Bosnia and Herzegovina Power System: From the First Luminaires to the Modern Power System. Part II: Trends and Challenges

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Abstract This two-part chapter presents historical overview of the development of Bosnia and Herzegovina's (B&H) power system with its trends and challenges in the future. B&H has a very wealthy and turbulent history of power system development which went through different development phases over time. It is possible to single out some very successful and progressive phases during more than 120 years. A very interesting period in this area is the period up to the First World War, when development of B&H power industry followed the development trends in Europe and USA. Also, the period after the Second World War presents a period of intensive construction of power plants, transmission and distributions grids, and an intense increase of power consumption. At the end of the twentieth century, the B&H power system experienced a significant destruction and power consumption in 2010 came again to the level of consumption from 1991. Today, B&H power system has been renewed and became a modern power system which is the part of the European power system. Also, in this paper we present some important dates and events related to the development of B&H power system, as well as trends and challenges in the sector of power distribution and power generation systems, with presentation of related specific technical indicators.

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1 Introduction

Development of power systems over time following different organizational forms of the entire power sector, different ownership structure and organization of large power companies. In the last two decades, significant impact on the power sectors had the restructuring, deregulation and opening of the electricity market. Developed countries have significant experience in this area, while in B&H, some of these processes are still ongoing. On the other hand, requirements for more intensive construction and the use of renewable energy are set and for B&H, so that today in B&H large number projects are in preparation (wind power plant, photovoltaic power plant, etc.). Also, an interesting scientific and technical analysis can be found in the areas of establishing a system for monitoring power quality, the integration of electric vehicles in power systems, and generally, applications of new technology in all segments of power distributions and generation systems.

This paper is the continuation of [1]. Trends and challenges in power distribution systems is discussed in Sect. 2, while Sect. 3 deals with trends and challenges in power generations. Section 4 is reserved for concluding remarks.

2 Trends and Challenges in Power Distribution Systems

Power distribution systems worldwide in recent years experienced significant changes. By integrating a large number of distributed generators, distribution networks becoming a (relatively) more complex distribution systems. Also, increasingly stringent requirements related to power quality require from the operators to change the current approach, significant investment in the power distribution system and the application of modern measurement and control devices. These changes are also apply to power distribution systems in B&H. However, achieving the desired level or the value of certain parameters is not possible overnight, so that many activities are long-term processes with significant investments.

The above-mentioned processes have led to major changes in the way the organization and functioning of the power distribution companies, as well as their relationship with the consumers. The quality of services that companies provide customers increasingly gaining in importance. With the introduction of regulations and standards governing the quality of services in distribution, as well as systems for measuring and monitoring the quality parameters, power distribution companies are encouraged to raise the power quality and services. On the other hand, distribution system operators pay special attention to the losses of electricity, which is an important technical and economic indicator.

2.1 Losses in Power Distribution Systems [2]

The power losses in distribution system have a significant influence on the efficiency of the whole electricity supply system. Based on [2], for some European country average losses in transmission networks are between 1 and 2.6 % and the losses in distribution networks are between 2.3 and 11.8 %. Today, the power losses in distribution system JP EPBIH is about 10 %, while the total power losses for B&H have a slightly higher percentage (taking into account the indicators of other two operators in B&H). Structure of power losses in distribution systems JP EPBIH is presented in Table 1. These indicators are the result of the measurement data, appropriate models of distribution network and load flow and losses calculations. As can be seen, the most significant losses in JP EPBIH were identified in the low voltage networks (about 61.68 %). This is an expected result given that the average length of the low voltage network is relatively large (about 3.2 km/transformer).

In the other words, JP EP BIH in 2011 was 7543 transformer substations 10(20)/0.4 kV and the total length of low voltage network about 24,190 km. Also, transformers represent significant sources of power losses (about 22.68 %), in particular transformer iron losses (16.20 %). This is a result of the installation of large number power transformers with higher values of rated powers. Finally, losses in power distribution systems, JP EP BiH in the period from 1996 with trends and projections to 2030 is presented on Fig. 1.

