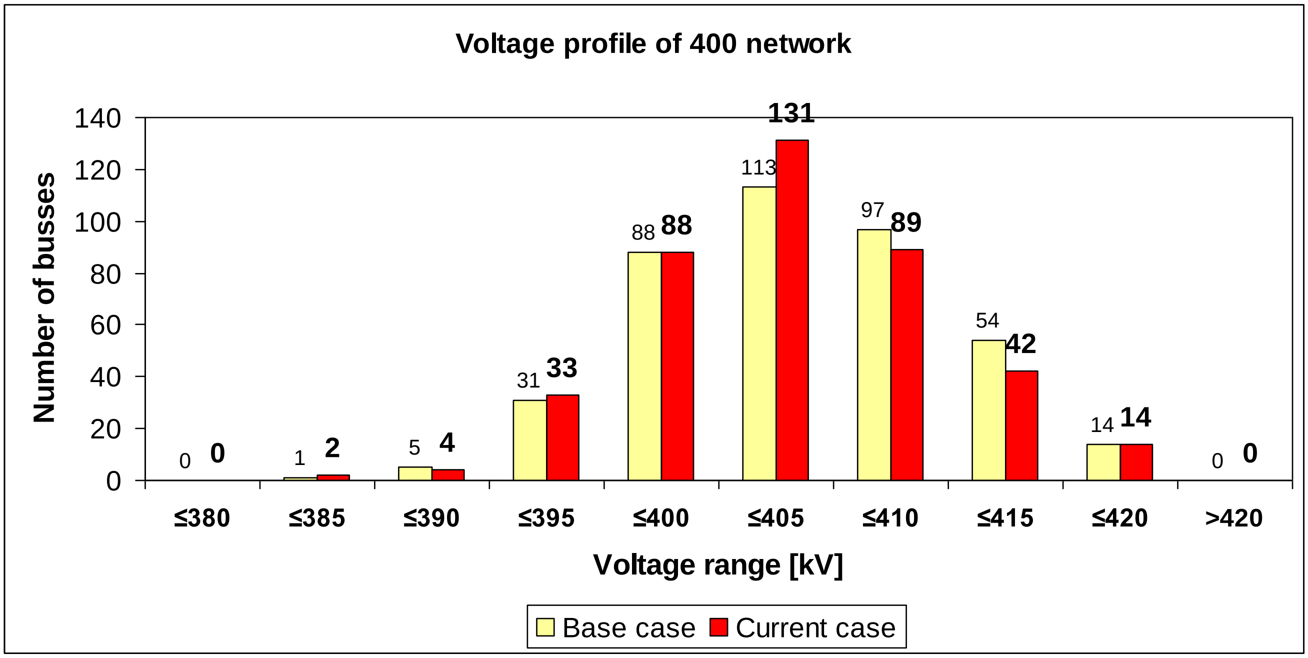
FRMBUS,	FROMBUSEXNAME,	TOBUS,	TOBUSEXNAME,	CKT,	STS,	MW,	MVAR,	MVA,	%I	
31210,	LDIVAC2 220.00,	156,	XPA_DI21 220.00,	1 ,	1,	323.66,	-7.55,	323.75,	87.89	
31410,	LDIVAC1 400.00,	31411,	LDIVAC1P 400.00,	1 ,	1,	585.51,	125.03,	598.71,	101.67	*
31410,	LDIVAC1 400.00,	31411,	LDIVAC1P 400.00,	2 ,	1,	585.51,	125.03,	598.71,	101.67	*

Total 3 items

Table 9-12 Significant changes of branch flows in comparison against base case scenario

X------- FROM BUS	--------X		X-------- TO BUS	---------X		CKT	IN WORKING CASE MW	MVAR	IN Winter MAX 2015 - Base Case MW	MVAR	DELTA MW	%
11	[XMO_KO11	400.00]	18401	[WMOST41	400.00]	1	-283.5	-42.1	-170.0	-41.8	113.5	40.0
11	[XMO_KO11	400.00]	20078	[HKONJS11	400.00]	1	283.5	42.1	170.0	41.8	-113.5	40.0
13	[XTR_PG11	400.00]	14405	[WTREBI1	400.00]	1	-239.2	-78.9	-353.8	-59.7	-114.7	47.9
13	[XTR_PG11	400.00]	36017	[0LASTV11	400.00]	A	239.2	78.9	353.8	59.7	114.7	47.9
24	[XSO_NI11	400.00]	12431	[VSOFIW1	400.00]	1	-466.6	-41.1	-294.4	-52.4	172.2	36.9
24	[XSO_NI11	400.00]	34020	[JNIS2 1	400.00]	1	466.6	41.1	294.4	52.4	-172.2	36.9
71	[XME_DI11	400.00]	20097	[HMELIN11	400.00]	1	-754.7	-54.5	-635.6	-46.5	119.1	15.8
71	[XME_DI11	400.00]	31410	[LDIVAC1	400.00]	1	754.7	54.5	635.6	46.5	-119.1	15.8
74	[XER_SM11	400.00]	20037	[HERNES11	400.00]	1	325.7	-99.9	153.6	-87.1	-172.1	52.9
74	[XER_SM11	400.00]	34045	[JSMIT21	400.00]	1	-325.7	99.9	-153.6	87.1	172.1	52.9
75	[XSA_AR11	400.00]	24039	[MSAFA 11	400.00]	1	197.3	-33.0	97.0	-7.1	-100.3	50.8
75	[XSA_AR11	400.00]	28008	[RARAD 1	400.00]	1	-197.3	33.0	-97.0	7.1	100.3	50.8
79	[XSA_SU11	400.00]	24039	[MSAFA 11	400.00]	1	-18.9	-143.9	-168.4	-128.1	-149.4	789.0
79	[XSA_SU11	400.00]	34050	[JSUBO31	400.00]	1	18.9	143.9	168.4	128.1	149.4	789.0
84	[XRO_MU11	400.00]	28039	[RROSIO1	400.00]	1	37.1	31.1	298.2	-15.4	261.1	704.2
85	[XPF_DJ11	400.00]	28004	[RP.D.F1	400.00]	1	-320.4	-99.0	-216.9	-142.9	103.5	32.3
85	[XPF_DJ11	400.00]	34010	[JHDJE11	400.00]	1	320.4	99.0	216.9	142.9	-103.5	32.3
184	[XRI_PE11	400.00]	34086	[JPEC 31	400.00]	1	-49.6	27.5	63.0	16.5	112.6	227.1
184	[XRI_PE11	400.00]	36001	[0RIBAR11	400.00]	1	49.6	-27.5	-63.0	-16.5	-112.6	227.1
211	[XUG_SM11	400.00]	14402	[WTUGLJ1	400.00]	1	223.2	-77.0	121.6	-55.3	-101.6	45.5
211	[XUG_SM11	400.00]	34045	[JSMIT21	400.00]	1	-223.2	77.0	-121.6	55.3	101.6	45.5
219	[XNA_BE11	400.00]	24004	[MBEKO 11	400.00]	1	218.4	-27.1	89.5	-1.5	-128.9	59.0
219	[XNA_BE11	400.00]	28009	[RNADAB1	400.00]	1	-218.4	27.1	-89.5	1.5	128.9	59.0
220	[XKA_PG11	400.00]	10014	[ATIRA21	400.00]	1	-124.3	-43.8	-23.8	-57.4	100.5	80.9
220	[XKA_PG11	400.00]	36005	[0PODG211	400.00]	1	124.3	43.8	23.8	57.4	-100.5	80.9

12450	[VCAREV1	400.00]	12460	[VVARNA1	400.00]	1	-89.2	40.9	34.4	26.6	123.6	138.6
12460	[VVARNA1	400.00]	12470	[VBURGA1	400.00]	1	180.5	-73.5	67.3	-65.6	-113.2	62.7
20037	[HERNES11	400.00]	20203	[HZERJA11	400.00]	1	370.4	-56.9	246.5	-62.8	-124.0	33.5
24001	[MAISA 11	400.00]	24048	[MSZOL 11	400.00]	1	107.2	-3.9	265.7	-25.2	158.5	147.9
24004	[MBEKO 11	400.00]	24048	[MSZOL 11	400.00]	1	57.6	-38.7	-100.6	-7.8	-158.2	274.5
24019	[MGYOR 11	400.00]	24024	[MLITR 11	400.00]	1	-90.4	17.9	26.7	-3.3	117.1	129.5
24024	[MLITR 11	400.00]	24033	[MPAKS 11	400.00]	1	-453.6	12.3	-329.4	-3.0	124.2	27.4
24025	[MMART 11	400.00]	24033	[MPAKS 11	400.00]	1	-261.1	-94.9	-157.8	-97.8	103.2	39.5
24033	[MPAKS 11	400.00]	24039	[MSAFA 11	400.00]	1	65.9	65.3	262.6	35.9	196.6	298.2
28002	[RURECH1	400.00]	28004	[RP.D.F1	400.00]	1	135.2	-24.8	29.2	-9.2	-106.0	78.4
28003	[RMINTI1A	400.00]	28008	[RARAD 1	400.00]	1	329.7	-67.7	174.8	-58.0	-154.9	47.0
28003	[RMINTI1A	400.00]	28034	[RSIBIU1	400.00]	1	-162.7	-15.2	-38.8	-30.2	123.9	76.2
28007	[RSLATI1A	400.00]	28011	[RBUC.S1	400.00]	1	109.0	-40.0	213.4	-48.3	104.4	95.8
28008	[RARAD 1	400.00]	28009	[RNADAB1	400.00]	1	244.0	-77.7	104.0	-48.7	-139.9	57.4
28010	[RDOMNE1	400.00]	28011	[RBUC.S1	400.00]	1	-211.0	-33.3	-98.1	-51.4	112.9	53.5
28011	[RBUC.S1	400.00]	28015	[RPELIC1	400.00]	1	-225.9	-6.2	-113.8	-23.5	112.1	49.6
28011	[RBUC.S1	400.00]	28016	[RGR.IA1	400.00]	1	-259.5	8.4	-119.2	-11.5	140.2	54.0
28015	[RPELIC1	400.00]	28973	[RCERNA1	400.00]	1	-294.0	39.5	-184.2	31.0	109.8	37.3
28022	[RSMIRD1	400.00]	28024	[RGUTIN1	400.00]	1	406.2	-69.6	293.1	-77.8	-113.0	27.8
28024	[RGUTIN1	400.00]	28031	[RBRASO1	400.00]	1	108.7	-40.8	-71.8	-29.3	-180.5	166.0
28028	[RRAHMAN 1	400.00]	28974	[RMEDGI1	400.00]	1	178.0	-22.0	20.0	-19.6	-158.0	88.7
28031	[RBRASO1	400.00]	28034	[RSIBIU1	400.00]	1	155.6	-75.7	-52.4	-73.9	-208.0	133.7
28034	[RSIBIU1	400.00]	28036	[RIERNU1	400.00]	1	498.5	-11.5	322.8	-8.7	-175.7	35.2
28036	[RIERNU1	400.00]	28037	[RGADAL1	400.00]	1	246.6	-73.2	65.3	-46.7	-181.3	73.5
28037	[RGADAL1	400.00]	28039	[RROSIO1	400.00]	1	146.1	-88.1	-34.5	-56.4	-180.6	123.6
28973	[RCERNA1	400.00]	28974	[RMEDGI1	400.00]	1	389.6	-46.9	539.1	-51.1	149.5	38.4
34001	[JBGD8 1	400.00]	34030	[JOBREN11	400.00]	1	84.0	-174.1	-100.0	-152.5	-183.9	219.1
34001	[JBGD8 1	400.00]	34075	[JBGD201	400.00]	A	28.0	60.7	142.2	47.5	114.2	407.5
34015	[JKRAG21	400.00]	34079	[JJAGO41	400.00]	1	-53.2	-18.6	50.4	-32.3	103.6	194.7
34020	[JNIS2 1	400.00]	34079	[JJAGO41	400.00]	1	192.6	10.5	81.9	20.2	-110.7	57.5
34025	[JNSAD31	400.00]	34078	[JSRBOB1	400.00]	A	422.7	-32.3	302.2	-36.6	-120.5	28.5
34030	[JOBREN11	400.00]	34040	[JRPMLA1	400.00]	2	-5.3	-144.9	-180.1	-142.3	-174.7	999.9
34031	[JOBREN12	400.00]	34040	[JRPMLA1	400.00]	1	-5.5	-146.1	-181.8	-143.4	-176.3	999.9
34035	[JPANC21	400.00]	34075	[JBGD201	400.00]	A	259.4	-76.4	146.1	-69.1	-113.3	43.7
34040	[JRPMLA1	400.00]	34045	[JSMIT21	400.00]	1	679.7	-82.9	420.5	-97.0	-259.2	38.1
34050	[JSUBO31	400.00]	34078	[JSRBOB1	400.00]	A	-291.2	67.7	-157.5	55.8	133.7	45.9
34070	[JTKOSB2	400.00]	34086	[JPEC 31	400.00]	1	199.8	-1.8	90.7	6.7	-109.2	54.6
36005	[0PODG211	400.00]	36017	[0LASTV11	400.00]	A	342.7	-24.7	225.2	-8.0	-117.5	34.3



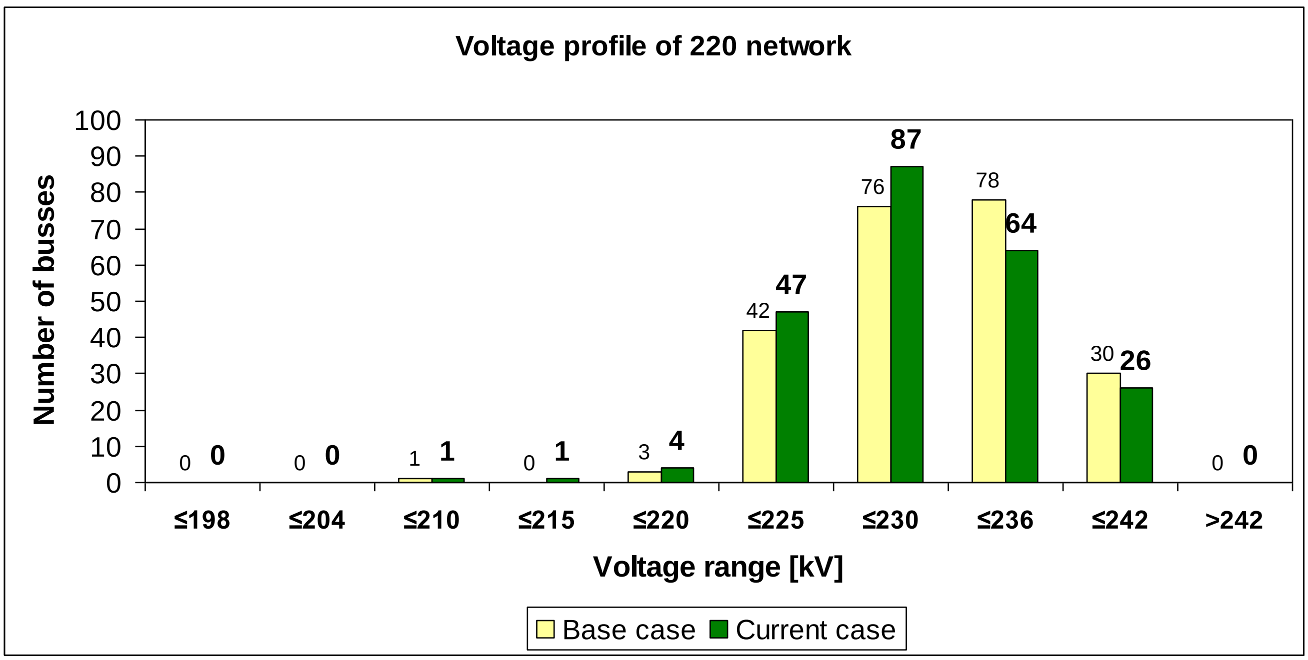


Figure 9-6 Voltage profile of 400 and 220 kV network in analyzed region

9.4. Winter MAXIMUM 2015, Scenario 4 (All regions (Max) → rest of ENTSO-E)

Table 9-13 Area summary of analyzed region

	FROM	TO LOAD		TO				-NET INTERCHANGE-		
	GENE-	AT AREA	TO BUS	GNE BUS	TO LINE	FROM	TO	TO TIE	TO TIES	DESIRED

X-- AREA --X	RATION	BUSES	SHUNT	DEVICES	SHUNT	CHARGING	LOSSES	LINES	+ LOADS	NET INT
10	1303.2	1536.5	0.0	0.0	0.0	0.0	49.7	-283.0	-283.0	-283.0
AL	433.6	555.2	-107.2	0.0	0.0	598.2	484.9	98.8	98.8	
20	9022.0	7603.7	0.0	0.0	14.6	0.0	193.7	1210.0	1210.0	1210.0
BG	3172.8	3045.8	193.7	0.0	123.4	3148.1	2552.8	405.1	405.1	
30	3193.2	2603.2	0.0	0.0	0.0	0.0	72.0	518.0	518.0	518.0
BA	836.3	714.5	0.0	0.0	0.0	894.8	729.3	287.3	287.3	
40	3272.5	3483.0	0.0	0.0	0.0	0.0	101.5	-311.9	-311.9	-312.0
HR	596.6	1074.2	0.0	0.0	0.0	1373.5	1036.4	-140.5	-140.5	
50	13173.7	12371.1	0.0	0.0	0.0	0.0	277.6	525.0	525.0	525.0
GR	1445.2	4654.6	171.0	0.0	23.7	6441.6	3163.0	-125.5	-125.5	
60	1583.3	1731.0	0.0	0.0	0.2	0.0	26.1	-174.0	-174.0	-174.0
MK	399.4	529.7	0.0	0.0	2.5	447.4	302.5	12.1	12.1	
70	10926.2	8937.9	0.0	0.0	79.8	0.0	246.5	1662.0	1662.0	1662.0
RO	613.3	2731.1	0.0	0.0	232.7	4591.4	2635.4	-394.5	-394.5	
75	3458.9	2514.0	0.0	0.0	8.7	0.0	77.2	859.0	859.0	859.0
SI	1270.2	811.0	0.0	0.0	52.4	586.8	1019.3	-25.8	-25.8	
80	54784.8	54622.0	0.0	0.0	0.0	0.0	758.8	-596.0	-596.0	-596.0
TR	4434.6	7792.0	1176.1	0.0	0.0	17243.3	12804.3	-94.5	-94.5	
90	7494.0	7240.5	0.0	0.0	11.3	0.0	200.2	42.0	42.0	42.0
RS	2306.8	2389.5	0.0	0.0	66.0	1832.7	2272.2	-588.2	-588.2	
91	971.4	877.5	0.5	0.0	2.2	0.0	30.2	61.0	61.0	61.0
ME	151.8	318.4	-33.0	0.0	16.2	282.0	248.3	-116.1	-116.1	
COLUMN	109183.3	103520.5	0.5	0.0	116.7	0.0	2033.5	3512.1	3512.1	3512.0
TOTALS	15660.5	24615.9	1400.6	0.0	516.9	37439.7	27248.4	-681.6	-681.6	

