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Analysis and performance of hydro generation of electricity from small hydropower plants

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Abstract: The application of the latest technology in HPPs of the Dragash region and the generation benefits with multifunctional approach enable sustainable operation of generators with full efficiency in the environment where it is part of this research. Exploitation of energy resources from renewables, particularly the utilization of hydro resources through engineering works called hydropower plants today is of particular importance not only nationwide but also wider. Electricity represents one of the most eminent and underlying sources of human activities. Energy sources are different, as are the modes, equipment and plants for its generation. Indeed the geographical position and the influence of climate conditions influence the potential of the exploitation of the generating energy in the minimal flow of water flow in the turbines by the decanters. The paper highlights the use of advanced SMART technology, the form of communication between plants installed in hydropower plants and the generating performance with some characteristics of turbines used in hydropower plants, as well as the results of efficiency analysis for small hydropower plants. Nowadays various types of turbines are used in the power system of the hydroelectric power generation type. Whereas the efficiency analysis of small and large hydropower plants depends on the design, size, and amount of water flowing into the profile in which a small power hydropower plant are generated electricity in the region of Dragash.

Keywords: energy efficiency, HPP machinery, turbine automation, regulation voltage.

1 Introduction

Most of the hydropower plants planned to be built in Kosovo fall mainly in special natural and protected areas where the hydropower potential is smaller. Problematic remains the fact that 62% of existing and planned small hydropower plants are located within areas of special natural importance, such as national parks, strict nature reserves, special protected areas, and areas with numerous features of natural, plant habitats and animal. Based on the strategic plan for alternative energy sources and pre-feasibility studies for the identification of water resources for small hydropower plants in Kosovo, 77 sites for small hydropower plants, with a capacity of about 128 MW, with a production of 621 GWh have been identified per year under average hydrological climatic conditions. The underlying objective is to stimulate the use of renewable energy sources, a 'feed-in' tariff scheme has been set up in Kosovo [1]. Above all, this incentive measure for RES aims to meet the energy targets of RES planned for 2020, as required by Directive 2009/28 / EC, transposed and implemented under the auspices of the Energy Community Secretariat.
Energy sector laws, in particular the Energy Law, have consistently dealt with resources renewable energy in terms of inducing the optimization regarding their utilization. This includes the establishing of annual and long-term targets of energy production from these sources. The main criterion for the mechanical study and selection of machinery is the full utilization of the aquatic energy of the selected hydro technical axis, to gain maximum power in the hydro turbines, which will be transmitted to the generator on the shaft to produce electricity [2].

In the respective case, relying on the turbine type diagram, the most appropriate choice for the water regime given by the hydrological study and the working height is for the Frencis type figure 1. After then the parameters in the diagram, it has been drawn the conclusion that turbines subjected to performance work are of the type Frencis. For minimal feeds that the Frencis aggregate does not reach, we propose to build an efficient turbine prototype that can generate electricity from water flows with a minimum amount of up to 20% that fits our project, or by dividing it into two aggregates [3].

- Shaft Francis turbine – H = (2 ÷ 20) [m]
- Kaplan turbine - H = (3 ÷ 40) [m]
- Mitchell-Banks turbine – H = (10 ÷ 100) [m]
- horizontal axis of Francis turbine – H = (25 ÷ 100) [m]
- Pelton turbine – > 100 [m].

2 Energy produced in power plants

Based on the size of the hydroelectric power plant, the energy produced ie. river volume flow, hydropower power is estimated using the following equation:

$$P = q\,\rho\,g\,h\,k \qquad (1)$$

Where in;
P - gained power and electricity (electricity), W;
q - volume of available water volume, m3 / s;
ρ - water density (approximate value is 1000 kg / m3);
g - acceleration of gravity (gravitational forces), 9.81 m / s2;
h - height of the water column, ie the available water drop (m);
k - operation coefficient of a hydropower plant receiving values between 0 and 1;
The coefficient k depends only on the type of turbines built in hydropower plants.
As the turbines are larger and more modern, k is approaching the value of 1 [5].

2.1 Equipment for building HPP

Devices which bear SMART technology for small hydropower automation have the option of a synchronous or asynchronous generator solution as a unit of hydraulic power and all the metering elements it possesses, such as procedures, protection and control regulations for the equipment required for automatic starting, the generator (stimulant), and obligatory network synchronization and secure normal and emergency aggregate network. The most important benefits are the automation of SMART modules for small hydro: power installation (MWh) turbine generator, stimulation regulator, temperature control module, synchronizer to start and stop the protection system for all types of Francis, Bankijevu, Pelton, Kaplan turbines ect. [4].