Table 1 Structure of losses in power distribution systems JP EPBIH

	MWh	%
Losses in distribution lines 35 kV	10,579.11	2.67
Losses in distribution lines 20 kV	1,888.53	0.48
Losses in distribution lines 10 kV	49,543.39	12.49
Lossse in transformers (iron losses)	64,262.93	16.20
Losses in transformers (copper losses)	25,704.88	6.48
Losses in low-voltage grid	244,622.45	61.68
Total	396,601.29	100

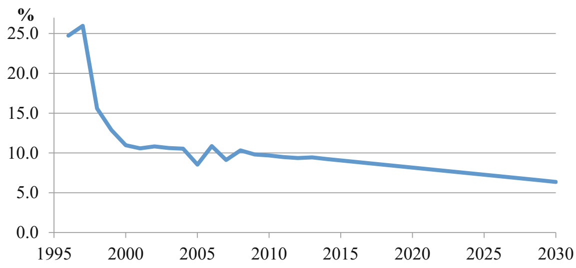

Fig. 1 Losses in power distribution systems, JP EP BiH trends and projections by 2030 [9]

Very high level of power losses in distribution networks in the period from 1996 to 2000 was the consequence of the war destruction. The planned implementation of systematic measures in the coming period would lead to the level of power losses about 6 %. System measures include the implementation of modern system of measurement (AMR), shortening the length of the low voltage network, reactive power compensation, etc.

2.2 Quality of Electric Power Supply—Reliability Indices [3]

A strong impetus for companies to achieve the required level of quality is the introduction of financial penalties that companies have to bear in cases when some specific indicators does not meet the quality standards. In JP EPBIH, since 2005 is established a system for monitoring quality of electric power supply—reliability indices (System Average Interruption Duration Index (SAIDI), System Average Interruption Frequency Index (SAIFI)). Reliable supply of electricity is one of the most important parameters of quality of electricity supply. According to most of the world statistics of operating events, 80–90 % of the interruption of power supply occurs in the distribution system. Therefore, the greatest responsibility for the reliability of power supply goes to the operators of the distribution systems.

Reliability indices SAIDI and SAIFI for JP EP BiH (trends and projections by 2030) are presented in Figs. 2 and 3. Compared to EU countries, reliability indices

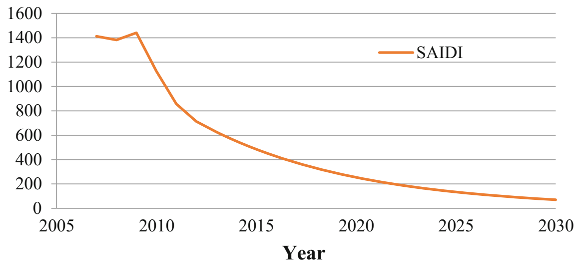

Fig. 2 SAIDI (minutes per end consumer), JP EP BiH trends and projections by 2030 [9]

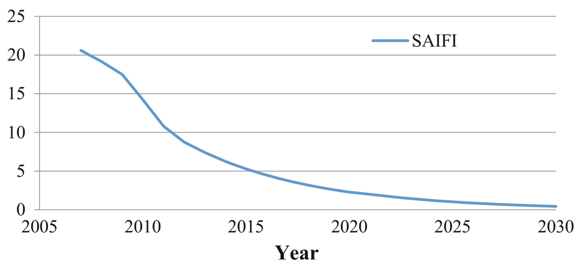

Fig. 3 SAIFI (number of interruptions per customer), JP EP BiH trends and projections by 2030 [9]

of the distribution network of EP BIH (SAIFI/SAIDI = 8.75/713, for 2011) are significantly higher of the reliability indices achieved in the European Union. For example, in Slovenia 2011: SAIFI/SAIDI = 2.79/203, in Austria 2010: SAIFI/SAIDI = 0.66/31.77. In order to raise the level of security to a higher level, it is requires significant investments in construction and modernization of distribution network.