Table 9-14 Zone summary in Serbia

	FROM	TO LOAD		TO				-NET INTERCHANGE-	
	GENE-	AT ZONE	TO BUS	GNE BUS	TO LINE	FROM	TO	TO TIE	TO TIES
X-- ZONE --X	RATION	BUSES	SHUNT	DEVICES	SHUNT	CHARGING	LOSSES	LINES	+ LOADS
90	6661.0	6111.4	0.0	0.0	9.7	0.0	175.7	364.2	364.2
EMS	1850.1	2011.1	0.0	0.0	57.4	1574.3	2005.2	-649.3	-649.3
901	833.0	1129.1	0.0	0.0	1.6	0.0	24.5	-322.2	-322.2
KOSTT	456.7	378.4	0.0	0.0	8.6	258.4	267.0	61.1	61.1
COLUMN	7494.0	7240.5	0.0	0.0	11.3	0.0	200.2	42.0	42.0
TOTALS	2306.8	2389.5	0.0	0.0	66.0	1832.7	2272.2	-588.2	-588.2

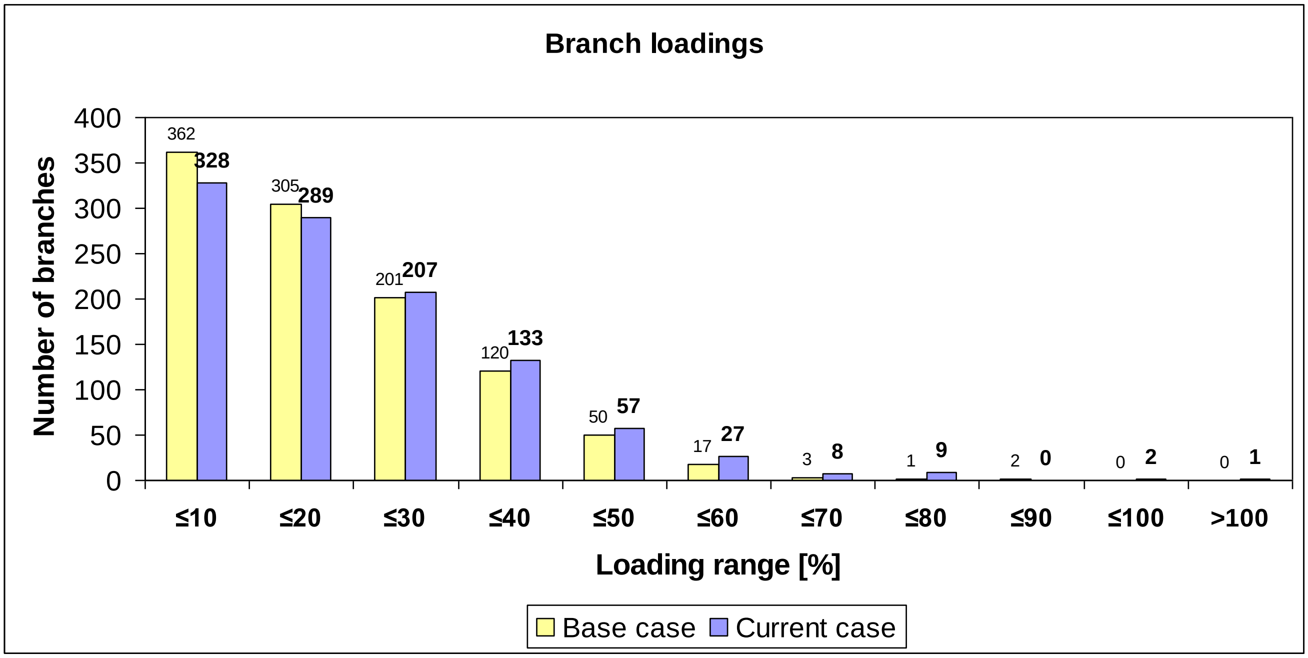


Figure 9-7 Branch loadings in analyzed region

Table 9-15 Branches loaded over 80% of their thermal limits

FRMBUS,	FROMBUSEXNAME,	TOBUS,	TOBUSEXNAME,	CKT,	STS,	MW,	MVAR,	MVA,	%I	
31210,LDIVAC2	220.00,	156,XPA_DI21	220.00,	1 ,	1,	532.41,	23.66,	532.94,	147.95	*
31410,LDIVAC1	400.00,	31411,LDIVAC1P	400.00,	1 ,	1,	516.63,	107.74,	527.74,	90.05	
31410,LDIVAC1	400.00,	31411,LDIVAC1P	400.00,	2 ,	1,	516.63,	107.74,	527.74,	90.05	

Total 3 items

Table 9-16 Significant changes of branch flows in comparison against base case scenario

X------- FROM BUS		--------X	X-------- TO BUS		---------X	CKT	IN WORKING CASE MW	MVAR	IN Winter MAX 2015 - Base Case MW	MVAR	DELTA MW	%
2	[XZE_KA11	400.00]	10020	[AZEMLA1	400.00]	1	397.3	-10.5	179.9	-2.9	-217.4	54.7
12	[XUG_ER11	400.00]	14402	[WTUGLJ1	400.00]	1	-245.8	113.2	-28.6	53.2	217.2	88.4
12	[XUG_ER11	400.00]	20037	[HERNES11	400.00]	1	245.8	-113.2	28.6	-53.2	-217.2	88.4
13	[XTR_PG11	400.00]	14405	[WTREBI1	400.00]	1	-118.3	-98.9	-353.8	-59.7	-235.5	199.0
13	[XTR_PG11	400.00]	36017	[0LASTV11	400.00]	A	118.3	98.9	353.8	59.7	235.5	199.0
24	[XSO_NI11	400.00]	12431	[VSOFIW1	400.00]	1	-549.0	-42.6	-294.4	-52.4	254.5	46.4
24	[XSO_NI11	400.00]	34020	[JNIS2 1	400.00]	1	549.0	42.6	294.4	52.4	-254.5	46.4
74	[XER_SM11	400.00]	20037	[HERNES11	400.00]	1	508.1	-106.0	153.6	-87.1	-354.5	69.8
74	[XER_SM11	400.00]	34045	[JSMIT21	400.00]	1	-508.1	106.0	-153.6	87.1	354.5	69.8
79	[XSA_SU11	400.00]	24039	[MSAFA 11	400.00]	1	187.8	-163.6	-168.4	-128.1	-356.2	189.6
79	[XSA_SU11	400.00]	34050	[JSUBO31	400.00]	1	-187.8	163.6	168.4	128.1	356.2	189.6
81	[XSK_KB11	400.00]	26111	[YSK 5 1	400.00]	1	-148.7	46.1	82.0	27.0	230.7	155.2
81	[XSK_KB11	400.00]	34072	[JUROS21	400.00]	1	148.7	-46.1	-82.0	-27.0	-230.7	155.2
84	[XRO_MU11	400.00]	28039	[RROSIO1	400.00]	1	-206.1	97.7	298.2	-15.4	504.3	244.7
184	[XRI_PE11	400.00]	34086	[JPEC 31	400.00]	1	-170.4	37.5	63.0	16.5	233.4	137.0
184	[XRI_PE11	400.00]	36001	[0RIBAR11	400.00]	1	170.4	-37.5	-63.0	-16.5	-233.4	137.0
206	[XFL_BI11	400.00]	26005	[YBITOL1	400.00]	1	419.9	28.0	100.5	40.0	-319.3	76.1
219	[XNA_BE11	400.00]	24004	[MBEKO 11	400.00]	1	316.0	-54.4	89.5	-1.5	-226.5	71.7
219	[XNA_BE11	400.00]	28009	[RNADAB1	400.00]	1	-316.0	54.4	-89.5	1.5	226.5	71.7
220	[XKA_PG11	400.00]	10014	[ATIRA21	400.00]	1	-265.6	-20.5	-23.8	-57.4	241.8	91.0
220	[XKA_PG11	400.00]	36005	[0PODG211	400.00]	1	265.6	20.5	23.8	57.4	-241.8	91.0
10010	[AELBS21	400.00]	10014	[ATIRA21	400.00]	1	356.4	53.3	87.7	80.8	-268.7	75.4
20037	[HERNES11	400.00]	20203	[HZERJA11	400.00]	1	484.9	-47.6	246.5	-62.8	-238.5	49.2
20078	[HKONJS11	400.00]	20147	[HOBROV11	400.00]	1	357.0	-12.5	122.3	-21.4	-234.7	65.7
20097	[HMELIN11	400.00]	20147	[HOBROV11	400.00]	1	-459.5	-1.5	-214.7	-51.4	244.8	53.3
24001	[MAISA 11	400.00]	24048	[MSZOL 11	400.00]	1	-48.3	36.9	265.7	-25.2	314.0	650.6
24004	[MBEKO 11	400.00]	24048	[MSZOL 11	400.00]	1	217.2	-73.4	-100.6	-7.8	-317.8	146.3

24019	[MGYOR 11	400.00]	24024	[MLITR 11	400.00]	1	-254.4	50.6	26.7	-3.3	281.1	110.5
24024	[MLITR 11	400.00]	24033	[MPAKS 11	400.00]	1	-607.0	33.7	-329.4	-3.0	277.6	45.7
24025	[MMART 11	400.00]	24033	[MPAKS 11	400.00]	1	-423.2	-88.3	-157.8	-97.8	265.4	62.7
24033	[MPAKS 11	400.00]	24039	[MSAFA 11	400.00]	1	-100.2	122.8	262.6	35.9	362.7	362.2
26064	[YSK 41	400.00]	26111	[YSK 5 1	400.00]	1	228.0	32.6	20.3	49.8	-207.7	91.1
28003	[RMINTII1A	400.00]	28008	[RARAD 1	400.00]	1	442.7	-71.8	174.8	-58.0	-267.9	60.5
28003	[RMINTII1A	400.00]	28034	[RSIBIU1	400.00]	1	-241.6	2.2	-38.8	-30.2	202.8	83.9
28008	[RARAD 1	400.00]	28009	[RNADAB1	400.00]	1	384.8	-103.7	104.0	-48.7	-280.8	73.0
28024	[RGUTIN1	400.00]	28031	[RBRASO1	400.00]	1	144.0	-35.6	-71.8	-29.3	-215.8	149.9
28031	[RBRASO1	400.00]	28034	[RSIBIU1	400.00]	1	277.1	-56.2	-52.4	-73.9	-329.5	118.9
28034	[RSIBIU1	400.00]	28036	[RIERNU1	400.00]	1	658.9	3.1	322.8	-8.7	-336.1	51.0
28036	[RIERNU1	400.00]	28037	[RGADAL1	400.00]	1	396.7	-92.2	65.3	-46.7	-331.4	83.5
28037	[RGADAL1	400.00]	28039	[RROSIO1	400.00]	1	295.8	-115.7	-34.5	-56.4	-330.3	111.7
28973	[RCERNA1	400.00]	28974	[RMEDGI1	400.00]	1	325.0	-46.1	539.1	-51.1	214.0	65.8
31420	[LMARIB1	400.00]	31435	[LCIRKO11	400.00]	1	-324.8	40.2	-98.0	26.4	226.8	69.8
31420	[LMARIB1	400.00]	31435	[LCIRKO11	400.00]	2	-350.4	43.0	-105.7	28.4	244.7	69.8
34001	[JBGD8 1	400.00]	34030	[JOBREN11	400.00]	1	144.0	-177.8	-100.0	-152.5	-243.9	169.4
34015	[JKRAG21	400.00]	34079	[JJAGO41	400.00]	1	-182.1	-9.4	50.4	-32.3	232.5	127.7
34015	[JKRAG21	400.00]	34088	[JTKOLB1	400.00]	1	-53.1	-122.0	-287.8	-100.7	-234.8	442.3
34020	[JNIS2 1	400.00]	34079	[JJAGO41	400.00]	1	338.2	15.8	81.9	20.2	-256.3	75.8
34025	[JNSAD31	400.00]	34078	[JSRBOB1	400.00]	A	593.0	-12.4	302.2	-36.6	-290.8	49.0
34030	[JOBREN11	400.00]	34040	[JRPMLA1	400.00]	2	175.6	-135.7	-180.1	-142.3	-355.7	202.5
34031	[JOBREN12	400.00]	34040	[JRPMLA1	400.00]	1	177.1	-137.0	-181.8	-143.4	-358.9	202.6
34031	[JOBREN12	400.00]	34088	[JTKOLB1	400.00]	1	53.3	60.7	289.8	58.8	236.5	443.4
34040	[JRPMLA1	400.00]	34045	[JSMIT21	400.00]	1	874.9	-54.6	420.5	-97.0	-454.4	51.9
34050	[JSUBO31	400.00]	34078	[JSRBOB1	400.00]	A	-476.9	79.0	-157.5	55.8	319.4	67.0
34070	[JTKOSB2	400.00]	34072	[JUROS21	400.00]	1	-148.4	11.2	82.1	-10.4	230.5	155.3
34070	[JTKOSB2	400.00]	34086	[JPEC 31	400.00]	1	317.8	-5.4	90.7	6.7	-227.2	71.5
36001	[0RIBAR11	400.00]	36012	[0MAOCE11	400.00]	1	-184.5	-47.4	-398.9	-21.2	-214.4	116.2
36005	[0PODG211	400.00]	36017	[0LASTV11	400.00]	A	444.5	-34.0	225.2	-8.0	-219.3	49.3
36010	[0PLJE211	400.00]	36012	[0MAOCE11	400.00]	1	184.9	21.2	400.5	9.0	215.6	116.6

