Problems of the Contemporary Electric Power System of Kosovo

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***Abstract* – The problems and challenges which Kosovo electrical power system (EPS) must deal with are discussed in this paper. The generation, transmission, and distribution in the current situation of the EPS of Kosovo are described. Numerous domestic and international research was examined, and the findings of those studies are reviewed.**

Focus has been placed on issues with Kosovo electric power system balancing, voltage stability, short circuits, carrying capacity of the transmission and distribution network, as well as the load and consumption forecasts over the next ten years. Consideration of actions or procedures that could be performed to improve the existing situation is also included. The analysis and recommendations are mostly related to studies like the Kosovo Energy Strategy and the development plan for the transmission and distribution networks of the country. The benefits of integrating renewable energy sources are introduced as means for improving the system stability and security of electricity supply. The transmission and distribution system's technical and commercial losses, as well as the steps that must be followed to reduce them, are reviewed and analyzed.

***Index Terms* – Generation, Load forecast, Power system stability, Challenges, Losses.**

I. INTRODUCTION

The origin of the problem of reliable electricity supply in Kosovo began with the deliberate destruction of the electricity system in all its elements by the former state regime, particularly in the 1990s. Since 1984, there has been no construction of new electricity generation units apart from some small hydro capacities that were insufficient to resolve the problem of security of the electricity supply for the growing demand [1], [2].

A large percentage of power plant units are currently close to the end of their lifetime. Almost all TPP Kosovo A's capacity would have been shut down or repaired by this time if a normal EPS development with reliable power supply requirements was in place [2].

The safety of the energy supply is one of the key elements for the nation's economic growth and improvement of social welfare. The best choices for the future of the energy industry should be established as soon as feasible since it will take time to construct a sustainable energy system [2]. The basic challenges facing the energy sector in Kosovo include [1], [2]:

- delays in the construction of new coal-based electricity generation capacities and rehabilitation of existing plants,
- insufficient generation capacities to cover the peak demand in the winter season,
- lack of secondary and tertiary power reserves in the system due to lack of flexible generators,
- large part of domestic generation is based on lignite,
- limited capacities of thermal energy power systems.
- lack of natural gas infrastructure,
- significant technical and commercial losses in the electricity distribution network,
- inability to correctly manage cross-border flows by the transmission system operator (TSO) because of obstruction by the Serbian TSO,
- underuse of energy saving potentials,
- underuse of potential renewable energy resources,
- lack of an effective competitive market in the electricity sector.

An important set of requirements that Kosovo must soon meet in the energy sector is the implementation of the energy protocol related to energy market competition, environmental protection, energy efficiency (EE), and renewable energy sources [3], [4]. According to energy strategies research the following fundamental challenges and difficulties must be considered:

- Adequacy in generation. Security of a sustainable, high-quality, safe, and reliable electricity supply,
- Power capacities necessary for maintaining voltage and dynamic power system stability,
- Integration in the Regional Energy Market,
- Construction of new thermal system capacities,
- Absence of natural gas supply,
- Fulfillment of targets and obligations in energy efficiency, renewable energy sources, and
- Environmental protection.

II. CHALLENGES FOR THE KOSOVO ELECTRICAL POWER SYSTEM

The "Long-Term Energy Balance 2019–2028," which is in accordance with the stipulations made in the Energy Strategy 2017–2026, adds the year 2029 and updates the peak value for the previous year 2018 based on measurements [3].

Table 1 and Fig. 1 estimate the trajectory of power consumption for the years 2020–2029 under three main growth

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scenarios [2], [4]. The annual average rise is around 1.38% and characterizes the base scenario of load increase.

TABLE 1
DEVELOPMENT OF ELECTRICITY DEMAND FOR THE PERIOD 2020-2029 UNDER THREE MAIN GROWTH SCENARIOS

Scenario	Real Peak demand 2014 [MW]	Result 2015 [MW]	Result 2020 [MW]	Result 2025 [MW]	Result 2029 [MW]
Low	1154	1129	1145	1161	1174
Base	1154	1129	1210	1251	1284
High	1154	1129	1276	1351	1410

