International Journal of Engineering Sciences & Research Technology

(A Peer Reviewed Online Journal)
Impact Factor: 5.164

IJESRT

Chief Editor
Dr. J.B. Helonde

Executive Editor
Mr. Somil Mayur Shah

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

DETERMINATION OF THE CHARACTERISTICS OF THE ELECTROMECHANICAL EQUIPMENT OF THE MICRO HYDROELECTRIC POWER PLANT AT THE GUEENI SITE ON THE KOKOULO RIVER IN PITA, GUINEA

[1]Jean Ouèrè Toupouvogui, [2]Ansoumane Sakouvogui, [3]Mohamed Ansoumane Camara, [4]Roger Marcelin FAYE and [5]Mamby Keita

[1]Department of Instrumentation and Physical Measurements, Higher Institute of Technology of Mamou, Guinea
[2]Energy Department, Higher Institute of Technology of Mamou, Guinea
[3]Electrical Engineering Department, Polytechnic Institute, Gamal Abdel Nasser University of Conakry, Guinea
[4]Roger Marcelin FAYE, Research, Innovation and Partnership of Amadou Mahtar MBOW University, Senegal
[5]Department of Physics, Faculty of Sciences, Gamal Abdel Nasser University of Conakry, Guinea

DOI: 10.57030/ijesrt.13.3.1.2024

ABSTRACT

When setting up a small hydroelectric power plant in isolated sites, the choice of electromechanical equipment remains a very important factor. This study is part of this dynamic. Its main objective is the determination of characteristics and the choice of electromechanical equipment for the micro hydroelectric power plant at the Gueeni site on the Kokoulo River in Pita in Guinea, with a variable hydrological regime. The methodology adopted is based on knowledge of the hydraulic parameters and the hydroenergetic characteristics of the site (hydraulic power, net power). Based on these elements, we determined with great precision; the type of turbine (Kaplan), with a rotation speed (586.58 rpm); the specific speed (47 rpm); the number of generator poles (10); the electrical power of the plant (2160 kW), the apparent power of the transformer (2700 kVA) and valve closing time (1.1 s). This study is part of the dynamic of evaluating the hydroenergetic potential of small developable waterfalls in isolated areas of Guinea

KEYWORDS: Micro hydroelectric power plant, electromechanical equipment, turbine, alternator, transformer

1. INTRODUCTION

The production of electrical energy is a challenge of great importance for the years to come. Indeed, the energy needs of industrialized societies continue to increase. Furthermore, developing countries will need more and more energy to carry out their development [1]. Today, a large part of the world's electrical energy production comes from fossil sources. The consumption of these sources gives rise to greenhouse gas emissions and therefore an increase in pollution [2].

The additional danger is that excessive consumption of natural resource stocks reduces the reserves of this type of energy in a dangerous way for future generations, which is why several directives have been adopted for the promotion of the electricity produced from renewable energy sources. The applications targeted by small hydroelectricity are the power supply of isolated, non-electrified sites, as well as the supplementary supply to the interconnected network, in particular through the association with other sources of renewable energy [3].
The electromechanical conversion systems commonly used in micro hydroelectric power plants are based on synchronous wound rotor machines or asynchronous cage machines, which have a simple configuration, but

IJESRT is licensed under a Creative Commons Attribution 4.0 International License.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

which can ensure efficient operation only with the help of mechanical control devices or electric [4]. The development of equipment in the context of large hydroelectricity is now strongly limited due to the scarcity of available sites, the consequences for the integrity of the landscape, for the quality of the water as well as for the underwater fauna that can result from such installations [5].

On the other hand, small hydroelectricity has strong development potential and it is expected that it will hold an important place in future electricity production by renewable energies, the targeted applications being the power supply of isolated, non-electrified sites, as well as the supply of addition to the interconnected network. Small hydroelectric developments combine numerous advantages which make them particularly profitable sources of financial income for independent producers [6].

