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Sub-assignment No 11: Bosnia and Herzegovina: Power Network Analysis for Wind Power Integration and Market Rules Advice

Task 1: Review and Assessment of the Existing Transmission Network in BiH

Final Report

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for the ISO BiH and EBRD

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Executive Summary

This Task 1 report forms part of a series of three reports in an assignment examining the potential for wind power development in Bosnia and Herzegovina (BiH). The overall objectives of the assignment are to:

- Determine the appropriate levels of wind power capacity which may be connected to the national grid
- Identify whether investment is needed to strengthen the national grid in order to increase the capacity of wind power which could be connected
- Clarify the market rules to be able to incorporate and dispatch new renewable generation supported by feed-in tariffs.

This Task 1 report comprises nine main sections. The first two sections provide an overview of the issues associated with the integration of wind energy into a power system and an overview on the power section in BiH. In Section 4 we develop a number of wind penetration scenarios with a range of potential total wind power installed capacities. This has been based upon a review of the wind projects that have already been authorised and credible views of those that are proposed or planned.

In section 5, we review:

- The frequency regulation and active power control techniques that are used in BiH and compare these with experience in various countries that have integrated wind capacity into the system
- The voltage regulation and reactive power compensation techniques used in BiH and compare these with experience in various countries that have integrated wind capacity into the system
- The needs of the Independent System Operator with respect to wind power plant data with reference to experience available from different countries and provide a list of ISO's future data requirements.

In section 6 we review the recently adopted Grid Code in BiH, which has been modified in order to accommodate the requirement for wind farms. We have suggested a number of further modifications to the Grid Code for consideration by the ISO. In section 7, we review the existing rules for cost-sharing associated with the grid reinforcements that are required as a result of wind farms wishing to connect to the network.

In Section 8, we review the wholesale electricity market in the context of how wind power plants should be included by the ISO into the hourly production plans and the wholesale market. In Section 9, we review wind energy forecasting techniques and associated applications that would be appropriate for the integration of wind farms into the BiH power system.

In this report we make a number of key recommendations including:

- Operational practices in BiH will need to change in order to accommodate WPP integration. Specifically there is a need for a properly functioning ancillary services market with clearly defined responsibilities, obligations and rights for all parties involved
- Additional reserve capability will be required. The magnitude of the additional reserve will be dependent upon:
    - The amount of WPP capacity connected
    - The accuracy of the wind forecasting system
    - The level of security that is acceptable to the ISO
- The Grid Code should be further enhanced with respect to:
    - The ride through requirements of WPPs
    - The operational responsibilities of WPPs
    - The data to be supplied to the ISO by WPPs
- The cost sharing arrangements between TRANSCO and WPP developers for grid reinforcement costs need to be finalised; while a methodology currently exists, a key parameter impacting upon cost sharing remains undefined and the overall basis for cost allocation is thus ambiguous
- The electricity market rules need significant enhancement with respect to:
    - The responsibilities for the payment of balancing costs associated with WPPs
    - The basis upon which balancing costs are derived
    - The pricing of ancillary services; and
- The ISO will require the installation of a wind energy forecasting system of sufficient accuracy that will be supplied with all the requisite input data before the first WPPs are commissioned.

1 Introduction

This Task 1 report forms part of a series of 3 reports in an assignment examining the potential for wind power development in Bosnia and Herzegovina (BiH). Under this task, taking into account technical constraints and requirements for the connection of large-scale commercial wind power to the transmission network, the following aspects will be covered:

- Approved and anticipated future projects, assessing the total installed capacity of wind power in BiH for the period 2010 to 2020;
- The operational requirements for increased penetration of wind power into the BiH transmission system.

A wind atlas for Bosnia and Herzegovina was recently established. The assessment shows that Bosnia and Herzegovina has significant wind potential. It is estimated that the total wind power potential capacity is about 3,000 MW, but only 900 MW - 1.300 MW of this total are initially estimated as being feasible. This potential has not yet been exploited. The new atlas shows the most promising areas for exploitation include regions around Bihać, Tomislavgrad, Livno, Glamoč, Mostar and part of the east Herzegovina, Trebinje and Gacko. To accommodate the future integration of wind energy, whose potential is geographically relatively concentrated and whose supply fluctuates depending on wind speed, ISO and Transco needs to assess, jointly with reputable international experts, the implication of installing wind power generation capacity by referring to international best practice.

While a substantial amount of wind power capacity is proposed or planned in BiH, none has yet been built or commissioned, and neither the ISO nor Transco have actual experience in the scheduling and dispatch of wind power. The ISO is concerned with the impact of proposed wind power projects on their power system control capabilities and have requested that a detailed analysis of the power system control capabilities is undertaken. Such analysis is the first objective of this assignment.

The EBRD has also consistently worked towards the creation of a regional energy market in the Balkans. This project would increase the electricity market opportunities in the region by promoting regional cooperation and by increasing the electricity exchange between BiH and neighbouring countries. The project should bring forward wind energy projects in BiH, thus accelerating the integration of renewable energy to the grid, and should help to maintain the stability, and reliability of the BiH power network.

There is also a need to clarify the market rules and also the process in order for ISO to be able to incorporate dispatch of new renewable generation supported by feed-in tariffs. This support will include assurance on cash flows from consumer towards renewable electricity producer under the feed-in tariff system and potential for balancing costs to be managed by new balance responsible parties.

The EBRD will closely follow the assignment and investment proposals resulting from the analysis of the network and identification of grid strengthening requirements which will be considered for financing, together with investments in wind power projects which the study will help to accelerate.

The bulk of this report therefore looks at different operational aspects of managing transmission operation as wind penetration increases. To do this our approach follows the following pattern for each main category examined:

- Existing BiH practice;
- International experience of management with increased wind penetration;
- Assessment of further requirements for BiH to operate its transmission system with increased wind penetration.

In accordance to the Terms of Reference the remaining sections of the report cover the following:

- Section 2 provides a background of Wind Power Plant (WPP) integration issues with global, European and regional overview
- Section 3 gives an overview of the BiH electricity sector
- Section 4 reviews scenarios of WPP projects in BiH
- Section 5 looks at technical requirements (active power regulation, voltage regulation and reactive power management and data requirements) for system operation as WPPs are integrated
- Section 6 examines grid code mandatory requirements
- Section 7 looks at cost sharing for grid reinforcement investments
- Section 8 reviews requirements for including wind dispatch within market procedures
- Section 9 looks at wind forecasting techniques needed as wind penetration increases.

Section 10 gives a summary of the findings together with our conclusions and recommendations.

2 Wind Power Plant (WPP) Integration Issues

Integration of wind power plants (WPP) has gradually evolved over the last 30 years from simple constant speed turbines to fully variable speed systems that enable active output control[1]. 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 optimised. 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.

Transmission System Operators (TSOs), or, in the case of BiH, Independent System Operator (ISO), however do need to meet a number of challenges associated with integrating increasing levels of wind power into their electrical power systems. These challenges stem from the nature of the power output from wind turbines:

- It cannot be dispatched;
- It has significant variability due to the changing wind resource; and
- Its output has significant uncertainty due to the difficulties in accurately forecasting the weather.

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.

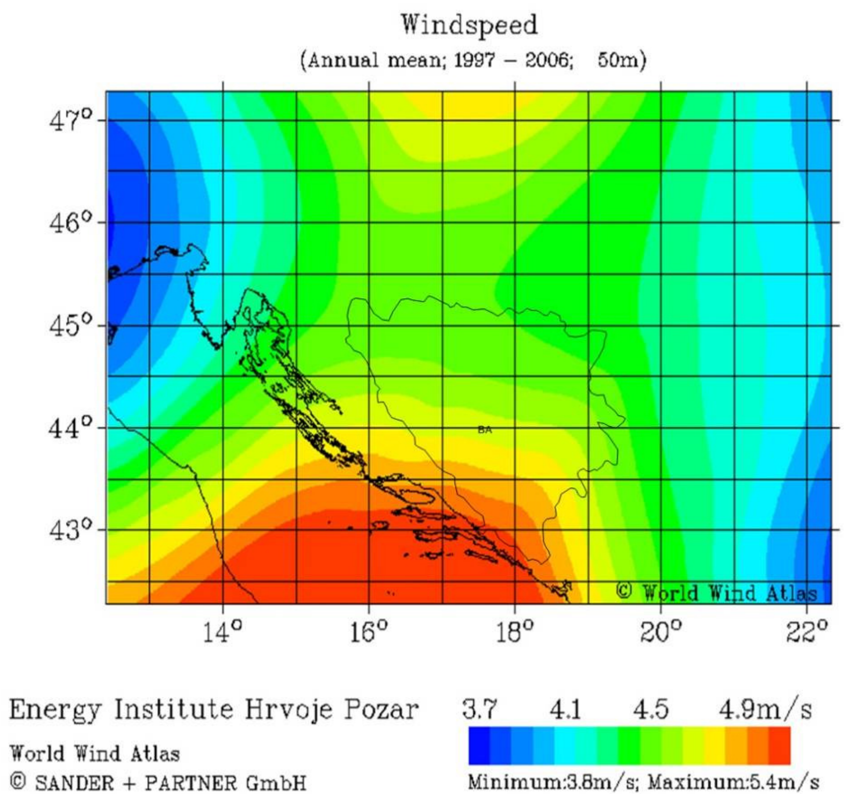
2.1 Wind resource

The southern part of BiH has the largest wind potential, as shown in Figure 1 with annual wind speed mean value of roughly up to 4.9 m/s at 50 m above the ground, which is very promising for WPP development.

WPPs in operation that are the closest to BiH are located in Croatia. The WPP integration process in Croatia started more than 10 years ago. Currently there are 6 WPPs (58 wind turbines) in operation, with total installed capacity of about 79 MW. For BiH it is important to keep in mind that in Croatia there is a total of 92 MW in four additional WPPs with construction permit already issued and its construction is expected in the near future. In addition, 6 WPP projects with installed capacity of 259 MW have location permits. Another 4 WPPs issued grid connection consent as a precondition for location permit. All locations are relatively close to the BiH border. So, it is positive sign for investors that this wider area is promising in wind potential. On the other side, unexpected (unscheduled) cross-border flows can be expected.

[1] EWEA Grid Report 2010

Figure 1 Annual wind speed mean values in BiH



2.2 Wind variability issue

As stated above, the largest challenge for large scale WPP integration in the system appears due to significant WPP generation variability, or, in other words, significant uncertainty of WPP output due to the difficulties in accurately forecasting the weather.

For the ISO the following information is important:

- the wind power variability and the extent to which can be forecasted;
- the wind turbine capabilities in providing ancillary services; and
- the expectations of future wind power installations.

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. 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.

Forecasting the output of wind farms 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 significantly over a 12 hour period. In extreme winds, wind turbines automatically shut down from their full rated power. Storm fronts can take around six hours to pass over an area of several hundreds of kilometres. Some examples of extreme, though rare, ramp rates recorded during storms include:

- Denmark: 2,000 MW decrease in 6 hours (12 MW in a minute) on 8th January, 2005;
- North Germany: over 4,000 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 1,550 MW of wind capacity at the rate of approximately 600 MW/hour over a 2½ hour period on February 24, 2007.

Key points that the ISO needs to bear in mind as wind energy penetration on the power system becomes significant include:

- There must be sufficient conventional power plants synchronised during periods with a low contribution from wind;
- There must be sufficient power plants with fast control capability (for primary and secondary reserve purposes) during high wind periods (i.e. there must be enough operational capacity with the ability to ramp up and down output within the required timescales);
- There must be sufficient tertiary reserve to cover all possible uncertainties of supply and demand in situations where there is a large decrease of total wind power production over the 4 to 6 hour time horizon (which could occur at the same time as the load is increasing);
- The ability to regulate down the available wind output during periods of low demand and high wind output.
- The extent to which trading with neighbouring countries is possible.

In BiH currently there is a gap between WPP investors' interest and wind energy potential from one side and WPP integration results from the other side. So far, there are no installed WPPs in BiH. WPP project development usually takes 2 – 4 years, depending on administrative procedures. Wind turbine delivery, construction and testing adds another 1 – 1.5 years. Currently, forecasting and the balancing mechanism are not established yet. This means that the status quo unduly favours WPPs, with most obligations being placed upon the ISO and practically no obligations on WPPs.

However, the SCADA system is regularly developed, and an ancillary service mechanism is in place albeit with certain problems in full application. Accordingly, ISO is facing big challenges for large WPP integration with many issues to be resolved in very near future.

3 BiH Electricity Sector Overview

The energy sector governance structure has been separated into:

- *State level* – Transmission divided into a system operator (NOS BiH – known in English as ISO) and a transmission company Elektroprijenos BiH (usually known as Transco in English);
- *Federation of Bosnia and Herzegovina* (FBiH) – with two vertically integrated power utilities responsible for generation, distribution and supply (EP HZHB and EP BiH),
- *Republika Srpska* (RS) – with one vertically integrated holding company (EP RS), but with 5 subsidiary generating companies and 5 subsidiary distribution and supply companies.

The following describes and summarises the relevant factors in the regulatory framework and the market structure for the electricity sector in BiH.

3.1 Main industry institutions

Energy policy in BiH is the responsibility of state and entity ministries (Ministry of foreign tade and economic relations BiH, Monistry of energy, mining and industry FBiH and Ministry of economy, energy and development RS).

Ministry of foreign trade and economic relations BiH is responsible for activities on the state level relating to energy policy, basic principles, activity coordination and harmonization of entity bodies and institutions at international level, including energy sector, environmental protection, development and natural resources (Law on ministries and other authorities of BiH). Also, in accordance to the Law on transmission, regulator and system operator in BiH, the Ministry is responsible for energ ypolicy creation.

In accordance to the Law on federal ministries and other authorities (article 9), Ministry of energy, mining and industry FBiH, among other, is responsible for energy policy creation. This Ministry acts in accordance to energy policy, adopts the laws and other acts, prepares legislative framework as well as other professional and activities defined by the Law and other legislation.

In RS, energy policy is in resposibility of the Government of RS. Ministry of economy, energy and development RS is responsible for adoption of measures of economic and development policy in energy sector.

Basec characteristics of regulatory agencies, system operator, transmission company and distribution companies are given as follows.

State Electricity Regulatory Commission (SERC)

The State Electricity Regulatory Commission (SERC) regulates the electricity transmission system in Bosnia and Herzegovina and has jurisdiction and responsibility over transmission of electricity, transmission system operations and international trade in electricity as well as generation, distribution and supply of electricity customers in Brčko District of Bosnia and Herzegovina.

The SERC's jurisdiction includes:

- issuance, modification, suspension, revocation, and monitoring of and enforcing compliance with licenses within its jurisdiction;
- regulating, approving and monitoring tariffs and tariff methodologies for transmission services, ancillary services and operation of the Independent System Operator (ISO), as well as supplying electricity customers in Brčko District of Bosnia and Herzegovina;
- issuance of rules and regulations within its competency, including revision and approval of market rules and grid codes, and terms and conditions for connection and access to network;
- establishment, monitoring and enforcement of rules related to fair and non-discriminatory third party access to the transmission network;
- monitoring and enforcement of conditions related to international trade in electricity, in particular ensuring that international technical requirements are met and adhered to;
- establishing, monitoring and enforcing quality standards for electricity transmission and ancillary services;
- coordinating and approving investment plans of the company for transmission of electricity, including the plans related to the transmission network and the quality of electricity transmission;
- monitoring of the efficiency of mechanisms and methods securing the system balance between demand and supply of electricity;
- consumer protection ensuring: fair and non-discriminatory treatment, high-quality services, competition and the prevention of anti-competitive activity;
- resolution of disputes among system users, in accordance with regulatory powers and applicable State laws;
- creation and maintenance of competitive markets when practicable, and prevention of any anti-competitive conduct;
- approving mechanisms for dealing with congestions of the electricity transmission system capacities;

- regulation of standards of service, codes of conduct and accounting requirements for licensees;
- issuance of annual reports and other public information about the SERC.

Regulatory Commission for Electricity in the Federation Bosnia and Herzegovina (FERK)

FERK was established in 2002 by the Electricity Law FBiH as specialized, autonomous, independent and non-profit organization in the Federation of Bosnia and Herzegovina. The Regulatory Commission's jurisdictions are:

- supervision and regulating the relations between power generation, distribution and electricity customers including power traders
- prescribing methodology and criterion for defining the prices for supplying of non-eligible customers
- defining of tariffs for distribution systems users and tariffs for non-eligible customers
- issuing and revocation of licenses for generation, distribution and tariffs for non-eligible customers
- issuing the preliminary construction permits and licenses for usage of power facilities except the facilities for power transmission
- defining General Conditions for Electricity Supply

Regulatory Commission for Energy in the RS (RERS)

RERS was established in 2002 by the Electricity Law RS as Regulatory Commission for Electricity as independent and non-profit organization in order to regulate monopoly and insure transparent and non-discriminatory activities of all electricity market participants in RS. In 2007 along with new Law on electricity RERS responsibilities and name was changed in Regulatory Commission for Energy with the following basic jurisdictions in electricity sector:

- supervision and regulating the relations between power generation, distribution and electricity customers including power traders
- prescribing methodology and criterion for defining the prices for supplying of non-eligible customers as well as methodologies for distributino grid connection
- defining of tariffs for distribution systems users and tariffs for non-eligible customers
- issuing and revocation of licenses for generation, distribution and tariffs for non-eligible customers

- issuing the preliminary construction permits and licenses for usage of power facilities except the facilities for power transmission
- defining General Conditions for Electricity Supply
- defining power generation prices.

Independent System Operator in BiH

Independent System Operator in Bosnia and Herzegovina NOS BiH (ISO) was established by the Law on Establishing Independent System Operator for the Transmission System in Bosnia and Herzegovina. The purpose of establishing the ISO is to ensure continuity of supply according to defined quality standards. Its main obligations are the management of the transmission system with the aim of ensuring reliability, development and application of guidelines which regulate the usage of the transmission system and development and enforcement of market regulations which are founded by provisions relating to the systems and auxiliary services in the transmission system.

The ISO is responsible for the Grid Code but must develop it in cooperation with Transco and DERK. ISO is also responsible for operation of the market and allocation of balancing costs. ISO's Board of Directors has representation of both Entities, which reflects the joint ownership of the institution between the governments of FBiH and RS.

Transmission company

Elektroprijenos BiH a.d. Banja Luka (Transco) is a company for the transmission of electric power in Bosnia and Herzegovina. The Law on Transmission and System Regulator and Operator of Electric Power, passed in 2002, created conditions for the establishment of a joint company for the transmission of electric power, which was accomplished in 2004 by the Law Establishing the Company for the Transmission of Electric Power in Bosnia and Herzegovina. Transco BiH is regulated by DERK. Its main obligation is the transmission of electricity and all activities related to the transmission of electricity which include (but are not restricted to the transmission of electricity) maintenance, construction and expansion of the energy system of BiH but excludes those activities assigned to the ISO. Transco is a shareholding company owned jointly by FBiH and RS with shareholders representation on the board in accordance to initial equity brought into the company. ISO and Transco are both confronted with the challenge of finding the best and most appropriate way in which new wind power capacities can be linked to the transmission grid and the impact of such new capacities on the operation and security of the BiH (and regional) electricity network.

Distribution and supply

In Federation of BiH there are two public power utilities, JP Elektroprivreda BiH d.d. Sarajevo (further in the text: EP BiH) and JP „Elektroprivreda Hrvatske zajednice Herceg Bosne" d.d. Mostar (further in the text: EP HZHB). Both are vertically integrated companies, whose activities are: generation of electric power, distribution of electric power and supply of electric power. Elektroprivreda BiH - Sarajevo (EP BiH)

In Republika Srpska there is Elektroprivreda Republike Srpska –Trebinje (ERS). ERS is a publicly held vertically integrated electric utility. Its activities comprise electricity generation, distribution, supply, export and import and the management of the Republika Srpska power system. In 2005 the Company was reorganised and registered as a holding company which comprises the parent company and 11 public companies (5 genco, 5 disco and one institute).

3.2 Market rules

Plans to make the electricity market a single market in BiH are yet to be elaborated. However, eligible customers can enter into direct contracting with licensed suppliers, which only implicitly gives an impression of a single market. The DERK is not authorized to conduct market surveillance tasks. Market design needs to be developed further.

The Market Rules are put in place for a transition phase, defining the way in which the ISO fulfils its obligations for management of the balancing mechanism. The Rules were prepared by the ISO and approved by the DERK in June 2006. Their full implementation is still in progress, as preconditioned by remote reading of electricity meters. This issue needs to be tackled if the balancing market is to be made fully functional. The Rules for the Competitive Market have not been drafted yet, and a leader for this task remains to be identified.

The Grid Code is in place. The ISO implements the Grid Code and other technical rules and business processes in accordance with the ISO Law and the Transco Law. The General Conditions for Connection to the Network appeared recently.

3.3 Current electricity sector capacities

Power generation

Total electricity generation in BiH is having the following main characteristics:

- total annual generation went up to 15 TWh,
- all existing power plants are hydro or coal fired,
- most of the facilities were put in operation between 1955 and 1989,
- all thermal power plants are designed to operate with domestic coal (lignite and brown coal),
- total installed generation capacity is about 3,900 MW, with more than 98% in the ownership of the three dominant companies: EP BiH, EP HZHB and ERS. The rest encompasses independent generators owning some twenty small hydropower plants and generators producing

electricity for self-consumption with surplus being injected in the power system[2],

- total annual electricity surplus in BiH varies between 570 GWh (2007) and 3 TWh (2009),

- the most important recent investment in generation is construction of HPP Mostarsko blato (60 MW) in 2010, with expected annual generation of 170 GWh,

- new TPP units are planned to be commissioned after 2015, such as TPP Tuzla, Unit 7 (450 MW) in 2017, TPP Stanari (300 MW) in 2015 and TPP Kakanj, Unit 8 (300 MW) in 2018.

- old unit 3 in TPP Tuzla (G3 - 100 MW) is supposed to be decommissioned in 2013, unit 4 (G4 - 200 MW) in 2019, unit 5 (G5 - 110 MW) in TPP Kakanj in 2018

An overview of installed generation capacities by type and ownership is given in Table 1.

Table 1 Installed generation capacities in BiH (MW)

Power plants	EP BiH	EP HZHB	ERS	Independent generators	Total
Hydro power plants > 5 MW	514.400	792.600	720.000		2,027.000
Hydro power plants < 5 MW	3.366		5.900	20.141	28.973
Thermal power plants	1,125.000		600.000		1,725.000
Industrial power plants				52.500	52.500
Gas power plants				0.298	0.298
Total	1,642.766	792.600	1,325.900	72.939	3,834.205

(Source: DERK 2009)

With 54% share of HPPs in total generation capacity, electricity generation in BiH strongly depends on hydrology, especially in EP HZHB in which all generation facilities are HPPs.

In the last decades BiH system continuously had an electricity surplus. Due to wider regional deficits and the BiH generation surplus wholesale market activities on BiH borders are relatively large.

Power transmission

Power transmission in BiH has the following characteristics:

[2] DERK Annual Report 2009, 2010

- full territory coverage, with well developed 400 kV (total 865 km), 220 kV (1524 km) and 110 kV (3919 km) network,
- well connected to the neighbouring systems with 36 interconnection lines operated on 400 kV, 220 kV and 110 kV voltage level,
- 144 HV and HV-MV transformer stations out of which 9 TS 400/X kV, 8 TS 220/X kV and 127 TAS 110/X kV,
- acceptable level of losses (2.6%),
- modernisation of system control is accomplished recently.

More detailed description of transmission system of BiH will be given in the Task 2 report.

Power distribution

Power distribution in BiH has the following characteristics:

- full territory coverage,
- covering the voltage structure of 35 kV and below,
- investments in renovation are needed,
- total power losses in distribution network in 2009 were 1,303 GWh or 14.23% in comparison with gross distribution consumption, which is a slight decrease compared to the previous year when losses amounted to 14.30%.

DSOs are responsible for metering installation, maintenance, reading and data management.

4 WPP projects in BiH

This section aims to address the first requirement in the TOR for Task 1, which requires the review "*projects already authorized and/or those proposed or planned to assess the total capacity of wind power in BiH to be installed in the period up to 2015*". ISO BiH has provided the basic information on planned wind power plants, and has developed scenarios to be analyzed. Therefore, rather than reviewing the individual projects, in this section we will analyse the scenarios with information provided by ISO BiH.

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 the southern part of the country with the largest wind potential. The total capacity of these projects is more than 3,000 MW (source: NOS BiH, ISO) although most of these projects will never be realised.

For 15 projects there are wind speed measurements on the site. In the Southern region of Herzegovina, construction preparations of the first two WPPs: Mesihovina (44 MW) and Podveležje (46 MW, phase one) have been started.

The possibility of wind power plants integration in the power system of Bosnia and Herzegovina is assessed by analyzing the variations in production (power) of wind power plants, as well as capability of the grid for taking over the energy produced in wind power plants in certain characteristic systems states, depending on the loading and the availability of other power plants and transmission infrastructure.

Wind power plants production variation analysis is done with following input parameters:

- wind farm development scenarios - how much wind power capacity at which location,
- wind speed data for each location.

4.1 Wind Power Plant Development Scenarios

For the purpose of this study, NOS BiH (ISO BiH) has provided the basic information on planned wind power plants in Bosnia and Herzegovina (around 50 projects[3]). For these planned wind power plants the following information are made available:

- name of the project
- planned total installed capacity
- number of units (wind turbines) and unit size in MW

[3] NOSBiH, Indikativni plan razvoja proizvodnje 2011. - 2020., Sarajevo, juni 2010.

- planned annual production
- investor
- expected year of commissioning
- list of issued project documentation (permits, contracts...)
- location

ISO BiH has agreed to analyze scenarios based on levels of wind energy penetration (2%, 5%, 10%, 15% and 20%) and different spatial distribution of wind farms across Bosnia and Herzegovina.

In determination of installed capacity for each scenario, the energy penetration level was calculated for a demand forecast for 2020 based on data from above mentioned Indicative Development Plan, in which there are four different prognoses. The average of these four prognosis (15.1 TWh by 2020.) is taken for further calculation. With the wind farms productivity assumption of around 2300 FLH, following scenario limits are defined:

- 150 MW
- 300 MW
- 600 MW
- 900 MW - concentrated
- 900 MW - wide distribution
- 1300 MW - concentrated
- 1300 MW - wide distribution

It was agreed with ISO BiH that scenarios with WPPs installed capacity between 150 MW and 900 MW will be analyzed in detail, while scenarios with 1300 MW of WPPs installed capacity will be analyzed on more general level. Transmission network analysis and necessary transmission investments, presented in Task 2 and 3, comprises scenarios between 150 MW and 900 MW of WPPs.

These scenarios are "filled" with wind farm locations selected from a list of around 50 wind farm locations and sizes provided by the ISO. In selection of the projects the following 10 criteria are used (listed according to priority):

- constructed or in construction
- issued construction (building) permit
- issued location permit (urbanism approval)
- issued grid connection approval

- positively concluded environmental impact assessment procedure
- wind energy potential
- resolved land use or land ownership rights
- concession
- wind climate measurements done or in progress
- listed as an project of public interest by the Government of Federation of BiH or defined in the Energy strategy of Republika Srpska

It is important to point out that for this kind of analysis it is not crucial to evaluate an individual WPP project itself, but the overall mutual impact on system operation, no matter of specific WPP project or investor. In that sense neither we nor ISO are making any arbitrary inclusion of any specific WPP projects.

ISO has also provided the Wind atlas of Bosnia and Herzegovina (Atlas). The Atlas is an application made by the Swiss company Sander + Partner GmbH that enables the creation of 30-years long 10-minute wind speed and direction data series (1978 - 2007). The application is based on reanalysis data which have been processed (refined) using sophisticated atmosphere modelling tool MM5 that takes into consideration a large number of atmospheric parameters (solar radiation, temperature at various levels, pressure, humidity, wind speed, wind direction, etc.) as well as terrain orography[4] and roughness. The final results (available from the Atlas application) are available in spatial resolution of 1 km (raster) and for 50 m, 80 m and 120 m height.

The data from the Atlas have been used in assessing wind potential of the site (6th criterion). The application allows for the exact coordinates to be inputted, but the 10-minute series can be obtained only for the closest point in the 1 km x 1 km grid (the closest point is found automatically in the application).

Based on the data available for the projects, Indicative generation plan (source: ISO), the WPP development scenarios as defined and verified by ISO.

In selection of the wind farm projects for the 150 MW, 300 MW and 600 MW scenarios, the defined criteria are prevailing. However, for extreme scenarios of 900 MW and 1300 MW the intention is to build up the rest of the capacity (over 600 MW) so that the resulting scenarios are different in terms of spatial distribution - one is concentrated, and the other is maximally distributed.

The resulting scenario regions are presented on Figure 2.

In all scenarios there is a significant concentration of wind farms in the wider area (cca 35 km x 35 km) around Tomislavgrad and wider area around Mostar. In

[4] Orography is the study of the formation and relief of mountains, and can more broadly include hills, and any part of a region's elevated terrain

"concentrated" scenarios the additional wind farms are selected as close as possible to these two areas, whereas in "wide distribution" scenarios, additional wind farms are selected on locations that are away from the two groups.

Having in mind that during study preparation (June - August 2011) the Ministry of energy, mining and industry RS nullified all contracts on public-private partnership with municipalities in RS, a new issue arose – how to treat WPPs in RS that appear in scenarios 900 MW and 1300 MW. For the new Indicative generation plan 2012/2012 RS nominated one WPP candidate - 50 MW in 2015, while its location would be defined later depending on the measurement results. Given that ERS is responsible for exploration of wind energy potential in RS, it had to be somehow taken into account within this study. Accordingly, we added additional scenario (A1, 200 MW) with 50 MW in Trebinje region. Its grid connection is foreseen at the OHL 110 kV Nevesinje - Gacko. This scenario will be analyzed in more detail in the Task 2.