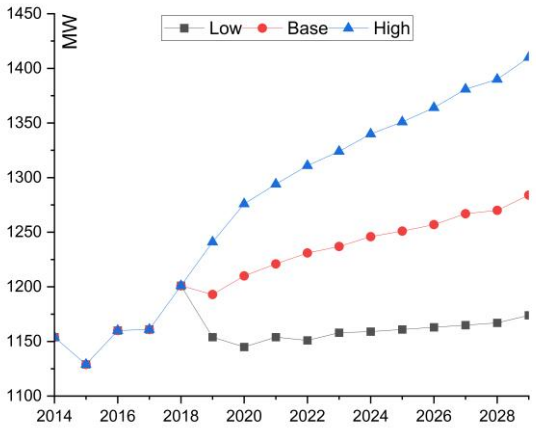

Fig. 1. Low, base, and high growth scenarios for the peak load

This load dynamic will be a major factor in determining how effectively the transmission network is operated [5].

The Carbon Border Adjustment Mechanism (CBAM), which the EU intends to implement, would impose an import tax on power exported to Union territory. This mechanism will apply to Energy Community countries, although implementing a carbon pricing scheme with prices approaching the level of EU emission allowance prices by 2030 can assure exemption from the CBAM payments.

The primary goals for achieving reliability and system stability in the Kosovo energy sector by following to the CBAM mechanism are [2], [4]:

a) Improve quality of supply indicators: System Average Interruption Duration Index (SAIDI) by 35% and System Average Interruption Frequency Index (SAIFI) by 30% by 2031,
b) Launch market-based reserve services and reach at least 170 MW of flexible regulation capacity by 2031,
c) Decrease the transmission and distribution losses to the current EU technical loss ratios by 2031 (9%),
d) Refurbish two Kosovo B power plant units and at least one Kosovo A power plant unit by 2024.

The electrical energy production by power plants in February 2022 was 548.04 GWh. The hydropower plant gross electrical energy generation, as shown in Table 2, was 4.17 GWh. Additionally, 38.37 GWh of electrical energy were generated in total using solar and wind energy. The gross amount of energy available in February 2022 was 680.7 GWh, but the amount of electrical energy consumed, as shown in Table 3 and on Fig. 2, was 469.92 GWh, or 7.39% more than it had been in the same month the year before. 8.43% of the overall use of power came from alternative sources [5].

TABLE 2
GROSS ELECTRICAL ENERGY GENERATION

Generation	2/2021 [GWh]	2/2022 [GWh]	Rate [%]
TPP - Gross Production	540.951	548.037	+1.31
HPP- Gross Production	21.286	4.188	-80.42
Wind and Solar - Gross Production	9.473	38.372	+305.05
Import	296.269	272.967	-7.87
Export	187.787	182.846	-2.63
Gross Electrical Energy available	680.191	680.698	+0.07

The energy export was 182.85 GWh, while the import in February 2022 was 272.97 GWh.

TABLE 3
TOTAL ELECTRICAL ENERGY CONSUMPTION

Consumption	2/2021 [GWh]	2/2022 [GWh]	Rate [%]
Household	299.626	345.895	+15.44
Commercial	90.554	103.558	+14.36
Industry	32.907	36.724	+11.60
Public Lighting and others	2.812	3.441	+22.38
220kV and 110kV Consumers	35.088	2.476	-92.92
Mining	8.936	12.560	40.55
Total Electrical Energy Consumption	469.923	504.655	+7.39

According to the draft of Kosovo's new energy strategy (2022–2031), the weakness of EPS of Kosovo is heavy reliance on imports during the summer season, especially since the post–pandemic energy crisis in 2021. Major impact has the war in Ukraine started in 2022.

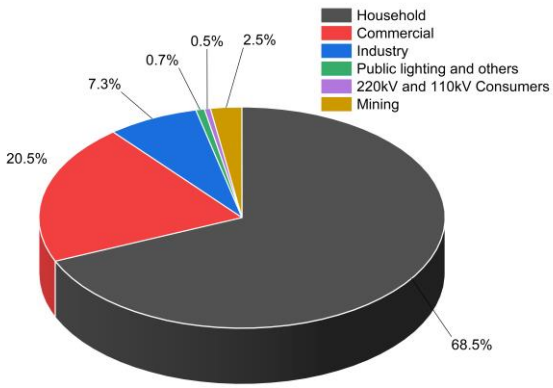

Fig. 2. Structure of electricity consumed by sectors in Kosovo (02/2022)

These factors have led to extremely high prices of gas and energy markets, and Kosovo consumers has been forced to pay very high prices for electricity imports. This energy crisis has demonstrated Kosovo's need for a significant reform in Electric Power System (EPS) to make it more stable, independent, and dynamic [3].