3 Trends and Challenges in Power Generation

Power generation system, mainly based on coal, is not compatible with international climate targets [4]. Problems which power sector based on coal face today are conducted with high CO_2 emissions comparing to lower CO_2-intensive energy resources, particularly various renewable energy sources (RES). Furthermore, criteria of power generation cost efficiency give more and more an advantage to the RES options (wind, solar, hydro) compared both to coal-based power generation and combine cycle gas turbine (CCGT) power plants. Environmental sensitivity issue and consequent stronger requirements posed to fossil-fueled power plants in relation to reduction of SO_2, NO_x and dust emissions, according to industrial emissions directive (IED), along with CO_2 taxes, significantly contribute to the above mentioned negative trend of cost effectiveness of conventional fossil-fueled power plants.

In the other hand, safe, reliable and sustainable energy supply is becoming one of the greatest challenges for the World [5, 6]. Key decisions have to be taken to drastically reduce carbon dioxide (CO_2) emissions and fight climate change. In 2007, the European Council adopted energy and climate change objectives for 2020 [5], i.e. to reduce greenhouse gases (GHG) emissions by 20 %, rising to 30 % if the conditions are adequate, to increase the share of renewable energy to 20 %, and to make a 20 % improvement in energy efficiency, what is stated in the Directive 2009/28/EC. However, Europe's energy systems are adapting too slowly. The security of internal energy supply is undermined by delays in investments and technological progress. Currently, only 45 % of European electricity generation is based on low-carbon energy sources, mainly nuclear and hydropower. Parts of the European Union (EU) could lose more than a third of their generation capacity by 2020 because of the limited life time of these installations. This means replacing and expanding existing capacities, finding secure non-fossil fuel alternatives, adapting power systems to renewable energy sources (RES) and achieving a truly integrated internal energy market [5]. In addition, thermal energy storage technologies coupled with renewable energy are also actively utilized for CO_2 reduction for different kinds of applications, such as heating, ventilation, and air-conditioning areas, for example see [6]. The European Council has also given a long-term commitment to the decarbonisation path with a target for the EU and other industrialized countries of 80–95 % cuts in GHG emissions by 2050, as stated in Energy roadmap 2050 [7]. In 2011, the European Commission set out sectorial CO_2 reduction trajectories with a mid-term view on 2030 to steer the decarbonisation of the economy on a manageable and cost-effective course. For the power sector, a CO_2 reduction range of between 54 and 80 % was proposed by 2030 compared to 1990 levels. It was analyzed in details in Power Perspectives 2030 [8], to response what is required between today and 2030 to remain on a pathway to a decarbonized power sector by 2050. For power industry, efforts are needed to substantially increase the uptake of RES, high-efficiency cogeneration, district heating and cooling. Use of RES is one of the strategic objectives of the EU energy policy. Two important factors attached to their use are reduction of negative environmental impacts and decrease of dependence on fuel and electricity import [9, 10].

Although significant efforts have been undergone and are still ongoing to provide perspectives for clean coal based power generation (CCT—Clean Combustion Technologies) [11], power system of EU indisputably goes toward an energy transition (Ger: Energiewende), driven by the relevant EU legislation launched and forced by the need to reduce carbon emissions and to mitigate climate change. It is predicted that coal will lose its dominant role and keep only minor contribution in the future energy mix. In its Fifth Assessment Report, the Intergovernmental Panel on Climate Change (IPCC) also sees coal-based power generation as having no long-term prospects [12]. From the other side, the growing number and amount of renewables in the supply mix create transmission imbalances that need to be managed [13]. The gradual climb out of the global economic crisis means unnecessary investment in infrastructure must be avoided. Thus, in the future low-carbon power system, it is reasonable to place future efficient, environment friendly and flexible coal-based power plants serving as one of alternatives for the meeting the peak loads and secure reserve. Otherwise, despite of such a scenario for 2050 and beyond, the present trends all current estimations suggest that coal will keep its dominant role in the next 5–10 years. It is particularly expressed globally due to Chinese industrial expansion and progress of coal projects, although China has shown growing interest in market-based CO_2 pricing and is expected to establish a nationwide emission trading system by 2016 [11, 14]. Thus, coal will even reach its maximum use in the next few years. In the mid-term, focused on 2020 and 2030, problem of slow energy transition from high CO_2 coal-based power generation to low-carbon technologies, e.g. in Germany, may seriously treat the set decarbonisation goals, mainly due to high cost energy path, pointing the way to a more competitive energiewende, pivoting away from a focus solely on renewables development toward a more balanced approach. Furthermore, possible expansion of nuclear energy for base load is not so realistic option even in long-term due to highly expressed risk of nuclear power plants from security aspect.

