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ENERGY EFFICIENCY IN HPP ON THE RIVER NERETVA

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Abstract: For generating electricity in hydropower plant is necessary to ensure power supply to all equipment that is the continues part of production process. This type of energy represents the power plant's self-consumption in the primary process. The total self-consumption of hydropower plants is directly related to its type, size and location, and whether the hydropower plant is part of a cascade series or not. One of the long-term goals of JP EP BiH is to ensure high productivity and reduce the costs of production facilities, i.e. self-consumption. In 2020, JP EP BiH introduced an Energy Efficiency Policy, which committed to introducing high energy efficiency processes and the most modern technologies proven in practice, while intensifying the transition to more renewable energy technologies in generating mix, as well as increasing energy efficiency and energy savings in all existing activities and processes. As there is no single definition of energy efficiency, in generale it implies a reduction in energy consumption by influencing on the process, work methods and production techniques, in order to use less energy for the same amount of production. In practice, energy-efficient hydropower plants are those whose total self-consumption is less than 1.2% of the annual production. Therefore, it is necessary to precisely define the electricity consumers who have this treatment. In this paper, energy efficiency in HPP Jablanica, HPP Grabovica and HPP Salakovac has been observed from this aspect. With quality structural maintenance and progressive improvement of the energy efficiency of plants and equipment, there will be reduction of the total self-consumption. This directly increase the contribution of hydropower plants to the reduction of carbon dioxide emissions in the generation mix of JP EP BiH.

Keywords: hydroelectric power plants, energy efficiency, reduction in energy consumption

INTRODUCTION

„Hydropower plants (HPP) on the Neretva River (HPP Jablanica, HPP Grabovica and HPP Salakovac)" operates within the Public Enterprise Elektroprivreda Bosne i Hercegovine d.d. - Sarajevo (JP EP BiH) as its organizational part in the form of a branch office with headquarters in Jablanica and constitutes a technical unit of the vertically integrated system of the internal organization of the Public Enterprise. In 2020, JP EP BiH introduced an Energy Efficiency Policy, which committed to introducing high energy efficiency processes and the most modern technologies proven in practice, while intensifying the transition to renewable energy technologies, as well as increasing energy efficiency and energy savings in all activities and processes [1]. JP EP BiH introduced an energy efficiency management system according to the requirements of the ISO 50001 standard. In response to these activities, JP EP BiH HPP on the Neretva River adopted its Energy Efficiency Policy in 2024 and opted for the direction of introducing ISO 50001. The ISO 50001:2018 standard, or Energy Management System (EnMS), applies to all processes and activities that affect energy efficiency, energy consumption and energy management [2]. Within JP EP BiH, HPP on the Neretva River, the energy management system encompasses all levels of the organization and refers to employees, equipment, systems and processes that use energy within the hydropower plant.

This paper provides an overview of the activities carried out and the analysis of energy use and consumption in The HPP on the Neretva River, based on measurements and relevant data. This required a clear identification of the current types of energy use, an assessment of past and current energy consumption, and an analysis and identification of significant energy consumers (SEUs). For each SEU, relevant variables and current energy performance were determined. Employees/jobs in The HPP on the Neretva River that have an impact on each of the SEUs were also identified. In addition, opportunities for improving the energy performance of the SEUs were listed and prioritized.

1. BASIC INFORMATION ABOUT HYDRO POWER PLANTS ON THE NERETVA RIVER

The production facilities within The JP EP BiH HPP on the Neretva River are HPP Jablanica, HPP Grabovica

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and HPP Salakovac, Figure 1-3. The Hydropower Plant Jablanica is the first built power plant in the Neretva hydropower system. The first of six installed aggregates, with a capacity of 25 MW, were put into operation in 1955. After 40 years of operation and an average of 250,000 to 300,000 operating hours per aggregate, it was assessed that an inevitable increase in investment in plant and equipment maintenance was not profitable, so in 1997 a general renovation of electromechanical equipment and construction facilities began. The reconstruction and revitalization of the HPP Jablanica included increasing power, increasing reliability, reducing production costs, increasing electricity production, increasing static and dynamic stability, extending the service life, and increasing utility and expanding the operating area - the operating diagram. Within the revitalization of the A1 unit in mid-2008, the revitalization of all six units was completed, the operating life of the HPP Jablanica was extended for the next 30 to 40 years, and the power was increased from 150 to 180 MW (i.e. an increase in power per unit by about 25%) [3].