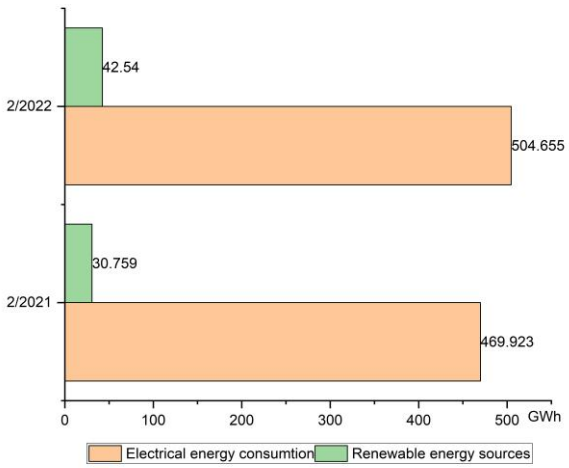

Fig. 3. Electrical energy consumption and RES contribution

The energy industry in Kosovo has had several difficulties because of poor planning and insufficient investment over the last decades [1], [4], including:

a) Dependence on old lignite-based electricity generation capacities, which provide inadequate reliability and flexibility, and are a major source of greenhouse gas (GHG) emissions and local pollution. Currently, the share of renewable energy sources (RES) in the electricity sector is only 20%, with RES in the energy sector dominated by biomass-based sources used for heating.
b) High energy consumption (and therefore, energy-related expenditure) relative to both the GDP and the population, due to a range of factors, including high voltage network losses and use of inefficient buildings and outdated technologies in both residential and commercial sectors (including the space and water heating).
c) High reliance on individual household heating systems based on electricity or on inefficient coal, or wood-burning equipment gives rise to both significant increases in the need for electricity imports and high GHG emissions and air pollution during the cold months.
d) High market concentration at both the wholesale and retail levels.

Energy Strategy predicts a dramatic rise in renewable energy sources, focusing primarily on wind and solar systems. In Kosovo B power plant is needed to implement environmental controls. One or two Kosovo A units will be shut down.

Because of this vision, five strategic objectives (major policy orientations) are established. Each of them has four key targets that must be achieved (see Fig. 4). Specific objectives that offer guidelines for specific tasks are further segmented into these strategic objectives. The Energy Strategy establishes short-term (2024) and long-term (2031) goals in accordance with the Administrative Instruction. Additionally, it is necessary to analyze and reform the legislative and regulatory framework to increase prospects for the growth of the private sector, particularly for Energy Service Companies (ESCO) markets [3].

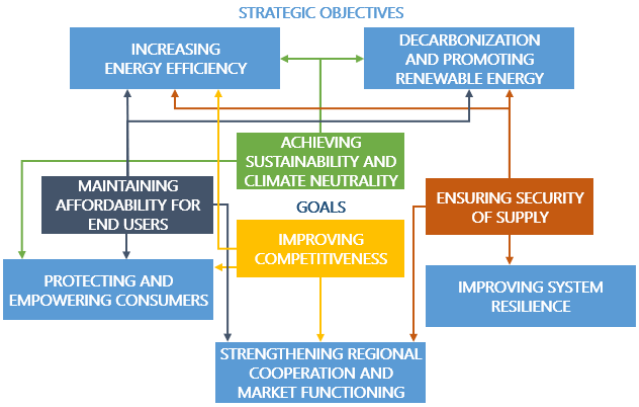

Fig. 4. Main goals of the Kosovo Energy Strategy (2022 – 2031)

III. Problems and Targets of Kosovo Electrical Power System

The thermal power plants Kosovo A and Kosovo B greatly dominate Kosovo's electricity generation. The combined installed nominal capacity of these two power stations is 1,513MW. The operating capacity of the units is substantially less than nominal values because of lifespan and maintenance circumstances. The lifetime of the Kosovo A units, which are from 35 to 50 years old, has already been reached. Over 90% of Kosovo's electrical energy production is from thermal power plants, which is a significant portion of the nation's overall production [1], [2].