Considering the issue with carbon intensive coal-based power generation to be enhanced in the next period, various ways of reducing coal-based power generation are currently under discussion. In Europe these include reforming the European Emissions Trading System the introduction of minimum efficiency levels or stricter flexibility requirements, national minimum prices for CO_2 emissions allowances, capacity mechanisms, a residual emissions cap for coal-fired power plants, CO_2 emissions performance standard, and network development planning that respects climate targets. These proposals apply to both new and existing coal-fired power plants. It should be kept in mind that these are just the operational and economic issues and measures. However, a holistic sustainable concept is required for future power system, as discussed in the next chapter.

3.1 Power Generation System of EPBiH—Current State

Power utility EPBiH is a typical power utility in South-East Europe. Annual electricity generation is near 8000 GWh and it comes from two coal-fired TPP, i.e. TPP Tuzla (1 × 100 MW + 2 × 200 MW + 1 × 225 MW) and TPP Kakanj (2 × 118 MW + 1 × 235 MW), three large hydro power plants (HPP), i.e. HPP Neretva (6 × 30 MW + 2 × 57 MW + 3 × 70 MW), with a minimal participation from small HPP (sHPP), approximately 1 %. Both TPP use domestic low-rank coal, and consume approximately 6,500,000 t per year. The current generation capacity structure of 70 %:30 % in favor of TPP provides some advantages like safe and reliable supply, but further penetration of RES into the generation portfolio is a commitment in order to contribute to the long-term sustainable development plans of the company and to comply with the European targets for reduction of GHG emissions as well as pollutant emissions. EPBiH supplies electricity to near 750,000 consumers in B&H, via its distribution network operated by the EPBiH´s distribution company, organized in five regional distributive parts. Furthermore, EPBiH exports about 20 % of electricity. Annual production of heat energy, generated in cogeneration power units of TPP Tuzla and TPP Kakanj, is approximately 400 GWh. The thermal energy for heating is supplied over long-distance district heating systems to the consumers in the city of Tuzla and city of Lukavac (from TPP Tuzla) and city of Kakanj (from TPP Kakanj). A part of the generated heat (steam) is supplied from TPP Tuzla to the process industry in Tuzla region [15]. Total annual emission of CO_2 in year 1991 was 9,500,000 t. Today the situation is more favorable, given that the six blocks with the lowest efficiency are decommissioned and all other existing coal-based power units have been reconstructed and modernized in the period between 2002 and 2012. Consequently, energy efficiency in TPP of EPBiH is increased for 30 % compared to the 1990 level; from 24 % up to the current 31 %. Projection of net efficiency of existing power units in Tuzla TPP and Kakanj TPP until their decommissioning as well as overall net efficiency of thermal power units of EPBiH is given in the Fig. 4.

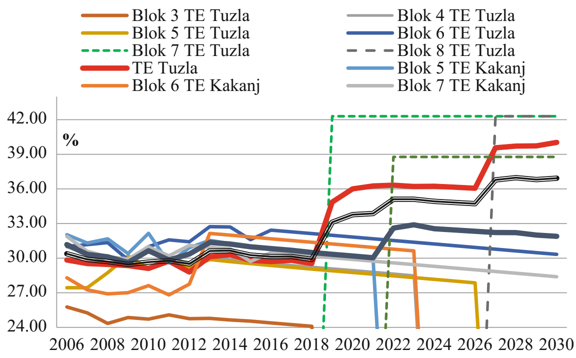

Fig. 4 Projection of overall net efficiency of thermal power plants of EPBiH by 2030