Figure 2 WPP development regions

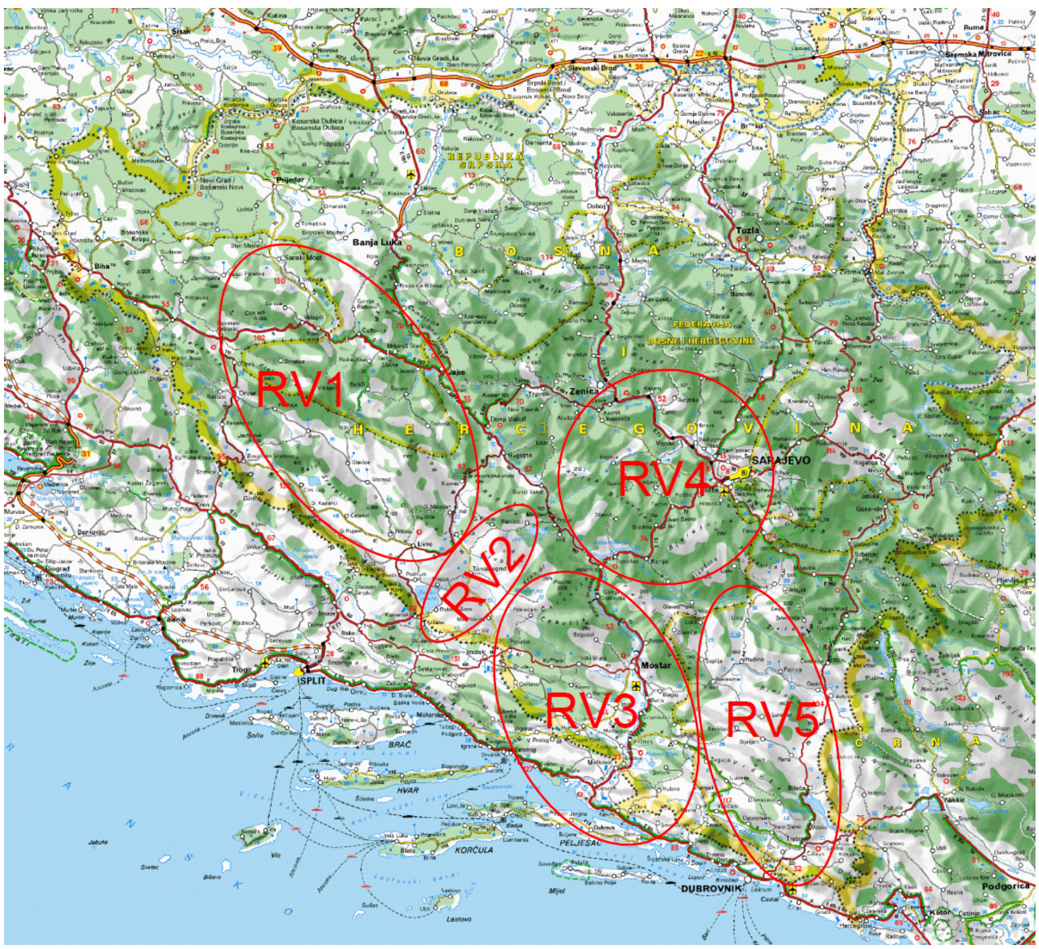


Table 2 WPP installed capacity per each scenario

Regions/total WPP installed capacity	150 MW	300 MW	600 MW	900 MW - A	900 MW - B	1300 MW - A	1300 MW - B
REGION 1	0	52	52	259	52	305	259
REGION 2	44	114	369	369	369	369	369
REGION 3	74	146	176	222	332	264	332
REGION 4	40	40	40	40	40	64	40
REGION 5	0	0	0	60	108	307	297
TOTAL	160	352	637	950	901	1309	1297

* additional scenario 200 MW is added as described later on

4.2 Wind Speed Input Data

For this study, ISO provided only the Atlas wind speed data, as described in the previous subsection. We decided to use data calculated for 80 m above ground level. Although 30 years of data are available for each location, due to calculation limitations 10 years of data are used in the period 1998 - 2007.

The key questions for this kind of analyses are input data availability and quality. Even though wind measurements on the site are by far the best possible input data, these kinds of data are not publicly available in BiH in the range needed in this study (from 150 MW to 1300 MW scenario). So, the authors believe that input data set used in the study is very relevant for the purpose of this kind of planning study. Atlas wind speed data are primarily intended to give a general picture of the wind energy potential, to compare different areas, assess the variability and perform other analysis that compare different areas or assess global potential. But, when analysing specific wind farms, on-site wind speed measurement is required. This study is focused on wider area and system impact and not on the specific sites.

When commenting on input data quality and using Atlas data for the analysis of production variations and regulation capacity the following should be kept in mind:

- All Atlas data are the result of a unified procedure, therefore, there is no error in measurement or any kind of bias due to system errors in measurements;
- The wind speed data series have a reliable time-stamp - which is extremely important for analysis of variation. The synchronicity of time-stamps of on-site measurements is always questionable, especially when the data series are provided from a number of different sources, tools and locations;
- Due to limitations in modelling (simplified terrain model, lower spatial resolution, etc.) modelling results (Atlas data) can never give as accurate presentation of the wind climate as on-site measurements. This accounts for not only average wind speed or distribution, but also for the variability of wind speed;

- The 1 km x 1 km resolution - or taking the data from the closest point in the grid - may lead to errors, especially in complex terrain;

Based on the considerations given above the following can be expected for the analyses of production variations and regulation capacity:

- Atlas data are expected to underestimate wind speed variability at each location;
- Due to the fact that the time series are 10 years long, some extreme variation events can be expected;
- Due to the simplified (smoothened) terrain model used for the calculation of the wind speed data series, the correlation of the wind speed data series (and therefore also wind energy production) between different points is expected to be higher than in reality .

4.3 WPP Production Analyses

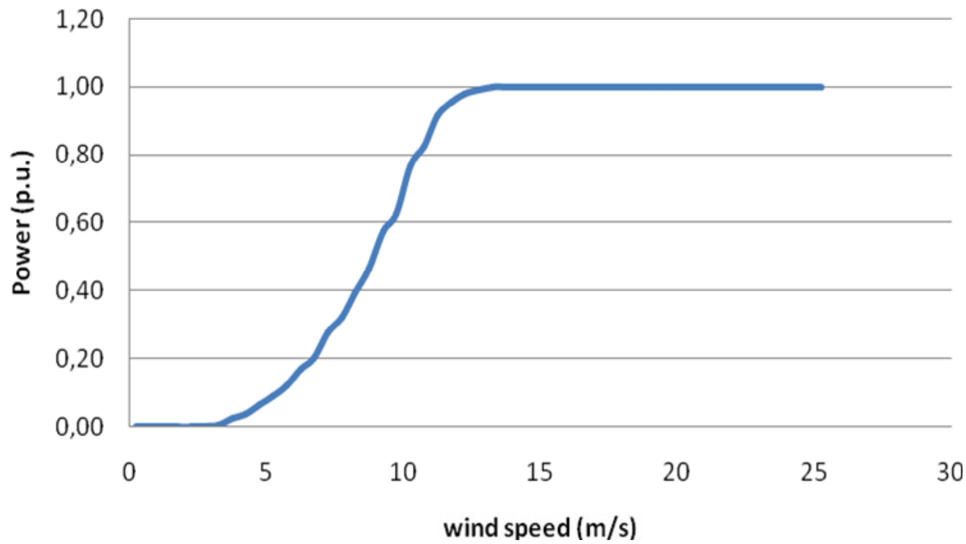
Within this section, the following analyses are made:

- WPP production calculation,
- WPP production variation analysis,
- System regulation capacity analysis.

4.3.1 WPP model and production calculation

In these analyses each wind farm is modelled as one wind turbine with the installed capacity equal to the installed capacity of the whole wind farm. Furthermore, all wind farms are assumed to have 80 m hub height and for all an average power curve has been calculated (in p.u.) as an average power curve of 10 different wind turbine types in the 1 MW to 3 MW class. The given power curve is defined for standard conditions (standard air density of 1.225 kg/m^3). This simplification has no significant impact on the study results.

Figure 3 Average WPP power curve



WPP power is calculated for each 10-minute interval on the basis of wind speed data for 80 m and the average power curve. When calculating wind farm power in such a way, the following should be considered:

- modelling the whole wind farm as one wind turbine increases the variations, because the effect of reduction of wind speed (and production) variations over a wind farm is neglected;
- the following sources of power reduction are neglected:
  - wake effect
  - reduction of power due to reduction of air density (compared to standard air density)
  - stand-still periods due to icing (probable on height over 1000 m)
  - losses in LV/MV/HV transformation and losses in the grid
  - hysteresis effect (stand-still during normal operating conditions while waiting for the wind speed to drop below a certain limit after a shut-down due to reaching cut-out wind speed).

Having in mind that this part of the study is focused on the variations in production, and not on the annual productivity, the stated simplifications can be accepted, especially taking into consideration that the wind speed data series are not available for the exact point in the wind farm, but for the closest point in the 1 km x 1 km grid.

After the wind farm power is calculated for each 10-minute interval the produced energy is calculated in following steps:

- energy produced in each 10-minute interval equals power x 1/6 hours

- all energy produced in 10-minute intervals is summed
- the sum of energy is normalised on one year
- the normalised production is reduced by 10% in order to account for losses[5]

The WPP load duration curve is determined in a statistical analysis over a series of 10-minute power data. A number of intervals are counted in which the power is equal to or larger then a certain level of power (in 5% steps). The resulting number of hours is then normalised to a one year period.

4.3.2 WPP 10-Minute Production Variation Analysis

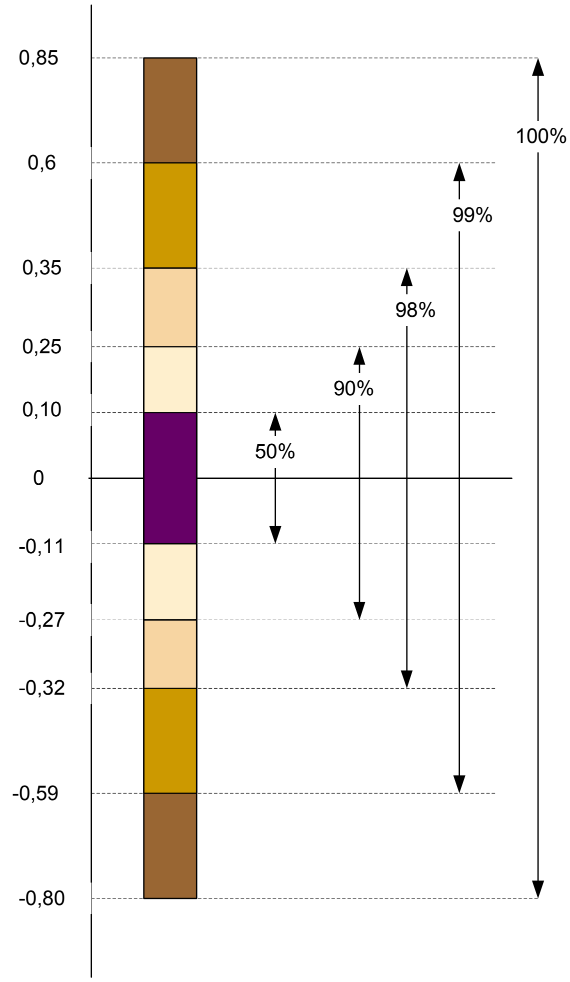
The analysis of production variations is based on a series of data calculated as a difference in power between two neighbouring 10-minute intervals. In a statistical analysis the frequency of certain intervals of variations are determined. Full range of production variations ranges from - 100% (fast reduction of power from full power to zero) to + 100% (switching on to full power, for instance after cut-out event). The - 100% to + 100% range is divided into forty 5% intervals, and for each 5% interval the frequency is determined by counting the defined calculated data series. The frequency of certain variation ranges is presented graphically in the figures below.

Within the analysis of production variations, the question - *what is the minimal range of variations that will not be exceeded for certain percentage of time?* is addressed graphically. These graphs are interpreted in a following way (see for example – Figure 4) – the whole column is divided in differently coloured sections that denote certain percentage of time, or cumulative probability. The range is counted from zero variations to higher variations (in absolute value). Starting from zero to positive and negative side, the first violet section of the column denotes the range of variations in which 50% of negative and 50% of positive variations occur: 50% of positive variations are in the range from 0% to 10% of total installed capacity and 50% of negative variations are in the range from 0% to - 11%. In a similar way, the next light-brown section of the column denotes the range of variation in which 90% of all variations occur. The darkest section of the column denotes the maximum range of positive and negative variations. The levels/ranges of variations on this graph are selected arbitrarily.

The distribution of sections of the column is nearly, but not fully symmetrical. The sections closer to zero are more symmetrical and become less symmetrical closer to the maximum range, because the more extreme variations are, the more random are such events.

[5] This figure reflects all losses, not just electrical losses, but lost output due to network unavailability and/or maintenance, loss of aerodynamic efficiency (on turbine blades), losses due to hysteresis effect, turbulences etc.

Figure 4 Ranges of WPP generation variations



The final analysis addresses the **regulation capacity** needed to balance the deviations of wind farms production (power) from some reference value in a 10-minute domain, which is the domain of secondary regulation operations.

The prior production variation analysis can only give indications on what to expect regarding these deviations. However, the system needs to be balanced when there is a difference between current production level (power) and current consumption level (load). In order to maintain the balance, system operators have to plan the production according to the forecast or plan of electricity consumption. The better the plan is, less deviations from the plan can be expected. Of course, sudden faults in the system (e.g. faults in the grid or power plant outage) also cause imbalances, which the system must be able to balance out. When an imbalance occurs, whether it is a deviation from the plan or a large fault in the grid, first response comes from the "fast" power plants capable for secondary regulation, meaning adjusting power production level within a timeframe of minutes to few tens of minutes. These operations may be controlled automatically (most usually) or on demand from a control centre. Then it is followed with adjustment of power production from other slower-responding power plants (tertiary regulation) that enables "fast" power plants to return to the optimal operating point (optimal with respect to production and regulation range). The tertiary regulation responds within a timeframe of tens of minutes to hours.

Integration of wind power into the system introduces an energy source whose production has limited possibility of power production control. Power can usually be only curtailed during periods of high wind and low consumption, but in most of the time wind conditions dictate the power production. In that sense power production from wind farms is variable, but reasonably predictable. On the other hand, in wind farms there are practically no faults that could cause the whole wind farm to instantly shut down - one or two wind turbines may shut down, but not the whole wind farm at the same moment. However, during high wind events the whole wind farm may shut down over a relatively short time interval as turbines cut out.

Operation of the system with wind farms, with respect to necessary regulation capacities, will primarily depend on the following:

- time resolution of the power plants production plan - are the power levels set for 5-minute, 15-minute, 30-minute, or hourly intervals.
- gate closure time - if the production plans, as well as forecast of the wind farms production are submitted close to the point (time) of realisation, then the forecast is much more accurate. For instance, in Finland the error for a day ahead forecast for 4 wind farms (aggregated) is around 10% of installed capacity of the 4 wind farms. The relative error drops down to around 8% for 6-hours-ahead forecast and below 6% for hour-ahead forecast.
- larger number of wind farms on a larger area improve accuracy of the forecast.

For the purpose of this analysis it was assumed that the power production of other power plants (other then wind farms) is determined according to a 4-hour forecast for production from wind farms. In other words, a constant power level is assumed for a group of wind farms during 4-hour periods. The power level is calculated as an average of power in twenty-four 10-minute intervals in the 4-hour period. The simulation of forecast with a 4-hour average is a rather conservative approach, because hourly forecast are now common in systems that operate with a significant share of wind power.

This kind of 4-hour constant wind forecast may correspond to system transitions from different quasi-stationary states - in each 4-hour period it can be assumed that the power system can balance out the power deviation and restore the optimal secondary regulation capability using tertiary reserve in that 4-hour period[6].

The results of the regulation capacity needs are presented in the same manner as the results of the production variation analysis.

[6] 4-hour duration of quasi-stationary states is assumed to be sufficient for restoring normal operating state. The larger and more robust the power system is, the shorter the duration and vice-versa.

Additionally, within the analysis of regulation capacity needs, the amount of energy expended in secondary regulation is also calculated. That amount is naturally equal to zero, because there is an equal amount of negative and positive deviations from the forecast (average), which is an average of 10-minute power data. So, the resulting energy is the total positive energy spent during balancing of wind farm output variations.

As mentioned above, the analyses presented here are based on Atlas data - 10 minute wind speed series. These data are extracted from the Atlas for a 10-years period (1998 - 2007) for the point in the 1 km x 1 km grid closest to the coordinate defined as representative for a given wind farm.

Productivity of the groups of wind farms in the 7 defined scenarios is presented in Table 3. Productivity is calculated assuming 10% losses.

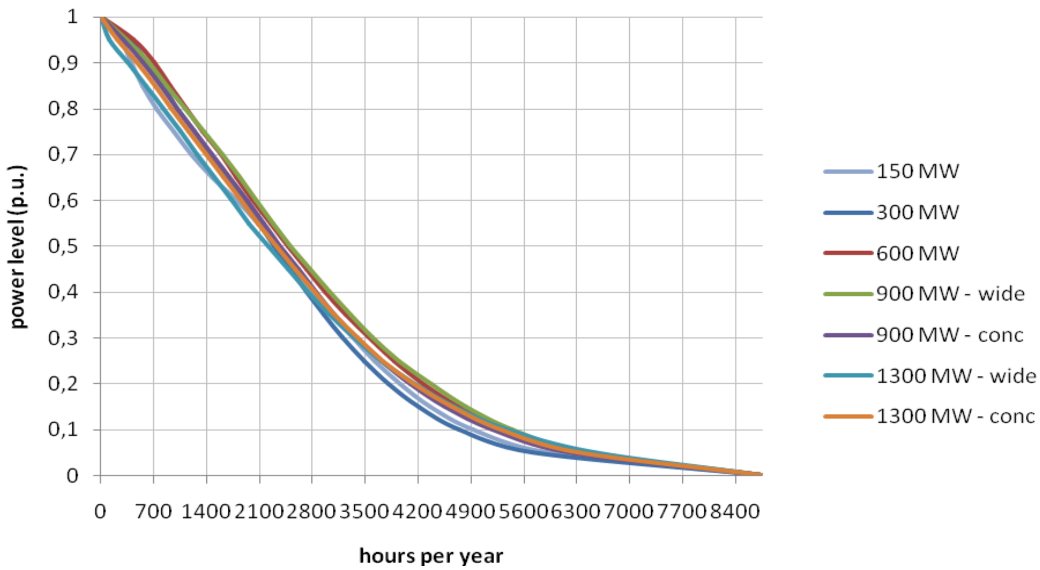
Table 3 WPP productivity per each scenario

Scenario	150 MW	300 MW	600 MW	900 MW - wide	900 MW - conc.	1300 MW - wide	1300 MW - conc.
Installed capacity (MW)	**160**	**352**	**637**	**950**	**901**	**1309**	**1297**
Productivity (FLH)	2259	2283	2510	2534	2393	2332	2378
Production (GWh)	**361.4**	**803.6**	**1598.9**	**2407.3**	**2156.1**	**3052.6**	**3084.3**

Having in mind that the productivity is calculated based on the long term data derived from Atlas for the closest point in the Atlas grid, it is reasonable to assume, that the wind speed in the exact point would be higher. Therefore, the productivity would also be higher. Still, the calculated levels of productivity are reasonably high.

The load duration curve for the 7 different groups of wind farms in presented on Figure 5.

Figure 5 WPP load duration curve per each scenario



The WPP load duration curve gives information on how many hours per year the WPP power output level is equal to or larger then a certain power level. For instance, for all seven scenarios around 2800 hours per year, the power level will be above 40% of total WPP installed capacity. In all seven scenarios, the results are relatively similar.

Some characteristic data on duration of certain power ranges or power levels is presented in Table 4.

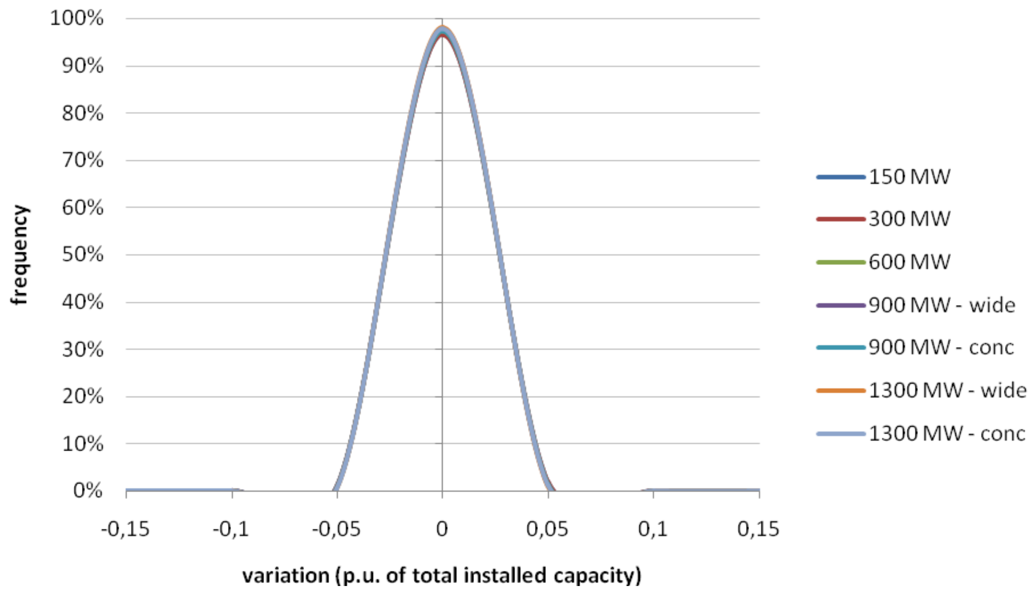
Table 4 WPP power output range time duration (h/yr)

	150 MW	300 MW	600 MW	900 MW - wide	900 MW - conc.	1300 MW - wide	1300 MW - conc.
	Duration (hours per year)						
P=0	185.71	109.47	77.62	55.72	36.81	21.59	24.14
P<=0.05	2856.17	3048.36	2414.51	2354.61	2571.54	2235.06	2447.86
P<=0.1	3838.11	4014.73	3394.62	3309.55	3579.67	3376.33	3473.38
P<=0.15	4397.87	4559.78	4022.35	3921.53	4201.76	4076.38	4116.36
P<=0.5	6436.36	6457.93	6273.18	6243.55	6379.90	6545.75	6432.33
P>=0.8	739.89	1012.75	1136.46	1126.75	1008.88	826.31	938.02
P>=0.9	2.71	4.27	4.79	4.30	3.85	2.41	3.26
P>=0.95	2.68	3.91	4.13	3.17	2.93	1.07	2.04
P=1	0.14	0.14	0.10	0.04	0.03	0.00	0.01

From Table 4 it can be concluded that the extremely high and low power levels become less frequent in scenarios with large installed capacity. As the number of wind farms is increased the total production tends to group more around the average power level. However, that reduction of extreme power level frequency (or grouping around the average power level) with increase in total wind power and/or number of wind farms is not very significant, due to the fact that the analysed area is relatively small in terms of weather systems. In other words, all wind farms experience similar weather patterns at the same time.

Based on the data and the methodology described in the previous sections, the following results are obtained - Figure 6.

Figure 6 WPP variation probability distribution[7]



The full range of variations is larger than the one presented on Figure 6, but the variations outside the -0.05 p.u. to 0.05 p.u. range are extremely seldom and therefore not visible on this graph. In the -0.05 p.u. to 0.05 p.u. range the frequency of variations is practically the same in all scenarios. That kind of result indicates the validity of the assumptions on input data:

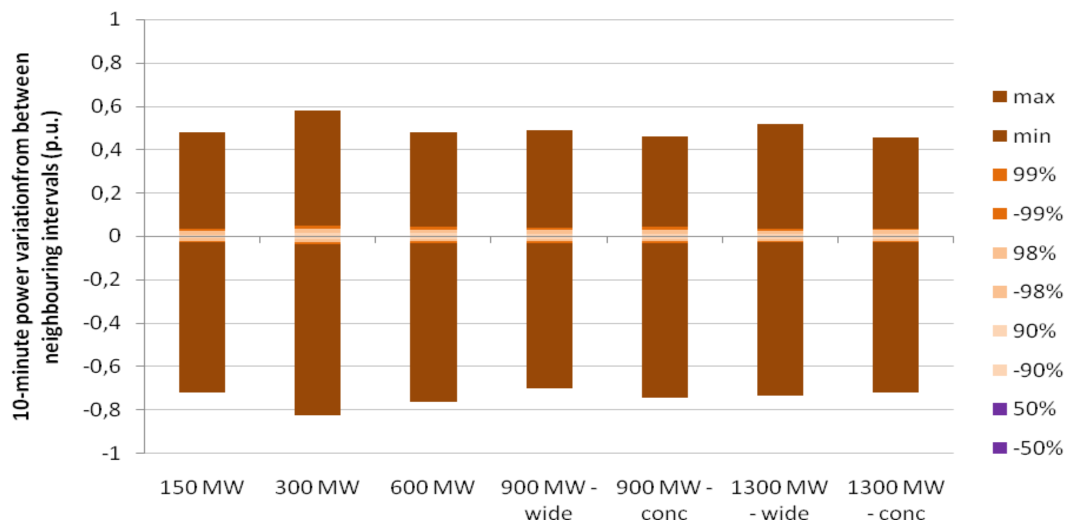
- The smoothed terrain model leads to a higher correlation of the wind speed time series across the analysed area;
- Local (on-site) effects that may lead to higher wind speed variations are not (cannot be) taken into consideration in the MM5 model - resulting in lower than real wind speed variability at each location.

In the aspect of this analysis, the effect described in the first point is conservative, while the effect of the second point may lead to underestimation of variations.

The results of this analysis are also presented in Figure 7 that shows the variations ranges for certain characteristic frequencies (shares of time):

[7] The similarity in the shape of these distribution curves is a consequence of using data from the wind Atlas.

Figure 7 WPP power output 10-min variations



The graph in Figure 7 show that 99% of all 10-minute variations in 10 years occur in the range of roughly ±3-4% of total 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% 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.

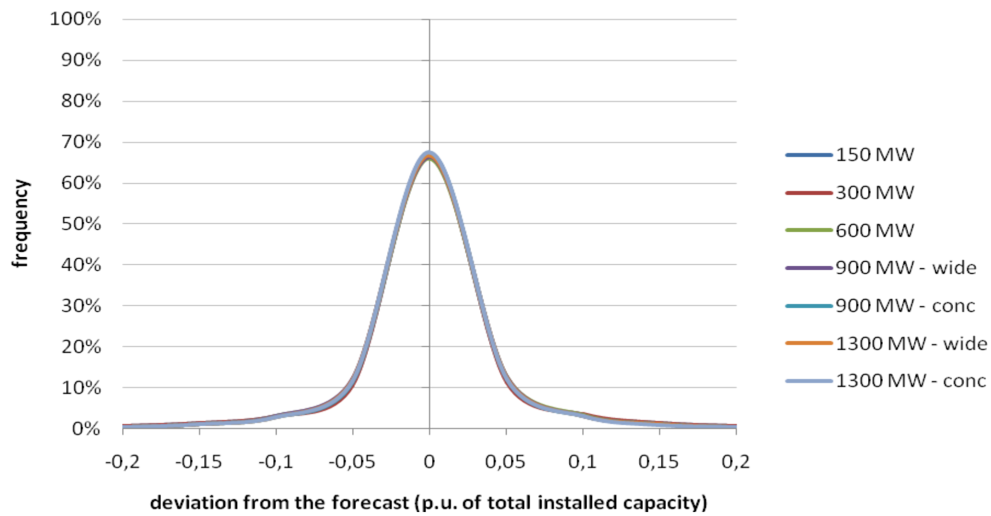
The range in which 50% of all variations occur is so narrow (roughly ±0.3% of total installed capacity) that it can hardly be seen on Figure 7.

We would advise caution when analyzing these results based on Atlas data - according to the similar analysis made for neighbouring systems (but using different wind speed data sources), the range of variations in which 50% to 99% of all variations occur may be significantly larger (i.e. three to five times larger), while the range of maximum variations may be more narrow. But, it has no significant impact on the overall study results, since variation range is not used in system reserve analysis. Instead, deviation from the forecast is used for system reserve needs and these inputs are reliable enough.

4.3.3 System Regulation Capacity for WPP Balancing

Based on the data and the methodology described in the previous sections, the following results are obtained - Figure 8 shows the frequency of certain deviation levels. Deviations are determined as a difference between the current 10-minute power level and the 4-hour forecast. It should again be noted that 4-hour forecast means that a constant value of wind power is planned (forecast) for a period of four hours. That forecast value is determined as an average of all 10-minute power levels in a given four-hour period.

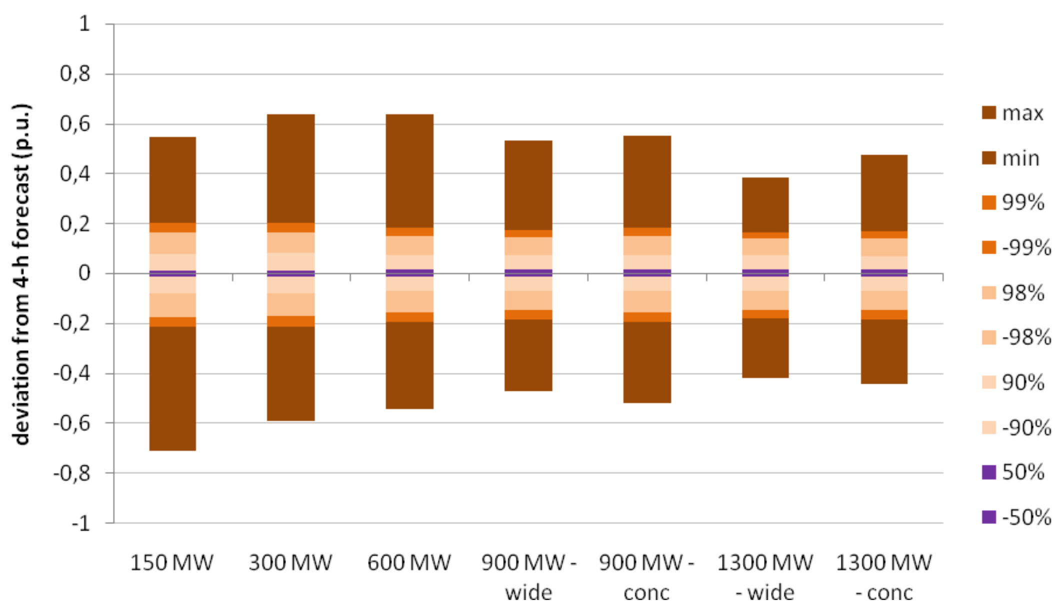
Figure 8 Level of WPP power output deviation from the forecast



Although there is significant difference in results (in terms of ranges and frequencies) between 10-minute variations and 10-minute deviations from 4-hour forecast, the results for the seven scenarios are in both cases very similar, adding to the assumptions stated in the previous section.

Above 99.5% of all deviations occur in the ±0.2 p.u. range, so the full range of the graph is not shown in order to better present the details. The results of this analysis are also presented in Figure 9, which shows the variations ranges for certain characteristic frequencies (shares of time):

Figure 9 WPP power output deviations from 4-h forecast



99% of all deviations occur in the range of around ±20% of total installed capacity, while the maximum deviations range from ±40% to ±60%, depending on the scenario.

When comparing ranges of deviations for widely distributed and concentrated scenario, a small but positive effect of geographical dispersion (reduced correlation) can be observed - deviation ranges for wide distribution scenarios are in both cases a bit narrower than in concentrated scenarios.