2.2 Generators synchronous and asynchronous

Synchronous and asynchronous type generators, three phase transformers and distribution system lines comprise the key link of the power system. The synchronous generator converts the mechanical power of the pT turbine into electric power and as matter of fact it is a tie between the generating unit and the electricity transmission network. Hydro generators, owing to their low rotational speed, are prepared with visible poles [7].

In the stator they contain three vented windings of current and voltage in the space of 120 °, while in the rotor usually in addition to the excitement winding fed with continuous current they also contain the winding of the horizontal and vertical relaxation system.

During the analysis of the synchronous generator, in order to make it solvable, a series of analyzes are performed with the measuring instrument system including the SMART operating meter of the following:

• The magnetic circuit of the synchronous generator is accepted as voracious; that the dependence of the magnetic fluxes on the electric current is linear and so the principle of superposition can be applied

• The stator and rotor coils that are actually scattered in the space are replaced by concentrated coils.

• Losses of active power in the magnetic circuit are inconsiderable.

• Magnetic induction in the air space of the synchronous generator, as well as voltage or current modes is expected to vary compliant to sinusoidal law.

• Active and reactive machine winding resistances are accepted independent of temperature and frequency, particularly the phenomenon of surface effect is ignored.

- Practice shows that the errors that cause the above releases are usually admissible [4-5].

2.3 Voltage regulation in synchronous generators

In the power system one of the main factors of electricity transmission is also the maintenance of a certain level of voltage at its various points (in cases where there are variations of voltages and frequencies), for the following reasons:

Various appliances that consume electricity are designed to operate at a certain voltage level, otherwise called nominal voltage. In the case of a voltage deviation from this value, the quality of the work of the equipment will be impaired. Nevertheless, the flow of lamp lighting relies a lot on voltage etc.

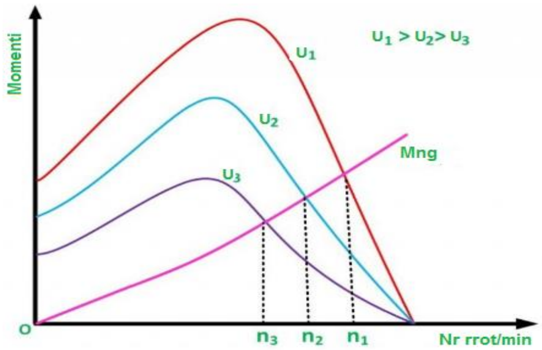

Figure 1 Asynchronous motor with different voltage

• Maintaining certain levels of voltage in the system is also related to the impact on the transmission capability of transmission lines. The voltage U1 (figure 1) at the initial phase of the transmission line is distinguished by the voltage of the system U and with ΔU, which is determined by the active P and reactive power Q passing through the line:

$$\dot{U}_1 = \dot{U} + \Delta\dot{U} \qquad (2)$$

From (2) and the vector diagram of Fig. 6 shows the phase difference between U1 and ΔU1.

$$P = \frac{|U_1|\cdot|U|}{x_l}\cdot \sin\delta_l = \frac{U_1\cdot U}{x_l} \qquad (3)$$

During instantaneous voltage reductions as well as short circuits in the system, maintaining synchronous operation of the plant generators, relies on the speed of resetting the voltage both during and after the short circuit disconnection. In the case of asynchronous modes, the success of resetting synchronous plant operation in the system depends on the speed of resetting voltage levels [5].

2.4 Performance of small HPP-s

The maximum flow water is 10m3 / s per second.
The technology exploited in Dikance HPP is 2 Francis Horizontal turbines.
One turbine has a generation capacity of 2700kV and the other has a generation capacity of 1300kV.