3.2 EPBiH Power Generation Development Targets with Long-Term Projections by 2030 and 2050

Despite these energy efficiency improvements achieved during the last fifteen years, EPBiH is facing new challenges; requirements for further energy efficiency improvements and CO_2 emissions reduction, mandatory for the company to keep and improve its position on the market and comply with the energy efficiency and environmental regulation, as well as low-carbon future. Considering the expected annual power demand until year 2030, as well as the planned generation portfolio development, a further step towards sustainability and generation portfolio optimization is projected, in order to reach specific energy and decarbonisation targets. The generation portfolio expansion is based on EPBiH plans for construction of new generation facilities in future, considering the necessity for replacement capacity to be constructed instead of existing TPP units planned to be decommissioned by 2030. In EPBiH's long term plans, the dynamics of decommissioning old TPP is already defined and stated in the company's strategic document Long-term strategic development of EPBiH. The choice of all other facilities commissioning dynamics is subject of analyses, regarding sustainability and decarbonisation criteria and is performed by experts from the company, see for example [15].

Additional aspects which have been considered are current investment plans for DeSOx and DeNOx facilities, in order to fulfill obligations according toLarge Combustion Plants Directive (LCPD) and Industrial Emission Directive (IED), Directive 2009/28/EC and Directive 2012/27/EU, and provide further operation of TPP units. The development plan results in new TPP projects, HPP projects, WPP projects, PVPP projects and biomass projects (BPP). Replacement of existing coal-based power units with new, more efficient and carbon capture and storage (CCS)-ready power units is essential in the development plan. At this moment, considering the planned consumption growth as well as exhausted life time and low efficiency of TPP units, a new generation facilities are planned to be built. Commissioning of replacement TPP unit in TPP Tuzla (TPPTU7—450 MW) is planned for 2021, and in TPP Kakanj (TPPKU8—300 MW) in 2023. Those units will be CCS ready, which will be taken into account, depending on scenario.

The development plan also includes cogeneration expansion for heating/cooling purposes, both in TPP Kakanj (new 170 MWh for long-distance district heating of Zenica city and new 300 MWh for long-distance district heating of Sarajevo city) and in TPP Tuzla (new 200 MWh for Tuzla and new 60 MWh for long-distance district heating of Zivinice city). For further reduction of CO_2 emissions, co-firing coal with biomass is planned at all EPBiH's TPP [15–17].

According to this biomass co-firing plans, co-firing coal with biomass is planned at all existing EPBiH's TPP; projected to use of 7 %w of biomass for average operation for 3000 h annually. Also, for new TPP units, higher amounts of biomass are planned to be co-fired, up to 25 % annually, depending on considered scenario. According to these plans, overall net efficiency of thermal power plants of EPBiH reaches 40 % in 2030, see Fig. 4, while overall CO_2 emissions from TPP falls down from the current 1140 kg/MWh to 950 kg/MWh in 2030, see Fig. 5.

Furthermore, EPBiH experts have made the plans and projections for power generation development by 2050 [18]. Three different scenarios have been analyzed, with different portfolio structures, in order to define measures to be taken to achieve defined CO_2 cuts:

(a) 55 % CO_2 cut compared to 1991 level—low CO_2 cut scenario (LOW CO_2 CUT)
(b) 65 % CO_2 cut compared to 1991 level—medium CO_2 cut scenario (MID CO_2 CUT)
(c) 80 % CO_2 cut compared to 1991 level—high CO_2 cut scenario (HIGH CO_2 CUT).

Table 2 shows installed capacities in EPBiH power system in 2050 for three considered scenarios. As can be seen, some thermal capacities planned in low CO_2 cut scenario would not be built in MID and HIGH scenarios while they would be replaced mostly by new HPP and wind parks.