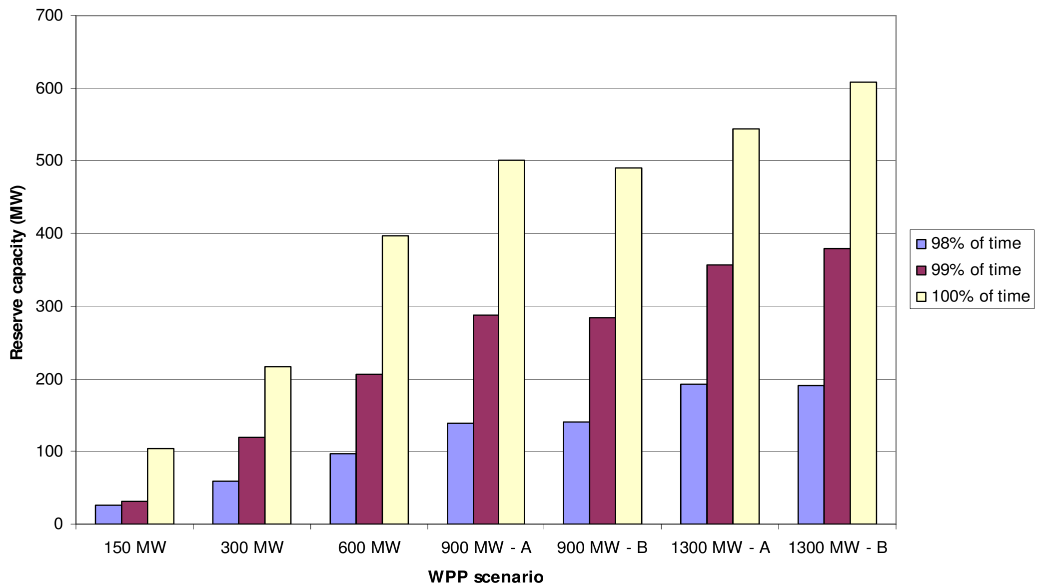
In terms of capacity expressed in MW required for regulation in each scenario, the results are presented in Table 5 and in Figure 10.

Table 5 Required system regulation capacity per each WPP scenario with 4-h average as WPP forecast

	150 MW	300 MW	600 MW	900 MW - wide	900 MW - conc	1300 MW - wide	1300 MW - conc
Installed capacity (MW)	160	**352**	**637**	**950**	**901**	**1309**	**1297**
Share of time	**Required secondary regulation capacity (MW)**						
98% of time (inadequate 175 hours a year)	26	59	97	139	140	192	190
99% of time (inadequate 88 hours a year)	32	120	207	287	284	357	380
Maximum - once in **ten** years	104	217	397	500	490	544	608

If the appropriate forecast tools are not available to predict the occurrence of production variation with acceptable certainty, then the ISO should at all times have enough regulation capacity to regulate the largest possible variation, no matter of its probability.

Figure 10 Required reserve capacity per each scenario



Based on these values as well as on the existing dispatchers' practice in BiH it is possible to estimate which level of system reserve is available for WPP integration.

In determining the required regulation capacity shown in Table 5 and Figure 10, the larger deviation (in absolute numbers) between the negative and positive is taken as reference. These results show the percentage of time in which the stated regulation capacity is adequate for balancing of wind power deviations (both positive and negative). In the remaining time (expressed in hours per year) that level of regulation capacity is inadequate. The amount of energy expended only in positive regulation (increasing power of other power plants, when the wind power is reduced during negative deviations) is shown in Table 6.

Table 6 System regulation energy in each WPP scenario

Scenario	150 MW	300 MW	600 MW	900 MW - wide	900 MW - conc	1300 MW - wide	1300 MW - conc
Energy expended in positive regulation annually (GWh)	18.67	43.00	77.27	112.65	107.44	154.49	150.70
Share of energy produced by wind farms	**5.16%**	**5.35%**	**4.83%**	**4.68%**	**4.98%**	**5.06%**	**4.89%**

The same amount of regulating energy would deliberately not be produced by conventional power plants during positive deviations of wind power.

Necessary regulation capacities are divided into three values for each scenario of WPPs construction, depending on the wind forecast error (real regulation capacity will be determined by this error, once the wind forecast techniques are applied in BiH), and percentage of time for which regulation capacity values will be sufficient to regulate wind speed and wind power plants production variations.

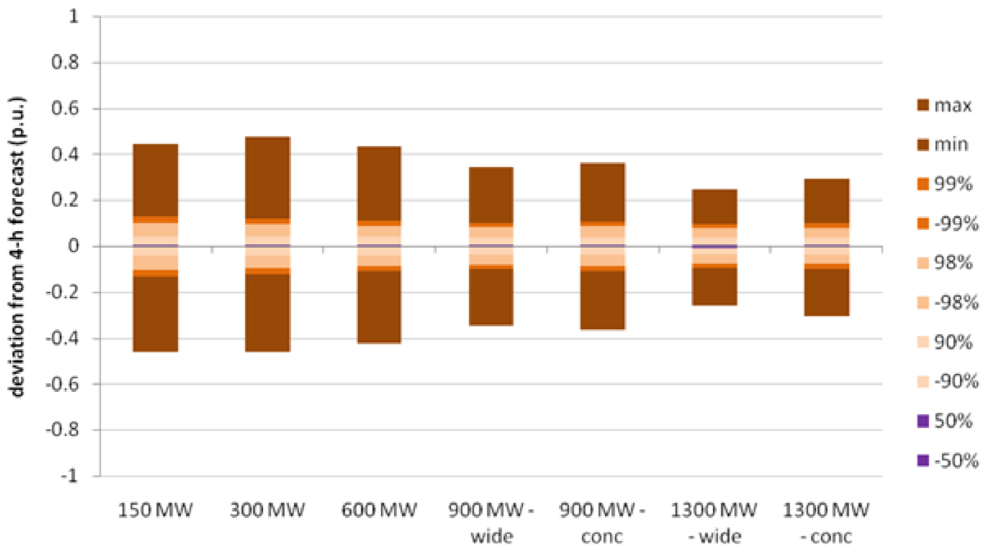
According to the Decree on ancillary services and dispatchers' practice, secondary regulation in BiH should practically always be available at around ±50 MW, as defined by ENTSO-E obligation. This capacity is adequate for unexpected load variations. It is important to point out here that in BiH there are three power companies with planned and realized consumption. So, total unexpected load variations on the system level are practically the sum of three variations. Usual deviation between realized and planned consumption is up to 5%. Section 5.1 provides an overview of the BiH experience in reserve provision. Above mentioned reserve capacity of about ±50 MW should be enough to cover load variations. But, for WPP integration additional secondary reserve capacity should be available, as given in Table 5.

In other words, with total available regulation capacities of existing ±50 MW it is not possible to regulate any WPP and thus significant additional regulating capability will be required when the first WPP is commissioned. If there is a desire to integrate 148 MW of WPP (scenario A), then the ISO needs an additional ±104 MW of maximum regulation capacity, as given in the Table 5. For the remaining scenarios there is a need for additional maximum regulation capacity of about ±217 MW (for scenario 300 MW), ±397 MW (for scenario 600 MW), ±500 MW (for scenario 900 MW) and up to ±600 MW (for scenario 1300 MW).

These values have been determined assuming that during 10 years period of time there will not be a single 10-minute period with inadequate reserve capacity, no matter how low its probability. Also, it is assumed that deviations are determined as a difference between the current 10-minute power level and the 4-hour forecast, where forecasted value is determined as an average of all 10-minute power levels in a given four-hour period. In other words, we assumed that forecast error is equal to deviation from 4-hour average. It has to be kept in mind that forecast equal to 4-hour average is not high level forecast quality. If we have better forecast tools, equivalent to 2-hours average, or 1-hour average, regulation needs would definitely be lower.

Figure 11 shows WPP power output deviations from 2-h forecast (in fact 2-hour average). If we compare it with WPP power output deviation from 4-h forecast (see Figure 9), here we clearly have much lower level of deviations. This implies much lower level of required reserve capacity than given in the case of forecast equal to 4-h average.

Figure 11 WPP power output deviations from 2-h forecast



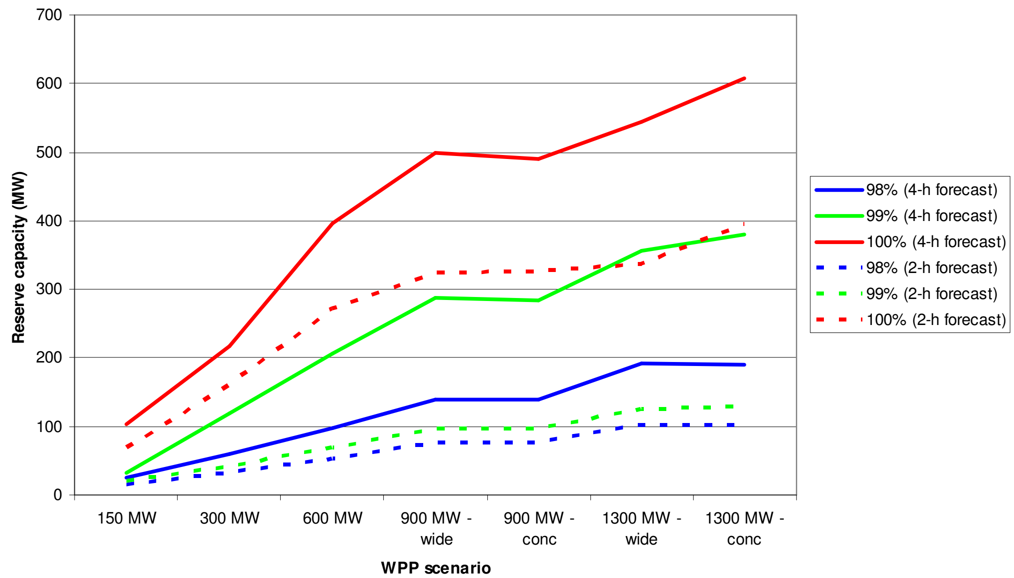
For this case in Table 7 required power system regulation capacity per each scenario is shown.

Table 7 Required system regulation capacity per each WPP scenario with 2-h average as WPP forecast

	150 MW	300 MW	600 MW	900 MW - wide	900 MW - conc	1300 MW - wide	1300 MW - conc
Installed capacity (MW)	160	**352**	**637**	**950**	**901**	**1309**	**1297**
Share of time	**Required secondary regulation capacity (MW)**						
98% of time (inadequate 175 hours a year)	15	33	53	76	76	101	102
99% of time (inadequate 88 hours a year)	19	41	68	96	96	125	128
Maximum - once in **ten** years	68	161	272	323	326	337	395

Comparison of these two levels of forecast error (forecast taken as 4-h average and forecast taken as 2-h average) is shown on the Figure 12, in which dotted lines present 2-h forecast while solid lines present 4-h forecast.

Figure 12 Comparison of required system reserve for two levels of forecast error



In other words, if WPP generation forecast has the same error as WPP generation deviation from previous 2-h average generation, then for integration of 150 MW of WPPs the BiH system would need 68 MW of additional reserve capacity just for WPPs. If forecast error is equal to 4-h average, then required reserve capacity for the same scenario would be 104 MW. Both numbers are obtained under assumption that 100% of the time BiH system will keep maximum reserve capacity, or in other words, in ten years BiH system would never have insufficient reserve capacity to cover WPP deviations. Clearly, if forecast error is equal to deviation from previous 1-h average, required reserve capacity would be even lower.

Additional reduction of regulation capacity is obtained if we observe number of hours per year during which regulation will be sufficient to cover wind production variations. For example, if for ISO it is acceptable to have adequate reserve for 99 % of time (insufficient for 88 hours per year), required reserve capacity would be additionally reduced. In the 150 MW scenario with forecast error equal to deviation from 2-h average required reserve capacity would be ±19 MW only, while in the same scenario with forecast error equal to deviation from 4-h average required reserve capacity would be ±32 MW. Moreover, if for ISO it is acceptable to have adequate reserve for 98 % of time (insufficient for 175 hours per year), required reserve capacity would be further reduced. In the same 150 MW scenario with forecast error equal to deviation from 2-h average required reserve capacity would be ±15 MW only, while in the same scenario with forecast error equal to deviation from 4-h average required reserve capacity would be ±26 MW.

Required reserve capacities for all other scenarios and timeframes are given in Figure 12, which is derived from the best input data that is currently available. However, based upon BiH practical experience with WPPs once they are in operation and the introduction and calibration of a wind forecast system, the ISO

BiH will have much more input data to inform the decision as to which level of security and probability is acceptable for their system needs.

Finally, other countries experience in the extent of 10-min and hourly variations of wind power and demand are shown in Table 8. Clearly, these variations are predictable, but they cause large amount of uncertainty. The better WPP forecast is, the lower reserve is needed.

Table 8 Hourly WPP generation variations as a share of installed wind capacity[8]

			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%		

1-hour WPP generation variations are in the range of 16-36% of WPP installed capacity. 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).

In comparison, in BiH for all scenarios the graphs given above show that 99% of all 10-minute variations in 10 years occur in the range of roughly ±4% of total installed wind capacity, which is of similar magnitude to the above mentioned values[9]. However, the maximum range of variations in BiH in 10 years is much wider, ranging from around -75% to 50% of total installed capacity. As mentioned above, these data are not fully comparable because BiH data are not obtained from operating WPPs and from the same region size. For example, in BiH scenario 150 MW the distance between these two WPPs is about 80 km, while in the largest scenario 1300 MW (wide scenario) the area is about 100 x 200 km^2. So, the values given in Table 8 can be taken for illustration purposes only. Based on comparison with wind results and experience from other countries it would be reasonable to assume that the results for BiH produced from Atlas data are likely to be an underestimate of reserve requirements.

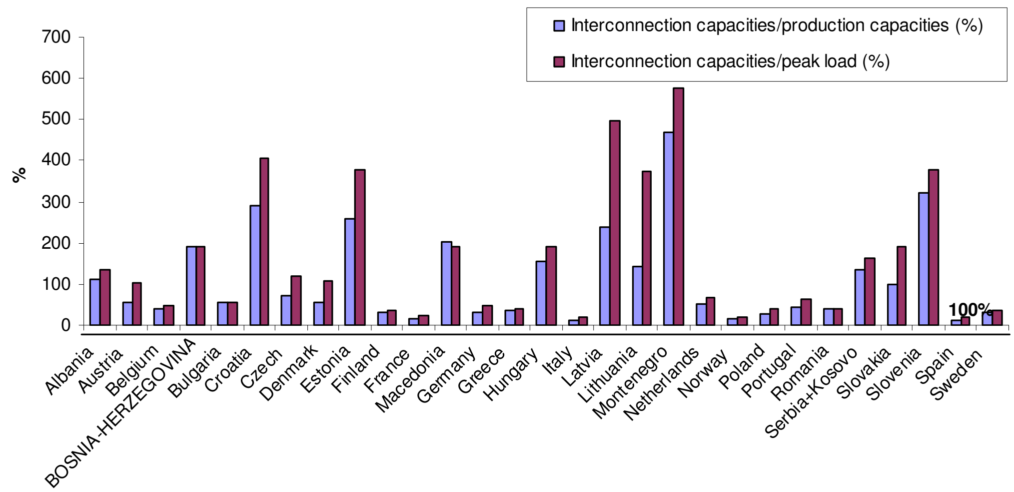
[8] Denmark, data 2000-2002 from http://www.energinet.dk; Ireland, Eirgrid data, 2004-2005; Germany, ISET, 2005; Finland, years 2005-2007 (Holmgren, 2008); Sweden, simulated data for 56 wind sites 1992-2001 (Axelsson et al., 2005); Portugal, INETI; EWEA, Grid Report 2010

[9] It is noted that using Atlas data may lead to underestimates in the 99% range, but there are currently no suitable measured wind data for BiH available

4.3.4 Cross-border issues

The BiH power system is very well connected to the neighbouring systems, as shown in Figure 13. Total installed interconnection capacity of BiH covers about 200% of its peak load and about 200% of total generation capacity.

Figure 13 BiH interconnection capacity in comparison to other European countries



WPP penetration in BiH could have certain impact on power system of neighbouring countries. Namely, most of the potential WPP locations are relatively close to the border. WPP penetration could impact some interconnector flows, which will need to be taken into account by both ISO/TSOs in the process of grid connection analyses. Fortunately, interconnection lines are not fully loaded, so preliminary speaking bottlenecks on the interconnections are not expected with WPP operation. All analyses in this study were done on regional power system models, verified by all TSOs from Slovenia to Turkey, including all WPPs in Croatia that have connection consent. Also, the 10 years network development plan for Croatian transmission system is taken into account. In this way, the impact of the neighbouring systems is taken into account.

However, a mechanism will need to be in place for within day international trading in order to properly accommodate the variability associated with wind output.

Due to strong interconnection to the neighbouring systems, ability to share power system reserves in between two systems should be analyzed separately. So far, each power system has respected UCTE/ENTSO-E Operational handbook provisions and other international obligations. In the region there is no reserve sharing. The only experience in that sense was an annual contract on tertiary regulation in between Slovenian TSO and HPP in southern BiH. We believe reserve sharing possibility could be useful for larger WPP integration in the future, but there are many assumptions to be fulfilled in advance. First of all, there is no ancillary service mechanism introduced so far in all regional systems. From the other side it is expected that a regional electricity market will be established with many market products. But, at this stage we believe that WPP integration possibilities should be determined using only BiH resources.

4.4 Summary of Scenario Analysis

This section aims to review the projects already authorised and/or those proposed or planned to assess the total capacity of wind power in BiH, to analyse expected WPP production and to comment on system regulation capacities needed for WPP balancing.

ISO BiH has provided the basic information on planned wind power plants, and has developed scenarios to be analysed. 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 the southern part of the country with the largest wind potential. The total capacity of these projects is more than 3,000 MW (source: NOS BiH, ISO) although most of these projects will never be realised.

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, phase one) have been under way since September 2010.

For determination of installed capacity for each scenario, the energy penetration level was calculated for a demand forecast for 2020 based on data from the above mentioned Indicative Development Plan, in which there are four different prognoses. The average of these four prognoses (15.1 TWh by 2020.) is taken for further calculation. With the wind farms' productivity assumption of around 2300 FLH, the following scenario limits are defined:

- 150 MW
- 300 MW
- 600 MW
- 900 MW - concentrated
- 900 MW - wide distribution
- 1300 MW - concentrated
- 1300 MW - wide distribution.

As mentioned before, additional scenario (A1, 200 MW) is also analyzed in the Task 2.

Scenarios, defined according to the list from IPP, with WPPs installed capacity between 150 MW and 900 MW were to be analysed in detail, while scenarios with 1300 MW of WPPs installed capacity would be analysed on a more general level.Transmission network analysis and necessary transmission investments, presented in the Task 2 and Task 3 reports, comprises scenarios between 150 MW and 900 MW of WPPs.

These scenarios are "filled" with wind farm locations selected from a list of around 50 wind farm locations and sizes provided by the ISO from the IPP list. In selection of the projects the following 10 criteria are used (listed according to priority):

- Constructed or in construction
- Issued construction (building) permit
- Issued location permit (urbanism approval)
- Issued grid connection approval
- Positively concluded environmental impact assessment procedure
- Wind energy potential
- Resolved land use or land ownership rights
- Concession
- Wind climate measurements done or in progress
- Listed as an project of public interest by the Government of Federation of BiH or defined in the Energy strategy of Republika Srpska.

It is important to point out that for this kind of analysis it is not crucial to evaluate a given WPP project itself, but overall mutual impact on system operation, no matter of specific WPP project or investor. In that sense neither we nor ISO are making any arbitrary inclusion of any specific WPP projects.

ISO has also provided the Wind atlas of Bosnia and Herzegovina (Atlas). The Atlas is an application made by the Swiss company Sander + Partner GmbH that enables the creation of a 30-year long 10-minute wind speed and direction data series (1978 - 2007).

The analyses presented here are based on Atlas data - 10 minute wind speed series for the point in the 1 km x 1 km grid closest to the coordinate defined as representative for a given wind farm. Productivity of the groups of wind farms in the 7 defined scenarios is expressed through full load hours in the range of 2259 h/yr to 2534 h/yr. Having in mind that the productivity is calculated based on the long term data derived from the Atlas for the closest point in the Atlas grid, it is reasonable to assume that the wind speed in the exact point would be higher. Therefore, the productivity would also be higher. Still, the calculated levels of productivity are reasonably high.

99% of all 10-minute variations in 10 years occur in the range of roughly ±3-4% of total 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% 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).

Deviations are determined as a difference between the current 10-minute power level and the 4-hour forecast. It should again be noted that 4-hour forecast means that a constant value of wind power is planned (forecast) for a period of four hours. That forecast value is determined as an average of all 10-minute power levels in a given four-hour period. 99% of all deviations occur in the range of around ±20% of total installed capacity, while the maximum deviations range from ±40% to ±60%, depending on the scenario.

When comparing ranges of deviations for widely distributed and concentrated scenario, a small but positive effect of geographical dispersion (reduced correlation) can be observed - deviation ranges for wide distribution scenarios are in both cases a bit narrower than in concentrated scenarios.

In terms of capacity expressed in MW required for regulation in each scenario, the results are presented in Table 5 and in Figure 10.

Additional reduction of regulation capacity is obtained if we observe the number of hours per year during which regulation will be sufficient to cover wind production variations. For example, if for ISO it is acceptable to have adequate reserve for 99% of time (insufficient for 88 hours per year), required reserve capacity would be additionally reduced. In the 150 MW scenario, with forecast error equal to deviation from 2-h average, required reserve capacity would be only ±19 MW, while in the same scenario with forecast error equal to deviation from 4-h average required reserve capacity would be ±32 MW. Moreover, if for ISO it is acceptable to have adequate reserve for 98% of time (insufficient for 175 hours per year), required reserve capacity would be further reduced. In the same 150 MW scenario, with forecast error equal to deviation from 2-h average, required reserve capacity would be only ±15 MW, while in the same scenario with forecast error equal to deviation from 4-h average required reserve capacity would be ±26 MW.

5 Technical requirements for WPP integration

After several months of preparation and consultation, new technical requirements for WPPs in BiH were adopted by DERK and introduced in May 2011. A Grid Code Upgrade section has been added to the BiH Grid Code, entitled "Technical requirements for WPP connection to the grid". (See discussion in section 6 below)

Technical requirements for connection and operation of WPPs are:

- Requirements related to regulation of frequency and management of active power
- Requirements which are related to regulation of voltage and compensation of reactive power
- Requirements which are related to data on WPP in the process of application for connection to the grid and data during its operation.

The details on technical requirements for generation units and specifically WPPs in BiH are presented in the following sub-sections.

5.1 Frequency regulation and active power control techniques

This section reviews frequency regulation and active power control techniques in BiH with reference to experience in different countries, as outlined in the ToR second bullet point. Several relevant international experiences are included as comparisons and examples.

These requirements refer to the ability of wind farms to regulate i.e. to reduce their power output to a defined level (active power curtailment) either by disconnecting turbines or by pitch control action. In addition, most Grid Codes require wind farms (especially those of large installed capacity) to provide frequency response, which means to regulate their active output power according to the frequency deviations i.e. to contribute to the regulation of system frequency by either increasing or decreasing their MW output in response to any changes in system frequency. It should be emphasized also that the active power ramp rates usually must comply with the respective rates applicable to conventional power units.

While system frequency is usually (99.99 % of the time) maintained within normal operational range, the ISO has to ensure secure power system operation during the worst power system faults as well. This, the ISO has to ensure that all generators have the capability to tolerate incidents of high and low frequency excursions. The ISO therefore requires the generators to have capability of changing output power according to the system frequency changes. Since electricity cannot be stored efficiently, production and consumption must be constantly equalised and automatic frequency regulation has to be applied.

5.1.1 Experience of reserve provision in BiH

The model for the provision and use of all ancillary services in the power system of BiH is defined by the Tariff Pricing Methodology for Services of Electricity Transmission, Operation of the Independent System Operator and Ancillary Services and the Decision on Determination of Tariff for Ancillary Service. The number of participants in the ancillary service mechanism is reduced and in practice brought down to the three existing power utilities, eligible customers (Aluminij, d.d. Mostar) and Komunalno Brčko. Within this mechanism three power utilities are on the side of both receivables and payables, while eligible customers and ED Brčko are only on the side of payables. Some more details in reserve provisions experience in BiH are given in DERK's annual report[10], while some more values are obtained from ISO.

Ancillary services in BiH include the following:

- Primary regulation,
- Secondary regulation (P/f),
- Tertiary regulation (P/f),
- Voltage / reactive power regulation (U-Q),
- Black start capability,
- Energy for losses in Transmission network.

Primary regulation of power and frequency is an ancillary service provided by the generation units at their own expense.

In 2010 DERK determined values for capacity reserve for **secondary regulation** service. Price is set to 16,257 KM/kW per month. It is also determined that total monthly requirements (from 43 MW in June up to 59 MW in December) is split to 5 power plants, as shown in Table 9:

- HPP Jablanica,
- HPP Trebišnjica,
- HPP Višegrad,
- HPP Rama and
- HPP Bočac.

[10] DERK Energy Sector Annual Report 2009

Table 9 Secondary reserve capacity in 2010

Month 2010	Secondary reserve capacity (MW)					
	Required capacity	HPP Jablanica	HPP Trebišnjica	HPP Višegrad	HPP Rama	HPP Bočac
January	57	22	5	14	11	5
February	54	21	5	13	10	5
March	50	20	5	11	9	5
April	46	16	5	11	9	5
May	45	16	5	12	7	5
June	43	16	5	11	6	5
July	44	16	5	12	6	5
August	46	17	5	13	6	5
September	48	20	6	15	7	0
October	50	21	5	12	7	5
November	54	22	5	13	9	5
December	59	23	5	15	11	5

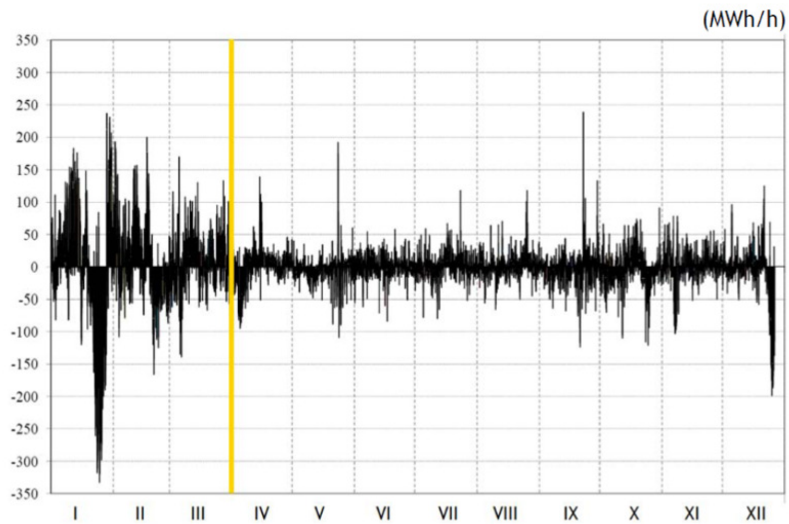
ISO administers the procedure for purchase of the ancillary service. Until the realization of technical preconditions for billing has been achieved, the energy delivered through the secondary regulation regime is treated (compensated) through the billing and compensation of unwanted deviations. Thus, all unscheduled deviations are currently measured and then compensated by returning the energy involved either the following day or week and no money changes hands.

Besides above mentioned HPPs there is a possibility for other power plants to participate in secondary regulation as well. Having in mind very well developed HPP portfolio in BiH as well as ISO experience in P/f regulation, it seems that BiH is technically capable of fulfilling its system reserve needs. But the main problem is [the absence of the] ancillary service mechanism application and payments. It is not usual that the system operator is not allowed to actively participate in the ancillary service mechanism. But, in the BiH case, the system operator can only monitor other subjects' behaviour, so definitely this principle should be improved by giving adequate responsibilities to the system operator.

The price for **tertiary regulation** is set at 5,216 KM/kW and the tariff set for electricity delivered through the tertiary regulation regime is 23.295 pf/kWh. This kWh price is calculated as triple the value of an electricity price of the most expensive generation unit in the system. ISO BiH administers the procedure for purchase of ancillary service of tertiary regulation from licensed electricity generators/public utilities comprising generation units. All 3 utilities (EP HZHB, EP BIH, ERS) are obliged to provide mentioned required capacity (250 MW) for provision of the ancillary service. Public utilities must provide this service within the scope of 80 – 100% of the reserve offered with a possibility to nominate other generation units. ISO BiH should identify the users who pay for electricity delivered through the tertiary regulation regime. Duration of one-off utilisation of tertiary reserve can last up to 6 hours from the moment of ISO BiH order, with maximum usage 4 times within one month. Minimum time between two engagements is 48 hours.

Despite all above mentioned regulations and definitions, currently the biggest problems in the ancillary service mechanism in BiH, as well as in WPP integration analyses are non-allowed deviations of whole the BiH system with respect to daily schedules or market plan. Since the end of 2008 to date , unwanted, i.e. non-allowed, unscheduled hourly deviations from the daily schedules has been reaching drastic levels, which disturbed normal operation of the system, and caused an adverse reaction by the ENTSO-E block coordinator. More precisely, the largest deviation (imbalance) of BiH system on interconnector flows in 2009 was +240 MWh/h and -330 MWh/h, as shown in Figure 14 (negative deviation implies system surplus, while positive deviation implies system deficit).

Figure 14 Unwanted hourly deviations of BiH system interconnector flows in 2009



Source: DERK)

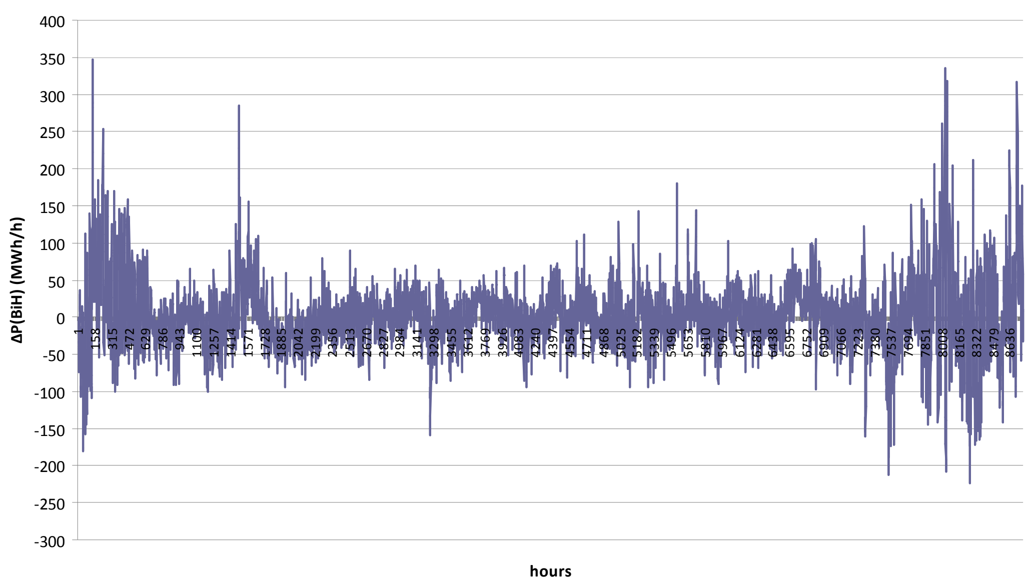
Due to above mentioned problem, DERK insisted on introducing settlements and payments for unwanted (non compliant) deviations as stipulated by the Market Rules as these deviations are in breach of both the market rules and the ENTSO-E rules. Since then (April 1, 2009, see Figure 15) according to statements of all stakeholders, these deviations have been reduced to more acceptable levels till the end of 2009.