Table 1. Climatic conditions and efficiency of utilized energy in HPP Dragash

Time of the year as %	Natural water inflow	Ecological flow	Water flow available to be used	Water flow passing the turbines	Total efficiency (turbines, generators and transformers)	Net Head	Installed capacity	Electricity generation
%	m³/s	m³/s	m³/s	³/s	%	m	kW	kWh
8.30%	13.023	0.249	12.774	10.5	84.82%	45.5	3,975.51	2,890,512.68
16.70%	8.271	0.249	8.022	8.022	85.72%	45.5	3,069.50	2,258,664.29
25.00%	6.76	0.249	6.511	6.511	84.87%	45.6	2,472.00	1,797,340.20
33.30%	6.102	0.249	5.853	5.853	85.94%	45.6	2,250.23	1,636,093.81
41.70%	5.248	0.249	4.999	4.999	85.51%	45.7	1,916.47	1,411,894.13
50.00%	4.989	0.249	4.74	4.74	83.60%	45.7	1,776.44	1,290,057.52
58.30%	4.161	0.249	3.912	3.912	80.40%	45.7	1,410.14	1,025,286.47
66.70%	3.589	0.249	3.34	3.34	84.73%	45.8	1,271.50	935,620.61
75.00%	3.042	0.249	2.793	2.793	85.29%	45.8	1,070.25	778,157.55

83.30%	2.381	0.249	2.132	2.132	79.92%	45.9	767.21	557,825.08
91.70%	1.611	0.249	1.362	1.362	67.35%	45.9	413.06	303,943.02
100.00%	1.026	0.249	0.777	0.777	0.00%	46		
							Total kWh/year	**14,885,395.36**

The results measured in compliance with the feasibility plan and the measurements of energy produced by water turbines at HPP Dikance 2 in the two types of Frenzies and Piston turbines [6]. Francis type generator with 4 MW installed power, the characteristics of which are presented in the table, show some operating factors of operation (generation) of electricity dependent on flow of water with capacities of 5.3 m3 / s, amount of water used during generation of 5.5 m3/s. According to statistical analysis the efficiency of electricity generation on average is over 80%, which means that the efficiency of generation relies on the amount of water flows [7]. The generator and the turbine are connected to each other on a vertical axis. Pouring of water through the pipes (installed ducts) produces rapid water flow through the turbine - generator, and the generator provides electricity [8]. The energy acquired by the power plant is equal to the production of height (H) and amount of water (Q) according to the expression:

$$P = 9.81 * Q * H * ŋ \quad (kW) \qquad (4)$$

Where are:

Q-quantity of electricity (m3/s),

H-height (fall) of water (m)

ŋ- coefficient of exploitation of generator and turbine.

The water deposed from the turbine continues further into the tailgate which is closed to the dam, as it is often the continuation of the river. The control gate enable the continuity of the turbine activity. In case of closure, dispose of drainage channels and excess water will either surround the riverbed itself, or open the gates to remove it.

Generating a Dependent Service on Factories and Installations on the premises, does not allow you to be efficient in generating citizen turbines when it is reduced at a large extent reduced the amount of road possible [9-10].

Table 2 Generating power of generators in Dragash

Percentage	Large turbine	Generator 3200kVA	Small turbine	Generator 1600 kVA	Transformer
	%	%	%	%	%
100	92.70%	97.40%	92.83%	97.10%	94.00%
90	93.87%	97.40%	93.44%	97.10%	94.00%
80	93.40%	97.40%	92.72%	97.10%	94.00%
70	91.40%	97.30%	90.60%	97.10%	94.00%
60	87.91%	97.30%	87.03%	97.69%	94.00%
50	82.86%	97.00%	81.83%	96.60%	94.00%
40	75.94%	96.65%	74.52%	96.15%	94.00%
30	66.18%	96.30%	64.12%	95.85%	94.00%
20	52.42%	95.60%	53.23%	94.80%	94.00%
10	0.00%	0.00%	0.00%	0.00%	0.00%

The efficiency of the generating power shown in Table 3 presents the comparative data divided by the generating potentials for the 3200KVA and 1600 KVA turbines while maintaining the same voltage transformation of 94%. Generator with higher generating power of 3.6-4 MW, for full water potential up to 50% has better performance, while generator with lower performance has less than 50% of generating potential. Consequently, if the amount of water reaches 20% the generation ratio is 52% and 53%.

Table 1 Comparison of data between planning and setting up HEC

Production of electric energy in turbines of water generator in Dikance HEC, Francis turbine			
Month	Planning (MWh)	Realization (MWh)	% Efficiency Ppr/Pinst
January	2,187,516	738	34
February	2,186,500	1850	85
March	2,189,153	1011	46
April	2,190,757	1326	60
May	2,192,567	1234	56
June	2,193,377	2047	93
July	2,199,127	1431	65
August	2,184,676	1123	51
September	2,182,445	954	43
October	2,185,895	1456	66
November	2,196,546	1259	57
December	2,194,765	1458	66
January	2,184,556	1345	61
February	2,185,925	1250	57

The SMART Monitoring Center of the entire production process is monitored by the PC system for electricity generation, the generation information system, and the protection of power plants and a complete set of other HEC operational information [11].