The main electrical and hydraulic components of a hydroelectric power plant are the turbine, alternator and auxiliary systems. This equipment is housed in a compact building, designed to facilitate maintenance of the installations [7]. A turbine is a device equipped with fins, blades or vanes (the whole of which is called blading), to which a fluid imparts a rotational movement transmitted to a mechanism via a shaft placed in the center of the device. There are several types of turbines classified into two main families: action turbines and reaction turbines [8]. The alternator (synchronous machine) is an electrical machine producing an electric current whose frequency is determined by the rotational speed of the rotor: “generator” operation in two quadrants of the torque-speed plane [9].

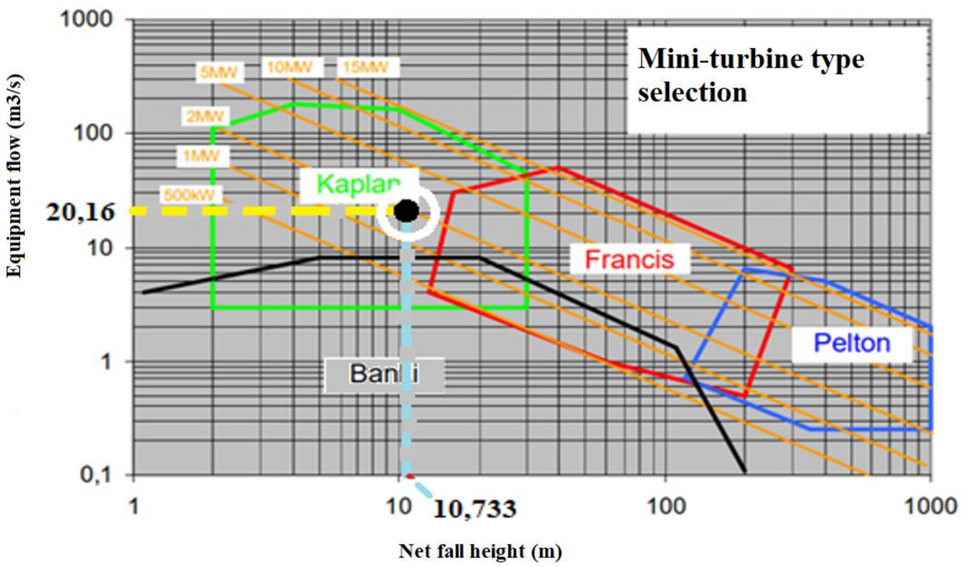
An electric transformer is an electrical machine allowing the voltage and current intensity values delivered by an alternative electrical energy source to be modified into a system of voltage and current of different values, but of the same frequency and the same shape. [10].

2. METHODOLOGY

This study is a continuation of our research work on the valorization of renewable energy sources for the production of electricity in isolated areas. The methodology consists of determining the characteristics of the electromechanical equipment of the micro hydroelectric power station of the Gueeni site on the Kokoulo river in Pita by referring to the hydroenergetic potential of this site [2].

2.1 Choice of turbine

The choice of turbine type mainly depends on the equipment flow rate, the net head or the specific rotation speed [11].



After the projection our choice falls on the Kaplan turbine.

IJESRT is licensed under a Creative Commons Attribution 4.0 International License.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Characteristic of Kaplan turbine

Specific speed (n_{sp}) : It is calculated by relation 1.

$$n_{sp} = \frac{2.294}{H_n{}^{0.486}} \quad (1)$$

Rotation speed (n) : It is calculated by relation 2.

$$\mathrm{n} = \frac{\mathrm{n_{sp}} \times \mathrm{E}^{3/4}}{\sqrt{\mathrm{Q_{equi}}}} \quad (2)$$

Where: E- Specific energy (gH_n) ; H_n- Net fall height. SO : $\mathrm{n} = \frac{27\times(9.81\times28.264)^{3/4}}{\sqrt{9.781}} = 586.58\ \mathrm{tr/mn}$

Wheel outer diameter : It is determined by relation 3.

$$\mathrm{D_{ex}} = 84{,}5 \times (0{,}79 + 1{,}602 \times \mathrm{n_{sp}}) \times \frac{\sqrt{\mathrm{H_n}}}{60\times\mathrm{n}} \quad (3)$$