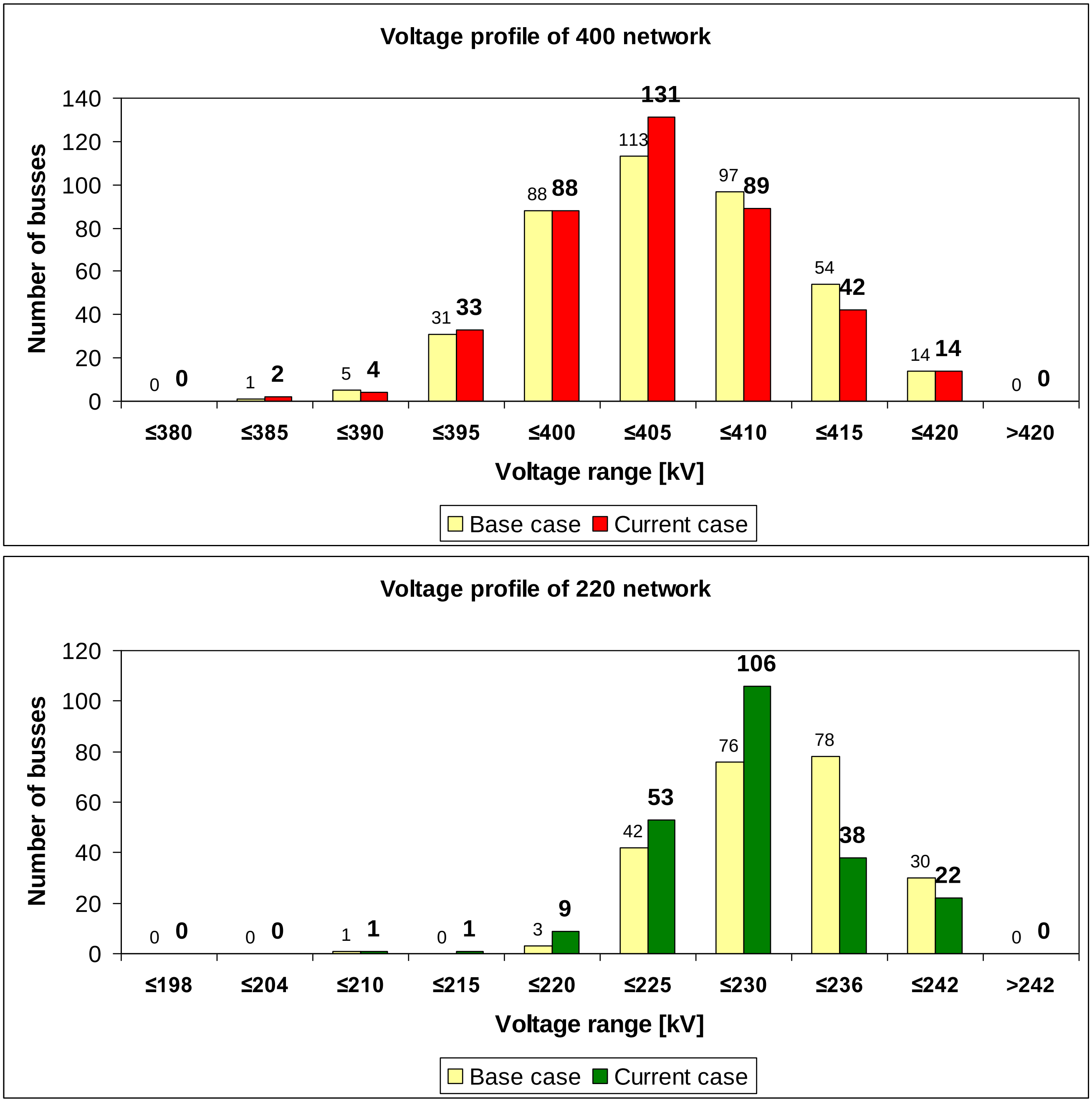


Figure 9-8 Voltage profile of 400 and 220 kV network in analyzed region

9.5. Winter MAXIMUM 2020, Scenario 1 (Adriatic + Aegean (Max) → Black Sea (Min))

Table 9-17 Area summary of analyzed region

FROM	TO LOAD		TO				-NET INTERCHANGE-		
GENE-	AT AREA	TO BUS	GNE BUS	TO LINE	FROM	TO	TO TIE	TO TIES	DESIRED

X-- AREA --X	RATION	BUSES	SHUNT	DEVICES	SHUNT	CHARGING	LOSSES	LINES	+ LOADS	NET INT
10	1901.9	1765.2	0.0	0.0	0.0	0.0	56.7	80.0	80.0	80.0
AL	479.3	636.1	-106.0	0.0	0.0	586.7	495.0	40.9	40.9	
20	9264.4	8393.4	0.0	0.0	15.5	0.0	194.5	661.0	661.0	661.0
BG	3575.7	3343.1	231.2	0.0	182.7	3323.9	2782.5	360.1	360.1	
30	3654.7	2662.5	0.0	0.0	0.6	0.0	107.5	884.0	884.0	884.0
BA	685.6	207.8	0.0	0.0	1.3	968.9	964.7	480.7	480.7	
40	4047.8	4436.2	0.0	0.0	0.0	0.0	168.6	-556.9	-556.9	-557.0
HR	772.3	1114.4	0.0	0.0	0.0	1575.0	1571.8	-339.0	-339.0	
50	14424.4	13426.0	0.0	0.0	0.0	0.0	308.4	690.0	690.0	690.0
GR	2244.1	5067.4	203.6	0.0	23.2	6694.3	3715.0	-70.8	-70.8	
60	1956.3	1974.4	0.0	0.0	0.2	0.0	29.7	-48.0	-48.0	-48.0
MK	504.3	609.6	0.0	0.0	2.5	471.3	342.8	20.8	20.8	
70	11288.6	10176.3	0.0	0.0	90.1	0.0	276.1	746.0	746.0	746.0
RO	2128.8	3213.2	1403.0	0.0	270.7	5537.6	3125.5	-346.0	-346.0	
75	4643.7	2887.0	0.0	0.0	9.8	0.0	191.8	1555.1	1555.1	1555.0
SI	2157.0	863.0	0.0	0.0	61.3	856.1	2234.0	-145.3	-145.3	
80	77800.0	77342.9	0.0	0.0	0.0	0.0	995.1	-538.0	-538.0	-538.0
TR	7373.0	11034.0	994.2	0.0	0.0	22762.8	18342.3	-234.7	-234.7	
90	8833.1	7867.4	0.0	0.0	12.8	0.0	202.9	750.0	750.0	750.0
RS	2434.5	2621.5	0.0	0.0	81.4	2082.2	2354.4	-540.5	-540.5	
91	1650.1	1022.9	0.5	0.0	3.6	0.0	32.1	591.0	591.0	591.0
ME	295.9	365.1	-32.9	0.0	21.3	417.9	368.3	-8.1	-8.1	
COLUMN	139465.0	131954.3	0.5	0.0	132.6	0.0	2563.4	4814.1	4814.1	4814.0
TOTALS	22650.5	29075.2	2693.1	0.0	644.3	45276.7	36296.3	-781.8	-781.8	

Table 9-18 Zone summary in Serbia

	FROM	TO LOAD		TO				-NET INTERCHANGE-	
	GENE-	AT ZONE	TO BUS	GNE BUS	TO LINE	FROM	TO	TO TIE	TO TIES
X-- ZONE --X	RATION	BUSES	SHUNT	DEVICES	SHUNT	CHARGING	LOSSES	LINES	+ LOADS
90	7435.6	6544.7	0.0	0.0	10.5	0.0	173.1	707.3	707.3
EMS	1862.6	2167.2	0.0	0.0	68.2	1788.5	1998.3	-582.6	-582.6
901	1397.5	1322.7	0.0	0.0	2.3	0.0	29.8	42.7	42.7
KOSTT	571.8	454.3	0.0	0.0	13.1	293.7	356.0	42.1	42.1
COLUMN	8833.1	7867.4	0.0	0.0	12.8	0.0	202.9	750.0	750.0
TOTALS	2434.5	2621.5	0.0	0.0	81.4	2082.2	2354.4	-540.5	-540.5

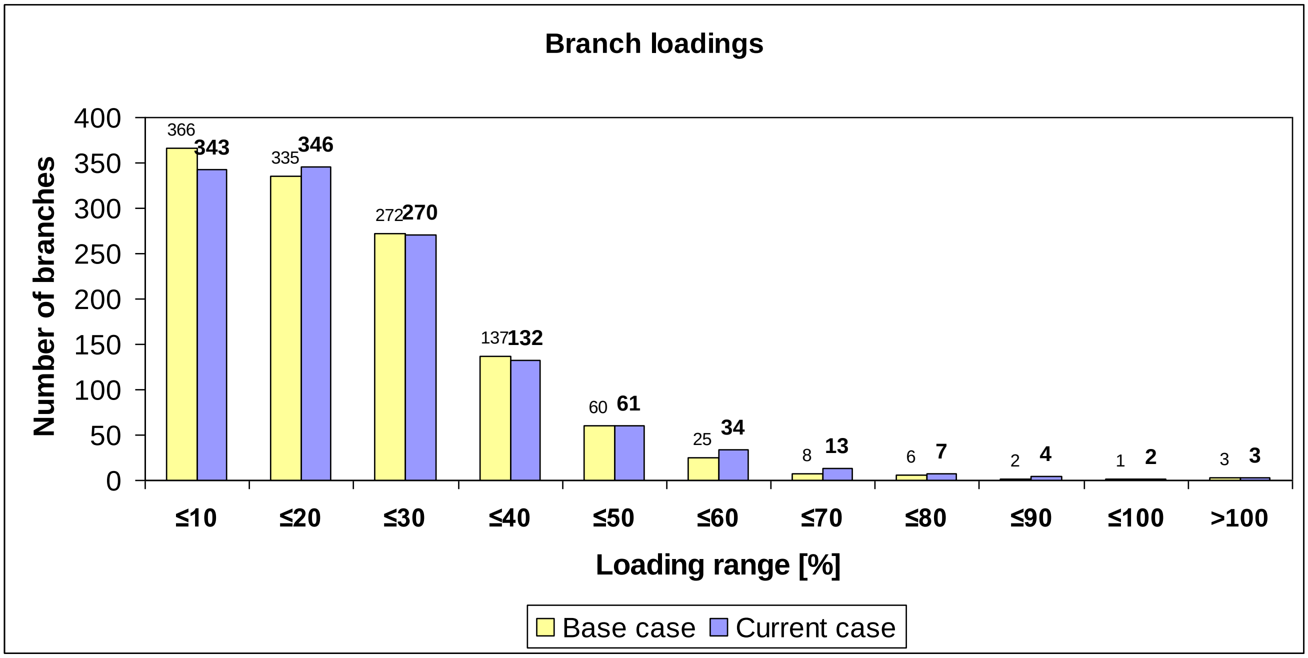


Figure 9-9 Branch loadings in analyzed region

Table 9-19 Branches loaded over 80% of their thermal limits

FRMBUS,	FROMBUSEXNAME,	TOBUS,	TOBUSEXNAME,	CKT,	STS,	MW,	MVAR,	MVA,	%I	
10006,AVDEJA2	220.00,	10005,AKOMAN2	220.00,	1 ,	1,	-267.03,	5.79,	267.10,	80.25	
12474,VMI 1	400.00,	12274,VMI 2	220.00,	1 ,	1,	583.15,	162.25,	605.30,	93.16	
20168,HTE SI21	220.00,	20103,HMRACL21	220.00,	2 ,	1,	258.94,	7.72,	259.05,	85.38	
31405,LOKROG1	400.00,	503,XUD_OK11	400.00,	1 ,	1,	1228.21,	209.49,	1245.94,	98.56	
31405,LOKROG1	400.00,	31438,LHAVCE1	400.00,	1 ,	1,	1075.79,	157.65,	1087.28,	86.01	
31410,LDIVAC1	400.00,	71,XME_DI11	400.00,	1 ,	1,	-885.74,	-24.87,	886.09,	82.20	
31430,LBERIC1	400.00,	31405,LOKROG1	400.00,	1 ,	1,	1191.86,	280.67,	1224.47,	113.28	*
31430,LBERIC1	400.00,	31405,LOKROG1	400.00,	2 ,	1,	1191.86,	280.67,	1224.47,	113.28	*
31438,LHAVCE1	400.00,	504,XUD_AV11	400.00,	1 ,	1,	1310.18,	99.87,	1313.98,	106.51	*

Total 9 items

Table 9-20 Significant changes of branch flows in comparison against base case scenario

X------- FROM BUS	--------X		X-------- TO BUS	---------X		CKT	IN WORKING CASE MW	MVAR	IN Winter MAX 2020 - Base Case MW	MVAR	DELTA MW	%
12	[XUG_ER11	400.00]	14402	[WTUGLJ1	400.00]	1	-329.6	103.3	-238.1	84.5	91.4	27.7
12	[XUG_ER11	400.00]	20037	[HERNES11	400.00]	1	329.6	-103.3	238.1	-84.5	-91.4	27.7
20	[XBG_TH11	400.00]	12433	[VBLAGO1	400.00]	1	38.5	-19.5	-124.7	2.8	-163.2	423.7
21	[XDO_IS11	400.00]	12461	[VDOBRU1	400.00]	1	83.9	-19.0	233.8	-30.8	149.9	178.6
21	[XDO_IS11	400.00]	28974	[RMEDGI1	400.00]	1	-83.9	19.0	-233.8	30.8	-149.9	178.6
22	[XKO_TI11	400.00]	12440	[VAEC_41	400.00]	1	-63.7	-46.0	29.9	-44.0	93.7	147.0
22	[XKO_TI11	400.00]	28001	[RTANTA1	400.00]	1	63.7	46.0	-29.9	44.0	-93.7	147.0
23	[XKO_TI12	400.00]	12440	[VAEC_41	400.00]	1	-63.5	-46.0	30.2	-44.0	93.7	147.6
23	[XKO_TI12	400.00]	28001	[RTANTA1	400.00]	2	63.5	46.0	-30.2	44.0	-93.7	147.6
71	[XME_DI11	400.00]	20097	[HMELIN11	400.00]	1	-891.6	-71.1	-738.1	-92.8	153.6	17.2
71	[XME_DI11	400.00]	31410	[LDIVAC1	400.00]	1	891.6	71.1	738.1	92.8	-153.6	17.2
79	[XSA_SU11	400.00]	24039	[MSAFA 11	400.00]	1	292.7	-216.2	183.8	-201.7	-108.9	37.2
79	[XSA_SU11	400.00]	34050	[JSUBO31	400.00]	1	-292.7	216.2	-183.8	201.7	108.9	37.2
85	[XPF_DJ11	400.00]	28004	[RP.D.F1	400.00]	1	129.1	100.2	-7.4	95.2	-136.5	105.7
85	[XPF_DJ11	400.00]	34010	[JHDJE11	400.00]	1	-129.1	-100.2	7.4	-95.2	136.5	105.7
181	[XVA_IS11	400.00]	12994	[VSVOBO14	400.00]	1	96.8	35.2	282.4	20.3	185.6	191.8
181	[XVA_IS11	400.00]	28974	[RMEDGI1	400.00]	1	-96.8	-35.2	-282.4	-20.3	-185.6	191.8
197	[XMI_BA11	400.00]	12471	[VMI3 11	400.00]	1	-161.2	-70.8	-287.0	-58.7	-125.8	78.0
198	[XMI_HA11	400.00]	12471	[VMI3 11	400.00]	1	-216.2	-108.0	-387.0	-93.7	-170.8	79.0