According to DERK's report, on an hourly basis of each balance responsible party are calculated and paid pursuant the provisions of Market Rules. Pursuant to Market Rules, ISO BIH uses regulated electricity prices at outlets of generating units for calculation of prices for non-allowed deviations.

After hourly nominations are received, ISO BIH calculates and announces the imbalance price to be used during the following day for all settlement periods during the following day (exchange program). There is one imbalance price for hours in which the BiH control area has a surplus of capacity/energy, that is, hours in which the system is 'long' and another imbalance price for hours in which the BiH control area lacks capacity/energy, that is, hours in which the system is 'short'. The system is considered 'long' in an hour during which the regulation error of the control area is positive. 'Top-up Imbalance Price' (VCD_d) for Day *d* equals the regulated energy price of the most expensive generating unit nominated for that day *d* and is applied during those settlement periods for which the system turns 'short'. 'Spill Imbalance Price' (NCD_d) for Day *d* equals the regulated energy price of the cheapest generating unit nominated for that day *d* and is applied during those settlement periods for which the system turns 'long'.

But, in 2010 the situation got worse again, especially at the beginning and the end of the year, as shown in Figure 15 and Figure 16. The largest deviation of BiH system interconnector flows in 2010 was +347 MWh/h and -224 MWh/h. In 2010 35 hours (equivalent to one and half days in a row) these deviations were larger than ±200 MWh/h as shown on the Figure 16 and Figure 17 .. Even though these deviations are naturally compensated within Control Block in between local TSOs involved (Croatia and Slovenia), under coordination of ENTSO-E control block coordinator (Slovenian ELES), it is very big issue that must be resolved before WPP integration can commence in the BiH system.

Figure 15 Unwanted hourly imbalance of BiH system toward interconnection in 2010



Source: ISO BiH

Figure 16 Histogram of unwanted hourly imbalance of BiH system in 2010

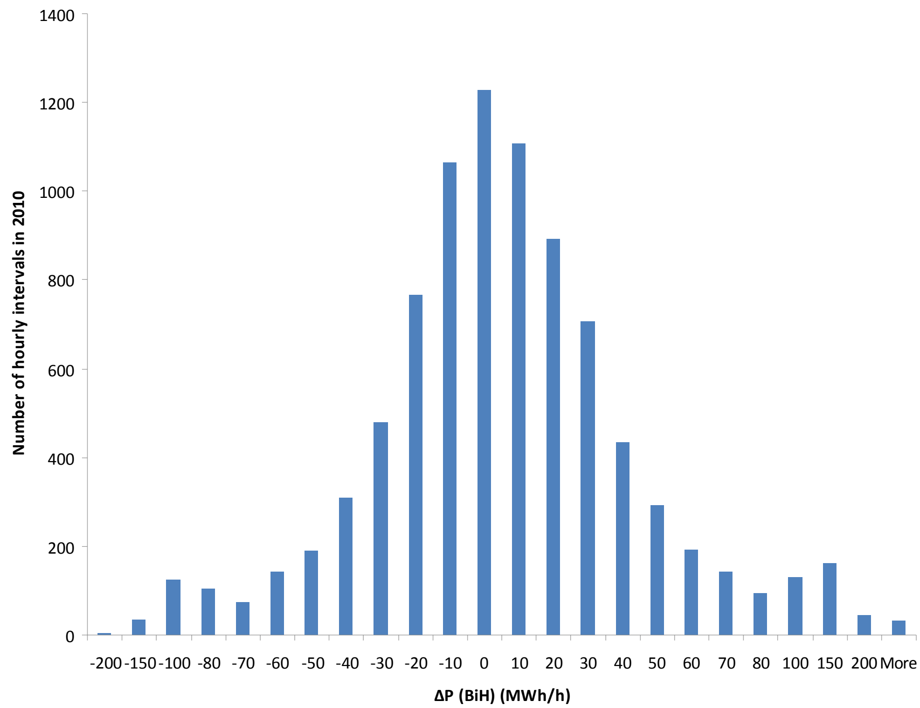
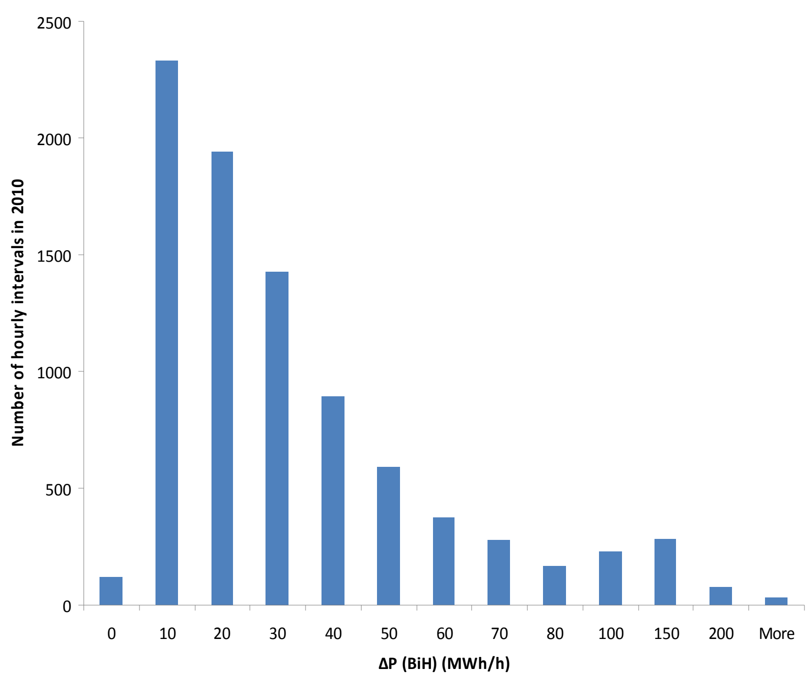


Figure 17 Histogram of absolute values of unwanted hourly deviations of BiH system in 2010



In 2010, 632 hours (or 7,2% of the year) the BiH system had unscheduled, non compliant deviations towards neighbouring systems that were larger than 100 MWh/h.

5.1.2 WPP impact on system balance

WPPs will increase this imbalance problem, especially before an adequate wind forecasting system is applied and calibrated to local specifics. Moreover, neighbouring systems are also facing the problem of unwanted deviations. In the absence of improved operating practices, larger system operation problems could be expected. Accordingly, it is crucial to make ancillary service mechanism in BiH work properly and fully, with all responsible parties having their respective roles clearly defined, with all their responsibilities, obligations and rights. Also, the ancillary service mechanism has to be fully enforced in all neighbouring countries before all of them integrate large share of WPPs as planned.

Within this sub-section we analyze:

- the level of deviation in between planned and realized system load in BiH (note that in the previous sub-section we analyzed total system imbalance toward neighbouring systems which comprises of load and generation deviations from the plan),
- the level of deviation in between forecast and realized WPP production,
- the level of deviations of the sum of two above mentioned independent values.

For this purpose we were given input data on planned and realized system load (consumption) in 2010 by ISO. Figure 18 shows the deviation between realized and forecast system load in BiH. It goes up to ±350 MWh/h, with average absolute value of 49 MWh/h.

Figure 18 Hourly deviation between realized and planned system load in 2010

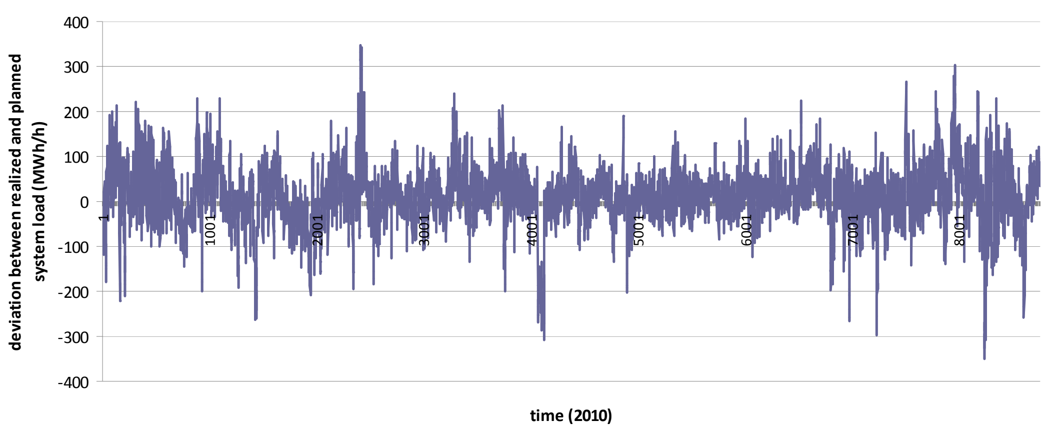


Figure 19 Histogram of hourly deviations between realized and planned system load in BiH 2010

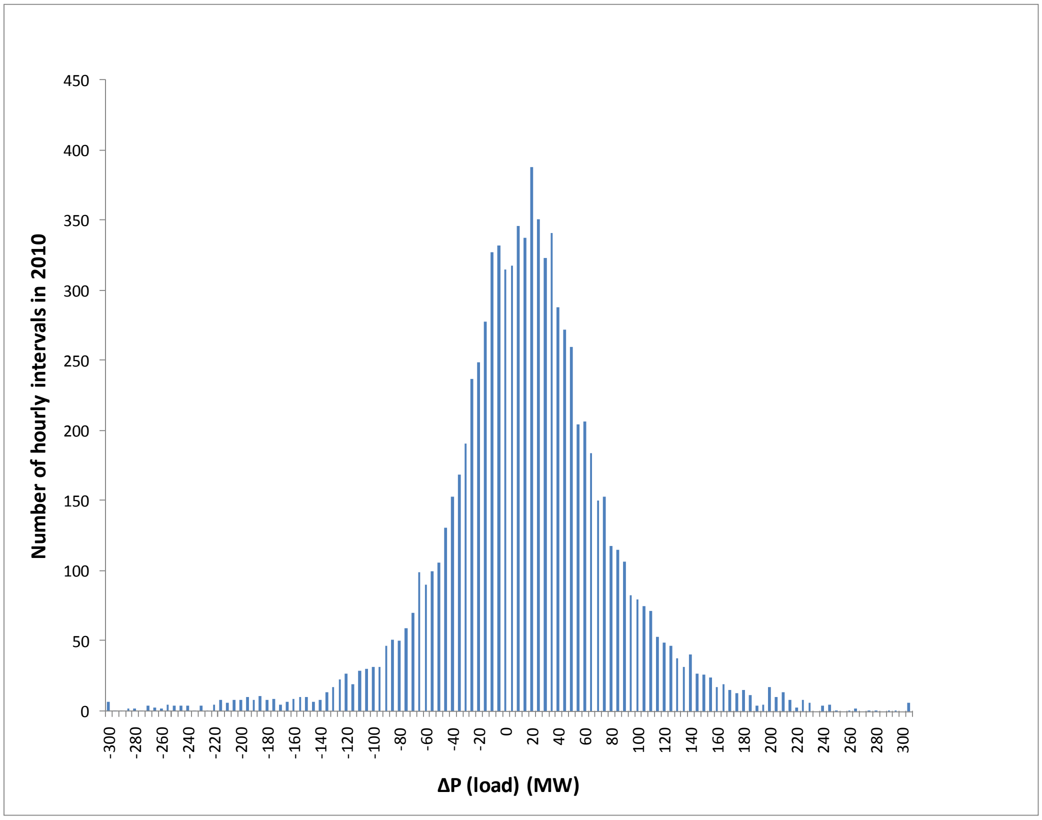


Figure 19 shows the histogram of hourly deviations between realized and planned system load in BiH in 2010. Having in mind that system peak load is 2100 MW and system minimum load is 800 MW, these deviations are extremely large. It is usual to have load deviation on the level of up to 5%, depending on the consumption structure, but these values for BiH are several times higher. It implies that load forecasting needs to be significantly improved before WPP integration starts. In addition, some analysis of why such large deviations from the forecast have been experienced would be appropriate.

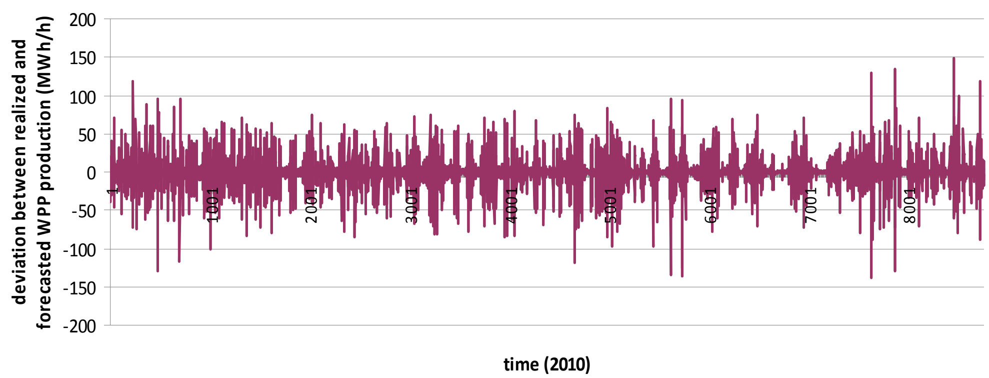
The difference between total system imbalance toward neighbouring systems (Figure 15) and load deviation from the forecast (Figure 18 clearly shows that the other variables (HPP, TPP generation) are also significantly deviating from forecast. Forecasting thus needs to become more accurate. For 2010, the correlation coefficient[11] between system imbalance and load deviation from the forecast is -0.35, which is rather low.

On the other side, for the purpose of this analysis only, we used available WPP production data for average windy year (assumed to be 2010) in the scenario with

[11] It is obtained by dividing the covariance of the two variables by the product of their standard deviations

340 MW of WPP installed capacity. Hourly deviations between realized and forecasted (4-h average) generation is calculated and presented in Figure 20

Figure 20 Hourly deviation between realized and forecasted WPP production



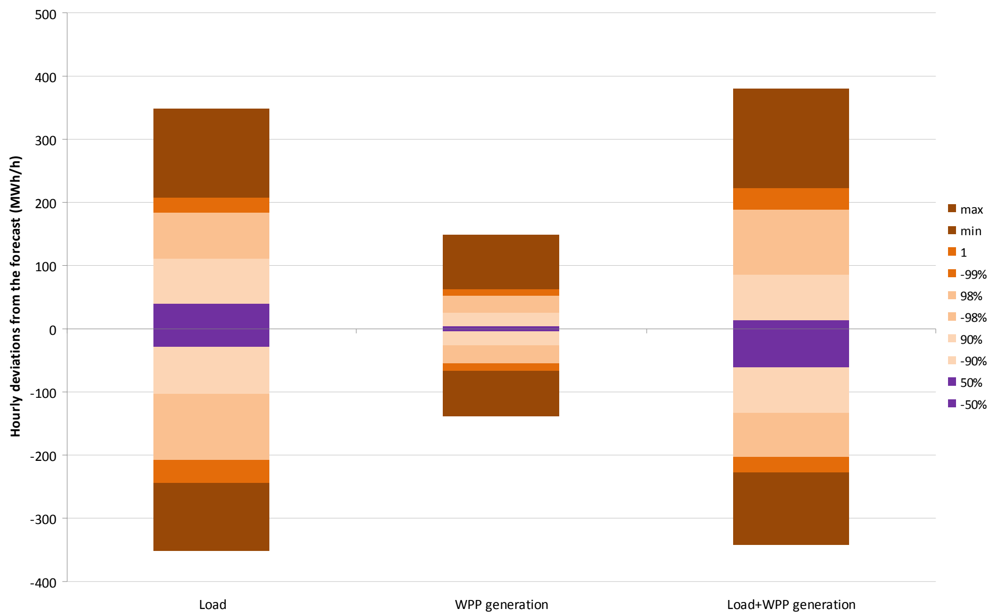
Clearly, the level of deviation is much lower than in the current case of system load. Maximum deviation between realized WPP production and 4-hours average is +148 MWh/h (-139 MWh/h). Accordingly, its impact on load deviations is not expected to be very high. However, this may change in the event that load forecasting techniques are significantly improved (which should be readily achievable).

If we assume that these two variables are happening simultaneously, we would get illustration of potential impact of WPP on the system load deviations from the plan.

Naturally, since there are no exact WPP data for 2010, this kind of analysis can be taken for illustration purposes only. Moreover, these two variables (load and WPP generation) are independent variables. It means that its mutual relationship is not strongly correlated and can be different from one time horizon to another. For this kind of analyses it has to be kept in mind that load and WPP variations are of the opposite direction, meaning that negative load deviation and positive WPP deviation are to be summed (and vice versa) to get total variations that the dispatcher is supposed to balance in practice.

If we put load deviations and WPP deviations from the forecast together in the same time domain, we got output as shown in Figure 21. In this example WPP integration would slightly increase total deviations of expectation. For example, maximum total positive deviation (load + WPP) is 379 MW, while maximum load deviation was 348 MW. Also, 50% of the time load deviations from the forecast are in the range <-29 MW, 40 MW> , while with WPP inclusion total deviations from the forecast (load+WPP) are in the range <-61 MW, 13 MW> (so it is asymmetrical impact of WPPs). The details are shown in Figure 21.

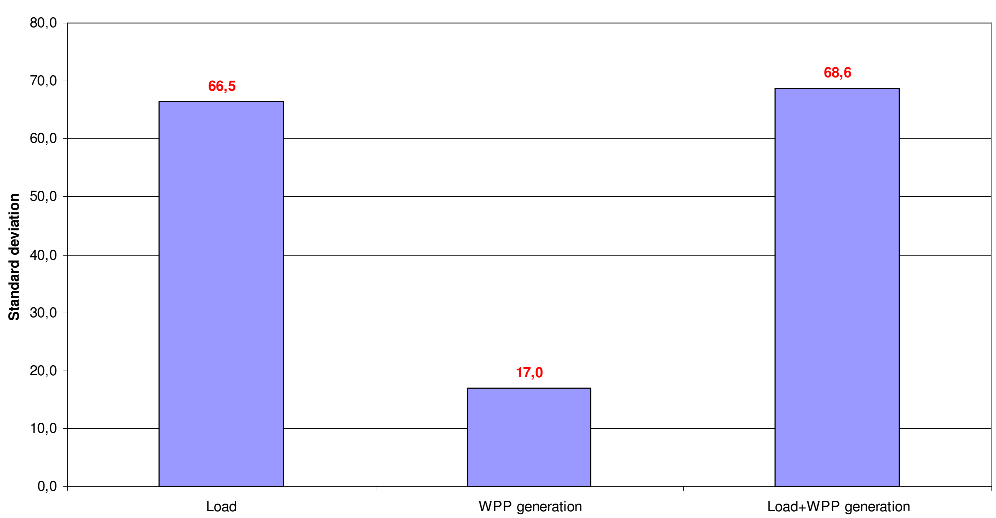
Figure 21 Hourly deviations from the forecast in all three cases



Total impact of WPP can be easily indicated with standard deviation value, as shown on the Figure 22. Standard deviation is quite a good indicator in this case, since deviation distribution is close to Gaussian (normal) distribution in which 99% of the cases are covered by three standard deviations.

Having in mind all above mentioned assumptions for this illustration example, it is clear that WPP will have negative impact on overall system deviations from the forecast: standard deviation with WPPs is equal to 68,6, while standard deviation without WPPs is 66.5 This analysis is based upon existing load forecasting practices.

Figure 22 Standard deviation from the forecast for all three cases



Finally, based on all above mentioned, the conclusions on forecasting, reserve provision experience and potential impact of WPPs are as follows:

- load forecast should be significantly improved,
- HPP generation forecast should also be improved and respected as much as possible (including periods with extreme hydrological conditions), especially part related to secondary reserve provisions,
- TPP generation forecast should be fully respected. It is not usual nor acceptable that TPPs are deviating from the forecast significantly, as it is the case in BiH. So, this part should be easiest to improve,
- Large load and generation deviation from the forecast as it is now assume:
  - significant operating problems to whole control area (Croatia, Slovenia and BiH),
  - significant additional system balancing costs,
  - significant operational barrier and additional cost for WPP integration,
  - additional costs to final consumers in BiH.

Accordingly, it is ***strongly recommended*** that all market participants in BiH, including balancing responsible parties, improve and respect their forecasts as far as is reasonably possible. Otherwise, WPP integration in BiH system would cause serious system imbalances with significant additional costs.

5.1.3 Grid code international experience of frequency control

The ability of active power curtailment is required in the Grid Code of Germany with a ramp rate of 10% of the current grid connection capacity per minute. However, according to this Grid Code when frequency exceeds the value 50.2 Hz wind farms must reduce their active power with a gradient of 40% of the available power of the wind turbines per Hz[12]. The Danish code requires a ramp rate in the range 10 to 100% of rated power per minute, while the Grid Code of Ireland prescribes a ramp rate of 1-30 MW per minute. In fact, the Irish code demands a frequency response system, which will control active power according to a prescribed response curve. The British code requires that wind farms have a frequency control device capable of supplying primary and secondary frequency control, as well as over-frequency control.

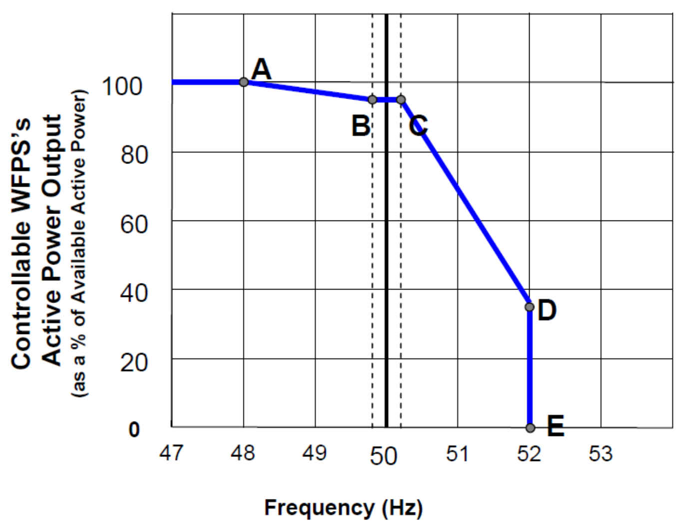
[12] E.g. for an increase in system frequency from 50.2Hz to 50.3Hz a wind farm must reduce its output by 4%.

An example of a frequency response power curve from the Irish Grid Code for Wind Power Generators is provided in Figure 23. The same frequency response curve for WPPs is a requirement in BiH Grid Code.

In this example, under normal transmission system frequency ranges, the wind farms operate with an active power output as set by the line 'B' - 'C'. If the system frequency falls below point 'B', then the frequency response system acts to ramp up the wind farm's active power output, in accordance with the Frequency/Active Power characteristic defined by the line 'B'-'A'. Where the system frequency is below the normal range and is recovering back to the normal operating range, the wind farm's frequency response system acts to ramp down the active power output in accordance with the Frequency/Active Power characteristic defined by the line 'A'-'B'. A frequency dead-band applies between the system frequencies corresponding to points 'B' and 'C', where no change in the wind farm's Active Power output is required.

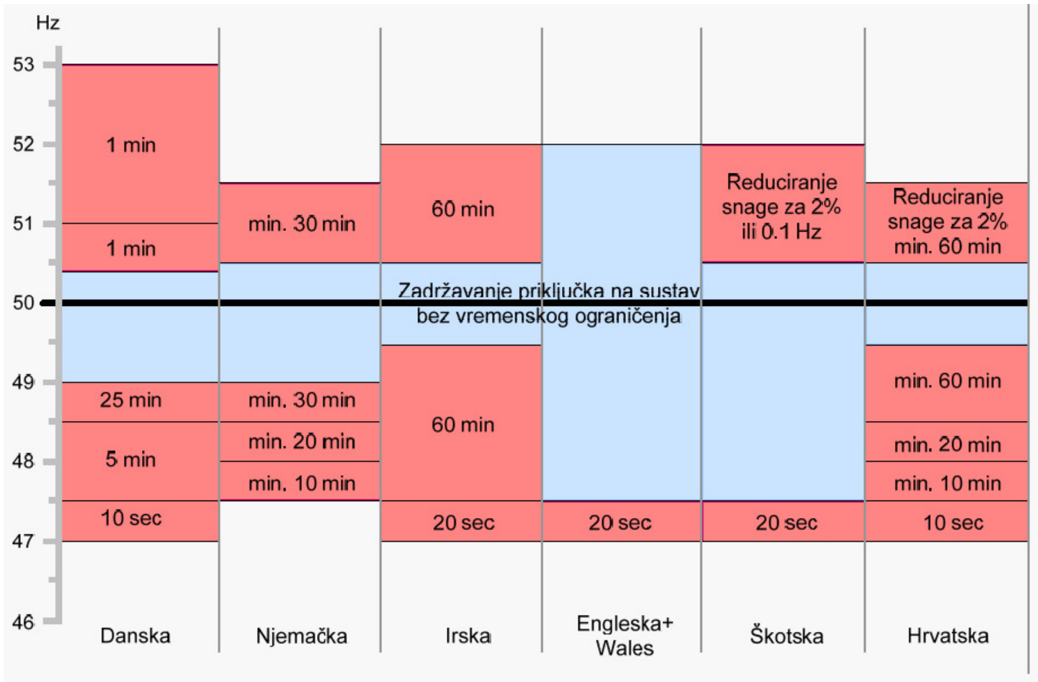
Once the system frequency rises to a level above point 'C', the Frequency Response System acts to ramp down the wind farm's active power output in accordance with the Frequency/Active Power characteristic defined by the line 'C'-'D'-'E'. At System Frequencies greater than or equal to 'D'-'E', there should be no Active Power output from the wind farm.

Figure 23 P/f curve



Required tolerance on frequency variation in Grid Codes of different TSOs can vary significantly. For example, a continuous operation is required in the range from 49.5 Hz to 50.5 Hz in Grid Code of Ireland and Croatia. The lower bound of this range is set at 49 Hz in Grid Codes of Germany and Denmark. The required range of continuous operation in Grid Codes of Belgium is from 48.5 Hz to 51 Hz. However, the widest (and thus most onerous) continuous operation limits for frequency, from 47.5 Hz to 52 Hz, appear in the Grid Code of Great Britain (GB), as shown in Figure 24

Figure 24 Power system frequency bounds in different countries (Source: FESB)



In addition to above requirements, Grid Codes usually contain requirements related to higher frequency deviation, but for some time period. The most extreme frequency limits are 47 Hz and 54 Hz, but these limits are specified in different Grid Codes. A general rule is that in countries characterized by a quite isolated power system with weak interconnections (like Ireland), required frequency limits that are wider. In the Grid Code of Ireland wind farms are required to continue working for at least 60 minutes in the event that frequency is in ranges 47.5 to 49.5 Hz or 50.5 to 52 Hz. Additional 20 seconds of operation is required if the frequency is in range from 47 Hz to 47.5 Hz both in Ireland and GB, as shown in Figure 24.

However, the very well interconnected German transmission system does not specify such onerous requirements. The Grid Code of Germany requires 30 minutes of wind farms operation in the event that the frequency is in ranges 48.5-49 Hz or 50.5-51.5 Hz. Furthermore, a 20 minutes period is required in the event that the frequency is in range from 48 Hz to 48.5 Hz, and an additional period of 10 minutes in the event that the frequency is in range 47.5 to 48 Hz. Similar bounds are valid in Croatia. Newly adopted BiH Grid Code upgrade defines frequency requirements for WPPs in BiH as follows:

- uninterruptedly stay in operation with normal generation output values for frequency range from 49,5 Hz to 50,5 Hz;
- remain connected to the transmission grid for frequency range from 47,5 to 52,0 Hz for a duration of 60 minutes;
- remain in operation on the transmission grid for frequency range from 47,0 to 47,5 Hz for a duration of 20 seconds requesting that in each moment system frequency be above 47,5 Hz.

Clearly, it is equal to Irish requirements given above.

5.2 Voltage regulation and reactive power management

This subsection reviews voltage regulation and reactive power management techniques in BiH with reference to experiences in different countries, as outlined in the ToR third bullet point.

Wind farms are often installed in remote areas and therefore the resultant reactive power flows on long, and often radial, lines can result in material power losses and low voltages. In addition, some wind turbine technologies, particularly the older turbine designs, have very limited capabilities regarding power factor regulation. Thus the ability of wind farms to control reactive power is an important requirement of modern Grid Codes. In other words, recently adopted Grid Codes in a number of countries require wind farms to provide reactive power regulation, often in response to power system voltage variations, as in the case of conventional power plants. The specified reactive power control requirements are related to the characteristics of each network since the influence of the reactive power injection to the voltage level is dependent on the network characteristics. Grid Codes prescribe that the TSO may define a set-point value for voltage, power factor and/or reactive power at the wind farm's connection point.

The generators, transformers and other elements of an inductive nature consume reactive power that is to be produced or taken from the system. If the network user consumes reactive power from the system, the available line capacity for active power flow is reduced. In comparison to active power, reactive power cannot be efficiently transmitted across large distance hence it is to be locally regulated with the aim of: satisfying protection requirements, maintaining active power transmission and maintaining appropriate voltage quality. Greater value of reactive power flows result in a greater level of losses in the network. The flow of reactive power contributes to active power system losses. It is necessary to reduce reactive power flow in the network in order to reduce power losses. Reactive power control can be realized using: synchronous generators, synchronous condensers, regulating transformers, static VAR systems, switched reactors and capacitor banks.

In general, **primary voltage regulation** is realized through automatic voltage regulators of synchronous machines, transformer tap position adjustments and devices for reactive power compensation. These services are provided by Reactive power reserve contracts for voltage regulation which define fees for participation in primary voltage regulation and penalties for unwarranted inactive voltage regulators.

Coordinated operation of devices for voltage and reactive power regulation is achieved through **secondary voltage regulation** activated by ISO's instructions. Contracts for providing the ancillary services define fees for participation in secondary voltage control.

Tertiary voltage regulation represents long-term process of voltage and reactive power optimization. By using OPF software, actual voltage and reactive power profile is compared with desired profile. Discrepancies are resolved by corrective instructions for issue by TSO to appropriate parties included in regulation.

Voltage and reactive power regulation in the BIH power system is performed by use of synchronous generators and network transformers with automated regulation of transmission volume. Within the BIH transmission network there are no connected shunt capacitors, reactors or other compensation devices. Within BIH power system only primary regulation of voltage and reactive power is performed.

Synchronous generators are connected within BIH power system to networks of all three voltage levels which means that they can directly influence voltage conditions. Hydro units of HPP Čapljina are designed in a way that they are able to operate in compensation regime and thus, significantly control the voltage in the network.

Most often the regulation of 400/x kV transformers is possible in non-voltage condition[13] (except 400/115 kV transformer Banja Luka 6) with regulating steps 1x5% (400/220 kV) or 2x2.5% (400/110 kV), while regulation of 220/110 kV and 110/x kV transformers is automated (under load), with the smallest regulation steps of 12x1.25%.

In BiH, the Grid Code specifies voltage requirements in transmission network. First of all the voltage at the connection point of the user to the transmission network under normal conditions is to be maintained:

- for 400 kV network between 380 kV and 420 kV,
- for 220 kV network between 198 kV and 242 kV,
- for 110 kV network between 99 kV and 121 kV.