Wheel internal diameter: It is determined by relation 4.

$$D_{in} = (0{,}25 + \frac{0{,}0951}{n_{sp}}) \times D_{ex} \quad (4)$$

Cavitation coefficient : Cavitation is a phase change phenomenon where water in the liquid state changes to the vapor state by decreasing pressure without adding heat to the fluid flows. It is determined by relation 5.

$$\sigma = 1{,}5241 \times \mathrm{n_{sp}^{1.46}} + \frac{\mathrm{V}^2}{2\times\mathrm{g}\times\mathrm{H_n}} \quad ;\text{Where: } \mathrm{V} = \sqrt{2\mathrm{gH_n}} \quad (5)$$

Suction height : It is determined by relation 6.

$$\mathrm{H_s} = \frac{\mathrm{P_{atm}} - \mathrm{P_v}}{\rho\times\mathrm{g}} + \frac{\mathrm{V}^2}{2\times\mathrm{g}} - \sigma \times \mathrm{H_n} \quad (6)$$

Where: V- Speed of the water jet in the turbine; P_v- Vapor pressure; Z- Altitude upstream of the fall; P_0 - Hydrostatic pressure (N/mm^2); P_{atm}- Atmospheric pressure (atm). $P_{atm} = P_0 \left(1 - \frac{0{,}0065\times Z}{288{,}15}\right)^{5{,}255}$

As this value is negative, it will be necessary to install the turbine wheel below the restitution level.

Turbine efficiency : It is determined by relation 7.

$$\eta_{\mathrm{turb}} = \frac{\mathrm{P_n}}{\mathrm{P_h}} \quad (7)$$

Mechanical power : It is calculated by relation 8 [12].

$$\mathrm{P_{mec}} = \mathrm{Q_{equi}} \times \mathrm{H_n} \times \rho \times \mathrm{g} \times \eta_{\mathrm{turb}} \quad (8)$$

Choice of generator

The transformation of mechanical energy into electrical energy is ensured by a converter which makes it possible to obtain alternating current electrical energy from mechanical energy. As part of our project, the turbine is directly adapted to the alternator without the intermediary of a speed multiplier so the speed of the turbine is equal to that of the alternator. The number of pole pairs is calculated by the relation (9.)

$$\mathrm{p} = \frac{60\times\mathrm{f}}{\mathrm{n_s}} \quad (9)$$

Where: n_s - Generator rotation speed; P : Number of generator pole pairs; f - Generator frequency (50Hz).

IJESRT is licensed under a Creative Commons Attribution 4.0 International License.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

Consequently we have a generator of 10 poles or 5 pairs of poles.

Electric power
It is calculated by relation 10 [13].

$$P_{el} = \eta_g \times P_{mec} \quad (10)$$

Choice of transformer
The choice of transformer depends on its apparent power, the voltage of the transmission lines and the electrical energy produced by the power plant [14].

It is calculated by relation 11.

$$P_{app} = \frac{P_{el}}{\cos\varphi} \quad ; \text{With : } \cos\varphi = 0{,}8 \quad (11)$$

He number of generator is calculated by relation 12.

$$Z_G = \frac{P_h}{P_{él}} \quad (12)$$

Where : Z_G- Number of generator; P_h - Hydraulic power.
For the implementation of this project we need 02 generators of the same capacity.

Securing the plant
This speed depends on the elasticity of the water and the material of the penstock. It is determined by relation 13.

$$C = \sqrt{\left(\frac{K}{\rho(1+\frac{K\times D}{E\times e})}\right)} \quad (13)$$

Where: C- Speed of the wave in m/s; K- Modulus of compressibility of water (2.1×10^9 N/m^2); E- Modulus of elasticity of the penstock material (2.1×10^{11} N/m^2); D- Diameter of the penstock (m); e- Wall thickness of the penstock (mm); ρ - Density of water.

Critical time
This is the time taken for the pressure wave to reach the valve. It is determined by relation 14.

$$T_c = \frac{2\times L}{C} \quad (14)$$

Where: T_c- Critical time (s); L - Length of the penstock (m); C- Speed of the pressure wave (m/s).