206	[XFL_BI11	400.00]	26005	[YBITOL1	400.00]	1	210.9	-4.0	61.2	5.8	-149.6	71.0
207	[XCM_ST11	400.00]	12432	[VCMOGI1	400.00]	1	-62.3	-0.7	-189.6	15.3	-127.3	204.2
207	[XCM_ST11	400.00]	26112	[YSTIP 1	400.00]	1	62.3	0.7	189.6	-15.3	127.3	204.2
214	[XMI_NS11	400.00]	12474	[VMI 1	400.00]	1	-55.8	-36.6	-253.7	-15.8	-197.9	354.8
12431	[VSOFIW1	400.00]	12432	[VCMOGI1	400.00]	1	195.7	-0.5	303.6	-9.9	107.9	55.1
12431	[VSOFIW1	400.00]	12432	[VCMOGI1	400.00]	2	195.7	-0.5	303.6	-9.9	107.9	55.1
12441	[VNPPBE1	400.00]	12452	[VOCIFL1	400.00]	1	351.6	104.6	200.7	105.0	-150.9	42.9
12450	[VCAREV1	400.00]	12451	[VKARLO1	400.00]	1	136.8	-19.1	232.0	-23.2	95.3	69.6
12450	[VCAREV1	400.00]	12451	[VKARLO1	400.00]	2	136.8	-19.1	232.0	-23.2	95.3	69.6
12450	[VCAREV1	400.00]	12460	[VVARNA1	400.00]	1	148.7	31.3	18.0	37.9	-130.8	87.9
12452	[VOCIFL1	400.00]	12994	[VSVOBO14	400.00]	1	138.0	93.5	-29.8	107.5	-167.8	121.6
12460	[VVARNA1	400.00]	12461	[VDOBRU1	400.00]	1	70.9	54.5	-30.3	65.3	-101.3	142.8
12460	[VVARNA1	400.00]	12470	[VBURGA1	400.00]	1	-15.2	-59.3	196.6	-75.8	211.8	999.9
12460	[VVARNA1	400.00]	12994	[VSVOBO14	400.00]	1	-85.1	90.9	-251.4	101.3	-166.3	195.5
12470	[VBURGA1	400.00]	12472	[VMI2 1	400.00]	1	-199.3	-105.2	-98.4	-114.3	100.9	50.6
12470	[VBURGA1	400.00]	12474	[VMI 1	400.00]	1	-171.1	-96.4	-38.2	-108.5	132.8	77.6
12471	[VMI3 11	400.00]	12472	[VMI2 1	400.00]	1	27.9	-25.3	-73.5	-23.6	-101.4	363.5
14402	[WTUGLJ1	400.00]	16402	[WTUZL41	400.00]	1	-166.8	12.6	-30.9	-1.7	135.9	81.5
20097	[HMELIN11	400.00]	20502	[HBRINJ11	400.00]	1	-944.0	119.7	-751.3	79.3	192.7	20.4
20147	[HVELEB11	400.00]	20256	[HTEDAL11	400.00]	1	386.5	17.5	276.1	1.6	-110.4	28.6
20256	[HTEDAL11	400.00]	20503	[HLIKA11	400.00]	1	374.8	-24.7	283.5	-40.8	-91.3	24.4
20256	[HTEDAL11	400.00]	20503	[HLIKA11	400.00]	2	374.8	-24.7	283.5	-40.8	-91.3	24.4
20502	[HBRINJ11	400.00]	20503	[HLIKA11	400.00]	1	-578.5	10.9	-459.6	14.1	119.0	20.6
20502	[HBRINJ11	400.00]	20503	[HLIKA11	400.00]	2	-525.7	8.6	-417.6	11.1	108.1	20.6
26022	[YDUBRO1	400.00]	26112	[YSTIP 1	400.00]	1	143.8	-17.8	-21.4	8.2	-165.2	114.9
28007	[RSLATI1A	400.00]	28011	[RBUC.S1	400.00]	1	100.7	-40.1	-1.5	-27.0	-102.2	101.5
28024	[RGUTIN1	400.00]	28031	[RBRASO1	400.00]	1	-36.5	-41.2	69.9	-53.4	106.3	291.6
28028	[RRAHMAN1	400.00]	28974	[RMEDGI1	400.00]	1	-220.1	-51.8	-70.0	-67.4	150.0	68.2
28973	[RCERNA1	400.00]	28974	[RMEDGI1	400.00]	1	927.9	131.9	823.5	134.1	-104.4	11.3
28974	[RMEDGI1	400.00]	29562	[RSTUPI1	400.00]	1	323.2	34.8	162.2	48.0	-161.0	49.8
31420	[LMARIB1	400.00]	31435	[LCIRKO11	400.00]	2	-256.5	123.0	-165.8	105.2	90.7	35.4
34005	[JBOR 21	400.00]	34010	[JHDJE11	400.00]	1	-472.3	-50.2	-571.2	-48.3	-98.9	20.9
34005	[JBOR 21	400.00]	34020	[JNIS2 1	400.00]	1	442.6	-8.2	539.6	-7.8	97.0	21.9
34020	[JNIS2 1	400.00]	34070	[JTKOSB2	400.00]	1	-30.4	-62.8	79.6	-79.0	110.0	361.4
34050	[JSUBO31	400.00]	34078	[JSRBOB1	400.00]	A	-592.2	112.8	-494.5	104.7	97.7	16.5

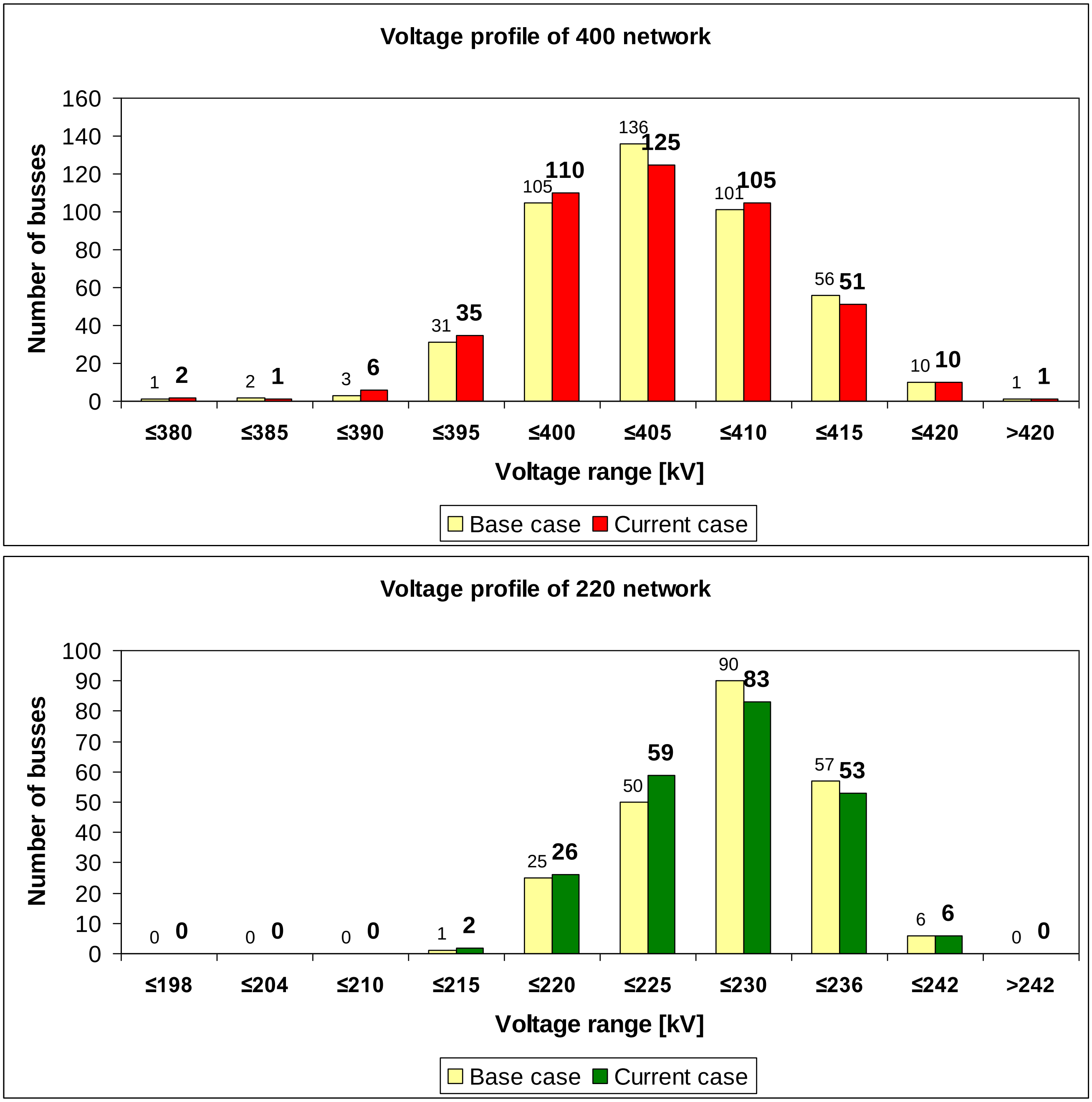


Figure 9-10 Voltage profile of 400 and 220 kV network in analyzed region

9.6. Winter MAXIMUM 2020, Scenario 2 (Aegean + Black Sea (Max) → Adriatic (Min))

Table 9-21 Area summary of analyzed region

	FROM GENE-	TO LOAD AT AREA	TO BUS	TO GNE BUS	TO LINE	FROM	TO	-NET INTERCHANGE- TO TIE	TO TIES	DESIRED

X-- AREA --X	RATION	BUSES	SHUNT	DEVICES	SHUNT	CHARGING	LOSSES	LINES	+ LOADS	NET INT
10	1783.9	1765.2	0.0	0.0	0.0	0.0	75.7	-57.0	-57.0	-57.0
AL	604.7	636.1	-102.8	0.0	0.0	568.2	675.5	-35.9	-35.9	
20	10124.0	8393.4	0.0	0.0	15.4	0.0	240.2	1475.0	1475.0	1475.0
BG	3773.8	3343.1	230.9	0.0	181.7	3294.1	3131.9	180.1	180.1	
30	3518.9	2662.5	0.0	0.0	0.6	0.0	201.6	654.2	654.2	654.0
BA	1488.4	207.8	0.0	0.0	1.2	913.7	1682.3	510.9	510.9	
40	3382.2	4436.2	0.0	0.0	0.0	0.0	261.6	-1315.7	-1315.7	-1316.0
HR	1578.6	1114.4	0.0	0.0	0.0	1477.8	2381.3	-439.3	-439.3	
50	14441.2	13426.0	0.0	0.0	0.0	0.0	325.2	690.0	690.0	690.0
GR	2525.2	5067.4	204.0	0.0	23.1	6680.9	3870.9	40.7	40.7	
60	1966.6	1974.4	0.0	0.0	0.2	0.0	40.0	-48.0	-48.0	-48.0
MK	636.3	609.6	0.0	0.0	2.4	462.2	445.3	41.1	41.1	
70	13312.0	10176.3	0.0	0.0	87.3	0.0	492.2	2556.1	2556.1	2556.0
RO	2479.5	3213.2	0.0	0.0	262.8	5385.0	4976.0	-587.5	-587.5	
75	4423.4	2887.0	0.0	0.0	9.4	0.0	211.7	1315.3	1315.3	1315.0
SI	2598.2	863.0	0.0	0.0	58.8	819.7	2435.9	60.2	60.2	
80	78523.2	77342.9	0.0	0.0	0.0	0.0	926.3	254.0	254.0	254.0
TR	6576.3	11034.0	998.1	0.0	0.0	22788.4	17610.0	-277.5	-277.5	
90	8954.1	7867.4	0.0	0.0	12.3	0.0	324.3	750.1	750.1	750.0
RS	3752.3	2621.5	0.0	0.0	78.4	1987.3	3562.8	-523.0	-523.0	
91	1602.3	1022.9	0.5	0.0	3.5	0.0	54.4	521.0	521.0	521.0
ME	521.5	365.1	-31.6	0.0	20.5	400.9	582.6	-14.4	-14.4	
COLUMN	142031.8	131954.3	0.5	0.0	128.6	0.0	3153.3	6795.1	6795.1	6794.0
TOTALS	26534.8	29075.2	1298.7	0.0	629.1	44778.2	41354.6	-1044.6	-1044.6	

Table 9-22 Zone summary in Serbia

	FROM	TO LOAD		TO				-NET INTERCHANGE-	
	GENE-	AT ZONE	TO BUS	GNE BUS	TO LINE	FROM	TO	TO TIE	TO TIES
X-- ZONE --X	RATION	BUSES	SHUNT	DEVICES	SHUNT	CHARGING	LOSSES	LINES	+ LOADS
90	7556.6	6544.7	0.0	0.0	10.1	0.0	284.8	717.0	717.0
EMS	3030.6	2167.2	0.0	0.0	65.6	1702.7	3102.7	-602.2	-602.2
901	1397.5	1322.7	0.0	0.0	2.2	0.0	39.5	33.1	33.1
KOSTT	721.7	454.3	0.0	0.0	12.8	284.6	460.1	79.2	79.2
COLUMN	8954.1	7867.4	0.0	0.0	12.3	0.0	324.3	750.1	750.1
TOTALS	3752.3	2621.5	0.0	0.0	78.4	1987.3	3562.8	-523.0	-523.0

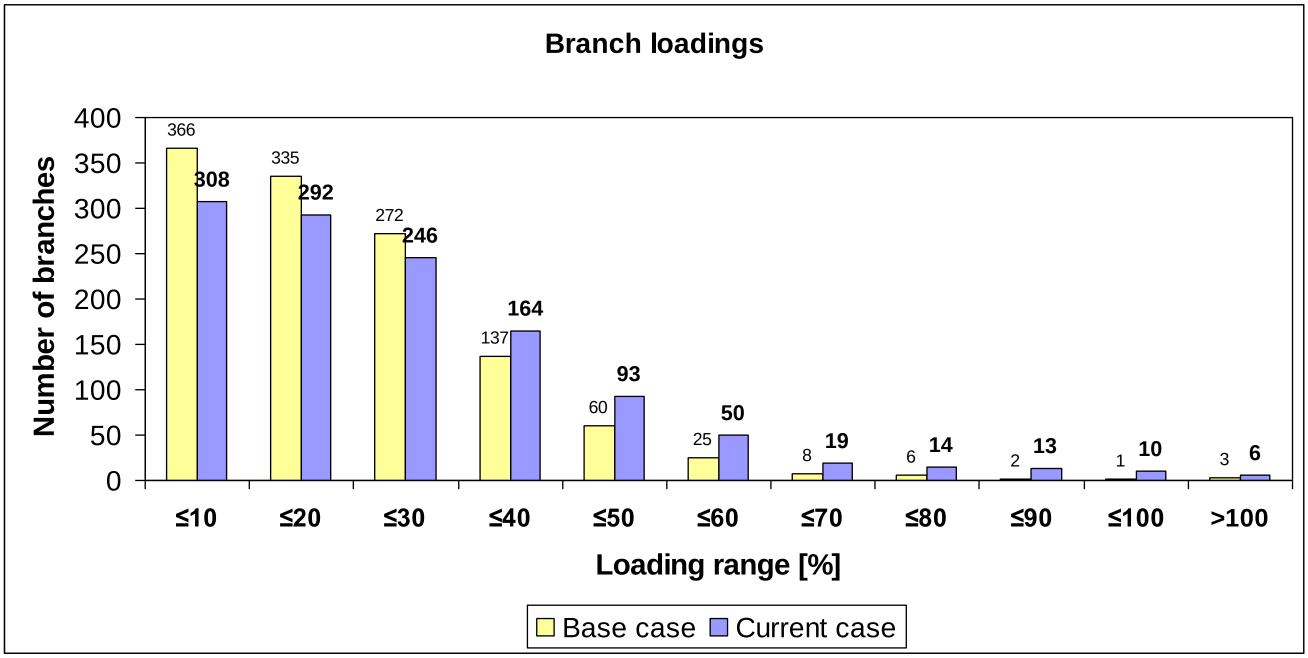


Figure 9-11 Branch loadings in analyzed region

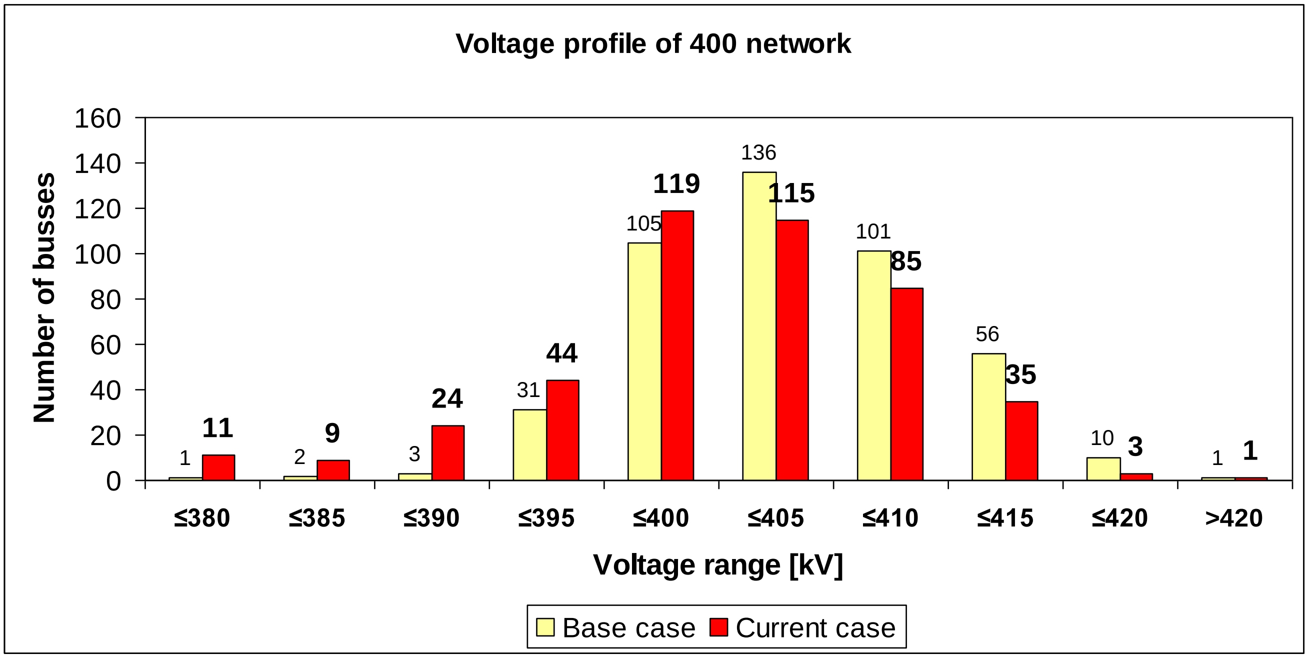
Table 9-23 Branches loaded over 80% of their thermal limits