Also, the values of voltage at the connection points of the user to the transmission network may have the following variations:

- in the network 400 kV: 360 - 420 kV,
- in the network 220 kV: 187 - 245 kV,
- in the network 110 kV: 94 - 123 kV.

Special provisions of the Contract on Connection with the network user may allow, for a particular connection point, major or minor acceptable deviation of voltage from the rated value at the connection point. Bigger deviation of voltage from nominal value on the connection point is allowed only in terms of compliance with procedures on isolation coordination.

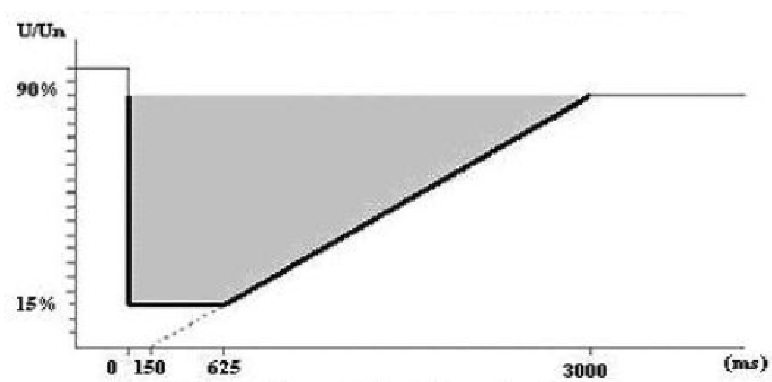
[13] i.e. using off load tap changers.

Independently of the type, WPP generators, in accordance with their technical characteristics must fulfil the following aspects:

- maintenance of voltage within prescribed limits
- automatic regulation of voltage/ reactive power
- capability to generate reactive power
- capability to pass through the state of fault (ride through capability)

WPP in BiH must remain connected to the transmission grid in case of decline of voltage on any phase or possibly on all 3 phases when metering amount on block transformer is above bold black line on the diagram given in Figure 25.

Figure 25 WPP voltage requirement curve



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

- 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 for at least 600 ms or until the voltage on the transmission grid returns into limits of normal operation.
- 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.

5.2.1 Fault ride through capability

With the high utilization of wind power a simultaneous loss of several thousand MW wind generation became a realistic scenario in many power systems. Therefore, the large increase in the installed wind capacity connected to a power system necessitates that wind generation remains in operation in the event of certain network disturbances. That is why, the main requirement in all grid codes that have been issued recently, include the wind farms' response to voltage dips in the power system.

The Fault Ride Through capability of wind turbines means that these facilities must withstand voltage dips to a certain percentage of the nominal voltage and for a specified duration without disconnection. This requirement, known also as the Low Voltage Ride Through capability, is described by a voltage versus time characteristic, denoting the minimum required immunity of the wind power station.

The requirements depend on the specific characteristics of each power system and the protection employed and they deviate significantly from each other. For example, in the event of voltage dips up to 92% of the rated voltage, the Grid Code of Belgium requires an ability of wind farms to remain connected for at least 1.5 seconds. However, for voltage dips in the range of 50 to 92% wind farms must remain in operation for 0.7 seconds, while for all voltage dips below 50% of the rated voltage (down to 0%!) wind farms have to remain in operation for 0.2 seconds. Similarly demanding are Grid Codes of Germany, UK, Denmark, New Zealand and Sweden. All of them require an ability of wind farms to remain connected during voltage dips down to 0%[14]. The Grid Code of Spain requires an ability of wind farms to remain connected for 0.5 seconds if voltage dips are up to 20% of the rated voltage. This time interval increases linearly to 1 second with changes of voltage dips from 20% to 80% of the nominal voltage. A similar voltage versus time characteristic is required in Grid Codes of USA and Ireland[15]

An illustration of a typical Grid Code ride through requirement is provided in Figure 26, but it is noted that there are significant variations in the detail of the ride through requirement contained within Grid Codes in different jurisdictions, as shown in Figure 27.

[14] German, Danish and UK codes require this for 0.15 seconds, the New Zealand code for 0.2 seconds and the Swedish code for 0.25 seconds.

[15] 0.7 seconds for voltage dips of 15% and a linear increase of the required time in operation to 3 seconds for voltage dips of 90%.

Figure 26 Typical fault ride through requirement

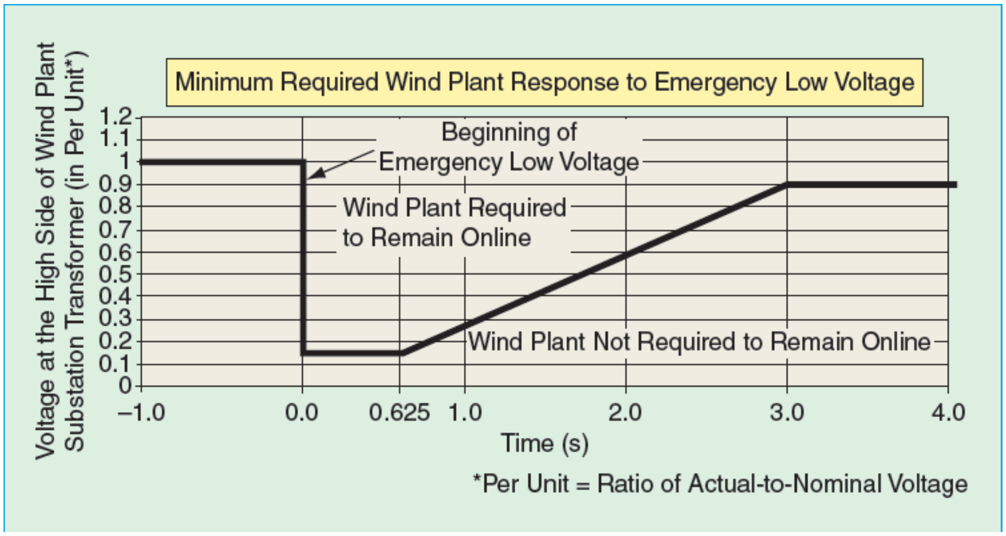
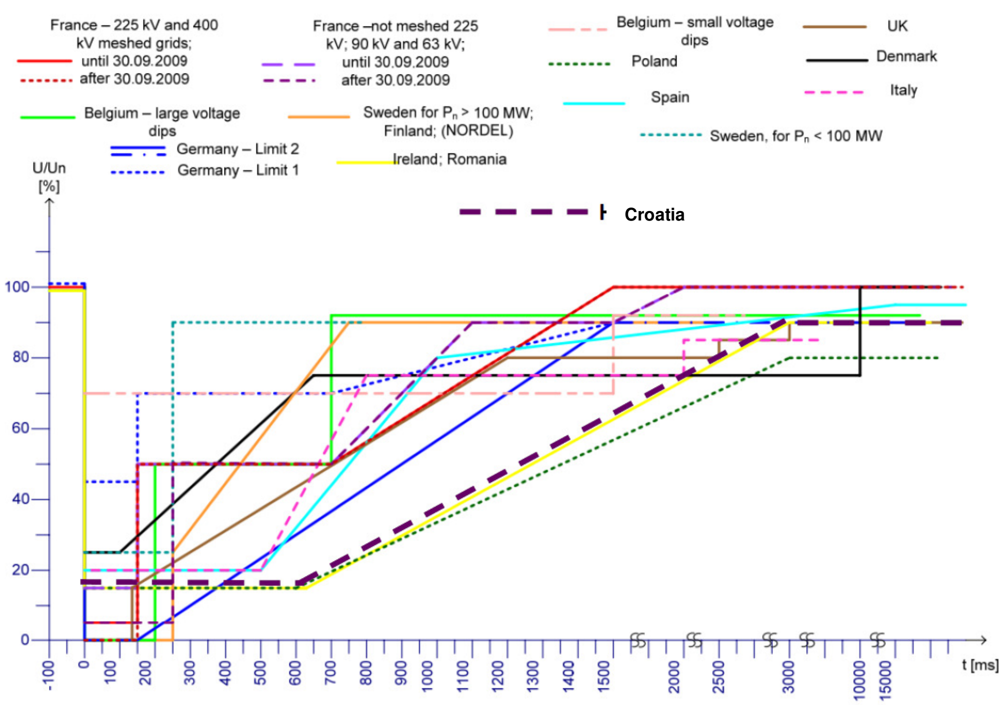


Figure 27 WPP fault ride through requirement in different countries



Source: FESB

WPP fault ride through requirements in the BiH Wind Grid Code are similar to those in Ireland and Croatia (The Grid Code in BiH is discussed Section 6).

However, it must be noted that these requirements apply to the connection point to the network, generally at HV level. Taking into account typical impedance values for the step-up transformers and interconnecting lines, a relatively simple calculation indicates that a voltage dip to 0% at high voltage level corresponds to around a 15% voltage dip at the lower voltage level at the wind turbine terminals.

It also should be noted that specifications may vary with the nominal voltage level of the network and/or with the wind farm power. For example, wind farms connected to the Danish grid at voltages below 100 kV are required to withstand less severe voltage dips than the ones connected at higher voltages, in terms of both voltage dip magnitude and duration. Similar differences can be observed in the regulation governing the connection of wind farms below and above 100 MW on the Swedish transmission system.

In addition to straight Fault Ride Through requirements, recently adopted Grid Codes usually require the possibility of wind farms for fast active and reactive power restoration to the pre-fault values, once the system voltage returns to a normal operation level. Some Grid Codes also impose increased reactive power generation by wind turbines during the disturbance (overexcited operation regime), in order to provide necessary voltage support to the power system. In other words, following network faults wind turbines have to supply a definite reactive current depending on the instantaneous voltage and to return quickly to normal operation regime once the network faults have been cleared by system protection.

These requirements are also treated in a quantitatively different way in different Grid Codes. For example, the active power restoration rates specified by the German and British/Irish Grid Codes are significantly different: while the British code requires immediate restoration (at 90% in 0.5 s after voltage recovery), E.ON Netz requires restoration with a rate of 20% of the nominal output power (reaching 100% in 5 seconds after voltage recovery). A reason for the less severe requirement of the German code may be its strong interconnection to the European transmission system. On the hand, the need for a fast active power restoration to the pre-fault values is more crucial for system stability in the weakly interconnected British system.

As mentioned above, requirements for reactive current supply during voltage dips are also incorporated in recently adopted grid codes. This requirement means that wind farms should support the grid by generating reactive power during a network fault, to support and for faster restoration of the grid voltage. For example, the German code requires wind farms to support grid voltage with additional reactive current injection during a voltage dip, but also with increased reactive power absorption in the event of network voltage levels higher than nominal. The voltage control must take place within 20 milliseconds (ms) after fault recognition by providing additional reactive current on the low voltage side of the wind turbine 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. The above applies for all disturbances in voltage levels that are greater than ±10% of the nominal voltage.

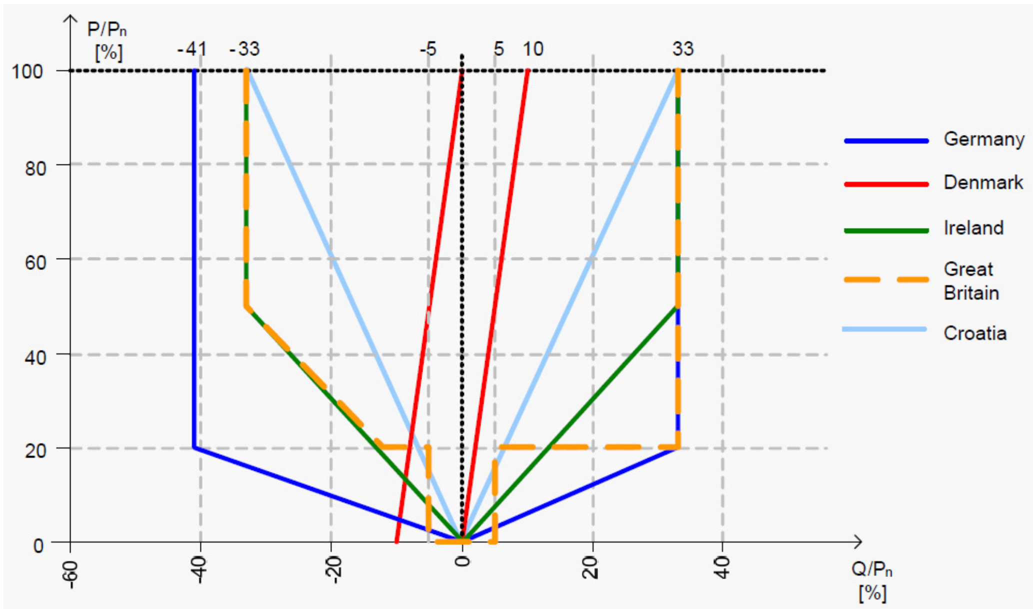
According to the Spanish Grid Code, wind power plants are required to stop drawing reactive power from the network within 100 ms after a voltage drop and to be able to inject reactive power within 150 ms. Injections of reactive power are required for all voltage dips over 15%. The required reactive current changes linearly from 0 to 0.9 of the rated current while the voltage dip changes from 15% to 50%. However, the Spanish code does not require the possibility of additional reactive power absorption by wind farms in the event of voltages higher than nominal. Finally, both UK and Ireland Grid Codes specify that wind farms must produce their maximum reactive current during a voltage dip caused by a network fault.

5.2.2 Grid Code international experience of voltage control

According to the British code, wind farms have to be able to ensure power factor in the range of 0.95-underexcited to 0.95-overexcited at all voltage levels which are ±5% around the nominal. The Grid Code of Germany requires an ability of wind farms to function in lagging or leading power factor mode but only in the event of over-voltages. More precisely, at the nominal voltage it requires just over-excited mode i.e. the power factor in the range from 1 to 0.925-overexcited. However, with a value of 1 as a boundary value the power factor changes linearly with voltage value at the connection point. In the event of approximately 11% over voltage (123 kV instead if 110 kV, 245 kV instead of 220 kV and 420 kV instead of 380 kV) this limitation of the power factor is 0.95-underexcited. Similarly, in the event of approximately 9% under voltage (96 kV instead if 110 kV, 193 kV instead of 220 kV and 350 kV instead of 380 kV) this limitation of the power factor is 0.95-overexcited. In other words, in the event of 11% overvoltage at the connection point, the wind farm should be able to ensure its power factor within the range from 0.95-underexcited to 0.925-overexcited. In the opposite case, i.e. in the event of 9% under-voltage at the connection point the wind farm has to be able to operate with the power factor in the range from 0.95-overexcited to 0.925-overexcited.

Some Grid Codes also prescribe the reactive power variation capability as a function of the active power. For example, if the active power generation is in the range from 50% to 100% of the nominal capacity, both the British and the Irish codes require an ability of the wind farm to inject or withdraw reactive power i.e. to operate in the range of power factors from 0.95 leading to 0.95 lagging. The Irish code additionally requires a power factor equal to 0.835 lagging or leading, at active power output levels below 50% of the rated capacity. The reactive power characteristics that are required by the several Grid Codes are illustrated in Figure 28.

Figure 28 Reactive power characteristics in different countries



Source: FESB

Regarding voltage limits, the usual continuous operation limit for voltage is 95 to 105% of the nominal voltage, although in some cases, like Denmark, the lower bound is set to 90% of the nominal voltage. In the event of more severe voltage drops, a reduction of injected wind farm's active power is allowed. In BiH for 400 kV network nominal voltage level is set to 95 to 105%, while 220 and 110 kV limits are set to 90 – 110% of the nominal voltage. It is the same in other regional countries.

5.3 WPP data requirements and ISO needs

This section addresses bullet point 4 of the ToR, which states: "*Review the system operator's needs with respect to wind power plant data in the network connecting procedure, with reference to experience in different countries and determine ISO's needs in this regard*".

5.3.1 Data requirements

Typically the Grid Code in any given jurisdiction will specify a data set that a WPP must provide to the TSO as part of the application to connect. This data tends to be fairly technical in its nature and is required by the TSO such that it can model the impact of a WPP upon the power system. The data set required will be dependent upon whether the wind farm is to be connected directly (i.e. synchronously) to the transmission network or whether it is connected through a back to back DC convertor (i.e. asynchronously). Data requirements also depend upon the design of the generator to be connected to the network (i.e. whether it is a squirrel-cage or doubly-fed induction generator that is driven by the wind turbine).

For a synchronously connected WPP, the technical data will include elements such as:

- The rated MVA
- The rated MW
- The rated terminal voltage
- The inertia constant, (MWsec/MVA)
- The stator reactance
- The magnetising reactance
- The rotor resistance
- The rotor reactance
- The generator rotor speed range (minimum and maximum speeds in RPM for doubly-fed induction generators)
- Converter MVA rating (for doubly-fed induction generators)
- Average site air density (kg/m^3), maximum site air density (kg/m^3) and minimum site air density (kg/m^3) for the year
- Number of pole pairs
- Blade swept area (m^2)
- Gear box ratio
- The rotor power coefficient versus tip speed ratio curves for a range of blade angles
- The electrical power output versus wind speed over the entire operating range of the wind turbine
- Details of the voltage/power factor control (and the Power System Stabiliser if one is fitted)
- The frequency control system parameters
- Details of protection settings for elements such as under and over frequency, under and over voltage, rotor over current, stator over current, high wind speed shut down level.
- Harmonic and flicker parameters

In addition to the above, a mathematical model of each type of wind generator will typically be required by the TSO. This model should be capable of representing the transient and dynamic behaviour of the wind farm under both small and large disturbance conditions. The model should include non-linear effects and represent all the equipment that is relevant to the dynamic performance of the wind generator. The model should also accurately represent the overall performance of the wind turbine over its entire operating range including representation of the supplementary control systems. The model resolution should be sufficient to accurately represent generator behaviour both in response to operation of transmission system protection and in the context of longer-term network simulations.

The model should be validated by the developer with validation being based upon comparing the submitted model simulation results against measured test results. Validation evidence will normally be required including the simulation and measured test results (including appropriate short-circuit tests).

In addition to above technical data for the wind farm, meteorological and operational data from the wind farm will be required for determining the forecast performance that can be achieved for a specific facility. Data from the wind farm is required in order to optimize the relationship between meteorological variables and the facility's specific power output and also to correct any weather forecast model errors.

Turbine availability information is normally required by the TSOs. Turbine availability lets the TSO know which turbines in the wind farm are available to run and which are shut down for maintenance or for other reasons. Any misreporting of turbine availability confuses the procedures used to construct the mathematical relationships between meteorological variables and power production.

Information regarding the spatial representation of the wind farm is also required. Small wind plants with relatively homogeneous characteristics may be well represented by one meteorological tower or the total output from all turbines. Large plants in complex terrain may need multiple meteorological towers or turbine-level data to adequately represent the spatial variability within the wind farm. An inadequate representation of the spatial variability in the wind plant data set can lead to lower forecasting quality.

In BiH Grid Code there are no specific detailed data requirements, so it is assumed that all data to be supplied from wind farm developers should be specified as part of the grid connection process.

We recommend the following data (values and graphs) on the wind power plant, which should be recorded during the trial run (commissioning test) and submitted to the ISO/DSO:

- Active power output of the WPP;
- Reactive power output of the WPP;
- Voltage of input transformer's low voltage side in the WPP's connection node to the transmission system;

- Voltage of input transformer's high voltage side in the WPP's connection node to the transmission system;
- Terminal voltage of wind aggregates.

These values (curves) need to be recorded for the following characteristic testing conditions of the WPP:

- WPP start up and shut down time;
- WPP response on sudden voltage changes;
- WPP response on system frequency changes (testing the frequency regulation system);
- WPP response on high wind speeds and abrupt wind changes;
- Other relevant WPP electricity quality details.

In addition to mentioned data, the WPP operator is obliged to provide the delivery of the following data to the ISO regularly and in real time:

- Availability of individual wind turbine,
- Power output of individual turbine,
- Meteorological data (wind speed, direction, temperature, etc.) and the forecast of the WPP production in the required short-term period of 3 – 48 hours. The time period and the forecast pace shall be specified subsequently. So far there are no any requirements on forecasting accuracy,
- Full WPP model for dynamic simulation.

Also, we suggest the inclusion of the following data set requirements for WPPs:

- Generator type,
- Generator impedances,
- Excitation limiter settings,
- Inertia constant,
- Governor control details,
- Pitch control,
- Converter rating and type,
- Block-transformer details,

- Power/wind speed curve,
- Internal power network details including protection settings,
- Maximum harmonic distortion,
- WPP control and telecommunication equipment details,
- Metering device characteristics.
- The stator reactance
- The magnetizing reactance
- The rotor resistance
- The rotor reactance
- The generator rotor speed range (minimum and maximum speeds in RPM for doubly-fed induction generators)
- Average site air density (kg/m^3), maximum site air density (kg/m^3) and minimum site air density (kg/m^3) for the year
- Number of pole pairs
- Blade swept area (m^2)
- Gear box ratio
- The rotor power coefficient versus tip speed ratio curves for a range of blade angles
- The electrical power output versus wind speed over the entire operating range of the wind turbine
- Details of the voltage/power factor control (and the Power System Stabiliser if one is fitted)
- The frequency control system parameters
- Details of protection settings for elements such as under and over frequency, under and over voltage, rotor over current, stator over current, high wind speed shut down level.
- Harmonic and flicker parameters

Current project development practice already assume most of the above mentioned data, but it is not required formally within the existing legislative framework, but through individual connection applications and testing. There is a whole set of operational standards and norms for the windturbines (EN 50160, IEC 615400, IEEE1547 etc.), but it is not supposed to be part of this analysis, so we won't go into details.

Finally, within this subsection data provision procedures are listed. Obviously, there are several stages on which WPP data should be exchanged with ISO. With inclusion of all the above, we believe that the given data set is adequate for further enlargement of the WPP share in the BiH power system. Provision of wind data and WPP output is foreseen in a very detailed manner (in testing, commissioning and regular operation mode). The data on the WPP submitted to the TSO shall, among other items, include active power output of the WPP, reactive power output of the WPP, voltage of input transformer's low voltage side in the WPP's connection node to the transmission system, voltage of input transformer's high voltage side in the WPP's connection node to the transmission system, terminal voltage of wind aggregates, availability of individual wind turbine, power output of individual turbine, meteorological data (wind speed, direction, temperature, etc.) and the forecast of the WPP production in the required short-term period of 3 – 48 hours. The time period and the forecast pace shall be specified subsequently. But, so far there are not any requirements on forecasting accuracy.

5.3.2 ISO Requirements – Connection and Operation

It is important to note that requirements regarding power quality, contribution to short-circuit level and protection system settings are usually defined in Distribution Codes i.e. these requirements refer to relatively small wind generation units that are connected to distribution networks. These requirements may be less of an issue for large wind farms connected to the transmission system. For grid connected wind farms, the main emphasis is placed upon the requirements that concern active and reactive power regulation, voltage regulation and wind farm behaviour during grid disturbances.

It is also important to note that Grid Code requirements regarding voltage support are usually specified at the point of common coupling between the wind farm and the power network. This means that requirements are placed at wind farm level, and that wind turbines may be adapted to meet them. On the other hand, wind turbine manufacturers usually specify performances of their wind turbines, rather than for the entire wind farm. It is also possible for some requirements to be met by providing additional equipment that is separate from the turbines. This is particularly the case with ensuring the required level of reactive power control which can be met using static VAR compensation equipment.

Within the same EBRD framework contract on "Western Balkans Sustainable Energy Direct Financing Facility: Institutional Capacity Building" we participated in the task entitled "Review of procedure for network access for RES and connection charges in BiH" issued in October 2010. This report examined the procedures and charges for connection of renewable energy generation (including wind) to the transmission and distribution networks in BiH. Also, another task related to "Assistance to FERC with its Book of Rules for Connections in FBiH" was issued in March 2011. Based upon these previous tasks, the additional revisions of legislative framework for WPPs in BiH and our review of the revised Grid Code we offer the following recommendations for improvement:

- The new Grid Code does not specify what data must be supplied by the WPP in order that the ISO can be operated the network securely. We recommend that these data requirements are included in a future draft of the Grid Code as discussed in the Section 6 below.

- WPP requirements for reactive power supply during voltage dips should be incorporated in more detail in future version of the Grid Code. This requirement means that wind farms should support the grid by generating reactive power during a network fault, in order to support and enable faster restoration of the grid voltage. The details of this kind of WPP voltage support should be in the Grid Code.

- In future versions of Grid Code it is recommended that the WPP developer is required to appoint a designated responsible operator who shall be contactable by the ISO at all times to discuss operational matters without undue delay and in any event within 15 minutes. Following a request from the ISO, the responsible operator shall be present at the WPP's connection point without undue delay and in any the event within one hour and shall be capable of taking any required appropriate actions. The responsible operator shall be contactable 24 hours a day, 365 days a year.

- Due to the complex power sector organization in BiH, it is suggested that the distinction between transmission and distribution network connections is made clearer. In particular, DERK Connection Rules do not specify any minimum installed generation capacity for connection to the transmission network (this is often set to either 5 MW or 10 MW), but rather the analysis should be undertaken for each application regardless of the project size. The procedure is thus not clear in the event that TRANSCO finds it more techno-economically acceptable to connect a RES development to the distribution network. On the other hand, distribution connection codes assume that all projects larger than 5 MW will be connected to the transmission network.

- Connection procedures and their timelines are currently the same regardless of the new generation installed capacity or the increase of existing network user installed capacity (this is an especially important issue for transmission network connections that can have wide range of installed RES capacities). It is suggested therefore to speed up or simplify small RES project connection procedure establishing the deadlines for issuing connection consents or simplifying elaboration and technical checking procedures.

- We suggest that the existing provisions on grid connection schemes be enhanced to include details on ownership unbundling; control, maintenance and switching responsibilities; protection system requirements; and metering point equipment (depending on connection voltage level and generation installed capacity).

- The process of a RES developer obtaining a connection to the network is one component of a very time consuming process that involves a requirement for the developer to obtain a series of permits and contracts from the various authorities involved. It would therefore be useful to develop a guide for RES developers (or even service within existing institutions on the one-stop-shop principle) detailing the necessary consents including all application forms (as currently included in Rulebook on Connection of Small Generation Power Plants to Distribution Network in Republika Srpska). In addition, it would be very beneficial to have the permitting process made as streamlined as is reasonably possible.

- Connection Rules establish the network connection procedure in which the ISO is to elaborate the conditions and to provide a technical solution for a user connecting to the transmission network. In order to be more efficient and transparent it is suggested that Connection terms of reference and other details (timelines, deadlines, revisions, dispute and adoption procedures etc) are made available to the public.

- In order to speed up the connection process to the transmission network it is recommended to introduce deadlines for every step in the connection procedure (i.e. deadlines for input data delivery, for ISO additional requests or clarifications, for elaboration preparation, adoption, issuing of connection consent etc.) as it is done in General Provisions for the distribution networks.

- The priority rights of RES generation in respect of connection and dispatch should be harmonized on all network voltage levels and throughout BiH; this requires that ISO, TRANSCO or DERK include priority access rights and priority connection in the rules for renewable generators. Also, ISO - TRANSCO dualism in decision making should be avoided.

- There is a real possibility of a number of RES developers connecting to the same area of the transmission network. Successive RES connections are likely to become increasingly expensive as more "deep" network reinforcement is required. Therefore there is currently an advantage to being the first developer. It would thus be appropriate to have clearly defined rules for the basis of sharing of connection costs in the event that more than one developer is interested in developing a RES project in the same area.

- It is possible to have many more RES project applications than the ability to integrate them into the system, especially in the areas with significant RES potential. A preliminary grid connection consent issued for one project might limit development of the other RES projects in the neighbourhood. According to the General Conditions preliminary grid connection consent is valid for 1 year and it can be prolonged for 1 more year, if needed. In order to avoid potential discrimination and abuse of issued connection consents it is suggested to set the criteria for prolongation of preliminary grid connection consents and to set the deadline for its expiry. Also, it is suggested to review if (preliminary) grid connection consent validity period of one year is adequate for all activities to be done within this period.

- There are serious issues due to the ambiguities associated with land ownership in BiH that impede RES development in general but also impact upon the connection of RES projects. There should be investigation of the possibility of providing assistance to RES developers in resolving issues associated with land ownership that impact upon their proposed development. Consideration could also be given to revising compulsory purchase legislation for land.

- The remits of the various authorities involved in the F BiH (Canton, Municipality, Federation) overlap because of inconsistencies in the laws and decrees (e.g. the definition of the capacity of an RES project that requires a particular authorization is not consistent within the various regulations). It would therefore be appropriate to review and revise the existing legislative framework as it impacts upon WPP development to ensure that all the legislation involved is consistent.

In addition to revision of existing connection procedures we strongly recommend:

- Upgrading of the existing ancillary service (AS) mechanism in BiH in order to clearly define the obligations and rights of AS providers and to ensure the integration of additional hydro power generators into existing secondary control.

- A requirement that any new power plant is designed and built with the ramping capability required by the ISO – this must be done at the design stage.

- As the MWs of wind capacity increases additional peaking capacity for the power system will be required in order to cover those periods when the wind does not blow. There may also be a requirement to re-optimize the production from storage hydro plants in order to provide additional reserve capability.

- A study of the practical options for reserve sharing across the SEE region in the future.

5.3.3 International experience of wind integration

Interconnection – Denmark

Interconnections to neighbouring power systems are an important factor in integration of wind energy. For example, for Denmark the availability of hydropower in Norway and Sweden via DC interconnectors is ideal and is often used to balance wind power output in western Denmark whereas the AC interconnection to the German thermal system in the south contributes to a stable frequency. However, the proposed construction of 20 GW of offshore wind power connected to the German power system in the vicinity of the Danish grid will affect the ability of the Nordic countries to balance wind-power generation between themselves and Germany.

The correlation between wind conditions in Denmark and Germany makes it more problematic for these two countries to rely on each other to balance their own wind-power generation. In the case of BiH there are a lot of interconnection capacities available, as shown on the Figure 13. Most of these interconnections are with Croatian power system. But, BiH neighbouring systems are having similar generation mix, similar size and similar operational practice, so it is not likely to have significant support in WPP integration from interconnected systems. At least not until regional market is put in place.

Planning – Ireland

In contrast to Denmark, the Irish power system currently has a minimal level of interconnection although there are plans to construct two HVDC links between Ireland and Great Britain by the end of 2012. The Irish government has set a target to have 40% of electricity generation from renewable energy by 2020 and there is currently over 1,400 MW of wind generation connected to the Irish system. More than 430 MW of this generation has some form of direct control from the National Control Centre to dispatch the wind output down if required. During 2008, wind-power plants were dispatched down three times for security reasons.

As more wind farms connect to the Irish system, it is expected that the operation of the power system will become more complicated. The management of this complexity will require better understanding the characteristics of the power system better and also stretching the use of the existing infrastructure (for example, using dynamic line rating).

For the Irish power system to work securely, efficiently, and safely with 40% renewable penetration, it will be necessary to develop a suitable portfolio of generation and demand controls to manage intermittency and thereby operate to acceptable standards. This is very important in a system like the island of Ireland that cannot rely on significant power flows from neighbouring systems.

In order to increase its understanding of the behaviour of the power system with large amounts of renewable generation, the Irish TSO has commissioned a series of studies, known as the Facilitation of Renewable which will:

- Identify any potential technical issues;
- Develop mitigation measures; and
- Provide a comprehensive strategy for the operation of the power system with large amounts of renewable generation.