Figure 1: Dam and HPP Jablanica

The HPP Grabovica underwent revitalization and general overhaul of Unit No. 2 in the period 2011-2012, and a general overhaul of Unit No. 1 in the period 2015-2016, after 30 years of operation of the unit.

Figure 2: HPP Grabovica

Revitalization of electromechanical equipment at the HPP Salakovac is planned in the coming years, with the aim of increasing reliability, extending service life and reducing electricity production costs. Basic technical data and information of hydropower plants on the Neretva river are given in Table I and II.

Figure 3: HPP Salakovac

Table I: Basic technical data of hydropower plants [3]

	HPP Jablanica	HPP Grabovica	HPP Salakovac
Year of commissioning	1955 -1958.	1981.	1981.
Average flow 1989 – 2018 [m3/s]	102,8	115,5	155,0
Installed flow [m3/s]	6 x 34,5	2 x 190	3 x 180
Total reservoir volume hm3	318	19,77	68
Useful volume of the reservoir hm3	288	5,43	15,6
Normal deceleration elevation m.n.m.	270,00	159,00	123,00
Number of units	6	2	3
Installed power [MW]	6 x 32,83	2 x 58,5	3 x 69,5
Annual production for balance sheet conditions [GWh]	693,0	260,4	356,6

Table II: Basic company information [3]

Sector	Energetics		
Activity	Electricity production (Activity according to KD 2010. 35.11)		
	2023	2022	2021
Average number of employees	303	312	323
Total electricity production (kWh)	1.565.654.727	1.125.620.325	1.665.488.953

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2. ENERGY EFFICIENCY AT THE HPP ON THE NERETVA RIVER

Energy efficiency has become one of the key topics of today. Energy savings, as a result of more efficient use of energy sources, have a significant impact on the economic and financial aspects of companies' operations, but also on the lives of consumers. The European Union has imposed the need for safe, clean and efficient electricity production, and electricity companies have been set requirements that are necessary, but also possible to meet in order to improve processes in production activities. One of the long-term goals of JP EP BiH in the electricity generation business is to ensure high productivity and reduce the costs of production facilities, i.e. own consumption. Monitoring and setting energy efficiency goals is an important factor in drawing attention to energy consumption and identifying opportunities for optimization, which leads to savings and return on investment within the Subsidiary. In addition, the implementation of energy efficiency measures in hydroelectric power plants and business facilities contributes not only to reducing energy production and maintenance costs, but also to reducing the negative impact on the environment. Quality planning requires consideration of all factors that affect the efficiency of the production process and permanent maintenance of plants and equipment. Improving the energy efficiency of plants and equipment, as well as reducing the HPP's own consumption, directly increases the contribution of hydropower plants to reducing the carbon footprint in the production mix of JP EP BiH. When producing electricity in all hydroelectric power plants, it is necessary to ensure power supply to the plants and devices, both primary and secondary equipment in the plants and facilities, without which the production process would be impossible. This means that in all plants it is necessary to ensure power supply to all devices that are in the function of producing electricity and that represent the power plant's own consumption in the process of producing electricity. This amount of electricity is defined by the technical characteristics of a particular hydroelectric power plant and the operating mode, which means that it can be influenced by changing technical solutions (if there is justification for this) and operating the production units in the optimal range. The value of self-consumption is also affected by the situation in the electric power system (EPS), since the operating regime of power plants cannot always be in the optimal range. The Electricity Balance (EEB), as the basic document that defines the annual and monthly plan for the production and consumption of electricity in the area of JP EP BiH, also plans the own consumption of power plants. When preparing the EEB, care is taken to fully utilize the available capacities in hydroelectric power plants, using the inflow of water at the desired reservoir levels. Therefore, when planning the operation of power plants, efforts are made to minimize own consumption, which is in the function of electricity production. The total self-consumption of a hydroelectric power plant is calculated in two categories: Transformation losses and Own consumption of the power plant. Transformation losses are defined by technical characteristics, associated block transformers and the operating mode of the aggregates. The self-consumption of a power plant includes primary and secondary equipment in plants and facilities. Primary equipment includes the group of consumers whose operation is necessary from the point of view of operational safety and security. The identification of significant consumers of electricity was carried out based on the analysis of installed capacity, percentage share in the total energy balance and their functional importance for the operational processes of the hydroelectric power plant. Energy consumption analysis in hydroelectric power plants can help identify critical points in the production process and implement improvements that lead to increased efficiency of plants and equipment. Reducing the HPP's own consumption through the use of energy-efficient technologies and an integrated energy management system enables a more sustainable way of producing energy and reducing negative environmental impacts and indicates improvements in asset management and more efficient use of resources. Maintaining an efficient energy management system paves the way for continuous improvement of production capacities and reducing the overall environmental impact of JP EP BiH's electricity production [4], [5], [6], [7], [8], [9].