FRMBUS,	FROMBUSEXNAME,	TOBUS,	TOBUSEXNAME,	CKT,	STS,	MW,	MVAR,	MVA,	%I	
10006,	AVDEJA2 220.00,	10005,	AKOMAN2 220.00,	1 ,	1,	-324.51,	-3.86,	324.53,	98.66	
10006,	AVDEJA2 220.00,	10016,	AKOPLI2 220.00,	1 ,	1,	275.91,	-15.98,	276.37,	98.28	
10016,	AKOPLI2 220.00,	88,	XKO_PO21 220.00,	1 ,	1,	256.75,	-35.82,	259.24,	92.84	
12474,	VMI 1 400.00,	12274,	VMI 2 220.00,	1 ,	1,	574.62,	162.95,	597.28,	92.14	
14201,	WPRIJ22 220.00,	111,	XPR_MR21 220.00,	1 ,	1,	258.61,	-42.83,	262.14,	83.92	
20097,	HMELIN11 400.00,	71,	XME_DI11 400.00,	1 ,	1,	1035.57,	78.80,	1038.57,	82.79	
20168,	HTE SI21 220.00,	111,	XPR_MR21 220.00,	2 ,	1,	-252.25,	61.42,	259.62,	88.83	
20168,	HTE SI21 220.00,	20103,	HMRACL21 220.00,	2 ,	1,	311.33,	1.61,	311.34,	106.53	*
20502,	HBRINJ11 400.00,	20097,	HMELIN11 400.00,	1 ,	1,	1095.56,	-52.12,	1096.80,	86.59	
28002,	RURECH1 400.00,	28045,	RURECH2 220.00,	1 ,	1,	354.75,	177.62,	396.73,	95.81	
28008,	RARAD 1 400.00,	29007,	RARAD2 220.00,	1 ,	1,	-286.41,	124.49,	312.29,	83.11	
28052,	RRESIT2A 220.00,	28047,	RP.D.F2A 220.00,	1 ,	1,	-265.87,	20.42,	266.65,	80.01	
28052,	RRESIT2A 220.00,	28047,	RP.D.F2A 220.00,	2 ,	1,	-265.87,	20.42,	266.65,	80.01	
28062,	RTG.JI2 220.00,	28045,	RURECH2 220.00,	1 ,	1,	-268.90,	-41.76,	272.12,	87.24	
28063,	RPAROS2 220.00,	28062,	RTG.JI2 220.00,	1 ,	1,	-271.15,	9.42,	271.31,	88.36	
28064,	RBARU 2 220.00,	28063,	RPAROS2 220.00,	1 ,	1,	-254.26,	52.39,	259.60,	84.53	
28065,	RHAJD 2 220.00,	28064,	RBARU 2 220.00,	1 ,	1,	-278.11,	70.01,	286.79,	85.16	
28071,	RTIMIS2 220.00,	28052,	RRESIT2A 220.00,	1 ,	1,	-304.62,	10.91,	304.81,	95.58	
28071,	RTIMIS2 220.00,	28052,	RRESIT2A 220.00,	2 ,	1,	-304.62,	10.91,	304.81,	95.58	
28087,	RIERNU2 220.00,	28036,	RIERNU1 400.00,	1 ,	1,	-329.08,	-45.79,	332.25,	85.39	
29007,	RARAD2 220.00,	28071,	RTIMIS2 220.00,	1 ,	1,	-258.73,	49.82,	263.48,	82.93	
31405,	LOKROG1 400.00,	503,	XUD_OK11 400.00,	1 ,	1,	1257.70,	210.31,	1275.16,	103.32	*
31405,	LOKROG1 400.00,	31438,	LHAVCE1 400.00,	1 ,	1,	1120.15,	151.15,	1130.30,	91.58	
31410,	LDIVAC1 400.00,	71,	XME_DI11 400.00,	1 ,	1,	-1021.69,	40.36,	1022.48,	97.15	
31430,	LBERIC1 400.00,	31405,	LOKROG1 400.00,	1 ,	1,	1229.23,	288.68,	1262.67,	119.46	*
31430,	LBERIC1 400.00,	31405,	LOKROG1 400.00,	2 ,	1,	1229.23,	288.68,	1262.67,	119.46	*
31438,	LHAVCE1 400.00,	504,	XUD_AV11 400.00,	1 ,	1,	1332.13,	85.21,	1334.85,	110.80	*
34045,	JSMIT21 400.00,	34040,	JRPMLA1 400.00,	1 ,	1,	-1447.49,	132.23,	1453.52,	112.61	*
36015,	0PODG121 220.00,	88,	XKO_PO21 220.00,	1 ,	1,	-252.58,	53.04,	258.09,	93.82	

Total 29 items

Table 9-24 Significant changes of branch flows in comparison against base case scenario

X------- FROM BUS		--------X	X-------- TO BUS		---------X	CKT	IN WORKING CASE MW	MVAR	IN Winter MAX 2020 - Base Case MW	MVAR	DELTA MW	%
84	[XRO_MU11	400.00]	28039	[RROSIO1	400.00]	1	-782.2	298.6	-72.6	72.9	709.6	90.7
34040	[JRPMLA1	400.00]	34045	[JSMIT21	400.00]	1	1473.6	138.8	904.6	-65.4	-569.0	38.6
28037	[RGADAL1	400.00]	28039	[RROSIO1	400.00]	1	881.2	-4.7	320.5	-67.1	-560.7	63.6
24	[XSO_NI11	400.00]	12431	[VSOFIW1	400.00]	1	-856.2	-52.3	-334.4	-40.6	521.8	60.9
24	[XSO_NI11	400.00]	34020	[JNIS2 1	400.00]	1	856.2	52.3	334.4	40.6	-521.8	60.9
14406	[WVISEG1	400.00]	16402	[WTUZL41	400.00]	1	851.4	-21.0	436.0	-71.3	-415.4	48.8
28031	[RBRASO1	400.00]	28034	[RSIBIU1	400.00]	1	586.4	-23.1	172.7	-136.8	-413.7	70.5
24033	[MPAKS 11	400.00]	24039	[MSAFA 11	400.00]	1	-463.3	235.7	-51.4	142.8	411.9	88.9
26064	[YSK 41	400.00]	26111	[YSK 5 1	400.00]	1	505.6	16.4	97.5	35.2	-408.1	80.7
28973	[RCERNA1	400.00]	28974	[RMEDGI1	400.00]	1	419.2	168.5	823.5	134.1	404.3	96.4
34020	[JNIS2 1	400.00]	34079	[JJAGO41	400.00]	1	575.3	3.5	174.7	-15.0	-400.6	69.6
198	[XMI_HA11	400.00]	12471	[VMI3 11	400.00]	1	12.5	-113.1	-387.0	-93.7	-399.4	999.9
34031	[JOBREN12	400.00]	34040	[JRPMLA1	400.00]	1	619.5	7.2	220.9	-108.3	-398.6	64.3
74	[XER_SM11	400.00]	20037	[HERNES11	400.00]	1	899.1	-82.0	503.8	-100.4	-395.3	44.0
74	[XER_SM11	400.00]	34045	[JSMIT21	400.00]	1	-899.1	82.0	-503.8	100.4	395.3	44.0
34030	[JOBREN11	400.00]	34040	[JRPMLA1	400.00]	2	614.1	7.6	219.0	-107.2	-395.1	64.3
184	[XRI_PE11	400.00]	36001	[0RIBAR11	400.00]	1	530.6	-66.1	138.1	-56.8	-392.5	74.0
184	[XRI_PE11	400.00]	34086	[JPEC 31	400.00]	1	-530.6	66.1	-138.1	56.8	392.5	74.0
34071	[JTKOSC1	400.00]	34086	[JPEC 31	400.00]	A	684.3	26.6	296.3	-14.7	-388.0	56.7
206	[XFL_BI11	400.00]	26005	[YBITOL1	400.00]	1	447.6	5.4	61.2	5.8	-386.4	86.3
220	[XKA_PG11	400.00]	10143	[ALEZHA1	400.00]	1	-629.1	15.5	-251.0	-27.3	378.1	60.1
220	[XKA_PG11	400.00]	36005	[0PODG211	400.00]	1	629.1	-15.5	251.0	27.3	-378.1	60.1
24004	[MBEKO 11	400.00]	24048	[MSZOL 11	400.00]	1	492.3	-181.0	120.1	-102.1	-372.2	75.6
36010	[0PLJE211	400.00]	36012	[0MAOCE11	400.00]	1	-441.6	81.9	-71.0	74.1	370.6	83.9
28003	[RMINTI1A	400.00]	28008	[RARAD 1	400.00]	1	723.9	56.3	354.8	-59.9	-369.2	51.0
24001	[MAISA 11	400.00]	24048	[MSZOL 11	400.00]	1	-345.8	212.2	20.1	74.0	366.0	105.8
34015	[JKRAG21	400.00]	34079	[JJAGO41	400.00]	1	-385.4	59.6	-21.0	10.5	364.4	94.6
36001	[0RIBAR11	400.00]	36012	[0MAOCE11	400.00]	1	193.2	-127.3	-167.9	-86.9	-361.1	186.9
34001	[JBGD8 1	400.00]	34030	[JOBREN11	400.00]	1	538.1	-155.8	180.0	-171.8	-358.1	66.6
13	[XTR_PG11	400.00]	14405	[WTREBI1	400.00]	1	190.4	-229.2	-167.3	-154.6	-357.6	187.9
13	[XTR_PG11	400.00]	36017	[0LASTV11	400.00]	A	-190.4	229.2	167.3	154.6	357.6	187.9
28002	[RURECH1	400.00]	28004	[RP.D.F1	400.00]	1	315.3	53.0	-30.2	35.0	-345.5	109.6
79	[XSA_SU11	400.00]	34050	[JSUBO31	400.00]	1	-527.8	172.4	-183.8	201.7	344.0	65.2
79	[XSA_SU11	400.00]	24039	[MSAFA 11	400.00]	1	527.8	-172.4	183.8	-201.7	-344.0	65.2
10014	[ATIRA21	400.00]	10145	[AELBA31	400.00]	1	-527.0	-73.6	-189.2	-104.2	337.9	64.1
20097	[HMELIN11	400.00]	20502	[HBRINJ11	400.00]	1	-1079.1	191.1	-751.3	79.3	327.8	30.4
11	[XMO_KO11	400.00]	20078	[HKONJS11	400.00]	1	730.2	12.2	404.7	26.5	-325.5	44.6
11	[XMO_KO11	400.00]	18401	[WMOST41	400.00]	1	-730.2	-12.2	-404.7	-26.5	325.5	44.6
28034	[RSIBIU1	400.00]	28036	[RIERNU1	400.00]	1	745.6	39.9	423.3	-29.3	-322.3	43.2
36005	[0PODG211	400.00]	36017	[0LASTV11	400.00]	A	770.7	-16.3	455.9	-4.3	-314.8	40.8
2	[XZE_KA11	400.00]	10020	[AZEMLA1	400.00]	1	535.1	2.9	222.9	-2.7	-312.3	58.4
28003	[RMINTI1A	400.00]	28034	[RSIBIU1	400.00]	1	-509.1	61.5	-197.8	-4.6	311.3	61.2
28008	[RARAD 1	400.00]	28009	[RNADAB1B	400.00]	1	595.1	-122.5	284.8	-83.7	-310.4	52.1
34050	[JSUBO31	400.00]	34078	[JSRBOB1	400.00]	A	-801.6	51.1	-494.5	104.7	307.1	38.3
20037	[HERNES11	400.00]	20203	[HZERJA11	400.00]	1	970.0	93.1	665.0	-6.8	-305.0	31.4
34031	[JOBREN12	400.00]	34088	[JTKOLB1	400.00]	1	-641.4	-70.8	-338.3	-13.0	303.1	47.3
14404	[WTGACK1	400.00]	18401	[WMOST41	400.00]	1	497.7	-17.4	196.8	-32.8	-300.8	60.5
28014	[RSUCEA1A	400.00]	28027	[RBISTR1	400.00]	1	374.3	-61.1	74.0	-100.6	-300.3	80.2
24024	[MLITR 11	400.00]	24033	[MPAKS 11	400.00]	1	-898.7	163.3	-600.3	-4.6	298.3	33.2
28027	[RBISTR1	400.00]	28037	[RGADAL1	400.00]	1	369.5	-25.4	72.8	-21.7	-296.7	80.3
219	[XNA_BE11	400.00]	24004	[MBEKO 11	400.00]	1	539.0	-90.3	242.3	-66.6	-296.7	55.0
219	[XNA_BE11	400.00]	28009	[RNADAB1B	400.00]	1	-539.0	90.3	-242.3	66.6	296.7	55.0
197	[XMI_BA11	400.00]	12471	[VMI3 11	400.00]	1	7.4	-77.7	-287.0	-58.7	-294.3	999.9
14401	[WBLUK61	400.00]	14410	[WTSTAN1	400.00]	1	-918.2	10.8	-624.6	-2.4	293.5	32.0
71	[XME_DI11	400.00]	31410	[LDIVAC1	400.00]	1	1029.9	31.5	738.1	92.8	-291.8	28.3
71	[XME_DI11	400.00]	20097	[HMELIN11	400.00]	1	-1029.9	-31.5	-738.1	-92.8	291.8	28.3
24019	[MGYOR 11	400.00]	24024	[MLITR 11	400.00]	1	-450.2	182.0	-164.1	9.5	286.1	63.5
34025	[JNSAD31	400.00]	34078	[JSRBOB1	400.00]	A	904.3	120.3	619.5	-26.7	-284.8	31.5
28004	[RP.D.F1	400.00]	28018	[RRESIT1A	400.00]	1	715.0	66.4	431.9	16.3	-283.1	39.6
28036	[RIERNU1	400.00]	28037	[RGADAL1	400.00]	1	403.8	-105.7	123.2	-72.1	-280.5	69.5