Accordingly, power generation from fossils (coal), which in low scenarios accounts 8.7 TWh in 2050, would be drastically decreased for HIGH CO_2 cut scenario, falling down to 3.5 TWh. In the same time, electricity generation from hydro and wind will be increased significantly for HIGH CO_2 cut scenario, reaching 57 % share of hydro and 15 % share of wind in total electricity generation in 2050

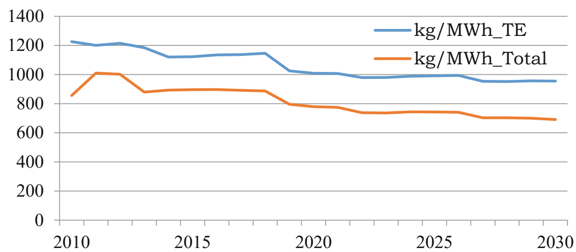

Fig. 5 Projection of reduction of CO_2 emissions from TPP of EPBiH by 2030 (kg CO_2/MWh)

Table 2 Comparison of installed capacity in MW in 2050 for all scenarios

	Low CO_2 cut	Mid CO_2 cut	High CO_2 cut
TPP	1500	1200	750
HPP	950	1200	1600
sHPP	150	190	250
WPP	550	800	950
Solar	100	150	300

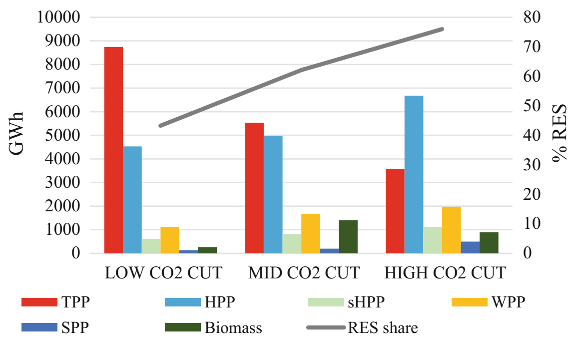

Fig. 6 Electricity generation by sources and RES share for considered scenarios

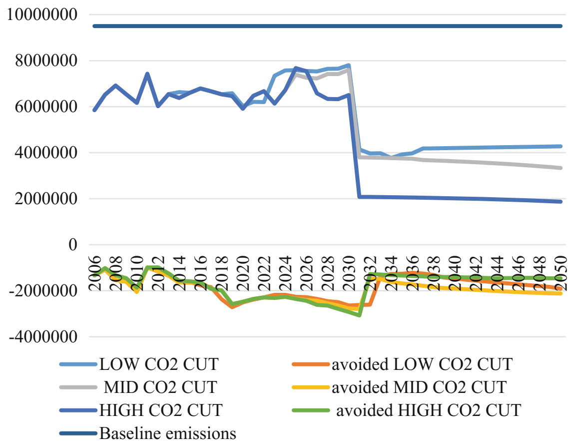

Fig. 7 Annual projections of CO_2 emissions and avoided CO_2 emissions for all scenarios (tones CO_2 per year)

for HIGH CO_2 cut scenario, see Fig. 6. Consequently, in HIGH CO_2 cut scenario, annual CO_2 emissions in 2050 falling down below 2,000,000 tones, which is more than double lower emissions compared to LOW CO_2 cut scenario, see Fig. 7.

In relation to emissions in 1990, 80 % of CO_2 reduction is achieved in HIGH CO_2 cut scenario compared to 55 % cut in LOW CO_2 cut scenario. According to the Multicriteria Assessment Analysis (MSA) performed [18], no matter what relation between weighting factors is considered, HIGH CO_2 cut scenario is preferable both from the environmental and economical aspect, since economic indicator is sum of CAPEX, OPEX and CO_2 fees indicators.

4 Conclusion

In this paper we present the trends and challenges of some parameters relating to power distribution and power generations systems of JPEPBIH. It is clearly that the indicators today are not the best and that the upcoming period requires significant investment and the application of new technologies. The fact is that Bosnia and Herzegovina has a great potential of RES, and that it is possible to sustainably exploit the available capacity for the drastically reduced the environmental impact of the power sector. Also, for new TPP units which will be commissioned, which are necessary for consumption coverage when generation from RES is low, the environmental aspect is included. For that purpose, in order to have sustainable future power generation system in 2050, those units are planned to cogenerate heat and electricity which would additionally contribute to decrease overall emissions on district heating coverage area. Also, the cost-efficient use of fuel will be the maximum in accordance with the best available techniques, and biomass co-firing should contribute to the ultimate goal.

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