3. MEASUREMENT OF HPP'S SELF-CONSUMPTION IN THE HPP ON THE NERETVA RIVER

In hydroelectric power plants, the largest part of the energy consumed for own consumption is taken from the tap-off transformers of the production units that are in operation, or through certain 35 kV plants, while the rest is taken from the EES. Therefore, in hydroelectric power plants, double power supply of all power plant facilities is enabled. In the HPP on the Neretva, a system of remote measurement and supervision, monitoring of production, as well as own electricity consumption, has been installed. The system for remote data collection from production facilities (Automatic meter reading, AMR) is an automated technological process of collecting data from measuring devices and forwarding them to a central database (server). For the purpose of continuous monitoring of production at the generator and the threshold of hydroelectric power plants, 15-minute, hourly and daily readings are performed and reports on the calculation of electricity at the generator, at the threshold of the power plant, as well as electricity for own consumption in the AMR system are automatically generated. According to the internal procedures of the JP EP BiH, the method of identifying the billing metering point, readings and mutual verification of the reading records is precisely defined. The procedures contain single-pole metering schemes and associated calculation formulas, individually for each of the power plants, which result in production at the generator and threshold of a given power plant, its own consumption and energy exchanged with Elektrodistribucija and Elektroprenos (delivered and received). According to the valid protocols on exchange between HPP on the Neretva and Elektrodistribucija, the measured energy in such cases increases by 2% or 4%, as defined by technical recommendations or the metering register for each individual case, while in the exchange between HPP on the Neretva and Elektroprenos it increases by 5%. HPPs on the Neretva deliver energy to Elektroprenos at voltages of 220 kV, 110 kV and 10 kV, and take over at 110 kV, while they deliver energy to Elektrodistribucija at 35 kV, 10 kV and 0,4 kV, and take over at 35 kV and 10 kV [10], [11], [12], [13], [14], [15], [16], [17], [18].

4. IDENTIFICATION OF SIGNIFICANT CONSUMERS

Significant energy consumers, which have the greatest impact on the overall consumption and operation of the plant, represent key energy consumers in hydropower plants. The identification of these consumers was carried out based on the analysis of installed capacity, percentage share in the total energy balance and their functional importance for the operational processes of the hydropower plant. All self-consumption consumers are grouped into three basic categories:

- Auxiliary systems of the generator – Systems that include air conditioning, cooling systems, drainage, heating and other support to ensure the smooth operation of the hydroelectric power plant;
- Power plant lighting – Includes internal and external lighting of the facilities;
- Block transformers – The largest energy consumers, responsible for the distribution of electricity.