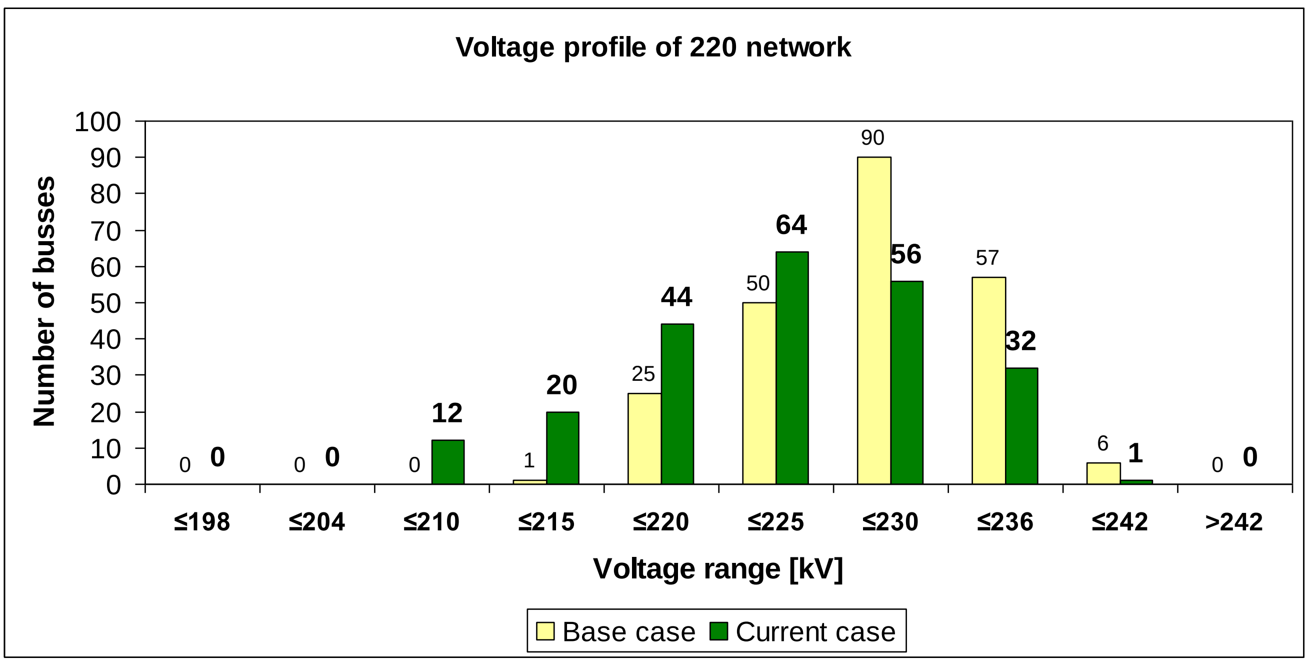


Figure 9-12 Voltage profile of 400 and 220 kV network in analyzed region

9.7. Winter MAXIMUM 2020, Scenario 3 (Continental SEE + Black Sea (Max) → Adriatic (Min))

Table 9-25 Area summary of analyzed region

FROM	TO LOAD	TO	-NET INTERCHANGE-

X-- AREA --X	GENE- RATION	AT AREA BUSES	TO BUS SHUNT	GNE BUS DEVICES	TO LINE SHUNT	FROM CHARGING	TO LOSSES	TO TIE LINES	TO TIES + LOADS	DESIRED NET INT
10	1777.6	1765.2	0.0	0.0	0.0	0.0	69.4	-57.0	-57.0	-57.0
AL	578.7	636.1	-103.4	0.0	0.0	572.2	616.3	1.9	1.9	
20	10177.3	8393.4	0.0	0.0	15.4	0.0	243.5	1525.0	1525.0	1525.0
BG	3769.9	3343.1	230.9	0.0	181.8	3294.3	3160.8	147.5	147.5	
30	3524.2	2662.5	0.0	0.0	0.6	0.0	207.2	654.0	654.0	654.0
BA	1562.9	207.8	0.0	0.0	1.2	907.3	1735.9	525.3	525.3	
40	3399.1	4436.2	0.0	0.0	0.0	0.0	279.0	-1316.1	-1316.1	-1316.0
HR	1743.1	1114.4	0.0	0.0	0.0	1452.7	2537.1	-455.6	-455.6	
50	13765.3	13426.0	0.0	0.0	0.0	0.0	339.3	0.0	0.0	0.0
GR	2726.1	5067.4	204.0	0.0	23.1	6678.7	4031.9	78.4	78.4	
60	1910.2	1974.4	0.0	0.0	0.2	0.0	35.6	-100.0	-100.0	-100.0
MK	608.7	609.6	0.0	0.0	2.4	463.5	405.3	54.9	54.9	
70	13517.4	10176.3	0.0	0.0	87.4	0.0	479.6	2774.0	2774.0	2774.0
RO	2407.2	3213.2	0.0	0.0	263.1	5394.6	4865.1	-539.7	-539.7	
75	4444.7	2887.0	0.0	0.0	9.2	0.0	233.6	1314.9	1314.9	1315.0
SI	2801.0	863.0	0.0	0.0	57.4	797.2	2688.4	-10.4	-10.4	
80	78527.0	77342.9	0.0	0.0	0.0	0.0	917.1	267.0	267.0	267.0
TR	6385.4	11034.0	998.6	0.0	0.0	22789.2	17419.7	-277.7	-277.7	
90	9542.5	7867.4	0.0	0.0	12.3	0.0	344.9	1318.0	1318.0	1318.0
RS	3871.6	2621.5	0.0	0.0	78.1	1978.4	3775.5	-625.1	-625.1	
91	1600.7	1022.9	0.5	0.0	3.5	0.0	52.8	521.0	521.0	521.0
ME	519.4	365.1	-31.7	0.0	20.6	401.6	565.9	1.1	1.1	
COLUMN	142186.1	131954.3	0.5	0.0	128.5	0.0	3202.0	6900.7	6900.7	6901.0
TOTALS	26974.1	29075.2	1298.5	0.0	627.8	44729.7	41801.7	-1099.4	-1099.4	

Table 9-26 Zone summary in Serbia

	FROM	TO LOAD		TO				-NET INTERCHANGE-	
X-- ZONE --X	GENE- RATION	AT ZONE BUSES	TO BUS SHUNT	GNE BUS DEVICES	TO LINE SHUNT	FROM CHARGING	TO LOSSES	TO TIE LINES	TO TIES + LOADS
90	8089.5	6544.7	0.0	0.0	10.0	0.0	308.1	1226.8	1226.8
EMS	3164.8	2167.2	0.0	0.0	65.3	1692.3	3342.9	-718.3	-718.3
901	1453.0	1322.7	0.0	0.0	2.3	0.0	36.8	91.2	91.2
KOSTT	706.8	454.3	0.0	0.0	12.8	286.1	432.6	93.2	93.2
COLUMN	9542.5	7867.4	0.0	0.0	12.3	0.0	344.9	1318.0	1318.0
TOTALS	3871.6	2621.5	0.0	0.0	78.1	1978.4	3775.5	-625.2	-625.2

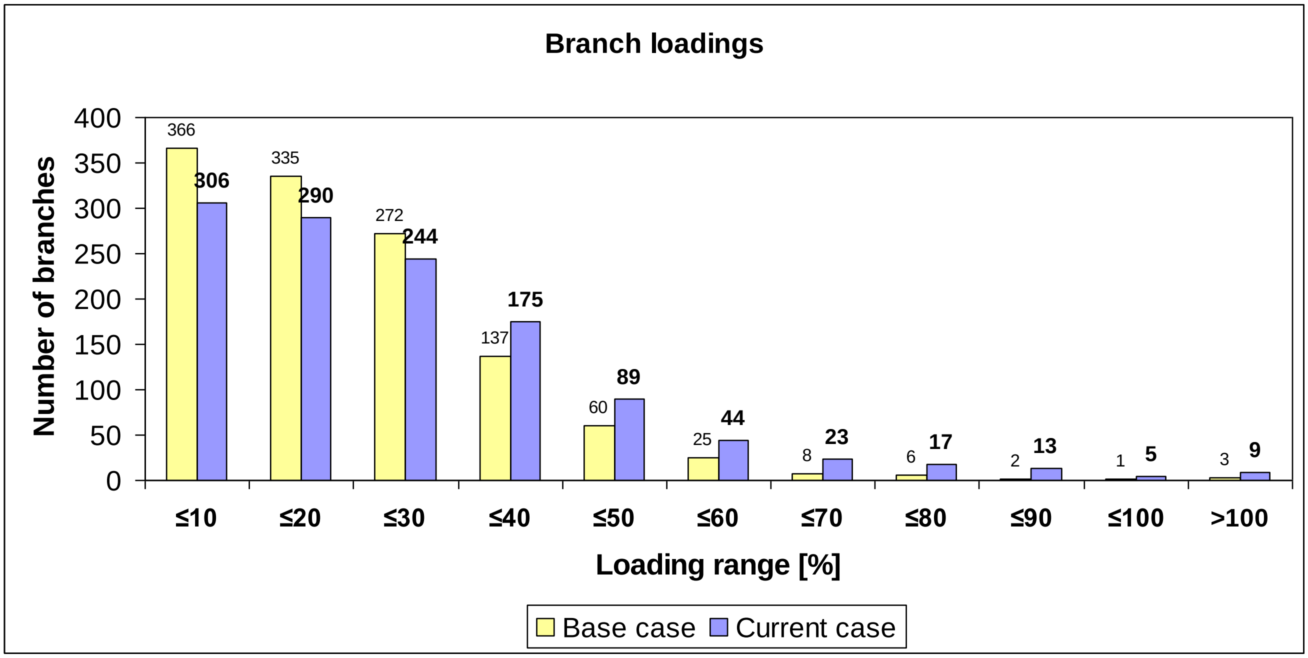


Figure 9-13 Branch loadings in analyzed region

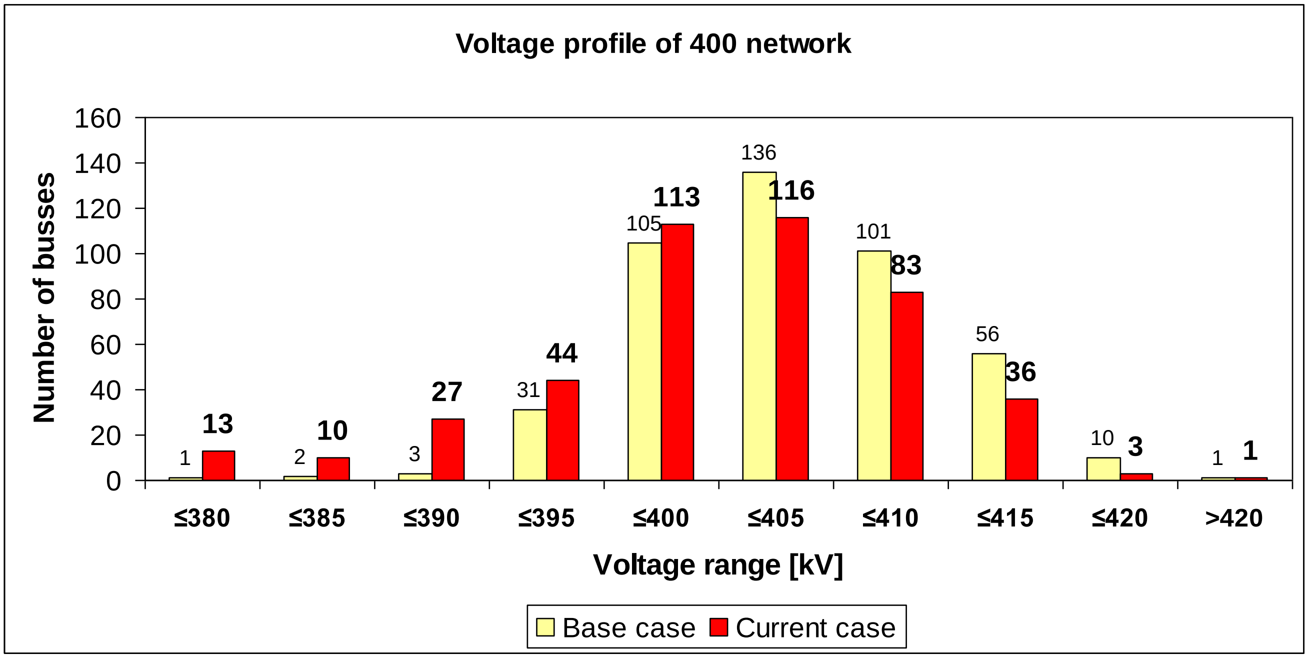
Table 9-27 Branches loaded over 80% of their thermal limits

FRMBUS,	FROMBUSEXNAME,	TOBUS,	TOBUSEXNAME,	CKT,	STS,	MW,	MVAR,	MVA,	%I	
10006,	AVDEJA2 220.00,	10005,	AKOMAN2 220.00,	1 ,	1,	-317.56,	-1.55,	317.56,	96.32	
10006,	AVDEJA2 220.00,	10016,	AKOPLI2 220.00,	1 ,	1,	250.35,	-14.74,	250.78,	88.97	
10016,	AKOPLI2 220.00,	88,	XKO_PO21 220.00,	1 ,	1,	231.81,	-31.35,	233.92,	83.53	
12474,	VMI 1 400.00,	12274,	VMI 2 220.00,	1 ,	1,	558.95,	161.80,	581.90,	89.77	
14201,	WPRIJ22 220.00,	111,	XPR_MR21 220.00,	1 ,	1,	263.78,	-39.07,	266.66,	86.08	
20097,	HMELIN11 400.00,	71,	XME_DI11 400.00,	1 ,	1,	1088.20,	108.52,	1093.59,	88.29	
20168,	HTE SI21 220.00,	111,	XPR_MR21 220.00,	2 ,	1,	-257.08,	59.13,	263.80,	91.18	
20168,	HTE SI21 220.00,	20103,	HMRACL21 220.00,	2 ,	1,	318.00,	4.29,	318.03,	109.92	*
20502,	HBRINJ11 400.00,	20097,	HMELIN11 400.00,	1 ,	1,	1133.52,	-28.08,	1133.86,	90.41	
28002,	RURECH1 400.00,	28045,	RURECH2 220.00,	1 ,	1,	363.01,	179.00,	404.74,	97.68	
28008,	RARAD 1 400.00,	29007,	RARAD2 220.00,	1 ,	1,	-307.37,	134.15,	335.37,	89.71	
28062,	RTG.JI2 220.00,	28045,	RURECH2 220.00,	1 ,	1,	-270.69,	-42.66,	274.03,	87.82	
28063,	RPAROS2 220.00,	28062,	RTG.JI2 220.00,	1 ,	1,	-272.10,	8.19,	272.22,	88.67	
28064,	RBARU 2 220.00,	28063,	RPAROS2 220.00,	1 ,	1,	-255.11,	51.21,	260.20,	84.75	
28065,	RHAJD 2 220.00,	28064,	RBARU 2 220.00,	1 ,	1,	-279.02,	68.84,	287.38,	85.41	
28071,	RTIMIS2 220.00,	28052,	RRESIT2A 220.00,	1 ,	1,	-325.77,	12.48,	326.01,	102.92	*
28071,	RTIMIS2 220.00,	28052,	RRESIT2A 220.00,	2 ,	1,	-325.77,	12.48,	326.01,	102.92	*
28087,	RIERNU2 220.00,	28036,	RIERNU1 400.00,	1 ,	1,	-329.00,	-45.70,	332.16,	85.22	
29007,	RARAD2 220.00,	28071,	RTIMIS2 220.00,	1 ,	1,	-273.56,	52.81,	278.61,	88.38	
31405,	LOKROG1 400.00,	503,	XUD_OK11 400.00,	1 ,	1,	1301.45,	237.75,	1322.99,	109.25	*
31405,	LOKROG1 400.00,	31438,	LHAVCE1 400.00,	1 ,	1,	1163.65,	175.72,	1176.85,	97.19	
31410,	LDIVAC1 400.00,	71,	XME_DI11 400.00,	1 ,	1,	-1072.39,	31.89,	1072.87,	103.65	*
31430,	LBERIC1 400.00,	31405,	LOKROG1 400.00,	1 ,	1,	1270.57,	326.27,	1311.80,	126.02	*
31430,	LBERIC1 400.00,	31405,	LOKROG1 400.00,	2 ,	1,	1270.57,	326.27,	1311.80,	126.02	*
31438,	LHAVCE1 400.00,	504,	XUD_AV11 400.00,	1 ,	1,	1374.79,	90.66,	1377.78,	116.95	*
34045,	JSMIT21 400.00,	34040,	JRPMLA1 400.00,	1 ,	1,	-1513.47,	135.74,	1519.54,	118.64	*
36015,	0PODG121 220.00,	88,	XKO_PO21 220.00,	1 ,	1,	-228.44,	44.32,	232.70,	84.40	

Total 27 items

Table 9-28: Significant changes of branch flows in comparison against base case scenario