Even though BiH system is having much higher interconnection capacities than Irish system, it is also important to follow Irish experience in WPP integration planning, since it is on the safe side for BiH case.

Reserve provision - Spain

By the end of 2010, total installed power capacity in Spain was over 97,000 MW. This figure included nearly 20,000 MW of wind power, and more than 4,000 MW of Solar power. Wind variability and forecast uncertainties are one of the main challenges for wind-energy integration in what is a weakly interconnected system. Any power imbalances (generation minus load) must not be greater than 1,300 MW and must be corrected within ten minutes otherwise, the Spanish interconnection with France may overload or even trip, isolating the peninsular system from the rest of Europe.

The biggest influence of wind energy on the Spanish system has been on spinning reserve requirements (including tertiary reserves). Reserve is available from the connected thermal units, run of river hydro plants, and pumped storage plants. Spinning reserve is evaluated continuously by the TSO with the goal of ensuring the appropriate amounts of reserves, (both upward and downward) in order to restore system balancing quickly and efficiently while minimizing the associated operational costs. If reserves are found to be insufficient to cover the expected uncertainties, thermal plant groups are switched on or off via a market-based mechanism called "technical constraints management."

The spinning reserves are quantified using the TSO's internal probabilistic wind prediction capability for every hour of the following day. In particular, the TSO's prediction tool provides an hourly value of wind generation with an 85% confidence interval. This approach saves reserves and reduces costs on those days with stable wind conditions, and the method itself increases the amount of reserve available for possible wind-forecast errors in those days when the wind generation is less predictable. On average, 630 MW of additional reserves must be procured to compensate for the wind-forecast errors that are anticipated day ahead (D–1).

The approach of pre-allocating spinning reserves in day D–1, taking into account the forecast impact of wind power on the overall system, is designed to keep sufficient reserves available at a reasonable cost. However, for approximately 15% of the time the reserves thus scheduled are too small to cope with the actual wind-energy forecast errors, and rescheduling of the connection of more thermal groups during peak hours or the disconnection of units in off-peak hours is necessary in real time as a consequence of wind-forecast errors. Thermal groups require a minimum notice time before they can deliver their full capacity which ranges from about two to three hours to switch on a gas turbine at a combined-cycle power plant to as much as 20 hours for a coal-fired power plant. Thus, if wind-prediction errors are not corrected six hours ahead of real time based on updated forecasts, thermal groups may not be able to be connected quickly enough to restore appropriate reserves. If the wind-forecast errors persist and consume all the available reserves then the TSO must invoke interruptible loads.

Difficult situations can also arise during off-peak hours, when the available downward reserves are usually lower. Real-time shutdown of combined-cycle units may be necessary. If wind-forecast errors persist up to within two hours of operation the situation cannot be corrected by shutting down thermal generation because of the time required by thermal plant to decrease production and disconnect in a stable and secure way.

BiH is having potential large system reserve in installed generation capacities. The ratio between installed generation capacities (3834 MW) and system peak load (~2100 MW) is about 183% of the peak load, which is among the highest in Europe (Spain is having around 209%)

5.4 Summary of Technical Requirements for WPP Integration

After several months of preparation and consultation, new technical requirements for WPPs in BiH were adopted by DERK and introduced in May 2011. A Grid Code Upgrade section has been added to the BiH Grid Code, entitled "Technical requirements for WPP connection to the grid". (See discussion in section 6 below)

Within this section technical requirements for connection and operation of WPPs were listed as follows:

- Requirements related to regulation of frequency and management of active power
- Requirements which are related to regulation of voltage and compensation of reactive power
- Requirements which are related to data on WPP in the process of application for connection to the grid and data during its operation.

The details on technical requirements for generation units and specifically WPPs in BiH are presented in this section, as well as other countries' experience in interconnection, planning and reserve provisions.

6 Grid Code mandatory requirements

This section aims to review the Grid Code, rules, and authorization procedures for grid connection as related to wind farms. Special emphasis is made on the treatment of intermittent power supply, as requested in the fifth bullet point of the ToR. Some of these points repeat areas discussed in section 5 above.

ISO BiH produced an update of its Grid Code which was adopted in May 2011 with a number of specific requirements which cover:

- The requirements related to regulation of frequency and management of active power;
- The requirements which are related to regulation of voltage and reactive compensation;
- The requirements which are related to data on WPP in the process of their application for connection to the grid and the data required during operation.

In this section we provide an independent review the requirements for a Wind Grid Code in BiH based upon international experience. This review focuses upon the rules and authorisation procedures for grid connection as they relate to wind farms, with special emphasis on the treatment of intermittent power supply on the power market. It also takes into account the technical constraints and requirements for the connection and operation of large-scale commercial wind farms to the transmission network.

6.1 The Grid Code in BiH

According to the BiH Grid Code provisions power system frequency boundaries should be kept as follows:

- Nominal frequency in Power System is 50.00 Hz.
- During normal operational conditions the frequency is to be maintained within the range of 49.95 Hz to 50.05 Hz.
- During disturbances in electric power system the frequency may be decreases to not less than 47.5 Hz and increase not higher than 51.5 Hz.

All generating units have to have the capability of continuous operation with nominal (rated) output power within frequency range from 49.5 Hz to 50.5 Hz, in line with ENTSO-E rules. If the frequency drops below 49.5 Hz (and down to 47.5 Hz) generating units must continue operation and production of active power as a response to system frequency decrease. If the frequency increases (to the level of 51.5 Hz) generating units must continue operation with adequate decrease of active power production as a response to system frequency increase.

This means that system for management of WPP also need to be capable to secure operation of each wind turbine with reduced active power if an instruction for reduction of WPP's output power is received.

In addition to this, P/f requirements for WPPs in BiH are as follows:

- remain connected to the transmission grid for frequency range from 47,5 to 52,0 Hz for a duration of 60 minutes;
- remain in operation on the transmission grid for frequency range from 47,0 to 47,5 Hz for a duration of 20 seconds requesting that in each moment system frequency be above 47,5 Hz;
- remain connected to transmission grid at the change rate of system frequency including boarder value of 0,5 Hz per second;
- change of active power of WPP as a result of a 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.

When a generation unit operates in an isolated mode, and still supplies Consumers, the speed regulator must be capable of maintaining frequency of the isolated system between 47.5 and 51,5 Hz, unless this causes the operation of the generator to be below the acceptable technical constraints and exceeding the allowed operating time at given frequency levels.

All generation units must be capable of providing primary frequency regulation, in accordance with the following minimum requirements:

- Control area of the speed regulator must be at least +/- two percentage (2%) of the registered capacity of the generation unit and must be adjustable according to the ISO instruction;
- Speed regulator must be capable of adjustments, according to ISO instructions, in order to operate with a governor droop characteristic of between 3% and 4% in case of hydro generation units, and between 4% and 6% for thermal generation units;

Speed regulator will not operate within the margins of ±10 mHz deadband.

Primary reserve

In accordance to the Grid Code all generation units connected to the transmission network must participate in the primary regulation and must keep droop settings of primary regulators to their set values and keep the regulators unblocked. Setting the statics of the primary regulators should be in the range of 3-4% for hydro generator and 4-6% for thermal generator.

In the interconnection, EES of BiH, as a single Control Area, must provide a set reserve of primary regulation at any time, in compliance with its share of generation in the total ENTSO-E generation. The range of primary regulation has been defined by the value of active power in which the system operates in both directions automatically in case of frequency deviation. That is, the power which has to be provided in accordance with the coefficient of contribution and current disconnection of the generation unit, power which is lower or equal to 3000 MW in the UCTE interconnection, according to the equation:

$$\mathbf{P_i = c_i P_U = \frac{E_i}{E_U} P_U} \quad \text{[MW]}$$

Where:

E_i = total output power on the busbar of all generation units of the *i* Control Area [MW]

E_U = total output power on the busbar on all generation units in the ENTSO-E interconnection [MW]

P_U = 3000 MW.

Frequency regulation and power exchange standards are defined by ENTSO-E Operational Handbook – Chapter 1.

Secondary reserve

This is defined pretty much the same as provided in ENTSO-E Operational Handbook. The objectives of the secondary regulation of frequency and power of exchange are:

- Realization of the planned program of power exchange between BiH and neighbouring systems in the interconnection,
- Take over frequency regulation from the activated primary regulation reserve as well as renewal of the required primary regulation reserve,
- Returning the system frequency to the set value.

In BiH all producers whose power plants have technical capabilities for automatic secondary regulation are obligated to indicate capabilities of their generators in their power balance. The producers whose generators get selected for the automatic secondary regulation will make an Agreement on Ancillary Services and will be adequately remunerated for it in accordance with the Tariff Methodology and Market Rules. The problem in practice is that there are no sanctions or penalties for those who don't comply.

Producers that have signed the Agreement on Ancillary services will deliver the secondary regulation power from plants mentioned in the item above. In accordance with that Agreement, the service will be activated automatically upon request from ISO by sending a signal from SCADA/EMS system in the centre of ISO.

Regulating power for the automatic secondary regulation is supplied from power plants participating in secondary regulation. Amount of regulating power is determined according to ENTSO-E guidelines and following formula:

$$R = \sqrt{a\,P_{\max} + b^2} - b$$

Where:

R – recommended reserve in secondary regulation

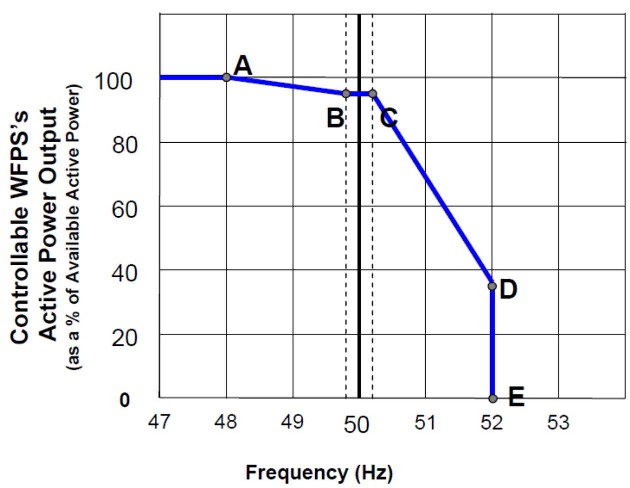
$P_{\max}$ - peak load (MW)

$a = 10$ and $b = 150$

Amount of necessary regulating power is determined by peak loads forecast on yearly level. According to these guidelines for electric power system of BiH required secondary reserve is at the level of ±55 MW.

For WPPs, newly adopted Grid Code requires Management System of WPP to 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. WPP output response to the system frequency must have characteristics as demonstrated in the Figure 29.

Figure 29 System frequency response curve for WPP output (% of available power)



Under normal transmission system frequency ranges, the wind farms operate with an active power output as set by the line 'B' - 'C'. If the system frequency falls below point 'B', then the frequency response system acts to ramp up the wind farm's active power output, in accordance with the Frequency/Active Power characteristic defined by the line 'B'-'A'. Where the system frequency is below the normal range and is recovering back to the normal operating range, the wind farm's frequency response system acts to ramp down the active power output in accordance with the Frequency/Active Power characteristic defined by the line 'A'-'B'. A frequency dead-band applies between the system frequencies corresponding to points 'B' and 'C', where no change in the wind farm's Active Power output is required.

Once the system frequency rises to a level above point 'C', the Frequency Response System acts to ramp down the wind farm's active power output in accordance with the Frequency/Active Power characteristic defined by the line 'C'-'D'-'E'. At System Frequencies greater than or equal to 'D'-'E', there should be no Active Power output from the wind farm.

Points A, B, C, D and E are dependent on the combination of system frequency, active power and the adjustment system for active power management. Adjustment of system management of active power can be different for each WPP depending on conditions of the system and location of WPP. ISO BiH can request change in adjustment system for active power management in real time.

Tertiary reserve

Required tertiary reserve is also defined by Grid Code. Tertiary reserve will be employed within 15 minutes from the moment when a dispatch order is issued and it is used in order to assist the secondary regulation by creating a required regulation range for it.

The criteria for employing tertiary reserve is an imbalance in the BiH system in the amount of 50 MW for a time period of 15 min. ISO dispatcher will issue an order for activating tertiary reserve in the amount: the imbalance value plus positive size/scope of the secondary regulation. During calculations ISO will charge Balancing responsible party (BRP) for the employment of tertiary reserve in the percentage of their share in the overall BiH imbalance in the period of those 15 min.

After issuing dispatch orders for the activation of tertiary reserve, ISO will, in the first hour in the intervals of 15 min, change the Schedule of the BRP which activated the tertiary reserve and the BRP for which the tertiary reserve was activated.

The Agreement on Ancillary services should clearly define minimum and maximum usage time of the reserve after the activation, maximum number of activations in a month and minimum time that must lapse between two activations. It is the duty of the ISO to ensure that adequate tertiary reserve is always available. It should also define the cases which are considered disobedience of instructions issued by ISO for the activation of tertiary reserves[16].

All generation companies whose plants have technical capabilities for tertiary regulation are obligated to submit in their power balance their capabilities for the tertiary regulation for the following year by months. Generation companies whose plants get selected for tertiary regulation will make an Agreement on Ancillary services and will be appropriately reimbursed according to Tariff Methodology and Market Rules. Here we have the same problem as within secondary reserve requirements: there are no sanctions for those who have technical capacities for tertiary regulation but they don't contribute. At the same time ISO should not allow

[16] It is noted that there are currently no penalties for disobeying instructions from the ISO.

any generation company to contract the sales of tertiary reserve to other TSOs until the tertiary reserve is provided for the needs of the EES of BiH. Tertiary reserve plans should be in place by the end of August for the following calendar year (commencing in January).

To ensure normal functioning of the BiH electric power system during outages of production units, 250 MW in tertiary reserve is necessary – provided that required secondary reserve of 80 MW is included in the total reserve in such extreme conditions. According to these standards half of the required secondary and tertiary reserve must be provided within the control area, which amounts to 330 MW. Rest of the required reserve can be provided from other control areas.

6.2 Treatment of wind farms in a Grid Code

International experience strongly suggests that a TSO will need to procure higher amounts of reserve as compared with a system of similar size but without intermittent (wind) generation. In their 2009 report, Frontier Economics and Consentec indicated that based on experiences in Germany, Spain, and Portugal about 0.25 to 0.3 GW of additional reserve per GW of wind capacity added to the system is required. Evidence from Germany shows that at present, 7.5 GW of upward reserve and 6 GW of downward reserve are contracted, while the largest conventional production unit has a capacity of about 1.5 GW.

Many Grid Codes contain a provision for the System Operator to require wind farms to reduce their output when system security is threatened and we are of the view that such a provision would be appropriate in BiH.

6.3 Grid Code international experience

Generally speaking, the recently adopted Grid Codes stipulate that wind farms should contribute to power system control (both frequency and voltage) as much as conventional power plants and focus on wind farm behaviour in the event of abnormal operating conditions of the network (such as in the event of voltage dips due to network faults).

Technical requirements on wind farms' operation within Grid Codes and related documents varies (sometimes significantly) among power systems. This situation is recognised by ENTSO-E who are developing a set of recommendations that will applicable for all Grid Codes where wind generation is being connected[17]. The Grid Code for BiH must be compatible with those of its neighbouring TSOs.

The typical requirements for wind generators can be grouped in the following way:

- Tolerance - the range of conditions in the power system for which wind farms must continue to operate;
- Control of active power and frequency deviation response;

[17] See Requirements for Grid Connection Applicable to all Generators. ENTSO-E

- ❑ Control of reactive power and voltage control;
- ❑ Response during transient voltage dips in the power system;
- ❑ Protective devices; and
- ❑ Power quality.

However, it is important to note that requirements regarding power quality, contribution to short-circuit level and protection system settings are usually defined in Distribution Codes i.e. these requirements refer to relatively small wind generation units that are connected to distribution networks. These requirements may be less of an issue for large wind farms connected to the transmission system. For grid connected wind farms, the main emphasis is placed upon the requirements that concern active and reactive power regulation, voltage regulation and wind farm behaviour during grid disturbances.

It is important to note that all these Grid Code requirements are usually specified at the point of common coupling between the wind farm and the power network. This means that requirements are placed at wind farm level, and that wind turbines may be adapted to meet them. On the other hand, wind turbine manufacturers usually specify performances of their wind turbines, rather than for the entire wind farm. It is also possible for some requirements to be met by providing additional equipment separate from the turbines, which is particularly the case with ensuring requested level of reactive power control which can be met using static VAR compensation equipment.

6.4 ISO Grid Code requirements related to wind farms

6.4.1 General observations

Clearly, from the perspective of an ISO, making the Grid Code as onerous as possible for penetration of wind generators would make system operation easier. However, such an approach would involve additional difficulties for meeting of national energy policy objectives and may well not be justifiable on technical grounds.

With respect to Grid Code relating to wind farms operation we would recommend adopting the requirements which are state-of-the-art in modern Grid Codes, but at the same time bearing in mind main characteristic of the BiH Power System such as its size, generation structure, level of interconnection with neighbouring systems and general configuration of the transmission system. For example, the BiH Power System is rather small system and from that point of view the Irish code might be used as a model. However, the power system of Ireland is only weakly connected to the GB power system, which is quite different compared to BiH power system, which is strongly connected with neighbouring systems i.e. with European transmission network. Bearing that in mind some quantitative requirements in the BiH Grid Code probably could be more relaxed than in Irish code. From that point of view the German Grid Code might be used as a model.

6.4.2 Comments on the BiH ISO's proposed additions to the Grid Code

In the light of the review of the implications to the Grid Code of connecting wind turbines to the network that has been provided in this report, this section provides comments on the BiH ISO's draft update of the Grid Code produced in December 2010.

The two key areas of (a) frequency regulation and (b) voltage regulation in respect of wind turbines on the network have both been addressed in this BiH draft Code but in somewhat less detail than has been recommended in this report. Specifically, it is suggested that it would be appropriate to provide some additional detail in the Grid Code particularly associated with the following items:

- The fault ride through requirements of a wind farm; and
- The operational responsibilities of the wind farm operator.

In addition to the above two points, the draft Grid Code does not specify what data must be supplied by the WPP in order that the ISO can be operated the network securely. We recommend that these data requirements are included in a future draft of the Grid Code.

Potential suggested additions to the BiH Grid Code are provided in the sub sections below.

6.4.3 Suggested provisions for the BiH Grid Code

All Generators connecting to the Transmission System will be required to comply with the BiH Grid Code. Since Wind Turbine Generators (WTG) do not have the same characteristics as synchronous generators, it is appropriate include a set of Grid Code provisions specifically for Controllable wind farms. This section of the report provides a number of suggested specific requirements for wind farms.

It is noted that wind farms will also need to comply with all other clauses in the Grid Code which are applicable.

Key requirements for Wind Farms:

- 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.
- Ramping control of active power production 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.

- If the stability of the system is endangered and the problem cannot be solved by other control activities the ISO is empowered to reduce the active power output of Wind Farms connected to the system. Wind Farms have to be able to reduce active power in accordance with a value defined by the ISO.

- Wind Farms 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.

- Wind Farms must be able to continue operation during and after defined disturbances on the transmission network (fault ride through capability).

- Wind Farms 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.

- Wind Farms must be controllable from remote locations by telecommunication. Control functions and operational measurements must be made available to the ISO upon request.

Continuous operation requirements

Wind Farms shall have the capability to operate continuously at normal rated output at:

- Transmission System Frequencies in the range from 49.5 Hz to 50.5 Hz;

- Transmission System Voltage measured at the HV terminals of the Grid Connected Transformer in the range from 0.95 to 1.05 of the rated network voltage.

Active power control and frequency requirements

Wind Farms shall install Control Systems to allow performing of active power control and frequency response functions.

A Wind Farm Control System shall be capable of operating each WTG at a reduced level or of switching off some WTGs if the Wind Farm's active power output has been restricted by the ISO. The Control System shall be capable of receiving an on-line active power control set-point sent by the ISO and shall be able to reach the requested set-point within 15 minutes of receipt of the signal from the ISO. The rate of change of output to achieve the requested set-point should be no less than 10% of the current Wind Farm's active power output per minute.

Wind Farms shall have the capability to remain connected for at least 60 minutes in the event the Transmission System Frequency is in the range 47.5 to 49.5 Hz or in the range 50.5 to 52 Hz.

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

If the transmission system frequency is at a level above 52 Hz or below 47.5 Hz, the ISO accepts that Wind Farm may disconnect. Any WTG which has disconnected shall be brought back on load as fast as technically feasible (provided that the Transmission System Frequency has fallen below 50.5 Hz).

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 0.95 legging (under-excited) to 0.95 leading (over-excited).

In the event of under-voltages at the connection point which are within the continuous voltage operating range defined by this 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 this 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.

Wind Farms shall 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 shall be specified by the ISO within the approval for connection to the transmission network.

Wind Farms shall have a continuously acting voltage regulation system with similar response characteristics to a conventional automatic voltage regulator. The voltage regulation system shall be capable of receiving a set-point for the voltage at the connection point from the ISO. The voltage regulation system shall 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 shall be implemented by the Wind Farm within 20 seconds of receipt of the appropriate signal from the ISO.

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 0.95 of the rated voltage, a Wind Farm shall remain connected to the transmission system for at least the following specified period of time:

- 0.5 seconds if the voltage at the connection point drops to 15% of the rated voltage.
- Required time interval increases linearly to 2.5 seconds with changes of voltage at the connection point from 15% to 95% of the nominal voltage (0.025 seconds per percentage of voltage).

In addition to remaining connected to the transmission system during voltage dips, Wind Farms shall have the technical capability to provide the following functions:

- During a transmission system voltage dip Wind Farms are required to stop drawing reactive power within 100 ms after a voltage drop;
- 100 ms after a voltage drop Wind Farms shall start injecting reactive power. The maximal reactive power that should be reached corresponds to 1.25% of the rated reactive current per each percent of the voltage dip[18]). The maximal reactive power shall 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;
- Following the transmission system voltage recovering to the continuous operating range (±5% around the rated voltage) Wind Farms shall 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 ISO accepts that Wind Farms may disconnect. Any Wind Farm which has disconnected due to a voltage dip shall be brought back on load as fast as technically feasible.

Operational requirements

A designated responsible operator of a Wind Farm shall be contactable by the ISO at all times to discuss operational matters without undue delay and in any event within 15 minutes. Following a request from the ISO, the responsible operator shall be present at the Wind Farm's connection point without undue delay and in any the event within one hour and shall be capable of taking any required appropriate actions. The responsible operator shall 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 operator of the Wind Farm shall contact the ISO without undue delay.

[18] If the voltage drops to 15% of the rated value, the voltage dip is 80%, which means that the maximum reactive current which should be reached equals to 100% of the rated current

Provision of Operational Data

Responsible operators of Wind Farms shall submit their operation schedules to the ISO on hourly basis for a day ahead in a format and timescale as specified by the ISO.

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

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

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

- Wind speed;
- Wind direction;
- Air temperature;
- 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 Wind Farms shall, acting in accordance with the best professional practice, restore or correct the signals and/or indications as soon as possible.

Finally, there is a question how to implement technical requirements for WPPs: 1) to all WPPs, or 2) to specific WPPs depending on installed capacity or voltage level. There are different experiences in that sense. If all requirements are applied to all WPPs, then there is a possibility that for some WPP projects these requirements will be too high and too expensive without any positive impact on the system operation. On the other side, it these requirements are applied for specific WPPs only, then it could be arbitrary and discriminatory. Accordingly, we suggest to apply these requirements to all WPPs, while after getting operational experience with WPPs, this principle could be revised.

7 Requirements for cost sharing of grid reinforcements

There is currently much uncertainty in BiH regarding how much of the cost associated with grid reinforcements that will be required by wind farms will be paid by the WPP developers. In our report for FERK and RERS "Review of procedure for network access for RES and connection charges", in October 2010 we noted that there have been ongoing difficulties associated with the development of the transmission investment plan which is resulting in uncertainty regarding the future development of the transmission system. There is an increasingly urgent need for investment in the transmission network to proceed in order to maintain an efficient power sector, particularly associated with the connection of new power plants.

In the current circumstances, it is not possible for an investor in a wind farm to assess the level of connection cost at the transmission level. A greater degree of certainty as to general cost level should be possible following offers from TRANSCO (in consultation with the ISO). However, at present, we cannot be sure that TRANSCO is in a position to provide a definitive offer price to a prospective wind farm investor and this is obviously of concern.

A critical issue is that the detail of the calculation of the cost of the fixed (or "deep") component connection at the transmission level which is contained within the DERK's book of connection rules is still to be determined. A formula exists for this calculation (N = C times P where N is the cost, P is the connection capacity and C is the price per kW) but one key component, C, is still to be defined. TRANSCO and DERK were due to meet to discuss this issue, but the value of C remains undefined. The formula for calculating the fixed connection component is contained in Article 16 of the DERK Connection Rules. The basis for determining the fixed (deep) component of price in (KM per kW) of connected capacity (C) needs to be specified.

Given that we understand that TRANSCO has built up surplus funds in its depreciation account an interim option would be to set C to zero such that RES developers only pay a shallow connection cost until the charging methodology is agreed. This is of particular relevance to WPPs to be connected at transmission voltages. In any event, an agreed basis for the funding of future developments of the transmission network and the sharing of the associated costs between TRANSCO and developers costs must be found in order for any new power plants to proceed.

In addition, we recommend that in order to reduce uncertainty for investors:

- TRANSCO should quantify the national implications (both to system operation and development for RES investment in particular) associated with current delays in finalization of its transmission plans to ensure full market awareness of the costs and opportunities foregone. This is of particular importance because historic lack of investment will increase uncertainty as to the eventual level of the fixed component of connection charges; and
- We suggest that DERK revises Article 18 of its connection rule book to make it explicit that the developer should pay for any step up

transformers that are involved in the connection of a generator to the Grid. In the event that such step up transformers are shared between more than one user, an appropriate mechanism for cost sharing between users must be developed.

8 WPP inclusion in market procedures

In this section, we provide a preliminary discussion of the issues associated with integrating WPPs into the market procedures in BiH.. We will explore the associated issues further in our Task 4 report in which we will make a number of specific recommendations. .

Besides the purely technical requirements for WPPs which were discussed in section 5, special attention should be given to WPP inclusion in the market procedures. In other words, it is important to define how the variable energy generated by wind farms is included in the production schedule and into the market procedures. This is vital in order to assure the flow of payments for the energy and also payments associated with the imbalances created where unpredictable wind generation delivers energy into the market.

Two specific buyers have been designated to purchase all electricity produced by all renewable energy sources from qualified producers at prices determined by the FIT within FBiH and RS respectively. Nonetheless, a clear basis for incorporating the renewable energy produced into the overall electricity market will be required and the ISO will need to have access to both a forecast of the renewable energy output and the actual energy output in order to operate the system in a cost effective manner.

The provision of ancillary services is required for the security and stability of the power system and for maintaining the quality of electricity delivered to the customers. Ancillary services include voltage regulation, frequency control and reserve provision, and “black start”. Since the ISO is responsible for the safe and reliable operation of the transmission grid, it is responsible for purchasing ancillary services in a power market. Provision of some ancillary services is normally mandatory for all generators as defined by the Grid Code. State-of-the-art wind power plants are technically capable of delivering ancillary services such as voltage and frequency control. While historically WPPs have typically not provided ancillary services, revised Grid Code provisions referencing WPPs or Wind Grid Codes in some European countries now require WPPs to have a certain degree of ancillary services provision capability.

Balancing costs in any power market will typically depend upon the marginal costs of providing balancing services. The applicable market rules may have a significant influence on the magnitude of the balancing costs, as the technical costs of balancing can be very different from the market price.

In electricity markets, the forecasting errors associated with wind farm output can result in high imbalance costs and market mechanisms vary significantly in terms of how these impact upon wind power producers. In a number of markets, wind farms are treated just like any other generator and are financially responsible for any deviations from their predicted output and are penalized for any imbalances that result. In other markets, wind producers are not subject to imbalance costs with the result that other market players must fund the imbalance costs. The latter situation is understood to apply in BiH.

Integrating wind generation information into system operation both in real-time and using updated wind output forecasts day-ahead and within day will help to manage the variability and forecast errors associated with wind power. Shortening the gate closure time in a market helps reduce the cost of wind integration as the forecast uncertainty associated with wind output reduces significantly within a few hours of actual production. Well-functioning hour-ahead and day-ahead markets can help in providing the balancing energy required by the variable-output wind plants on a cost-effective basis . In addition, the ability to trade energy and reserves across international interconnections can significantly reduce the cost of wind integration.

The basis of trading wholesale energy in the power market will be contingent upon the market design adopted. The two fundamental options are trading power and energy on the basis of bilateral contracts and trading power and energy through some form of a power Pool arrangement. In either case it is important to clearly establish the basis upon which the variable and unpredictable power output from wind farms will be traded in the market.

In BiH a production plan is prepared by each generation company and sent to the ISO for verification. The ISO adds transmission losses and transits and verifies the production plan.

By its nature wind generation cannot be dispatched but wind output does need to be accommodated within the hourly production plans. If several hundreds of WPPs are added to total generation mix, it is possible that total available generation is significantly higher than total system load during the light load periods . This will result in problems in power system balance, forced export, more expensive contracts on import or spilling energy. So far in BiH there are no foreseen contractual arrangements between generation companies and the ISO (and especially not with future WPPs) or any other mechanism to deal with the surplus energy that could result from operational wind capacity.

With the first WPPs operation expected in the near future, the existing approach needs to be changed. Besides market procedures, more secondary and tertiary control will be needed and adequate ancillary system should be established. Currently, it seems that conventional power plants participating in system control are not motivated to participate more, even though the technical capability to do so does exist. As previously mentioned, it is not clear from a financial perspective what is happening if power companies are not delivering the required reserve.

On the other side, the hour-ahead electricity market price can reach the level of 100 €/MWh, usually treated as emergency delivery, while hourly electricity surplus is usually 10% of base load electricity price (i.e. 5 €/MWh, treated as spill power). This means that with the first electricity market moves and with a larger WPP share with the existing balancing mechanism, financial loss associated with system balancing is inevitable.

Finally, it is clear WPP in BiH always have priority in being dispatched and usually have no obligation in forecasting their output (besides the above mentioned non-binding production predictions) or balancing. This is a crucial issue and its implications for the market could be significant.

For example, the minimum system load in BiH is currently at the level of 800 MW, while the peak load is at the 2100 MW level. From a WPP integration point of view, this large difference between maximum and minimum load level (a ratio of 1 : 2,6) is very unfavourable. This is one of the most critical issues for large WPP integration in BiH. Namely, the ISO practically has an obligation to accept the output for certain power plant generation due to either its heat/electricity consumption (for thermal plant) or due to wet hydrological conditions (for hydro plant). So, one of the most critical aspects of larger WPP integration in BiH system will be inclusion of WPPs in the power balance during light load periods . This aspect should be analyzed in more detail in the future WPP integration studies in BiH.