The identification of significant energy consumers in hydroelectric power plants is based on the following key criteria:

- Share in total electricity consumption: Consumers that have a significant percentage share in the total energy balance of the hydropower plant are considered key for consumption analysis and optimization. These consumers have a direct impact on the overall efficiency of the plant.
- Optimization and savings potential: Consumers with significant opportunities for improving energy efficiency, such as modernizing equipment or changing operating practices, are considered key for implementing energy optimization measurese.

The following tables list significant consumers of electricity in hydroelectric power plants and their part in the own consumption of HPP [19], [20], [21], [22].

Table III. Electricity consumers in the HPP Jablanica

	Electricity consumers in the HPP Jablanica	(%)
1.	Auxiliary systems of the generator (air conditioning, cooling system, drainage, heating, etc.)	36
2.	Power plant lighting (interior and exterior)	21
3.	Block transformers	43

Table III. Electricity consumers in the HPP Grabovica

	Electricity consumers in the HPP Grabovica	(%)
1.	Auxiliary systems of the generator (air conditioning, cooling system, drainage, heating, etc.)	23,5
2.	Power plant lighting (interior and exterior)	3,5
3.	Block transformers	73

Table III. Electricity consumers in the HPP Salakovac

	Electricity consumers in the HPP Salakovac	(%)
1.	Auxiliary systems of the generator (air conditioning, cooling system, drainage, heating, etc.)	13,8
2.	Power plant lighting (interior and exterior)	5,2
3.	Block transformers	81

The operation of a large number of consumers, which participate in the own consumption of hydroelectric power plants, has already been optimized or, due to its role in the production process itself, it is impossible to achieve savings in terms of electricity consumption. A large number of consumers, which are part of the own consumption necessary for the safe and reliable operation of hydroelectric power plants, are working only in case of need, and have a relatively short operating time. In some auxiliary plants, high-efficiency pumps have already been installed and there are no technical possibilities for a different implementation method. Lighting is recognized as one of the major consumers of electricity in all plants of the HPP on the Neretva River, and therefore also recognized as a place for possible savings in electricity consumption for own needs, i.e. as a place to improve energy efficiency, given that the concept of this lighting dates back to the beginning of power plants. The lighting devices that are currently used in all HPP on the Neretva, as well as at the auxiliary facilities of HPP Jablanica, are outdated, inefficient, with a low utilization rate and mainly include fluorescent tubes, high-power bulbs and Na NPI bulbs, which, in addition to considerable electricity consumption, do not provide satisfactory lighting in the plants [22], [23].

5. ENERGY PERFORMANCE

The current consumption and energy use are continuously monitored in hydroelectric power plants (Table VI).

Table VI. Types of energy monitored by location

Energy	Location		
	Jablanica	Grabovica	Salakovac
1. Electricity			
1.1. Own consumption	✓	✓	✓
1.2. Transformers losses	✓	✓	✓
2. Water			
2.1. Amount of water used for production	✓	✓	✓
3. Operational readiness			
3.1. Availability	✓	✓	✓
3.2. Reliability	✓	✓	✓

Table VII. Energy indicators

Indicators	HPP Jablanica (2021-2023)	HPP Grabovica (2021-2023)	HPP Salakovac (2021-2023)	HPP on Neretva (2021-2023)	HPP on Neretva 2024
Specific expenditure (m^3/kWh)	4,03	12,76	10,07	8,95	8,90
Transformers losses (%)	0,33	0,75	1,51	0,73	0,73
Specific consumption of electricity for own needs (%):	0,36	0,30	0,22	0,31	0,25
Availability (%)	99,88	97,84	99,37	99,03	99,93
Reliability	highly reliable	highly reliable	highly reliable	highly reliable	highly reliable