Kosovo's transmission network was developed over the last 60 years in several stages of construction, expansion, reinforcement, and consolidation. Kosovo's transmission network consists of 1410.5 km of overhead lines and 37 substations, including 400kV, 220kV and 110kV voltage levels [4].

The horizontal transmission network has 16 transformers with 3750MVA total capacity (400/220kV, 400/110kV and 220/110kV) and installed transformer capacity of the vertical transmission network consists of 65 power transformers with 2320 MVA total capacity [4].

KOSTT used data recently given in the Long-Term Energy Balance 2019–2028 associated with the Energy strategy 2017–2026 for electrical energy generation forecast. Three scenarios are developed to forecast electrical energy production from internal sources. The following objectives are being used as the base scenario [4]:

a) Construction of Thermal Power Plant "Kosova e Re" with a capacity of 450 MW until 2023.
b) Closure of TPP Kosovo A.
c) Building a flexible HPP (accumulative or reversible) with a capacity of ≥ 200 MW by 2023.
d) Full revitalization of TPP Kosovo B in two years 2023 and 2024.
e) RES: 150 MW from wind, 205 MW small HPP, 30 MW solar and 14 MW from biomass.

It is important to analyze power system stability. In the past, KOSTT often limited the installed power plant capacity due to generator failures or short circuit near the generator occurring too close after a fault event.

Power system stability analyses in general and throughout the grid connection processes are urgently required because of the successful completion of numerous internal and external grid projects [15].

The publications referred to as [6] and [7] examine the power system stability and short circuit analysis of the electric power generator in TPP and wind distributed generators in Kitka wind park in Kosovo.

The development of a balancing group management system with appropriate contracts and accountable partners between the TSO and market players may be a solution for KOSTT to guarantee power system stability.

Differences between demand and supply can be measured for each balance group. There, it is possible to fulfill an objective relating to the topic of cost flow from system control to the TSO. The fault statistics for the 400/220 kV transmission system are developed in an outstanding direction, demonstrating Kosovo's progress toward meeting the requirements of western European nations. Several projects have already been implemented or are planned at the 110kV voltage level to [4]:

- Decrease of fault events
- Improve voltage quality
- Increase power supply reliability
- Reduce grid losses.

The 400-kV-interconnection lines to Serbia, North Macedonia and Montenegro guarantee a proper interconnection of Kosovo with the ENTSO-E-system. For this general statement it needs to be assumed, that the entire 400-kV system of the region comprising Serbia, Bulgaria, Greece, and Montenegro is operated following the (n-1)-criteria (Table 4) [4]. Each of these transmission lines has 1316 MVA thermal transmission capacity, which means that even when the (n-1)-criteria is considered, it may theoretically compensate for an outage of the Kosovo A and Kosovo B power plants. General descriptions and impedance determination of 400kV transmission overhead lines are analyzed in a paper referred to as [8].

TABLE 4
THE 400-KV-INTERCONNECTION LINES TO NEIGHBORING COUNTRIES

Transmission interconnection to:	Voltage level [V]	Net Transfer Capacity [MW]	Natural Power [MW]	Thermal Stability Limit [MVA]
Albania	400	500	500	1317
Albania	220	100	120	300
North Macedonia	400	500	500	1317
Montenegro	400	500	500	1317
Serbia	400	500	500	1317
Serbia	220	100	120	300
SUM		1950	2240	5868

In some areas, during the winter peak conditions, the 110-kV network does not meet the n-1 criteria. Voltages could be below $0.9*U_N$ in some places due to heavy loads and significantly longer lengths at 110 kV level, which cannot be adjusted by 110 kV power transformers' voltage control. This results in poor voltage quality for the consumers due to heavy loads at medium and low voltage levels [4].

Most medium and low voltage networks are outdated and not designed to carry load flows during the winter peak. These are frequently the main reasons for high grid losses and poor voltage quality for customers. Voltage stability issue in medium voltage (local area) in Kosovo is analyzed in a paper referred to as [9]. In the long term, the implementation of a well-regulated energy market across South-East Europe is recommended. For the option to control energy costs to the relevant market participants, the development of well-balanced individual national power systems appears to be necessary [10].