There are thus a number of key issues that will therefore need to be resolved including:

- Which parties will be responsible for paying the balancing costs associated with WPPs;
- On what basis will balancing costs in BiH be calculated;
- What market mechanisms will exist to allow parties to minimise their balancing costs;
- What will be the mechanism for passing balancing costs onto end use customers;
- Which parties will be responsible for providing data to the ISO such that it can accurately forecast the total output from WPPs;
- The financial mechanisms through which the ISO can discharge its balancing responsibilities associated with WPPs need to be clearly defined;
- During periods in which electricity supply is expected to exceed demand within BiH, what market mechanisms will be in place to deal with the associated surplus energy;
- What are the financial implications in the event that the ISO is required to request a reduction in output from WPPs; and
- The output from thermal plants can reasonably be expected to fall during consistently windy periods and this will have implications for the revenues of such plants and for their fuel suppliers.

We will discuss these issues in more detail in our Task 4 report.

9 Wind forecasting techniques

This section offers a high level review of forecasting techniques needed for the ISO to predict when and how much energy will be delivered from wind farms. It looks briefly at the current level of development of short-term energy supply forecasting in BiH.

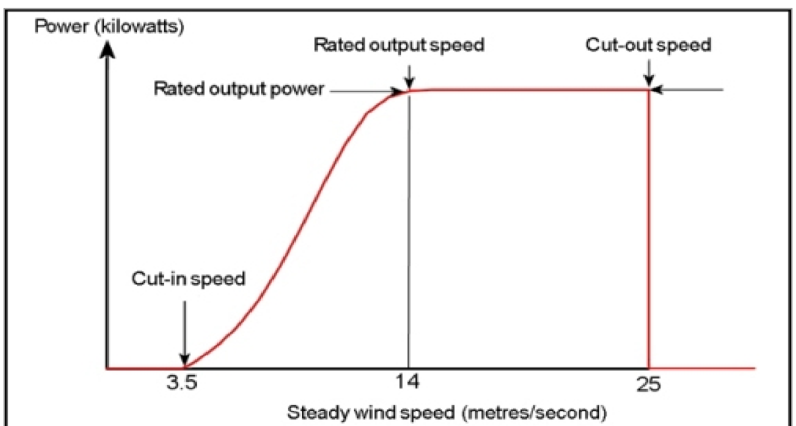
As the amount of wind generation capacity connected to a power system increases, the ISO needs to develop new operational procedures in order to:

- Provide a forecast of wind generation output data which supplements the operational information provided by the generators; and
- Adapt its approach to scheduling operating reserve such that it can target any additional reserve that is required in order to cater for wind generation output uncertainty over those periods when uncertainty is greatest.

Wind forecasting tools are thus an increasingly common tool for System Operators in scheduling generation units and assessing reserve requirements. Wind-integration studies typically include the impact of wind-forecast errors on wind integration costs, and the wind forecasts are developed as part of process of forecasting the output from wind farms.

In order to develop an understanding of the output characteristics of wind generation, it is necessary to understand the output characteristic of a wind turbine. A typical characteristic is illustrated in Figure 30.

Figure 30 Typical wind turbine power output with steady wind speed



Typical wind turbine power output with steady wind speed.

A typical wind turbine will start to generate electricity in wind speeds of around 4 m/s and increase output with increasing levels of wind from this point. Rated output from the wind turbine is obtained at wind speeds of around 15 m/s. In wind speeds of over 25 m/s, a wind turbine will cut out and will then restart once wind speeds drop. Typically, after cut-out a wind turbine will restart once the wind speed has been below 20 m/s for around three minutes.

At certain points on the power output curve, small variations in wind speed will result in large changes in output and this has implications for predicting the output from a wind farm. There is also a region where variations in wind speed have no impact on the output of the wind turbine. If a wind farm has many wind turbines, the wind effects are likely to be smoothed to a certain extent. Predictions of the output from wind generation can be informed by this power curve in conjunction with a forecast of wind speeds.

TSOs typically use a combination of physical modelling (essentially a wind turbine power output curve in conjunction with a wind speed forecast) and persistence methods[19] in order to produce a wind power output forecast over a range of timescales.

Wind forecasting tools can involve multiple forecast methods such as:

- Artificial Neural Networks which are 'trained' using historical wind and generation output data;
- Linear Regression Models which use established relationships between generation output and wind speed in order to produce forecasts;
- Physical wind turbine models which make use of turbine specific power output curves and a wind speed forecast in order to produce a generation output forecast; and
- Time series models to extrapolate from recent wind farm behaviour.

Having created a number of forecasts using different forecasting methodologies, wind forecasting tools can then allow multiple ensemble wind forecasts (which reflect the degree of weather forecast uncertainty) to be accessed and also compare these with metered wind farm outputs in order to select the most appropriate forecast method.

State-of-the-art wind-power production forecasts typically use a combination of physics-based and statistical models. Physics based atmospheric models that are used for weather forecasting are typically referred to as numerical weather prediction (NWP) models. In statistical models, on the other hand, forecasts are based on empirical relationships between a set of input and output variables.

Many forecasting systems use a number of individual forecasts rather than just a single forecast. This is because there is uncertainty in any forecasting procedure due to the uncertainty in both the input data and in the model configuration. Using a number of forecasts attempts to account for such uncertainty by generating a set of

[19] A persistence method assumes that the conditions at the time of the forecast will not change. The persistence method works well when weather patterns change very little and features on the weather maps move very slowly

forecasts through perturbing the input data and/or model parameters within their reasonable ranges of uncertainty.

The relative value of different data sources and forecasting techniques varies significantly with the forecasting period of interest. Short-term forecasts (from zero to six hours out) typically rely heavily on statistical models that exploit the recent data supplied from the wind plant. Longer-term forecasts, on the other hand, depend much more heavily on the NWP forecast values.

Numerical weather prediction models

The use of numerical weather prediction (NWP) models is an accepted method for producing a time-series wind farm output data. Essentially, NWP models are physics-based, numerical simulations run on supercomputers and are integrated with observed data sets, in order to recreate the weather for historical years and then generate a three dimensional wind speed data set on a grid.

A wind-speed time series can be extracted from the NWP output and then converted to wind power output using the appropriate wind turbine characteristics. This approach produces a temporally, spatially, and physically consistent wind data set. It also allows for modelling of proposed plants for which there is a lack measured of wind-speed data.

NWP models have important advantages. Because they consist of a set of equations based on the fundamental principles of physics, no training wind sample is needed to produce forecasts and the NWP model results are not constrained by wind history. For an unusual but realistic set of conditions, an NWP model can predict an event that has never previously happened in quite the same way. Because of the complexity of doing the simulation, NWP models have large computational overheads.

Statistical models

Because empirical relationships are derived from a sample of historical data that includes values of both the predictor and forecast variables, statistical models have the advantage of “learning from experience” without the need for explicit knowledge of the underlying physical relationships. Some of these statistical models can become quite sophisticated, finding complex multivariable and nonlinear relationships between many predictor variables and the desired forecast variable.

Statistical models are used in a number of ways in the wind-power production forecasting process. The basic approach is to use values from NWP models and measured data from the wind plant to predict the desired variables (e.g., hub height wind speed, wind-power output, etc) at the wind plant location. Because they can essentially learn from experience, the statistical models add value to NWP forecasts by accounting for subtle effects due to the local terrain and other details that can’t realistically be represented in the NWP models. Because they need to learn from historical examples, statistical models tend to predict typical events better than rare events unless they are specifically formulated for extreme event prediction and are trained on a sample that has a good representation of rare events.

Today, hourly, four-hourly and 12-hourly WPP generation variations can mostly be predicted and so can be taken into account when scheduling power units to meet the demand.

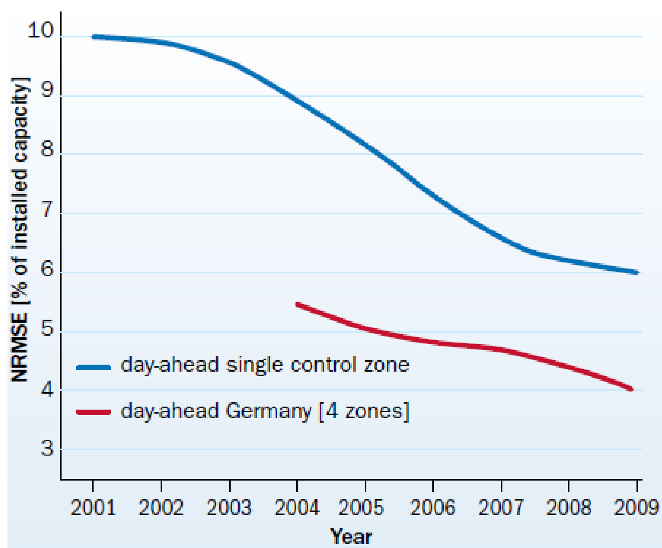
Two major factors have a significant influence on the accuracy of WPP forecast tools:

- the size of the area considered and
- the prediction horizon

With commercially available tools and methods today, forecast error (RMSE[20]) for a single wind power plant is between 10% and 20% of the installed wind power capacity for a forecast horizon of 36 hours.

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. Figure 31 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.

Figure 31 Normalised forecast error in Germany in last 9 years

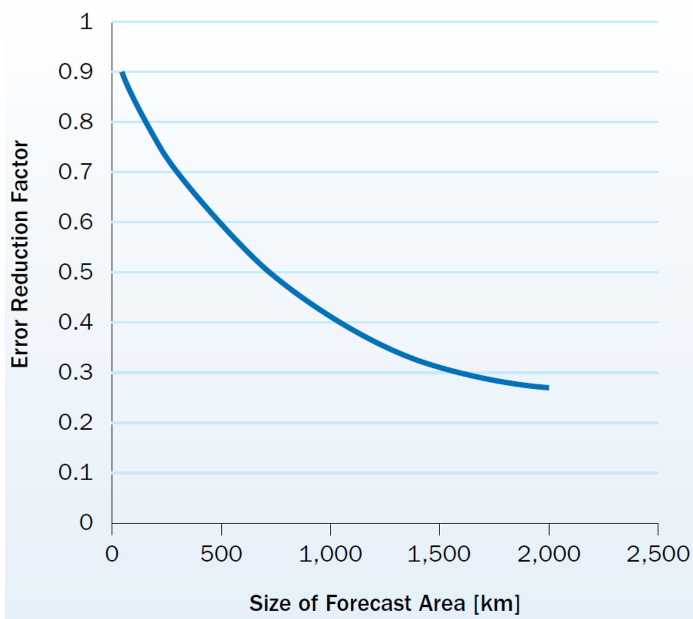


Source: Tambke, EWEA

The larger the area, the better the overall prediction is, as shown on the Figure 32.

[20] RMSE - Root Mean Square Error, normalised to the installed wind power

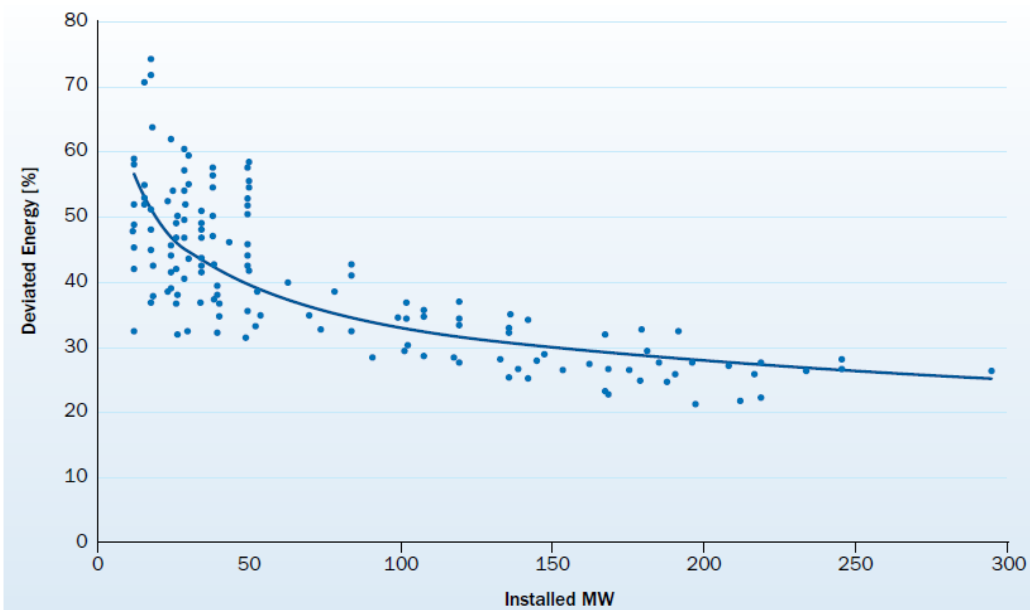
Figure 32 WPP forecast error reduction factor vs size of forecasted area



Source: Tambke, EWEA, 2010

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 Figure 33.

Figure 33 WPP deviated forecasted generation vs diversified installed capacity



Source: W2M

Implications for the ISO

In BiH, the ISO has no current plan to establish a wind forecasting system. In addition, the WPPs that are currently under development have no legal obligation to deliver either wind measurement or a binding wind forecasting data to the ISO. Accordingly, the necessary input data for any forecasting will be missing.

The ISO clearly needs to have its own wind energy forecasting system up and running successfully. A system that is sufficiently accurate will be needed by the ISO no later than the first major wind farm coming on line.

The existing wind forecasting mechanism in BiH is not suitable as it is not useful to the ISO because of lack of accuracy and speed/timing/data issues. We understand that the existing problems with the forecasting system are, however, supposed to be resolved as soon as possible, along with other RES legislation details.

9.1 Effect of wind power generation forecasting to the required power reserve

Before we enter into more detail elaboration of the effect of wind power generation forecasting to the required system energy reserve, we need to emphasise another important feature of wind energy use. Since the annual duration of use of installed wind power is short (1800-2500 h/year), there is a certain probability that in a critical period of electric power system (during peak or off-peak load and/or the lowest possible engagement of hydro energy), the engaged wind power occurs to be the most variable, negligible or even equal to zero. In that period, the highest regulation activity of reservoir hydro plants and thermal plants is needed. Therefore, the generation system, and especially in the small countries where the distribution of WPP is small, needs to ensure sufficient system reserve within the conventional power plants, in order to maintain the safety of energy supply in all hydrology and wind situations, that is, an adequate power reserve.

In illustrations given in previous subsections, from the point of view of required reserve energy, we observed the most conservative case, when there is no forecasting of wind power generation available. In other words, we assume the total wind power generation would be regulated through available secondary regulation. It is clear that with introduction of wind energy generation forecast, the need for required reserve lowers. The better the wind power generation forecast is, the lower system reserve is required, as illustrated in the following Figure 34, in cases of the large systems.

Figure 34 Relation between the quality of wind forecast and required system reserve

Source : Garrad Hassan, FESB

The reason for the use of the most unfavourable case from the aspect of wind energy generation forecast is the fact that the drive and development of the electric power system are dimensioned in relation to the extreme (the most unfavourable) condition, and not in relation to an average condition or the condition with assumed favourable circumstances. In fact, at the moment of preparation of this study, there are no wind power plants in operation in BiH, the obligation of forecasting of wind power generation is not foreseen, and therefore, there aren't related experiences/practices. Also, the tools for wind power generation forecasting is not selected, installed, tested, neither is it calibrated, and all mentioned, together with the geographical specifics, is greatly affecting the accuracy of the forecasting.

In order to define the effect of the wind power generation forecasting on the required system reserve, we will observe the experiences in other countries which are more experienced in wind power generation forecasting.

Having in mind exceptionally high variations of wind power generation, first we need to consider the overall development of the generation system in particular countries. The countries with high share of hydro and/or wind power generation have, as a rule, very high reserve in available power in relation to the peak load, as illustrated in the following Table 10 for year 2008. [21].

Table 10 System reserves

Country	Generation (HP+VPP)/ Consumption (%)	Reserve /Pmax (%)	Pinst(WPP)/reserve (%)
Switzerland	58.4	76.8	0.2
Austria	56.9	109.9	9.9
BiH	**39.7**	**115.6**	**0.0**
Montenegro	32.6	43.6	0.0
Romania	30.4	112..3	0.1
Croatia	29.6	37.2	1.8
Slovenia	27.6	70.4	0.0
Serbia	25.6	29.0	0.0
Portugal	24.5	68.8	47.0
Spain	20.7	108.6	36.2
Denmark	19.4	102.5	49.5
Germany	11.5	73.9	41.8
Total ENTSO-E	15.7	74.2	20.7

The reserve had been calculated as a difference between the total available energy of all power plants and the peak load of the system. For all ENTSO-E countries, which have a share of renewable energy sources in energy generation of an average 15.7%, the subject reserve is 74.2% of the system peak load. In the countries in which the share of renewable sources is high, the subject reserve is even greater than 100% (Austria, Bosnia and Herzegovina, Spain and Denmark)! In 2008, Montenegro had had significantly lower reserve (43.6%), and a share of renewable energy sources (hydro power plants) was around 33%. In the neighbouring countries with similar heritage (Slovenia, Croatia, and Serbia), the observed values were even lower, with an exception of Bosnia and Herzegovina, where the reserve was about 115%. The countries with developed wind power plants "take" 36-48% of the system reserve with their installed power (Germany, Spain, Denmark, Portugal).

[21] M.Kalea: Wind power plants in energy system , Round table HAZU and HO CIGRE, Zagreb, May 5, 2010.; Windenergieeinspeisung in Deutschland im 2007

German Experience

Over the course of greater integration of the wind power plants, a share of the conventional power plants must have high regulatory features (possibility of fast change MW/min). Available data from Germany for 2007 are stated as follows (in percentages of an average total installed power of wind power plants, which was in the beginning /end of the year 20622/22247 MW):

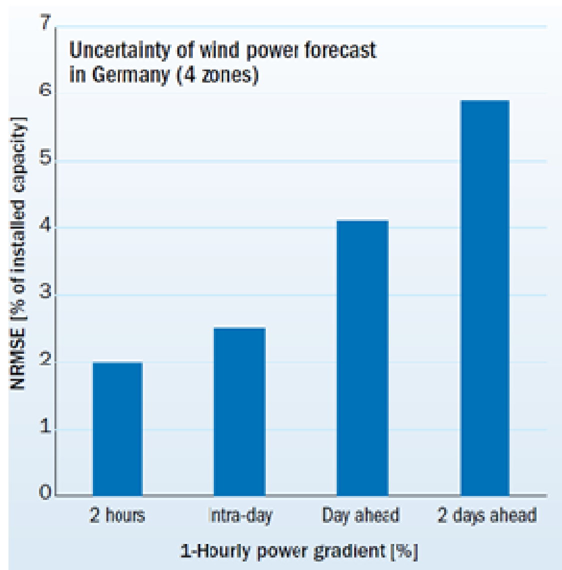
- Greatest (consecutive) 15-minute variation of the total engagement: 5.3%
- Greatest daily variation of the total engagement: 65%
- Number of months in which 15-minute variation was in the range: 4.3-5.3%
- Number of months in which the daily variation was in the range: 50-65%
- Maximal simultaneous engagement: 87.9%
- Minimal simultaneous engagement: 0.5%
- Number of months when the maximal engagement was lower than 75%
- Number of months when the minimal engagement was in the range of 0.5-1%

Having in mind the stated quite high ranges of the installed wind power in Germany, these individual values present very high powers. For example, 15-minute change of the engagement of 5.3% implies around 1,100 MW! Regardless of large territory of Germany, great distribution of wind power plants and high installed power of some 22,000 MW, recorded minimum simultaneous engagement of wind power plants was only 115 MW, and the maximum was around 18,380 MW! Therefore, the difference between minimum and maximum 10-minute engagement during the same year, was around 160 times.

Experiences of German system operators, with the forecast of wind power generation in 2009, are shown in the Figure 35. An average error in wind power generation forecast, on day-ahead basis, was about 4% of the installed capacity, which for today's installed power of 26,000 MW, implies an average error of 1,040 MW. Over a 2-hour period such average error is around 500 MW.

If we take into account that an average total installed power in wind power plants in Germany was equal to an arithmetic mean of power in the beginning and at the end of the year, therefore (22,247+20,622)/2 = 21,435 MW, realised duration of the utility of wind power plants in Germany in that year was 39,500 GWh/21,435 GW = 1,843 hours. Since there are 8,760 hours in a year, it indicates that the power plants would be operative in 21% of the year, in order to permanently generate by using installed power. Or, in more illustrative way: they would reach their annual generation if they were in operation on every fifth day in full power, followed by four days of standby. This is an important, but unfavourable feature of wind power plant use.

Figure 35 Average error in wind power generation forecast in Germany, in 2009



Source: Tambke 2010

Therefore, we would emphasise that this is an average, and not the highest error, and that this is one of the most advanced systems of wind power generation forecast in Europe and worldwide. As noted earlier, electric power system needs to be modelled for all possible conditions, and not for average ones. Figure 36 shows an "extraordinary" condition, in which the day ahead variation was 9% (2,130 MW), and not the average 4%.

Figure 36 Wind power generation forecast error in Germany

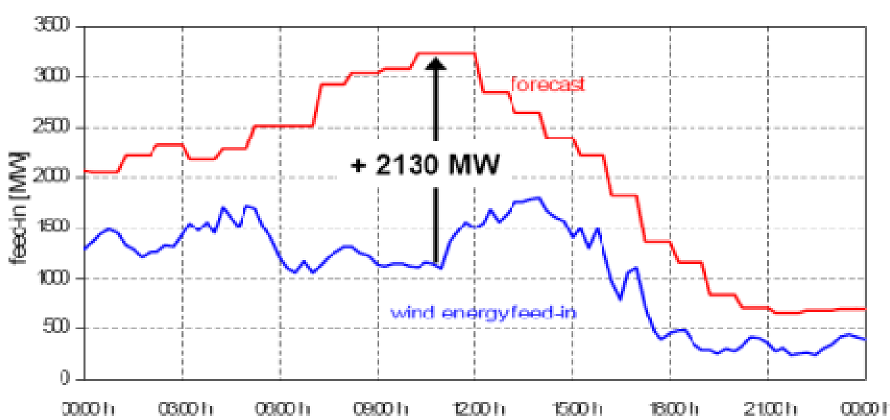
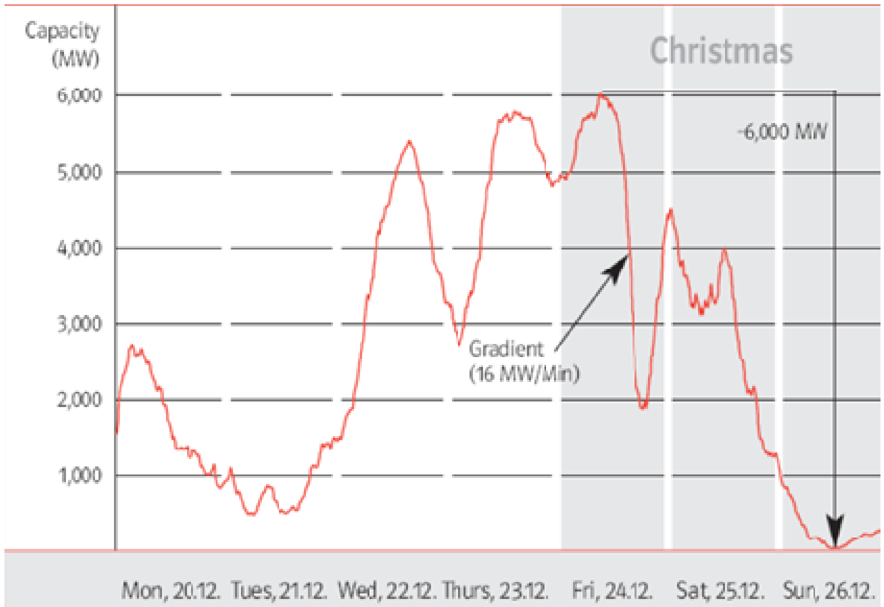


Figure 37 shows an extreme example, when the change in generation was 6,000 MW (or around 25% of total installed capacities) in just 48 hours. Regardless of the quality of forecast, it is very difficult to provide a reserve for such change in generation. The reserve needs to be provided for all mentioned states, regardless of the probability of their occurrence.

Figure 37 Highest recorded error in wind power generation forecast in Germany



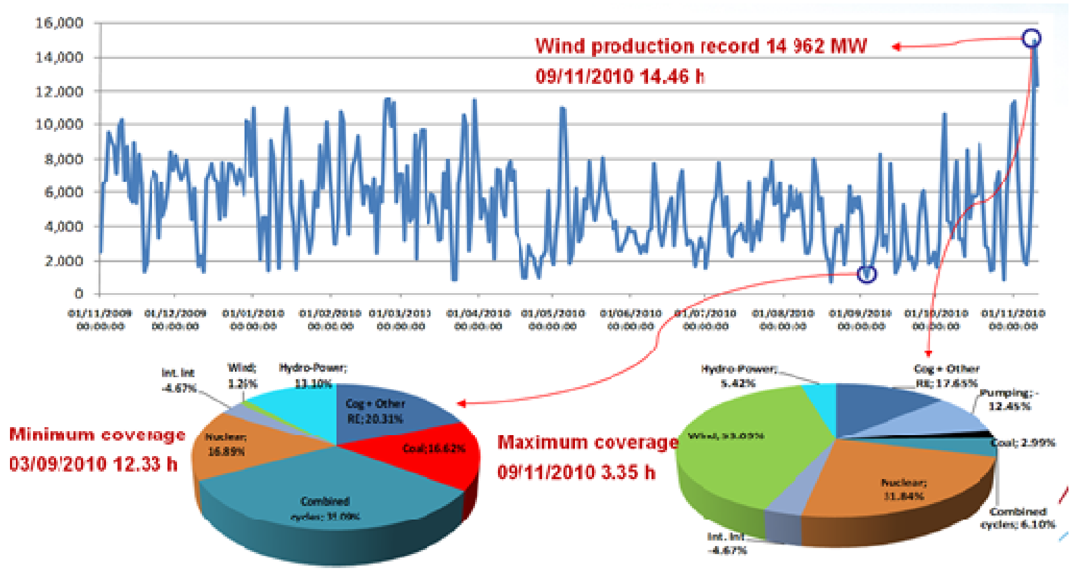
In the following text, we bring you the experiences from Spain, as other most advanced systems from the aspect of wind power generation forecast[22].

Spain Experience

Figure 38 shows the wind power generation in period 2009-2010, where the maximum recorded current wind power generation was 14,962 MW, and the lowest generation was less than 1,000 MW. Therefore, in spite of relatively large geographical distribution of wind power generation, the difference between maximal and minimal generation in the observed period was more than 15 times.

[22] REE, RES Integration into Spanish System, USEA RES workshop, Istanbul, March 2011.

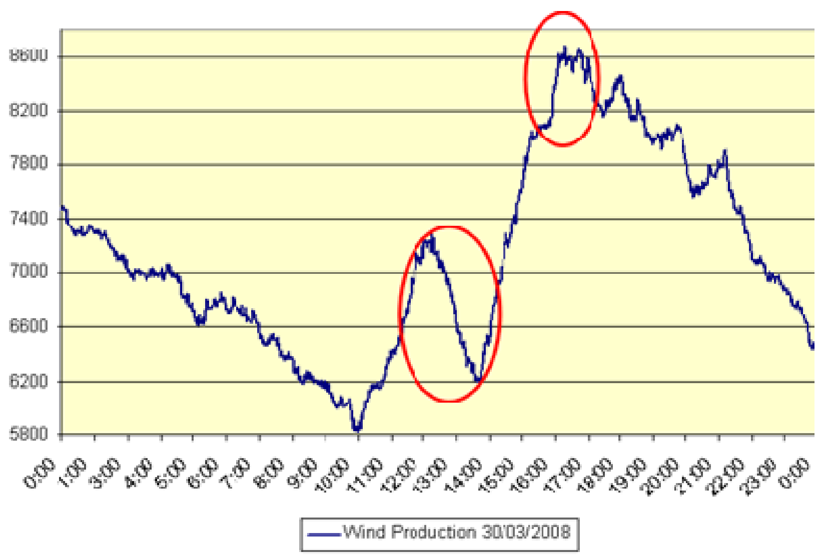
Figure 38 Wind power generation in Spain in period 2009 – 2010



Source: REE

Similar to German experience, the highest recorded positive power gradient in wind power generation was 1,172 MW/h (or more precisely 586 WM in 30 min), while the highest negative power gradient was -785 MW/h (more precisely 1,110 MW in 1:25h), as shown in Figure 39.

Figure 39 Wind power generation in Spain on 30.3.2008.



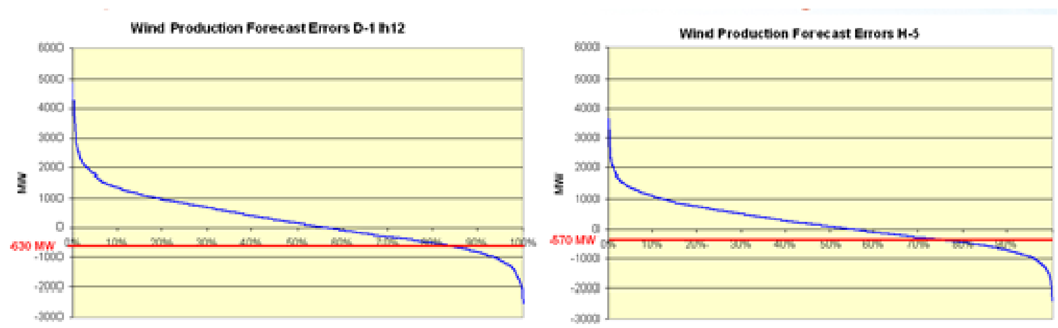
Source: REE

Over the course of a day-ahead wind power generation forecast (D-1) at 12:00 h, the congestion analyses are carried out as well. As per experience in wind power forecast in Spain, at that moment, there is a probability of 15% that the wind power generation would be lower by 630 MW from the forecasted value (Figure 40, left). There data should also be used as an input for analyses of network overload.

The same is valid for the 5h ahead interval (H-5), which is the usual time required for thermal power plan start-up. Still, there is 25% chance that, regardless of wind power forecasts, the wind power generation would be lower by 570 MW than the forecasted value, i.e., 15% probability that the generation would be some 600 MW lower than the forecasted value (Figure 40, right).

Therefore, the reserve required is examined within two stated time intervals (D-1 and H-5) and accompanying uncertainty in forecasts is calculated in the final reserve provision.