For safety reasons, this time is ten (10) times longer than the critical time.

$$t = 10 \times T_c \quad (15)$$

Transient pressure
If the transient regimes depend directly on the sudden variation in the flow speed in the pipe. These speed variations are the cause of pressure variations (also called water hammer) which can be positive or negative. The excess pressure is determined by formula 16 [15].

$$\Delta_p = P_o\left[\frac{N}{2} \pm \sqrt{\left(\frac{N^2}{4} + N\right)}\right] \quad (16)$$

IJESRT is licensed under a Creative Commons Attribution 4.0 International License.

With: Δ_p - Transient overpressure in meters of water column; P_o - Hydrostatic pressure at sea level; N - Coefficient which depends on the closing time of the valve and the speed of the water in the penstock calculated by relation 17 [16].

$$N = \left(\frac{L_c \times V_c}{g \times P_o \times t}\right)^2 \quad (17)$$

With: L_c - Length of the penstock (m); V_c - Water speed in the penstock (m/s); T - Valve closing time (s); g- Acceleration of gravity (m/s^2).

The pressure that the penstock can withstand is the sum of hydrostatic pressure due to the gross head and the overpressure

$$P_t = P_o + \Delta_p \quad (18)$$

3. RESULTS AND DISCUSSIONS

The results obtained during this study are illustrated in table 1.

Table 1. Hydroenergy characteristics of the Gueeni site on the Kokoulo River in Pita

Designation	Symbol	Value	Unit
Turbine type	-	Kaplan	-
Specific turbine speed	n_{sp}	47	tr/m
Turbine rotation speed	n	586.58	tr/m
Wheel outer diameter	D_{ex}	1.56	m
Wheel internal diameter	D_{in}	0.6	m
Cavitation coefficient	σ	2.1	-
Suction height	Ha	-31.1	m
Turbine efficiency	η_{tur}	90	%
Mechanical power	P_m	24000	kW
Number of generator poles	n_{pg}	10	-
Electric power	$P_{él}$	2160	kW
Apparent power of the transformer	P_{ap}	2700	kVA
Pressure wave speed	C	592.55	m/s
Critical time	T_C	0.11	s
Valve closing time	t	1.1	s
Transient pressure	Δp	10.2×10^{-4}	N/mm^2

The results in Table 1 show that based on the main hydroenergetic characteristics of the Gueeni waterfall on the Kokoulo River in Pita with a net power (2700 kW) [2], the type of turbine suitable for this site is the Kaplan. With a rotation speed of 586.58 rpm, for a specific speed of 47 rpm; the number of poles of the generator is 10, the electrical power is 2160 kW, for an apparent power of the transformer of 2700 kVA and valve closing time is 1.1 seconds. These results represent a good database for the choice of electromechanical equipment for the site's power plant.

4. CONCLUSION

The Republic of Guinea has a very immense hydroenergy potential, estimated at more than 6000 MW for guaranteed energy of 19300 GWh/year. Some sites of pico, micro and small hydroelectric power stations of developable waterfalls, still remain unidentified and studied by researchers and services of the National Energy Directorate. This study, which is a continuation of our work, made it possible to determine the characteristics and choice of electromechanical equipment for the micro hydroelectric power plant at the Gueeni site on the Kokoulo River in Pita, a town in middle Guinea, in Fouta Djallon. The results obtained will serve as basic data for the construction of the plant.