X------- FROM BUS		--------X	X-------- TO BUS		---------X	CKT	IN WORKING CASE MW	MVAR	IN Winter MAX 2020 - Base Case MW	MVAR	DELTA MW	%
11	[XMO_KO11	400.00]	18401	[WMOST41	400.00]	1	-743.7	-15.8	-404.7	-26.5	339.0	45.6
11	[XMO_KO11	400.00]	20078	[HKONJS11	400.00]	1	743.7	15.8	404.7	26.5	-339.0	45.6
13	[XTR_PG11	400.00]	14405	[WTREBI1	400.00]	1	182.3	-221.8	-167.3	-154.6	-349.6	191.8
13	[XTR_PG11	400.00]	36017	[0LASTV11	400.00]	A	-182.3	221.8	167.3	154.6	349.6	191.8
24	[XSO_NI11	400.00]	12431	[VSOFIW1	400.00]	1	-782.2	-53.5	-334.4	-40.6	447.8	57.3
24	[XSO_NI11	400.00]	34020	[JNIS2 1	400.00]	1	782.2	53.5	334.4	40.6	-447.8	57.3
71	[XME_DI11	400.00]	20097	[HMELIN11	400.00]	1	-1081.7	-52.5	-738.1	-92.8	343.7	31.8
71	[XME_DI11	400.00]	31410	[LDIVAC1	400.00]	1	1081.7	52.5	738.1	92.8	-343.7	31.8
74	[XER_SM11	400.00]	20037	[HERNES11	400.00]	1	926.0	-81.5	503.8	-100.4	-422.2	45.6
74	[XER_SM11	400.00]	34045	[JSMIT21	400.00]	1	-926.0	81.5	-503.8	100.4	422.2	45.6
79	[XSA_SU11	400.00]	24039	[MSAFA 11	400.00]	1	554.0	-179.5	183.8	-201.7	-370.2	66.8
79	[XSA_SU11	400.00]	34050	[JSUBO31	400.00]	1	-554.0	179.5	-183.8	201.7	370.2	66.8
84	[XRO_MU11	400.00]	28039	[RROSIO1	400.00]	1	-782.2	298.7	-72.6	72.9	709.6	90.7
130	[XVI_BB1	400.00]	14406	[WVISEG1	400.00]	1	640.1	-109.4	316.5	-113.1	-323.6	50.6
130	[XVI_BB1	400.00]	34085	[JBBAST1	400.00]	1	-640.1	109.4	-316.5	113.1	323.6	50.6
184	[XRI_PE11	400.00]	34086	[JPEC 31	400.00]	1	-486.8	56.8	-138.1	56.8	348.7	71.6
184	[XRI_PE11	400.00]	36001	[0RIBAR11	400.00]	1	486.8	-56.8	138.1	-56.8	-348.7	71.6
198	[XMI_HA11	400.00]	12471	[VMI3 11	400.00]	1	-29.2	-110.3	-387.0	-93.7	-357.8	999.9
219	[XNA_BE11	400.00]	24004	[MBEKO 11	400.00]	1	542.6	-83.6	242.3	-66.6	-300.3	55.3
219	[XNA_BE11	400.00]	28009	[RNADAB1B	400.00]	1	-542.6	83.6	-242.3	66.6	300.3	55.3
220	[XKA_PG11	400.00]	10143	[ALEZHA1	400.00]	1	-557.9	-3.8	-251.0	-27.3	306.9	55.0
220	[XKA_PG11	400.00]	36005	[0PODG211	400.00]	1	557.9	3.8	251.0	27.3	-306.9	55.0
510	[XTU_BL11	400.00]	14401	[WBLUK61	400.00]	1	-629.7	50.1	-326.2	6.6	303.5	48.2
510	[XTU_BL11	400.00]	20503	[HLIKA11	400.00]	1	629.7	-50.1	326.2	-6.6	-303.5	48.2
14401	[WBLUK61	400.00]	14410	[WTSTAN1	400.00]	1	-944.1	7.2	-624.6	-2.4	319.4	33.8
14406	[WVISEG1	400.00]	16402	[WTUZL41	400.00]	1	864.3	-12.6	436.0	-71.3	-428.2	49.5
20037	[HERNES11	400.00]	20203	[HZERJA11	400.00]	1	996.6	119.4	665.0	-6.8	-331.6	33.3
20097	[HMELIN11	400.00]	20502	[HBRINJ11	400.00]	1	-1115.6	183.6	-751.3	79.3	364.2	32.7
24001	[MAISA 11	400.00]	24048	[MSZOL 11	400.00]	1	-353.9	215.7	20.1	74.0	374.1	105.7
24004	[MBEKO 11	400.00]	24048	[MSZOL 11	400.00]	1	499.7	-182.8	120.1	-102.1	-379.6	76.0
24024	[MLITR 11	400.00]	24033	[MPAKS 11	400.00]	1	-901.3	169.0	-600.3	-4.6	300.9	33.4
24033	[MPAKS 11	400.00]	24039	[MSAFA 11	400.00]	1	-484.1	235.8	-51.4	142.8	432.7	89.4
28003	[RMINTI1A	400.00]	28008	[RARAD 1	400.00]	1	709.3	69.4	354.8	-59.9	-354.6	50.0
28008	[RARAD 1	400.00]	28009	[RNADAB1B	400.00]	1	605.8	-126.0	284.8	-83.7	-321.0	53.0
28031	[RBRASO1	400.00]	28034	[RSIBIU1	400.00]	1	568.0	-22.7	172.7	-136.8	-395.3	69.6
28034	[RSIBIU1	400.00]	28036	[RIERNU1	400.00]	1	737.4	41.8	423.3	-29.3	-314.1	42.6
28037	[RGADAL1	400.00]	28039	[RROSIO1	400.00]	1	875.3	-0.5	320.5	-67.1	-554.8	63.4
28973	[RCERNA1	400.00]	28974	[RMEDGI1	400.00]	1	461.5	166.2	823.5	134.1	362.0	78.5
34001	[JBGD8 1	400.00]	34030	[JOBREN11	400.00]	1	720.5	-157.0	180.0	-171.8	-540.5	75.0
34001	[JBGD8 1	400.00]	34075	[JBGD201	400.00]	A	-492.4	51.2	-126.2	42.5	366.2	74.4
34015	[JKRAG21	400.00]	34079	[JJAGO41	400.00]	1	-333.7	43.8	-21.0	10.5	312.7	93.7
34020	[JNIS2 1	400.00]	34079	[JJAGO41	400.00]	1	506.5	5.2	174.7	-15.0	-331.8	65.5
34025	[JNSAD31	400.00]	34078	[JSRBOB1	400.00]	A	923.4	130.8	619.5	-26.7	-303.9	32.9
34030	[JOBREN11	400.00]	34040	[JRPMLA1	400.00]	2	646.0	32.4	219.0	-107.2	-427.0	66.1
34031	[JOBREN12	400.00]	34040	[JRPMLA1	400.00]	1	651.7	32.3	220.9	-108.3	-430.8	66.1
34035	[JPANC21	400.00]	34075	[JBGD201	400.00]	A	822.8	2.0	443.5	-36.8	-379.4	46.1
34040	[JRPMLA1	400.00]	34045	[JSMIT21	400.00]	1	1542.4	169.0	904.6	-65.4	-637.8	41.4
34050	[JSUBO31	400.00]	34078	[JSRBOB1	400.00]	A	-824.6	52.9	-494.5	104.7	330.1	40.0
34071	[JTKOSC1	400.00]	34086	[JPEC 31	400.00]	A	636.7	26.4	296.3	-14.7	-340.4	53.5



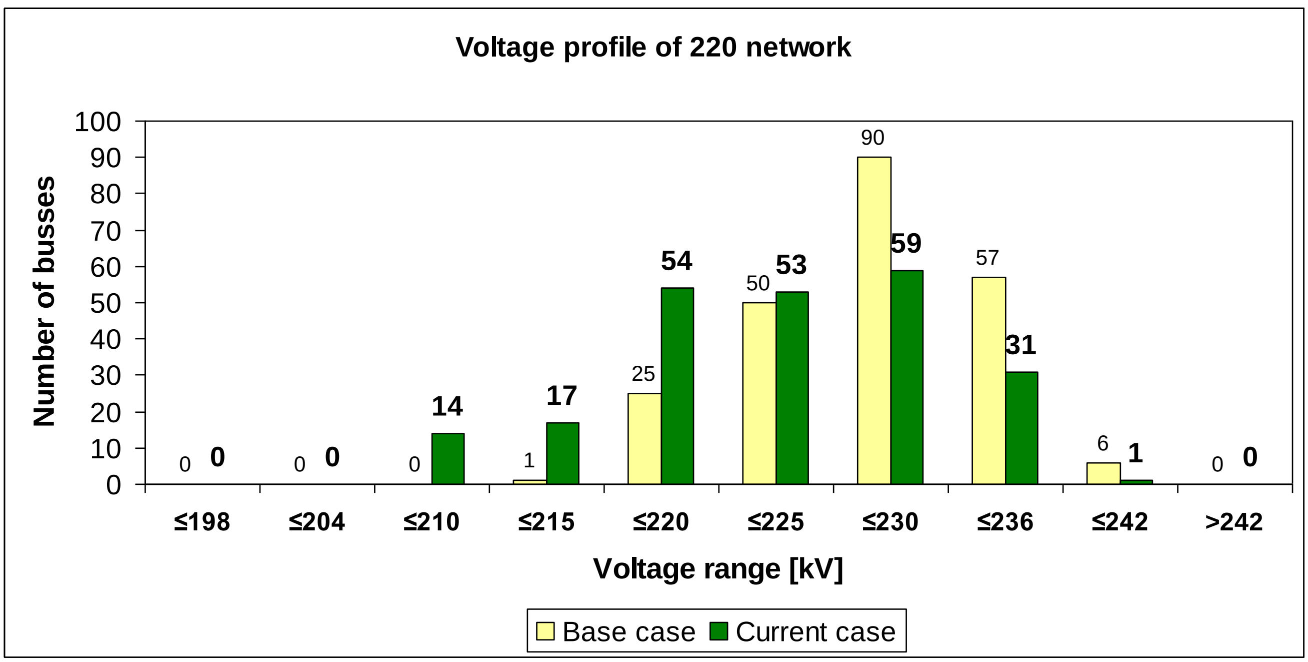


Figure 9-14 Voltage profile of 400 and 220 kV network in analyzed region

9.8. Winter MAXIMUM 2020, Scenario 4 (All regions (Max) → rest of ENTSO-E)

Table 9-29 Area summary of analyzed region

```
                FROM  TO LOAD           TO                                  -NET INTERCHANGE-
               GENE-  AT AREA   TO BUS  GNE BUS  TO LINE     FROM      TO     TO TIE  TO TIES  DESIRED
```

X-- AREA --X	RATION	BUSES	SHUNT	DEVICES	SHUNT	CHARGING	LOSSES	LINES	+ LOADS	NET INT
10	1925.5	1765.2	0.0	0.0	0.0	0.0	80.3	80.0	80.0	80.0
AL	640.7	636.1	-106.2	0.0	0.0	571.4	716.6	-34.5	-34.5	
20	10169.5	8393.4	0.0	0.0	15.5	0.0	235.6	1525.0	1525.0	1525.0
BG	3921.8	3343.1	234.9	0.0	181.3	3306.3	3081.7	387.1	387.1	
30	3820.3	2662.5	0.0	0.0	0.6	0.0	272.8	884.3	884.3	884.0
BA	1679.2	207.8	0.0	0.0	1.2	901.1	1997.6	373.8	373.8	
40	4281.5	4436.2	0.0	0.0	0.0	0.0	401.8	-556.6	-556.6	-557.0
HR	2266.3	1114.4	0.0	0.0	0.0	1454.4	3570.1	-963.8	-963.8	
50	14440.0	13426.0	0.0	0.0	0.0	0.0	324.0	690.0	690.0	690.0
GR	2549.0	5067.4	203.8	0.0	23.2	6688.1	3863.6	79.1	79.1	
60	1969.7	1974.4	0.0	0.0	0.2	0.0	43.1	-48.0	-48.0	-48.0
MK	553.8	609.6	0.0	0.0	2.4	458.7	461.0	-60.5	-60.5	
70	13700.2	10176.3	0.0	0.0	85.9	0.0	663.4	2774.6	2774.6	2774.0
RO	3466.6	3213.2	0.0	0.0	257.6	5307.4	6384.5	-1081.3	-1081.3	
75	4744.1	2887.0	0.0	0.0	9.5	0.0	292.4	1555.2	1555.2	1555.0
SI	3747.0	863.0	0.0	0.0	59.2	816.7	3454.2	187.2	187.2	
80	78536.1	77342.9	0.4	0.0	0.0	0.0	938.8	254.0	254.0	254.0
TR	6865.9	11034.0	1045.0	0.0	0.0	22631.8	17771.8	-352.9	-352.9	
90	9593.4	7867.4	0.0	0.0	12.3	0.0	395.3	1318.4	1318.4	1318.0
RS	4558.1	2621.5	0.0	0.0	78.2	1976.9	4262.5	-427.2	-427.2	
91	1673.4	1022.9	0.5	0.0	3.5	0.0	55.5	591.0	591.0	591.0
ME	536.6	365.1	-31.6	0.0	20.5	399.8	598.8	-16.5	-16.5	
COLUMN	144853.7	131954.3	0.9	0.0	127.4	0.0	3703.0	9068.0	9068.0	9066.0
TOTALS	30785.0	29075.2	1345.9	0.0	623.7	44512.7	46162.4	-1909.5	-1909.5	

Table 9-30 Zone summary in Serbia

	FROM	TO LOAD		TO				-NET INTERCHANGE-	
	GENE-	AT ZONE	TO BUS	GNE BUS	TO LINE	FROM	TO	TO TIE	TO TIES
X-- ZONE --X	RATION	BUSES	SHUNT	DEVICES	SHUNT	CHARGING	LOSSES	LINES	+ LOADS
90	8140.4	6544.7	0.0	0.0	10.0	0.0	356.3	1229.4	1229.4
EMS	3771.3	2167.2	0.0	0.0	65.4	1690.7	3813.6	-584.2	-584.2
901	1453.0	1322.7	0.0	0.0	2.3	0.0	39.1	89.0	89.0
KOSTT	786.8	454.3	0.0	0.0	12.8	286.2	448.9	157.0	157.0
COLUMN	9593.4	7867.4	0.0	0.0	12.3	0.0	395.3	1318.4	1318.4
TOTALS	4558.1	2621.5	0.0	0.0	78.2	1976.9	4262.5	-427.2	-427.2

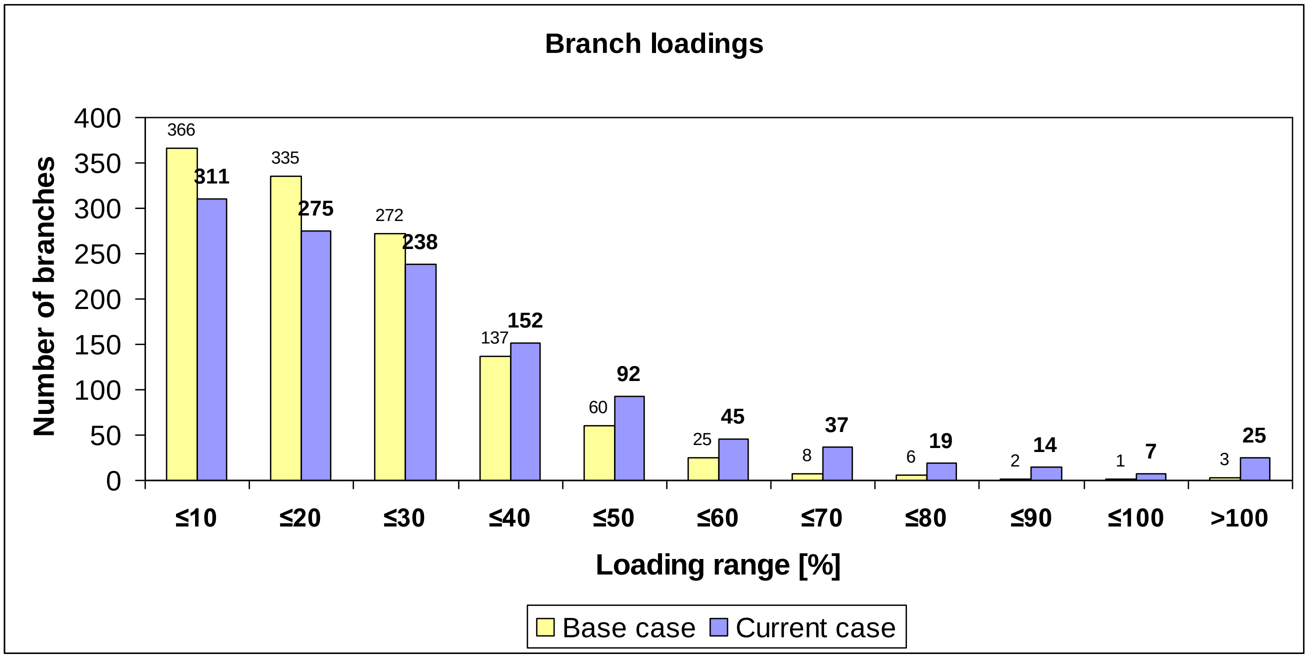


Figure 9-15 Branch loadings in analyzed region

Table 9-31 Branches loaded over 80% of their thermal limits

FRMBUS,	FROMBUSEXNAME,	TOBUS,	TOBUSEXNAME,	CKT,	STS,	MW,	MVAR,	MVA,	%I	
10006,	AVDEJA2 220.00,	10005,	AKOMAN2 220.00,	1 ,	1,	-332.76,	10.00,	332.91,	101.05	*
10006,	AVDEJA2 220.00,	10016,	AKOPLI2 220.00,	1 ,	1,	301.07,	-10.65,	301.25,	106.96	*
10016,	AKOPLI2 220.00,	88,	XKO_PO21 220.00,	1 ,	1,	281.27,	-33.76,	283.29,	101.50	*
12474,	VMI 1 400.00,	12274,	VMI 2 220.00,	1 ,	1,	578.33,	145.13,	596.26,	91.93	
14201,	WPRIJ22 220.00,	111,	XPR_MR21 220.00,	1 ,	1,	379.81,	-89.21,	390.15,	126.77	*
18202,	WJAJC22 220.00,	18200,	WHRAMA2 220.00,	1 ,	1,	-249.73,	14.52,	250.15,	82.97	
20037,	HERNES11 400.00,	74,	XER_SM11 400.00,	1 ,	1,	-1142.49,	273.68,	1174.81,	92.00	
20059,	HESENJ 220.00,	20096,	HMELIN21 220.00,	1 ,	1,	250.05,	-17.07,	250.63,	83.94	
20097,	HMELIN11 400.00,	71,	XME_DI11 400.00,	1 ,	1,	1399.10,	89.80,	1401.98,	114.32	*
20168,	HTE SI21 220.00,	111,	XPR_MR21 220.00,	2 ,	1,	-365.28,	140.53,	391.39,	134.22	*
20168,	HTE SI21 220.00,	20103,	HMRACL21 220.00,	1 ,	1,	242.91,	4.37,	242.95,	83.32	
20168,	HTE SI21 220.00,	20103,	HMRACL21 220.00,	2 ,	1,	393.84,	12.17,	394.03,	135.13	*
20202,	HZERJA21 220.00,	20103,	HMRACL21 220.00,	1 ,	1,	-243.73,	43.24,	247.54,	86.55	
20203,	HZERJA11 400.00,	20037,	HERNES11 400.00,	1 ,	1,	-1053.53,	365.75,	1115.22,	87.63	
20502,	HBRINJ11 400.00,	20097,	HMELIN11 400.00,	1 ,	1,	1544.47,	-34.62,	1544.86,	125.48	*
28002,	RURECH1 400.00,	28045,	RURECH2 220.00,	1 ,	1,	409.81,	244.05,	476.98,	115.87	*
28008,	RARAD 1 400.00,	29007,	RARAD2 220.00,	1 ,	1,	-369.41,	182.88,	412.20,	110.63	*
28018,	RRESIT1A 400.00,	28052,	RRESIT2A 220.00,	1 ,	1,	283.48,	192.77,	342.81,	87.04	
28039,	RROSIO1 400.00,	84,	XRO_MU11 400.00,	1 ,	1,	1078.10,	-250.25,	1106.76,	96.20	
28039,	RROSIO1 400.00,	28037,	RGADAL1 400.00,	1 ,	1,	-1035.56,	251.22,	1065.60,	92.62	
28052,	RRESIT2A 220.00,	28047,	RP.D.F2A 220.00,	1 ,	1,	-272.84,	11.10,	273.06,	83.86	
28052,	RRESIT2A 220.00,	28047,	RP.D.F2A 220.00,	2 ,	1,	-272.84,	11.10,	273.06,	83.86	
28062,	RTG.JI2 220.00,	28045,	RURECH2 220.00,	1 ,	1,	-321.15,	-60.73,	326.84,	107.96	*
28063,	RPAROS2 220.00,	28062,	RTG.JI2 220.00,	1 ,	1,	-330.19,	31.70,	331.71,	111.27	*
28064,	RBARU 2 220.00,	28063,	RPAROS2 220.00,	1 ,	1,	-302.85,	66.55,	310.08,	103.94	*
28065,	RHAJD 2 220.00,	28064,	RBARU 2 220.00,	1 ,	1,	-329.02,	113.83,	348.16,	105.33	*
28070,	RSACALZ2 220.00,	28071,	RTIMIS2 220.00,	1 ,	1,	-245.02,	20.36,	245.87,	80.21	
28071,	RTIMIS2 220.00,	28052,	RRESIT2A 220.00,	1 ,	1,	-371.88,	31.28,	373.19,	120.96	*
28071,	RTIMIS2 220.00,	28052,	RRESIT2A 220.00,	2 ,	1,	-371.88,	31.28,	373.19,	120.96	*
28084,	RGHEOR2 220.00,	28083,	RSTEJA2 220.00,	1 ,	1,	-230.01,	27.14,	231.61,	81.05	
28087,	RIERNU2 220.00,	28036,	RIERNU1 400.00,	1 ,	1,	-377.61,	61.82,	382.63,	95.72	
29007,	RARAD2 220.00,	28071,	RTIMIS2 220.00,	1 ,	1,	-318.41,	87.20,	330.14,	106.55	*
31405,	LOKROG1 400.00,	503,	XUD_OK11 400.00,	1 ,	1,	1403.67,	314.41,	1438.45,	118.03	*
31405,	LOKROG1 400.00,	31438,	LHAVCE1 400.00,	1 ,	1,	1242.01,	208.40,	1259.37,	103.34	*