Figure 40 Curve of probability of error in wind power generation forecast D-1 and H-5



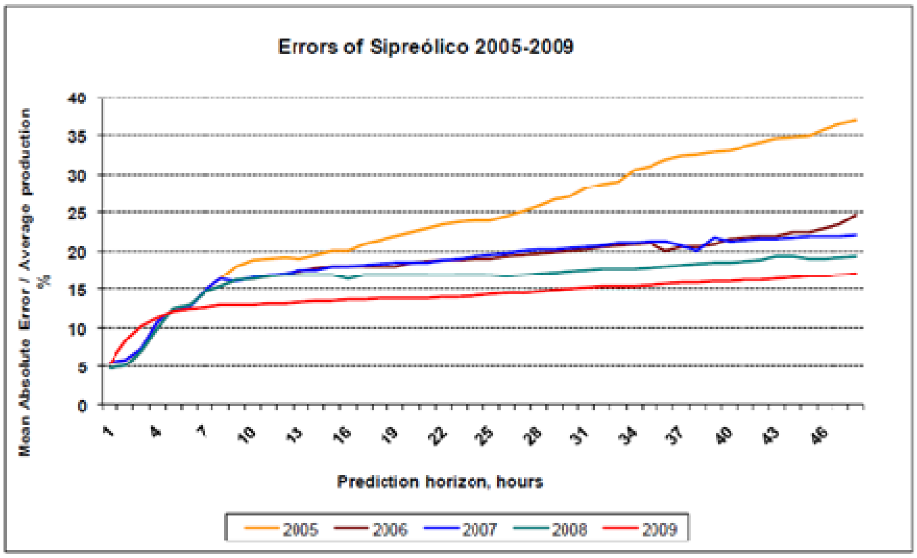
Source: REE

Due to the complexity of such forecast in Spain, a Control Centre for Renewable Energies (CECRE) was established within the system operator, with the following tasks:

- To integrate as much as possible RES, without endangering the system security,
- To organize an adequate operation, management and coordination of generation facilities.

In order to achieve that, a special tool was developed for wind power generation forecast - Sipreolico. An average error in generation forecast in period 2005 – 2009 is shown in Figure 41.

Figure 41 Error in forecasting by tool Sipreolico 2005. – 2009



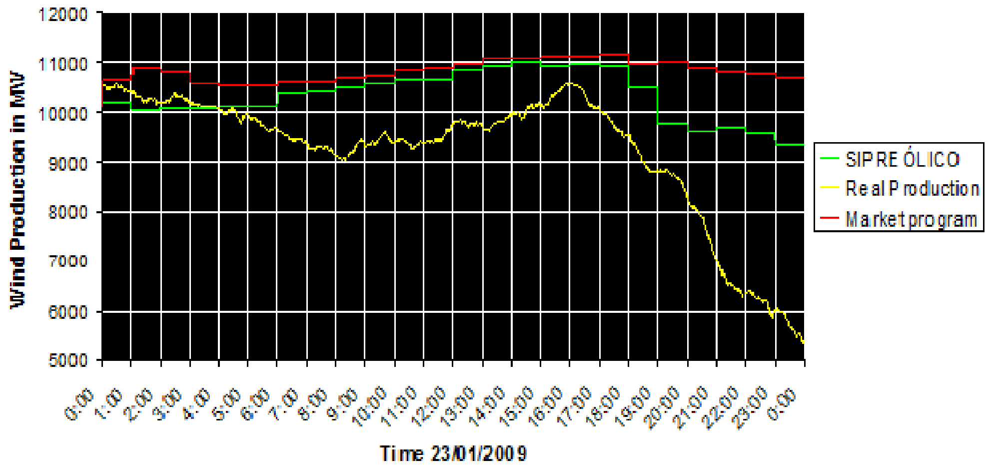
It is obvious that, by the time, the quality of wind power generation in Spain had improved significantly. In year 2005, the 24h ahead forecast implied forecast error of almost 25% of an average generation, while in year 2009, the error was under 15% and it did not increase significantly by the prolongation of time interval of the forecast. It is clear that development over the years and adaptation of forecast system, had contributed to decrease of the required system reserve, especially in day-ahead period, i.e. the cutting down the costs of wind power integration into the power system. However, one needs to have in mind that it is still a considerable reserve which needs to be provided in the system. Namely, 15% of an average generation of some 8,000 MW is 1,200 MW.

We need to note here that the forecast error in Spain is shown against the average generation in wind farms, and in Germany, this is shown against the installed power of wind farms.

Critical period for forecast are from 24 to 32 hours ahead period for definitions of a daily reserve (D-1), or 5 hours ahead for definition of reserve in real time.

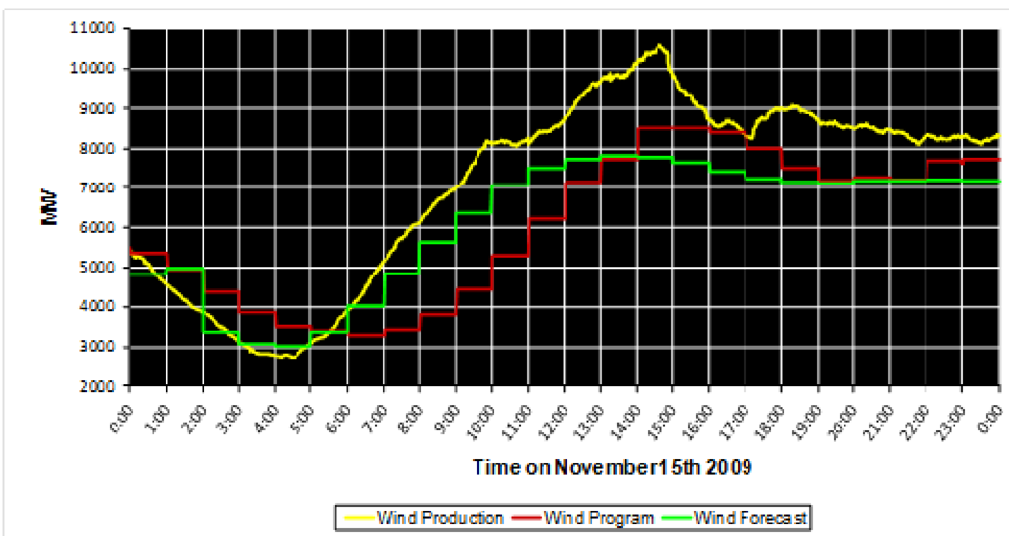
Similar to the case in Germany, average values significantly differ from the most critical extreme cases. For illustration purposes, in further text, we show the situation from 23rd to 24th of January 2009, when the Iberian peninsula was hit by a storm, with strong winds, causing the majority of wind power plants to cease their operations. In that period, the difference between the forecasted and real generation was more than 6,000 MWh/h (see Figure 42), which amounted to 75% of average generation (for the reminder, an average error is less than 15%). This example is in fact the reason why we used an initial approach in the previous section of this study when analysing the required reserve for BiH. In this particular example, Spain did not face system failure, since large thermal plants were in operation and able to provide the required reserve promptly.

Figure 42 Forecasted and real wind power generation in Spain on 23.1.2009



Following January 2009, a similar event occurred on November 15, 2009 at 14:50h, when the forecast values were some 2,800 MW lower than the real generation values, which was 35% of average generation. Additional problem was caused by the fact that the system load at that point was very low (24,000 MW). Therefore, the only solution was to promptly shut down wind power plants in the period 14:50 – 17:00 h, as shown in Figure 43.

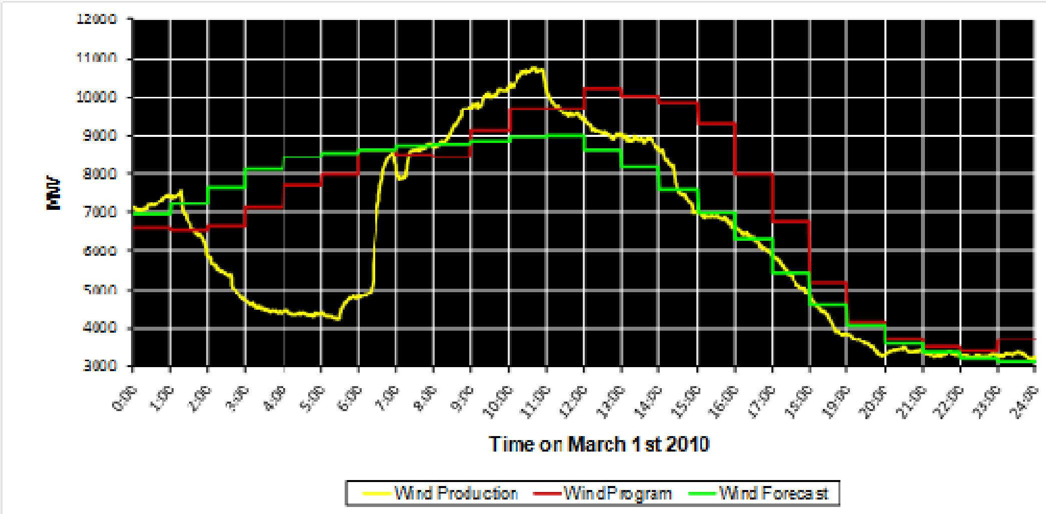
Figure 43 Forecasted and real wind power generation in Spain on 15.11.2009



After January and November 2009, a similar problem with the forecast occurred on March 1, 2010 (Figure 44). Wind power gerenation exceeded the forecasted values in some 1,800 MW, leaving the system entirely without tertiary reserve, while the available secondary reserve was very low. Therefore, a couple of thousands of MW of wind power was put out of operation again, in order to ensure the system stability, i.e. to keep in operations the highly loaded interconnectivity lines towards

France. After that, through the adjustments of schedules of conventional power plants, on an hourly basis, the system was restored to its normal operating regime.

Figure 44 Forecasted and real wind power generation in Spain on 1.3.2010



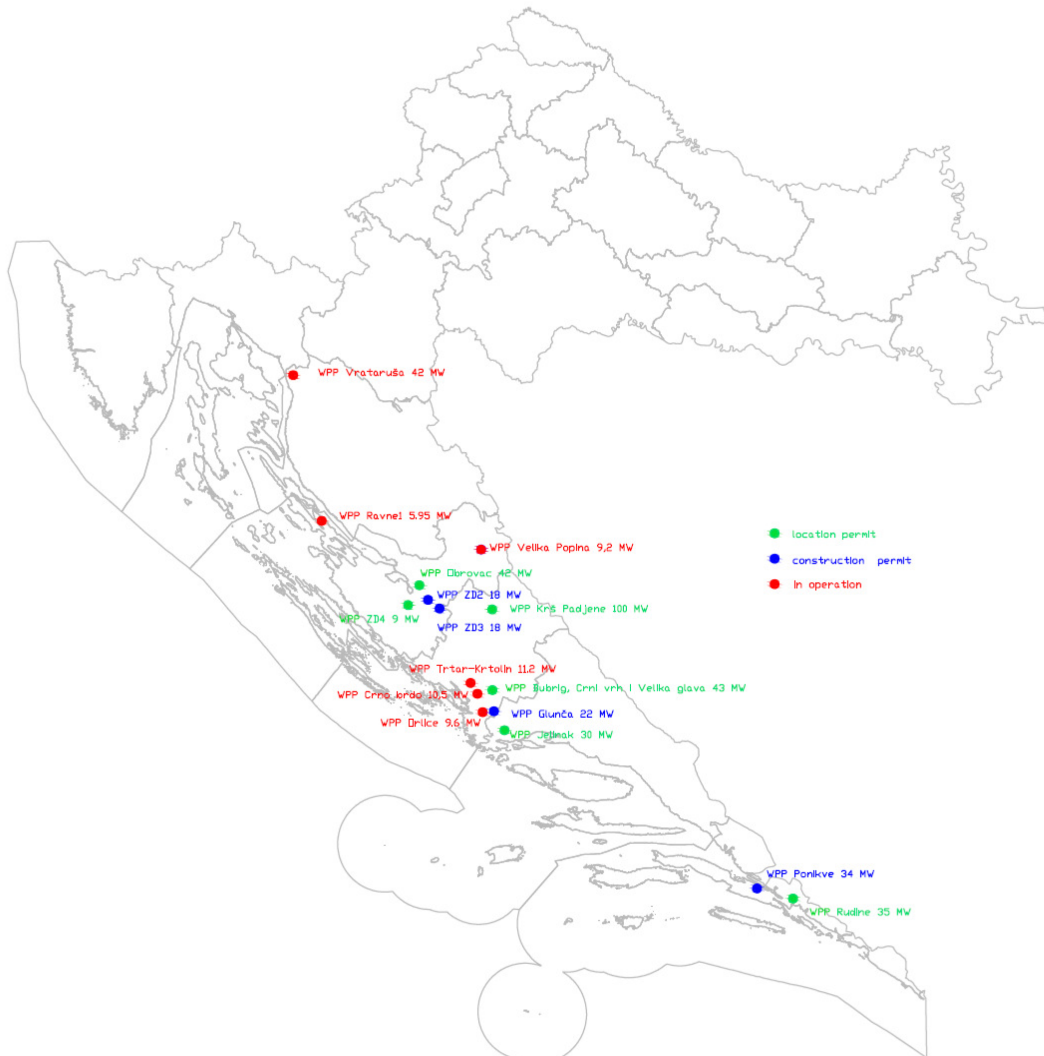
Croatian Experience

Croatian experience is of special interest for BiH system at least due to three reasons:

- Croatia and BiH are neighbouring countries with large operational interdependence, very well connected with 20 interconnecting lines with total installed capacity of agbout 5500 MVA. It is larger that sum of system peak loads.
- Most promising WPP locations are close to the border
- The power systems of Croatia and BiH have the same heritage and operational specifics.

Interest for WPPs in Croatia is huge. At the moment there are 137 WPP projects with more than 5500 MW of installed capacity. At this time there are 6 wind power plants in operation in Croatia, with total installed power of 78 MW. Additional 9.2 MW + 2x18 MW is under construction, and in the next year we expect additional 45 MW to be in operation. In addition to these 6 wind power plants currently in operation, 4 more WPPs have been approved for a construction permit, so that total installed power of WPPs which have a construction permit amounts to 170 MW. Another 6 wind power plants of total capacity 260 MW had received a location permit.

Figure 45 WPP locations and capacities in Croatia



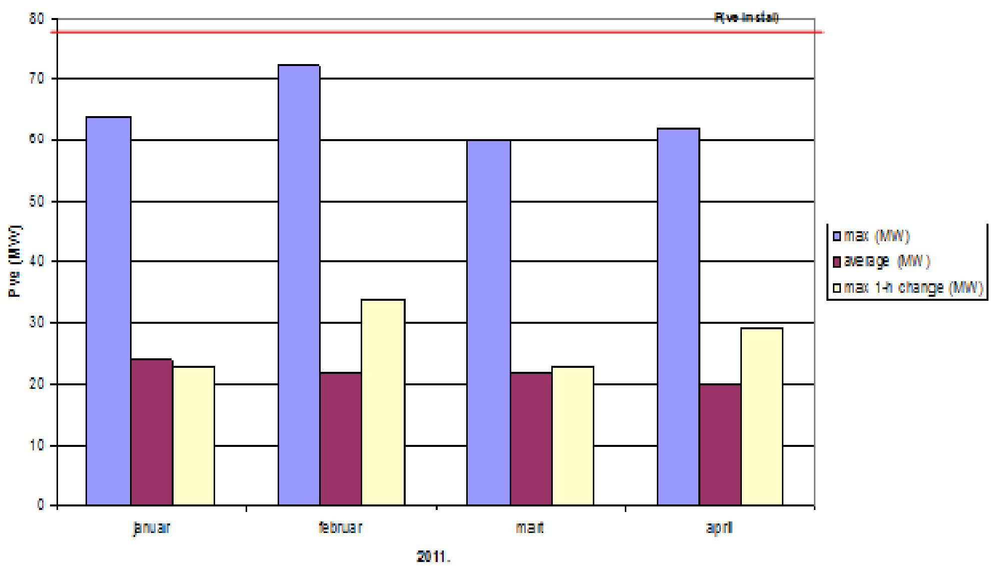
In Croatia there is still no forecast of wind power generation. According to the current regulation, wind power plants do not have any obligation to forecast own generation. A forecast system has been recently introduced in the national dispatch centre.

For illustration purposes, we can indicate that out of 78 MW of wind power installed capacity in 2011 (from the beginning of 2011, all stated wind power plants operate regularly), the maximum achieved current total generation was 72 MW (92% of total installed power), the minimum total generation was 0 MW, and an average was 22 MW (28% of total installed power). Maximum hourly positive variation in generation (increase in generation in relation to previous hour) was +34 MW (44%of installed power), while the maximum hourly negative variation in generation was -21 MW (27% of installed power).

In January 2011, the maximum hourly generation was 64 MW, and maximum hourly change was 23 MW. In February 2011, maximum hourly generation was 72 MW, and the maximum hourly variation in generation was 34 MW.

In March 2011, maximum hourly generation was 60 MW, while maximum hourly variation was 23 MW. In April 2011, (more precisely until April 29), the maximum generation was 62 MW, and maximum hourly variation was 29 MW. Stated values are shown in Figure 46.

Figure 46 Maximum and an average wind power generation in Croatia, and maximum hourly variations in wind power generation

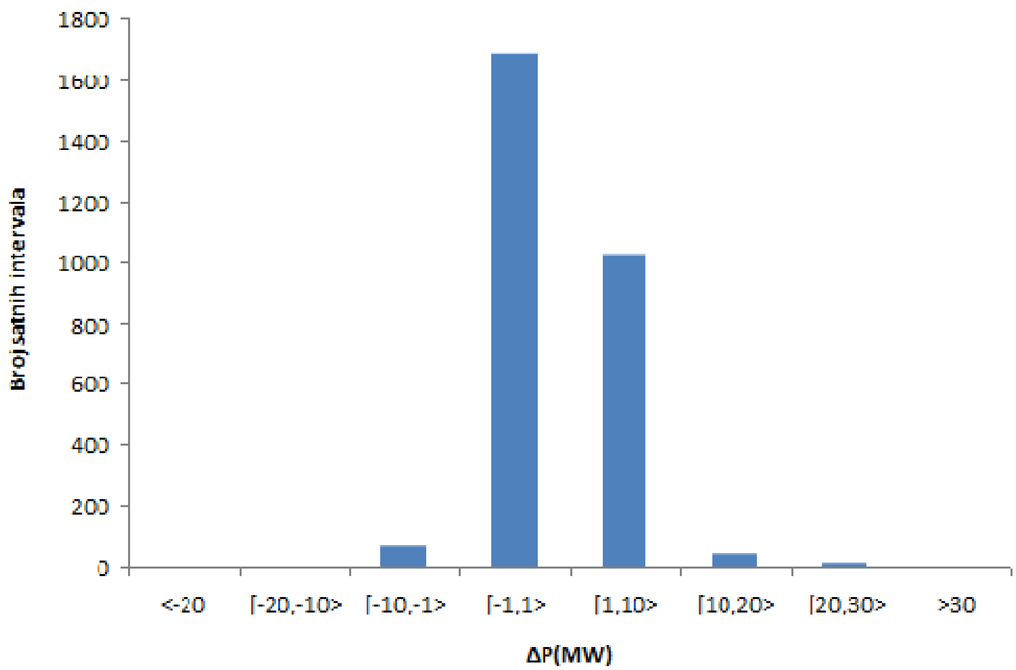


It is evident that the greatest hourly variations occur rarely. Therefore, in our analyses, we focus on how often particular ranges of hourly variation in wind power occur. We had analysed the first four months on 2011, that is, total of some 118 days or 2,831 hour. In that period, the greatest number of hourly intervals (1,681 hours or 59% of time) variation in wind power generation was in the range from -1 MW to 1 MW. Number of hourly intervals with the positive variation in generation from 1 – 10 MW was 1,023 (36% of time). Positive hourly variations in generation within range 10-20 MW had occurred in 43 hourly intervals (equivalent to almost two days), and a number of intervals with an hourly variation in wind power generation in the range 20 – 30 MW was 15. Only once in the observed period occurred hourly variations in wind power generation greater than 30 MW (maximum 34 MW). Stated values were recorded in the first four months in 2011. If we are to project the stated experiences to the entire year, then an hourly variation in generation in the range from 20 to 30 MW would be occurring in 3x15 = 45 hours or in almost two days in continuity.

Negative variations in wind power generation in the range from -1 MW to -10 MW were occurring in 65 hourly intervals. Hourly variations in wind power generation in the range from -10 MW to -20 MW occurred on 3 occasions, while the negative hourly variations in wind power generation greater than -20 MW did not occur.

Stated values are presented in Figure 47.

Figure 47 Histogram of hourly variations in wind power generation in Croatia



The locations of remaining wind power plants which are to be built are relatively close to the existing ones, therefore it is not likely that the mutual balancing of WPPs generation would increase. In other words, with the construction of new wind power plants we can expect the same or even greater level of variations in total wind power generation.

Conclusions on BiH

Having in mind the stated experiences from other countries, with incomparably favourable circumstances in the sense of distribution and forecasting of wind power generation (Germany and Spain), and a neighbouring country with similar wind and climate and electric power conditions (Croatia), we can conclude that for wind power generation in BiH the key specific features are reflected in:

- Small surface, that is, the low distribution of generation of future WPPs,
- Lack of experiences in forecasting of wind power generation,
- Lack of available data on wind metering at the concrete locations of WPPs,
- Lack of realistic, market mechanisms for provision of ancillary services (secondary and tertiary regulation),

- ❑ Lack of an organised regional market of electric power.
- ❑ Limited available power reserve in the system,

So we suggest that in the beginning the integration of WPP in electric power system of BiH, the conservative approach is to be used, as explained in the previous sections.

In fact, the calculation of some arbitrarily set expected error in forecast of wind power generation in BiH would imply the risk that, due to local specifics in planned period, one does not achieve targeted accuracy in forecasting and thus endanger the system operations; that is, limit the wind power generation.

The same type of data was used and was accepted in studies of wind power plants integration in electric power systems in neighbouring counties (Croatia, Montenegro, Serbia).

Based on the acquired experiences in variations in wind power generation, functioning of instruments for wind power generation forecasting, and experiences related to provision and payment of ancillary services, it will be possible to revaluate the concept of system reserves and accompanying costs.

10 Summary, conclusions, and key recommendations

This report is part of three reports with about 350 pages within this subassignment. This is the first time that wind energy potential integration in BiH is analyzed on the system level, including wind energy potential analysis, technical, legislative and economical aspects, respecting international experience and BiH specifics.

WPP projects in BiH

In BiH currently there is a gap in between WPP potential and investors' interest from one side and level of power system preparation for WPP integration from the other side. At the moment, there are many WPP projects under development, with no WPPs in operation. Within this Task we analyzed 7 WPP integration scenarios, as agreed with ISO, starting with 150 MW, ending up to 1300 MW (equivalent to 20% of total generation in 2020). These scenarios are "filled" with wind farm locations selected from a list from IPP of around 50 wind farm locations and sizes provided by the ISO. In selection of the projects 10 criteria are used. It is important to point out that for this kind of analysis it is not crucial to evaluate given WPP project itself, but overall mutual impact on system operation, no matter of specific WPP project or investor. In that sense neither the authors nor the ISO are making any arbitrary distinctions between specific WPP projects.

It is important to point out that for this kind of analysis it is not of crucial importance to evaluate specific WPP projects, but to evaluate its total impact on the system, no matter of specific project, location or investor. Distribution of specific projects in given scenarios does not have a significant impact on the results. Accordingly, ISO and consultants were not evaluating any specific WPP project.

The key questions for this kind of analyses are input data availability and quality. We believe that input data set used in the study is very relevant for the purpose of this kind of planning study. Atlas wind speed data are primarily intended to give general picture of the wind energy potential, to compare different areas, assess the variability and perform other analysis that compare different areas or assess global potential. But, when analysing specific wind farms, on-site wind speed measurement is practically mandatory. This study is focused on wider area and system impact and not on the specific sites.

In terms of WPP operation, ISO BiH has no experience in power system operation with WPPs share. Forecasting and balancing mechanism is not defined, meaning no specific obligations for WPPs in that sense. At the same time even though SCADA system and existing generation units are having good potential for WPP integration, the ancillary service mechanism (including payment arrangements) is defined but not fully implemented. Accordingly, ISO is facing very challenging conditions for WPP integration with many issues that need to be resolved in very near future.

This task gave an overview and assessment of existing system in BiH with references to international experience. In that sense, besides above mentioned Electricity Laws there is a large set of other relevant secondary acts, which makes BiH one of the most complex power sectors in Europe from a governance perspective. Even though this fact is not attractive to the WPP investors, due to promising wind potential it is expected to have several WPPs in operation very soon.

Frequency regulation and active power control techniques

Even though BiH has large HPP capacity and significant regulation abilities, in 2010 632 hours (or 7,2% of the year) BiH system had unscheduled deviations towards neighbouring system larger than 100 MWh/h.

WPPs will increase this problem, especially before adequate wind forecasting system is applied and calibrated to local specifics. Moreover, neighbouring systems are also facing the problem of unscheduled deviations. Unless there is significant improvement in operational practices, larger system operation problems could be expected. Accordingly, it is crucial to make ancillary service mechanism in BiH working properly and fully, with all responsible parties having their respective roles clearly defined, with all their responsibilities, obligations and rights. Also, the ancillary service mechanism has to be fully enforced in all neighbouring countries before all of them integrate large share of WPPs as planned.

To minimize adequate reserve capacity it is necessary to introduce an accurate wind forecasting system in BiH. If WPP generation forecast is having the same error as WPP generation deviation from previous 2-h average generation, then for integration of 150 MW of WPPs BiH system would need 68 MW of additional reserve capacity just for WPPs. If forecast error is equal to 4-h average, then required reserve capacity for the same scenario would be 104 MW. Both numbers are obtained under assumption that 100% of the time BiH system will keep maximum reserve capacity, or in other words, never in ten years BiH system would be out of reserve capacity to cover WPP deviations. Clearly, if forecast error is equal to deviation from previous 1-h average, required reserve capacity would be even lower.

Additional reduction of regulation capacity is obtained if we observe number of hours per year during which regulation will be sufficient to cover wind production variations. For example, if for ISO it is acceptable to have adequate reserve for 99 % of time (insufficient for 88 hours per year), the required reserve capacity would be reduced. In the 150 MW scenario with forecast error equal to deviation from 2-h average required reserve capacity would be ±19 MW only, while in the same scenario with forecast error equal to deviation from 4-h average required reserve capacity would be ±32 MW. Moreover, if for ISO it is acceptable to have adequate reserve for 98 % of time (insufficient for 175 hours per year), required reserve capacity would be additionally reduced. In the same 150 MW scenario with forecast error equal to deviation from 2-h average required reserve capacity would be ±15 MW only, while in the same scenario with forecast error equal to deviation from 4-h average required reserve capacity would be ±26 MW.

This is mathematical background and calculation of reserves that could be obtained from input that is available at the moment. Along with BiH practical experience with WPPs in operation and introduction and calibration of forecast system, ISO BiH will have much more inputs to decide which level of security and probability is acceptable for their system needs.

Voltage regulation and reactive power management

Grid Code provisions specify that reactive power management and voltage control are to be realized through provision of ancillary services while realization is done upon ISO request with the minimum active power loss principle. Every power plant is also obliged to deliver actual generators' operating curve and excitation limiter settings, as well as other excitation characteristics. Consequently, it is suggested to specify more detailed requirements in the Grid Code in WPP voltage support to the grid by generating reactive power during a network fault, to support and faster restoration of the grid voltage. In other words:

- ISO should ensure voltage quality to all network users, including WPPs, while WPPs should maintain given voltage ranges. Currently, it is unclearly defined that WPP has to be able to regulate connection node voltage and to achieve specified voltage value set by the ISO.
- Any potential problems with voltage instability should be resolved by the ISO and adequately treated in the WPP Requirements.
- It should be clarified what are the requirements for the excitation characteristics of any new power plant (and in particular wind generators). This is key to the ongoing ability of the ISO to manage the voltage profiles as the power system evolves.

WPP data requirements and ISO needs

ISO needs large amount of WPP data in the network connecting procedure. Current practice does not required it formally within existing legislative framework, but through individual connection applications and testing. Accordingly, the authors suggest to include large WPP data set requirements, as given in section 6.4.3.

Also, it is recommended in the future versions of Grid Code to include that a responsible WPP operator will be contactable by the ISO at all times to discuss operational matters without undue delay and in any event within 15 minutes. Following a request from the ISO, the responsible operator shall be present at the WPP's connection point without undue delay and in any the event within one hour and shall be capable of taking any required appropriate actions. The responsible operator shall be contactable 24 hours a day, 365 days a year.

Besides that, within this report 29 recommendations for WPP connection and operation improvement in BiH are provided. Finally, it is recommended to repeat this kind of technical analysis periodically for each WPP realized integration level.

Grid code mandatory requirements

The BiH ISO produced an update of the Grid Code in December 2010 (adopted by DERK in May 2011) which we have reviewed. The two key areas of (a) frequency regulation and (b) voltage regulation in respect of wind turbines on the network have both been addressed in this revised Code but in somewhat less detail than we would recommend. Specifically, it is suggested that it would be appropriate to provide some additional detail in the Grid Code particularly associated with the following items:

- The fault ride through requirements of a wind farm; and
- The operational responsibilities of the wind farm operator.

In addition to the above two points, the draft Grid Code does not specify what data must be supplied by the WPP in order that the ISO can be operated the network securely. We recommend that these data requirements are included in a future draft of the Grid Code. We have made a number of detailed suggestions regarding various additional provisions that could usefully be included in the BiH Grid Code.

Requirements for cost sharing of grid reinforcement

There is currently much uncertainty in BiH regarding how much of the cost associated with grid reinforcements that will be required by wind farms will be paid by the developers. There have been ongoing difficulties associated with the development of the TRANSCO investment plan which is resulting in uncertainty regarding the future development of the transmission system. There is an increasingly urgent need for investment in the transmission network to proceed in order to maintain an efficient power sector, particularly associated with the connection of new power plants.

In the current circumstances, it is not possible for an investor in a wind farm to assess the connection cost at the transmission level. A greater degree of certainty as to general cost level should be possible following offers provided by TRANSCO. However, at present, we cannot be sure that TRANSCO is in a position to provide a definitive offer price to a prospective wind farm investor and this is obviously of concern. We have made a number of detailed recommendations that would help in resolving this issue.

WPP inclusion in market procedures

The terms and conditions for WPPs are to be included by the ISO into the hourly production plans. WPPs are currently not obliged to participate in scheduling or in system balancing in any sense. There are three issues of utmost importance for the BiH power system in near future:

- To keep power system balance with additional share of WPPs (or in other words to define the market mechanisms to deal with extra wind conditions),
- To upgrade ancillary service mechanism (including adequate payment arrangements),
- To improve electricity balancing methodology and pricing system.

One of the topics that need to be analyzed in the future (as it was not part of this study) is generation commitment with large share of WPP. In other words, WPP dispatching in light load regimes during extreme hydrological and wind conditions is the next important topic.

Forecasting techniques

ISO has no established wind forecasting system. WPPs that are currently under development have no legal obligation to deliver wind measurement or binding wind forecasting data to the ISO. Accordingly, the required input data are missing.

The ISO clearly needs to have its own forecasting system up and running successfully with sufficient accuracy. It will be needed as soon as the first major wind farm comes on line.

Consequently, so far existing wind forecasting mechanism in BiH is not applicable, meaning that it is not useful to the ISO because of accuracy and speed/timing/data issues. It is expected to be applicable soon. However, it is suggested to introduce and implement binding WPP forecasting system. As stated before, the provisions of wind data and WPP output are foreseen in very detailed manner (in testing, commissioning and regular operation mode). The data on the WPP submitted to the ISO shall, among other things, include the forecast of the WPP production in the required short-term period of 1 – 48 hours. The time period and the frequency of forecasting should be specified subsequently. This would significantly help in reducing necessary reserve capacity, meaning reducing overall WPP integration costs.

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