2.5 Analysis of efficacity of turbines in small HPPs

The process concerned with carrying out the estimated flow, is primarily based on known recommendations in the field of design of small HPPs with derivation where it is expected to guarantee it for 25% of the year. According to the above, based on the stability curve of daily flows in the Dragashi 1 HPP intake axis, this flow is

Q_{ll} = 0.42 m^3 / s. the resulting HPP uptake results Q_o = 0.31 m^3/s. Indeed, the feed coefficient turns out to be $K_q = Q_{ll} / Q_0 = 0.42/0.31 = 1.35$ and with the following data:

Q_{log} = 0.42 = m^3/s and H = 169m, based on materials recommended in the field of hydropower machinery, two Pelton turbines [12-13] will be selected.

2.6 Performance of turbines in large hydro power plants

In this perspective, it is worth emphasizing that large hydropower plants do not differ from the principle of operation with small hydropower plants but it is normal that there are differences in terms of turbine size and installation power. Generally speaking these plants are accumulative and their management is easier and can be used in a more rational way. Francis and Pelton turbine types also apply to large HPPs. Another type of Kaplan type turbine which is used in some cases in high-capacity hydropower plants and also in large flows should be mentioned. [14]. Technical Indicators Fierza Hydropower Plant is of dam type and reservoir type. The dam is filled with stones and clay cores. The dam is 161.5m high and 380m long, the width of the dam ranges from 576 m at its base to 13m at the dam ridge. The Fierza Dam, when it was built, was the second of its kind in Europe to its height. The dam has a total volume of 8 million m^3. The dam has created a reservoir with a volume of 2.7 billion m^3 of water and an area of 72 km^2, Fierza Lake, which is the largest artificial lake in the country. The useful volume of the reservoir is 2.3 billion m^3 [15]. The HPP Fierza is foreseen as a first class offense in terms of risk. Likewise to any hydropower turbine whether small or large, the flow of water and altitude are considered as determinant factors to indicate the class or type of river or lake. The type of turbine designed for these types of hydropower plants is the vertical Francis type which are installed with a power of 125 MW and there are four turbines of this type [15].

CONCLUSION

Small hydropower plants help the sustainable development of RES in Kosovo. The type of technologies used to generate energy in terms of efficiency have differences in generation between turbines in the same river flow for the same installed power. The Dikanca 2 hydropower plant that is supplied through the Brod River according to the production plan in relation to the generation realization is at 62.5%. The methodology used in the generation analysis of water turbines ensures that the new technology used is efficient and effective in generating electricity. Internal areas of environmental sustainability are considered important therefore caution is required in the various discriminations that may occur with the environment. The use and implementation of technology in small HPPs enables functional operation at nominal generating stability. The analysis and generation performance is also influenced by the slope angle factor in the water supply pipe to the turbine blades. The inter-technological communication approach is multidisciplinary that enables stable and functional operation in monitoring and generation of electricity up to the distribution system at the level of 35 kV. The integration of the generating network and the distribution network provides the benefits of the subsidized price for several years and the longevity of the operating technology in the system. The efficiency of the technology exploited in the parameters between large and small turbines, the ratio is 89% to 87%. Generating power efficiency between 3600KVA and 1600kVA ratio varies from 97% to 96%. The voltage transformation for all types of generation is 94%. Electricity generation from water generator turbines at HPP Dikance 2 for Francis type turbines% efficiency Ppr / Pinst 64.6%. The Dragashi HEC stimulation system is ES202 type with a radiator bridge. The main functions of this system are feeding the rotor with continuous current and regulating the voltage. For the no-load regime, a simulation was conducted to test the regulator for a degree of excitation at the reference voltage. For the + 5% excitation at the reference voltage the override is 0, and the stabilization time is 0.597 sec. While for -5% excitation at the reference voltage the override is 0 and the stabilization time is 0.485 sec. The kinds of turbines which are installed in these hydropower plants are mainly of the Francis and Pelton type. Based on the analyzes carried out in this case, has been drawn the conclusion that small hydropower plants are prioritized for construction in the conditions offered by the territory of the Republic of Kosovo.

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