The evaluation of the energy performance indicators of electricity production and consumption in the HPP on the Neretva River is carried out on an annual basis, comparing them with the time-defined goals of increasing production and reducing electricity consumption in the HPPs (Table VII), while considering the hydrological conditions and conditions in the EES for the analyzed period. The evaluation of the energy performance of reliability and availability of the HPPs is carried out on an annual basis, checking and comparing them with the aim of enabling and maintaining a high level of availability and reliability of hydropower plants with as short as possible downtime periods caused by equipment and plant failures. By comparing the achieved values of the biological minimum, the amount of water used for protection against the harmful effects of lack of water, as well as the degree of satisfaction of other requirements that are in synergy with sustainable development and production from renewable sources, the energy indicators of water consumption for the needs of the production process are checked on an annual basis in accordance with the energy and environmental goals of the HPP on the Neretva River [8], [24].

6. OTHER ENERGY-RELATED FACTORS

The production of electricity in HPPs on the Neretva River is determined by the Production Plan for the current year, which is an integral part of the Electricity and Energy Balance (EEB). The EEB determines the volume and monthly dynamics of production at the threshold of each hydropower plant, as well as the annual plan of transformation losses and self-consumption for individual hydropower plants, and thus the annual production plan for generators. The EEB is prepared by the Sector of the Management and Trade in JP EP BiH, in accordance with the guidelines provided for long-term planning and use of reservoirs, based on the Instructions for Planning and Use of Reservoirs of JP EP BiH. This Instruction defines the desired and limit states of seasonal and multi-year accumulations at the beginning of the month and the nominal monthly production of all constructed hydroelectric power plants, based on the specific parameters of each accumulation, and in particular with due regard to the prescribed water restrictions. The production plan is implemented in accordance with the EEB and the daily "timetable", which is delivered to the HPP on the Neretva every day from the DC of JP EP BiH. Technical coordination of production is carried out by the chief engineer. This includes monitoring the production process by analyzing operating reports and operating events and initiating and monitoring the implementation of preventive and corrective activities, all in accordance with existing procedures. The chief engineer is responsible for the operational readiness of the hydroelectric power plant's facilities and devices. The execution of technical tasks is carried out by engineers, technicians and other professional staff of the plant. The coordination of the production process and the work of the shift staff during the shift is carried out by the shift leader. All requests arising from the needs of the EES, DDC are submitted to the shift leader via dispatches and verbal orders via means of communication (telephone or radio) and are implemented or forwarded in accordance with existing procedures. The production process in the hydroelectric power plant takes place continuously. Therefore, part of the working staff (shift staff) must be constantly present at the power plant facilities (engine room, dam, inlet structure and water level) for the purpose of management (performing necessary manipulations), monitoring the work process and recording all important events and technological data. The organizational and personnel structure (number of employees, work experience, required expertise and work skills, with established job descriptions, authorizations and responsibilities) of the shift and plant staff ensures optimal work and continuity of the production process [16], [19], [20], [21].

7. HPP'S OWN CONSUMPTION IN 2024

According to relevant scientific analyses and studies conducted for the purpose of optimizing hydropower plants, the total self-consumption of hydropower plants is directly related to the type, size and location, and whether the hydropower plant is part of a cascade series or not. Taking into account the criteria and results of the aforementioned studies, the average values of the total self-consumption for medium and large hydropower plants range from 0.5% to 2% of the achieved production on generators, while the most efficient hydropower plants are those with total self-consumption between 0.5% and and 1.2%. The conclusions drawn from these analyzes are summarized in Table VIII [5], [6], [7], [22].