31410,LDIVAC1	400.00,	71,XME_DI11	400.00,	1 ,	1,	-1372.65,	164.60,	1382.48,	134.01	*
31410,LDIVAC1	400.00,	31411,LDIVAC1P	400.00,	1 ,	1,	436.92,	117.56,	452.46,	81.03	
31410,LDIVAC1	400.00,	31411,LDIVAC1P	400.00,	2 ,	1,	436.92,	117.56,	452.46,	81.03	
31430,LBERIC1	400.00,	31405,LOKROG1	400.00,	1 ,	1,	1349.87,	374.52,	1400.87,	133.28	*
31430,LBERIC1	400.00,	31405,LOKROG1	400.00,	2 ,	1,	1349.87,	374.52,	1400.87,	133.28	*
31438,LHAVCE1	400.00,	504,XUD_AV11	400.00,	1 ,	1,	1497.76,	160.13,	1506.29,	127.48	*
34045,JSMIT21	400.00,	74,XER_SM11	400.00,	1 ,	1,	1169.90,	-24.73,	1170.16,	91.65	
34045,JSMIT21	400.00,	34040,JRPMLA1	400.00,	1 ,	1,	-1681.74,	169.73,	1690.28,	132.39	*
34078,JSRBOB1	400.00,	34025,JNSAD31	400.00,	A ,	1,	-1144.36,	11.26,	1144.42,	92.89	
34078,JSRBOB1	400.00,	34050,JSUBO31	400.00,	A ,	1,	1085.16,	-68.58,	1087.32,	88.26	
36015,0PODG121	220.00,	88,XKO_PO21	220.00,	1 ,	1,	-276.28,	55.33,	281.77,	102.62	*
36025,0HPIVA21	220.00,	115,XSA_PI21	220.00,	1 ,	1,	319.12,	55.60,	323.93,	80.81	

Total 46 items

Table 9-32 Significant changes of branch flows in comparison against base case scenario

X------- FROM BUS	--------X	X-------- TO BUS	---------X	CKT	IN WORKING CASE MW	MVAR	IN Winter MAX 2020 - Base Case MW	MVAR	DELTA MW	%
84 [XRO_MU11	400.00]	28039 [RROSIO1	400.00]	1	-1066.4	339.2	-72.6	72.9	993.7	93.2
34040 [JRPMLA1	400.00]	34045 [JSMIT21	400.00]	1	1717.8	217.8	904.6	-65.4	-813.2	47.3
20097 [HMELIN11	400.00]	20502 [HBRINJ11	400.00]	1	-1509.9	366.1	-751.3	79.3	758.6	50.2
28037 [RGADAL1	400.00]	28039 [RROSIO1	400.00]	1	1068.5	2.0	320.5	-67.1	-748.0	70.0
74 [XER_SM11	400.00]	34045 [JSMIT21	400.00]	1	-1157.7	144.2	-503.8	100.4	654.0	56.5
74 [XER_SM11	400.00]	20037 [HERNES11	400.00]	1	1157.7	-144.2	503.8	-100.4	-654.0	56.5
71 [XME_DI11	400.00]	31410 [LDIVAC1	400.00]	1	1388.3	-13.2	738.1	92.8	-650.2	46.8
71 [XME_DI11	400.00]	20097 [HMELIN11	400.00]	1	-1388.3	13.2	-738.1	-92.8	650.2	46.8
79 [XSA_SU11	400.00]	34050 [JSUBO31	400.00]	1	-831.2	302.8	-183.8	201.7	647.4	77.9
79 [XSA_SU11	400.00]	24039 [MSAFA 11	400.00]	1	831.2	-302.8	183.8	-201.7	-647.4	77.9
24033 [MPAKS 11	400.00]	24039 [MSAFA 11	400.00]	1	-693.6	612.7	-51.4	142.8	642.2	92.6
34031 [JOBREN12	400.00]	34040 [JRPMLA1	400.00]	1	861.2	1.0	220.9	-108.3	-640.4	74.4
34030 [JOBREN11	400.00]	34040 [JRPMLA1	400.00]	2	853.7	1.6	219.0	-107.2	-634.7	74.3
34001 [JBGD8 1	400.00]	34030 [JOBREN11	400.00]	1	777.4	-169.8	180.0	-171.8	-597.4	76.8
34050 [JSUBO31	400.00]	34078 [JSRBOB1	400.00]	A	-1078.5	133.1	-494.5	104.7	584.0	54.2
14406 [WVISEG1	400.00]	16402 [WTUZL41	400.00]	1	989.9	3.0	436.0	-71.3	-553.8	56.0
34025 [JNSAD31	400.00]	34078 [JSRBOB1	400.00]	A	1161.6	160.3	619.5	-26.7	-542.1	46.7
24004 [MBEKO 11	400.00]	24048 [MSZOL 11	400.00]	1	661.2	-215.6	120.1	-102.1	-541.1	81.8
24024 [MLITR 11	400.00]	24033 [MPAKS 11	400.00]	1	-1136.8	53.8	-600.3	-4.6	536.5	47.2
24001 [MAISA 11	400.00]	24048 [MSZOL 11	400.00]	1	-506.1	338.5	20.1	74.0	526.2	104.0
28031 [RBRASO1	400.00]	28034 [RSIBIU1	400.00]	1	688.1	-2.1	172.7	-136.8	-515.4	74.9
24019 [MGYOR 11	400.00]	24024 [MLITR 11	400.00]	1	-659.3	201.3	-164.1	9.5	495.2	75.1
24 [XSO_NI11	400.00]	34020 [JNIS2 1	400.00]	1	824.0	58.6	334.4	40.6	-489.6	59.4
24 [XSO_NI11	400.00]	12431 [VSOFIW1	400.00]	1	-824.0	-58.6	-334.4	-40.6	489.6	59.4
20502 [HBRINJ11	400.00]	20503 [HLIKA11	400.00]	1	-941.6	33.8	-459.6	14.1	482.1	51.2
20147 [HVELEB11	400.00]	20256 [HTEDAL11	400.00]	1	752.0	48.1	276.1	1.6	-475.9	63.3
20037 [HERNES11	400.00]	20203 [HZERJA11	400.00]	1	1117.1	159.8	665.0	-6.8	-452.1	40.5
28034 [RSIBIU1	400.00]	28036 [RIERNU1	400.00]	1	874.8	-22.0	423.3	-29.3	-451.5	51.6
28003 [RMINTI1A	400.00]	28008 [RARAD 1	400.00]	1	805.8	56.5	354.8	-59.9	-451.0	56.0
34020 [JNIS2 1	400.00]	34079 [JJAGO41	400.00]	1	624.7	18.4	174.7	-15.0	-450.0	72.0
12 [XUG_ER11	400.00]	14402 [WTUGLJ1	400.00]	1	-686.2	197.3	-238.1	84.5	448.0	65.3
12 [XUG_ER11	400.00]	20037 [HERNES11	400.00]	1	686.2	-197.3	238.1	-84.5	-448.0	65.3
24033 [MPAKS 11	400.00]	24056 [MDUJV 11	400.00]	1	783.6	151.0	336.4	30.0	-447.1	57.1
28008 [RARAD 1	400.00]	28009 [RNADAB1B	400.00]	1	728.5	-166.4	284.8	-83.7	-443.7	60.9
20502 [HBRINJ11	400.00]	20503 [HLIKA11	400.00]	2	-855.7	30.7	-417.6	11.1	438.1	51.2
36010 [0PLJE211	400.00]	36012 [0MAOCE11	400.00]	1	-505.2	86.7	-71.0	74.1	434.3	86.0
36001 [0RIBAR11	400.00]	36012 [0MAOCE11	400.00]	1	257.2	-132.2	-167.9	-86.9	-425.1	165.3
184 [XRI_PE11	400.00]	36001 [0RIBAR11	400.00]	1	556.4	-49.8	138.1	-56.8	-418.2	75.2
184 [XRI_PE11	400.00]	34086 [JPEC 31	400.00]	1	-556.4	49.8	-138.1	56.8	418.2	75.2
34015 [JKRAG21	400.00]	34079 [JJAGO41	400.00]	1	-436.7	62.0	-21.0	10.5	415.7	95.2
28973 [RCERNA1	400.00]	28974 [RMEDGI1	400.00]	1	410.3	251.8	823.5	134.1	413.2	100.7
220 [XKA_PG11	400.00]	36005 [0PODG211	400.00]	1	661.7	-9.1	251.0	27.3	-410.7	62.1
220 [XKA_PG11	400.00]	10143 [ALEZHA1	400.00]	1	-661.7	9.1	-251.0	-27.3	410.7	62.1
34035 [JPANC21	400.00]	34075 [JBGD201	400.00]	A	851.5	-8.0	443.5	-36.8	-408.0	47.9
34071 [JTKOSC1	400.00]	34086 [JPEC 31	400.00]	A	703.6	38.4	296.3	-14.7	-407.3	57.9
198 [XMI_HA11	400.00]	12471 [VMI3 11	400.00]	1	16.8	-145.6	-387.0	-93.7	-403.7	999.9
26064 [YSK 41	400.00]	26111 [YSK 5 1	400.00]	1	494.2	-2.9	97.5	35.2	-396.7	80.3
219 [XNA_BE11	400.00]	28009 [RNADAB1B	400.00]	1	-638.6	123.5	-242.3	66.6	396.3	62.1
219 [XNA_BE11	400.00]	24004 [MBEKO 11	400.00]	1	638.6	-123.5	242.3	-66.6	-396.3	62.1
34001 [JBGD8 1	400.00]	34075 [JBGD201	400.00]	A	-522.2	59.6	-126.2	42.5	396.0	75.8
24025 [MMART 11	400.00]	24056 [MDUJV 11	400.00]	1	-550.2	-103.2	-162.2	-70.5	388.0	70.5
28003 [RMINTI1A	400.00]	28034 [RSIBIU1	400.00]	1	-580.6	103.4	-197.8	-4.6	382.8	65.9
28014 [RSUCEA1A	400.00]	28027 [RBISTR1	400.00]	1	450.4	-40.4	74.0	-100.6	-376.4	83.6
34031 [JOBREN12	400.00]	34088 [JTKOLB1	400.00]	1	-713.3	-79.7	-338.3	-13.0	375.0	52.6
206 [XFL_BI11	400.00]	26005 [YBITOL1	400.00]	1	434.8	14.0	61.2	5.8	-373.6	85.9

28027 [RBISTR1	400.00]	28037 [RGADAL1	400.00]	1	443.9	-21.1	72.8	-21.7	-371.1 83.6

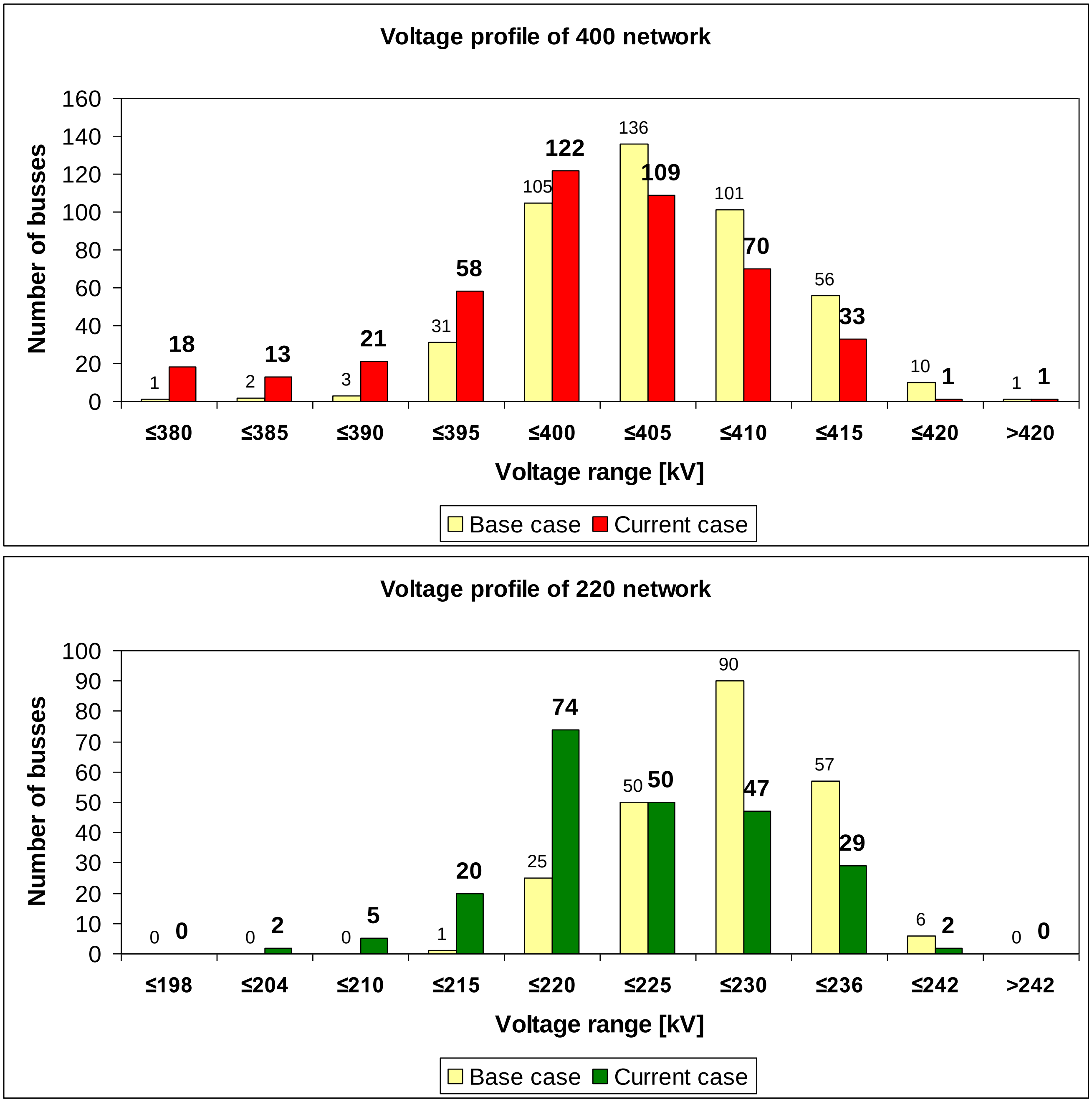


Figure 9-16 Voltage profile of 400 and 220 kV network in analyzed region