The recent changes imposed to the European energy market have resulted in whole new market balancing systems. Impact of Balancing mechanisms of Kosovo Energy market are analyzed in the paper referred to as [11]. Transmission losses in EPS of Kosovo are 1.18% and it is considered tolerable level according to the Energy Regulatory Office, but distribution losses, which reached 18.48% in 2021, are a major problem (Table 5). Technical losses account for around half of them, while commercial losses (electricity that has not been paid for) account for the other half. Roughly half of the commercial losses occur in Kosovo's northern regions. To reduce losses and to eliminate voltage stability issue on distribution power system of Kosovo, all 35kV/10kV substations must be replaced with 110/10(20) kV and 35kV lines must be replaced with 110kV lines [4], [13].

In general, 35kV level is not needed in distribution system. Also, Distribution company of Kosovo is working and replacing 10kV level with 20 kV level to decrease the normal load currents and losses. Soon, KOSOVO Distribution system will have 20kV voltage level instead of 10kV and 110/20 kV substations instead of 110/10kV.

Having a sufficient transmission and distribution infrastructure, integrating renewable energy is compulsory. System flexibility will increase with network modernization and as a result technical grid losses will also be reduced [12], [13]. Additionally, network investments provide prosumers with better integration options.

TABLE 5
DISTRIBUTION LOSSES (2021) AND TARGETS

Specific Objective	Baseline	Target for 2024	Target for 2031
Distribution losses	Total:18.48%,	14.5%	9%
Capability of RES capacity	147 MW	500MW	2000MW

Reducing the final energy consumption to a level of 1877 ktoe in 2031 is the overall goal for energy efficiency. Savings of 15.7% compared to the baseline energy consumption projection used in the EU research or savings of 22.2% compared to the 2007 PRIMES modeling assumptions (2226 ktoe), which are utilized as a baseline projection in the EnC study, are required to reach this target amount [3].

The average energy efficiency improvements made in the EU28 from 2005 to 2017 (referred to as the "EU28 Benchmark" in the EU research) are the basis for this goal. With a maximum average annual rise in final energy consumption of 1.9% during the following ten years, the target is reachable [14], [16].

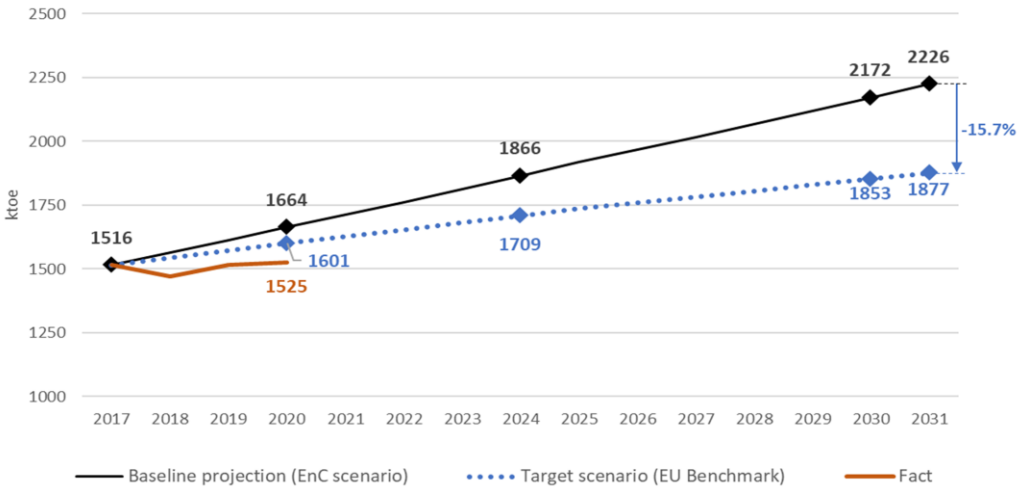

Fig. 5. Final energy consumption pathways and target for 2031

Fig. 5 shows the baseline and target consumption patterns as well as the actual consumption until 2020. Additionally, the figure shows that the real trend of the total energy consumption is lower than both paths. As a result, fulfilling the target will take a lot of work because it is mostly affected by direct consequences (like the COVID-19 pandemic) [3].

IV. Conclusion

The study's findings and analysis indicate that many Kosovo power plant units are reaching the end of their functional lifetime. Voltage stability and power system stability need improvement in distribution system by replacing 35kV lines and substations with 110kV ones and switching from 10kV to 20kV voltage in overall distribution system. Power losses in the distribution system are not at an acceptable level. The implementation of a well-regulated electricity market across South-East Europe is objectively necessary.

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