Table VIII: Average values (%) of total self-consumption of hydropower plants

TOTAL SELF CONSUMPTION IN HPP	Average values	Energy efficient power plants
	(%) achieved production on generators	(%) achieved production on generators
	0.5 – 2.0	0.5 – 1.2
Losses of transformation	0.3 - 0.7	0.3 - 0.5
Self-consumption	0.2 – 1.3	0.2 – 0.7

The recent the Electricity balance for 2024 provides the planned shares of block transformer transformation losses and own consumption in the total own consumption of the hydroelectric power plant, as well as the share of total own consumption in the gross production of hydroelectric power plants, Table IX [8].

Table IX: Planned values

Planned values	HPP Jablanica (%)	HPP Grabovica (%)	HPP Salakovac (%)
Losses of transformation_ block transformers	43	73	81
Self-consumption	57	28	19
Share of total own consumption in gross HPP production	0,7	1,1	1,7

According to the parameters from the previous tables, the most recent year 2024 was also analyzed. A comparative overview of the planned and achieved total own consumption in 2024 individually for HPP Jablanica, HPP Grabovica and HPP Salakovac, as well as HPPs on Neretva in total is given in Table X and in Chart 1.

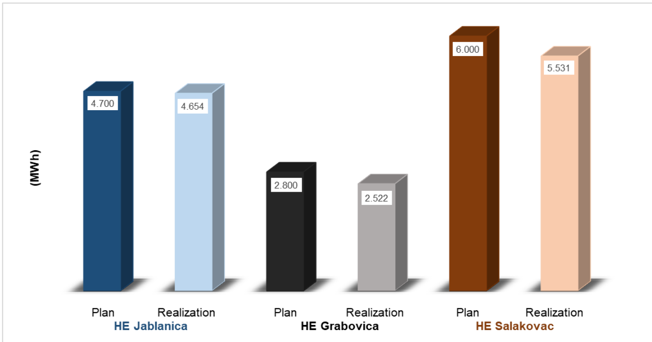

Chart 1: Plan and realization of self-consumption in the HPP Jablanica, HPP Grabovica and HPP Salakovac in 2024

The achieved total own consumption represents the achievement of 104.91% of the total annual plan of the Hydropower Plants on the Neretva River from the Electricity Balance for 2024. The energy efficiency of the reconstruction and revitalization of all six units of the HPP Jablanica can also be observed through the share of total own consumption in the total achieved annual production of the HPP Jablanica. Before the revitalization, losses of energy due to the increased of own consumption in 1999, amounted to 1.97% with a share of transformation losses of 1.58%. In 2024, they were only 0.73% with a

Table X: Plan and realization of the self consumption in the HPP on Neretva river in 2024

	HPP Jablanica			HPP Grabovica			HPP Salakovac			HPP on the Neretva		
2024.	Plan	Realiza-tion	%	Plan	Realiza-tion	%	Plan	Realiza-tion	%	Plan	Realiza-tion	%
Total self-consumption	0,70	0,73	104,43	1,10	1,05	95,88	1,70	1,65	96,99	1,00	1,05	104,91
Losses of transformation	0,30	0,35	117,54	0,80	0,75	93,16	1,50	1,48	98,66	0,70	0,74	106,03
Self-consumption	0,40	0,38	94,60	0,30	0,31	103,12	0,20	0,17	85,00	0,30	0,31	102,29

share of transformation losses of 0.35% with the achieved production at the threshold of the hydroelectric power plant of 91.01% of the annual plan from the Electricity and Energy Balance for 2024. During 2024, the minimum total own consumption in the HPP Jablanica was achieved in March and October of 0.31%, while the highest of 0.55% was achieved in December. The oscillations of these values are directly conditioned by the operating regime of the power plant and the situation in the EES. Given that, according to international criteria, the most energy-efficient hydropower plants are those whose own consumption does not exceed 1.2% of the annual production, and since the HPP Jablanica is well below this percentage, it can be classified as a highly energy-efficient power plant.

HPP Grabovica achieved 1.05% of total self-consumption, or 95.88% of the planned value for 2024. HPP Grabovica had a revitalization and general overhaul of Unit 2 in the period 2011-2012 and Unit 1 in the period 2015-2016, after 30 years of unit operation. The increase in energy efficiency was achieved by reducing the self-consumption of the entire power plant from 1.5% in 2010 to 1.08% in 2015, 1.11% in 2016, 1.21% in 2017, 1.01% in 2018 and to 0.98% in 2019. According to the realization of its own consumption of 1.05% in 2024, HPP Grabovica can be classified in the category of highly energy efficient power plants, with a share of transformation losses of 0.75% and with the achieved production at the threshold of the hydropower plant of 90.67% of the annual plan from the Electricity Balance for 2024.

HPP Salakovac achieved 1.65% of its total self-consumption, or 96.99% of the planned value for 2024. With this parameters HPP Salakovac is not energy efficient power plants. During 2024, the minimum total own consumption in HPP Salakovac was achieved in October of 0.10%, while the highest was achieved in July of 0.38%. HPP Salakovac, with a transformation loss of 1.48%, achieved production at the threshold of the hydroelectric power plant of 92.35% of the annual plan from the Electricity Balance for 2024.

According to the parameters from the previous table, HPP Jablanica and HPP Grabovica met the criteria for energy-efficient hydroelectric power plants in 2024. Accordingly, the minimum goal is to maintain the current state. Also, the replacement of the internal and external lighting systems in these power plants will be reflected in the reduction of self-consumption. HPP Salakovac did not meet the criteria for energy-efficient hydroelectric power plants given the share of total self-consumption in the achieved production. The goal is to try to reduce this percentage in the coming year so that it remains within the planned values by EEB. Having in mind the rehabilitation of the plant through the replacement of worn-out and out-ages equipment, it is expected that the efficiency criteria will be achieved in this power plant in the near future.

8. CONCLUSION

The main goal of electricity producers in the sustainable development strategy is to increase the energy efficiency of the state as well as the hydropower facility itself. Hydropower plants play an important role in maintaining the stability and security of electricity supply on the European market. By optimizing production costs, or increasing the efficiency of the production process, the plant becomes functional, economical, efficient and environmentally friendly under given operating conditions, and reaches the required quality and becomes competitive on the electricity market. HPP Jablanica is already an energy-efficient power plant, and its own consumption is within the optimal limits. It is necessary to take certain improvement measures so that both HPP Grabovica and HPP Salakovac reach a high level of efficiency, and HPP Jablanica maintains stay on high level. In this sense, it is necessary to plan investments that will explore the processes of the hydropower plant with a focus on optimizing energy use and improvements in terms of rationalizing its application, with the aim of continuously ensuring high reliability of the electricity generation system. An indispensable factor in this segment is also meeting the growing requirements of regulatory authorities for operation without interruptions associated with failures. The process of energy monitoring in the production process includes mapping consumption, accurate identification of key parameters in the energy process and monitoring their efficiency over time. Process monitoring and control can help identify weaknesses and failures, which enables the development of an adequate plan for performance improvement. Supervision and control enable the proper operation of equipment, minimization of energy losses and improvement of overall process efficiency. According to the relevant literature, there are two categories of investment projects in existing hydroelectric power plants, namely the renovation/replacement of primary equipment and facilities of the hydroelectric power plant on a "like for like" basis, where "repairs" generate an increase in production/income of up to 2.5%, and the upgrading/ reconstruction of equipment and facilities, including an increase in the installed capacity of the power plant, where the increase in production/income ranges from 10% to as much as 30%. Hydropower plant renovation generally aims to extend the lifespan, increase reliability, increase production/income, reduce the need for maintenance, and increase the level of automation. Management must find an innovative operating model that extends the lifespan of hydropower plants, while at the same time ensuring high availability and reliability of the plant and permanently address the evident impact of climate change on the operation of hydropower plants [22], [24], [25], [26], [27], [28], [29], [30], [31].

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