IJESRT is licensed under a Creative Commons Attribution 4.0 International License.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

REFERENCES

1. Doussou Lanciné Traore, Yacouba Camara, Sékou Camara, Ansoumane Sakouvogui, Mamby Keita, (2018). Evaluation of the Hydrological Parameters of the Kalako Fall on the Tinkisso River at Dabola (Republic of Guinea), International Journal of Sustainable and Green Energy, Vol.7, No.3, pp.16 – 20.
2. Ansoumane SAKOUVOGUI, Elhadj Ousmane CAMARA, Saidou BARRY, Mamby KEITA, Assessment of the hydroenergy potential of the Gueeni village waterfall on the Kokoulo River in Pita, Guinea. International Journal of Research and Review, Vol. 11; Issue: 1; ISSN: 2349-9788, pp. 154-161, (2024). https://doi.org/10.52403/ijrr.20240117
3. Shewei Wang, Kesheng Wang, Zhe Li, A Review on Data-driven Predictive Maintenance Approach for Hydro Turbines/Generators. International Workshop of Advanced Manufacturing and Automation (IWAMA 2016), pp 30 – 35.
4. Alberto Moro, Sebastian Muntean, Daniele Novara, Juan Ignacio Perez-Diaz, Emanuele Quaranta, Philippe Schild, Nicolaos Ioannis Kougias, George Aggidis, Francois Avellan, Sabri Deniz, Urban Lundin,
5. Theodossiou, Analysis of emerging technologies in the hydropower sector. Renewable and Sustainable Energy Reviews 113 (2019) 109257
6. Emanuele Quaranta, Riccardo Bergamin, Anton J. Schleiss, How to estimate the weight of hydropower electro-mechanical equipment, Available evidence, novel equations and challenges for engineering applications. Results in Engineering 18 (2023) 101067. https://doi.org/10.1016/j.rineng.2023.101067
7. E. Quaranta, P. Davies, Emerging and innovative materials for hydropower engineering applications: turbines, bearings, sealing, dams and waterways, and ocean power, Engineering 8 (2022) 148–158.
8. AlZohbi, G. The cost of electromechanical equipment in a small hydropower storage plant. Journal of Energy Systems, 2018; 2(4): 238-259, DOI: 10.30521/jes.457288
9. Araujo, Marcos Aurélio de; Gimenez Ledesma, Jorge Javier; Hideo, Oswaldo Methodology to rehabilitate hydroelectric power plants DYNA, vol. 89, no. 223, 2022, July-September, pp. 114-120 Universidad Nacional de Colombia DOI: https://doi.org/10.15446/dyna.v89n223.101291
10. Seweryn Lipiński, and Tomasz Olkowski, Estimation of the cost of electro-mechanical equipment for small hydropower plants – review and comparison of methods E3S Web of Conferences 19, 01023 (2017) DOI: 10.1051/e3sconf/20171901023.
11. A. H. Elbatran, et al, Operation, performance and economic analysis of low head micro-hydropower turbines for rural and remote areas: A review, Renewable and Sustainable Energy Reviews, Vol. 43, 2015, pp. 40–50
12. Okonkwo G.N and Ezeonu S.O, Design and installation of a mini hydro electric power plant Scholarly Journal of Engineering Research Vol. 1(1), pp. 11-15, March 2012.
13. S. O. Anaza, M. S. Abdulazeez, Y. A. Yisah, Y. O. Yusuf4, B. U. Salawu, S. U. Momoh, Micro Hydro-Electric Energy Generation- An Overview, American Journal of Engineering Research (AJER) Volume-6, Issue-2, 2017, pp-05-12.
14. Jean Ouèrè Toupouvogui, Mohamed Ansoumane Camara, Ansoumane Sakouvogui, Mamby Keita, Optimal Sizing of Capacitor Bank for Increasing Substation Capacity of Mamou, World Journal of Engineering and Technology, 2023, 11, 217-233. https://doi.org/10.4236/wjet.2023.112015
15. Guillermo Romero, Vicente S. Fuertes-Miquel, Óscar E. Coronado-Hernández, Román Ponz-Carcelén and Francisco Biel-Sanchis, Transient Phenomena Generated in Emptying Operations in Large-Scale Hydraulic Pipelines, MDPI, Water 2020, 12, 2313; doi:10.3390/w12082313
16. R Autrique1 and E Roda, Laboratory studies of water column separation, 6th International Conference on Pumps and Fans with Compressors and Wind Turbines, Conf. Series: Materials Science and Engineering 52 (2013) 022022. doi:10.1088/1757-899X/52/2/0.

IJESRT is licensed under a Creative Commons Attribution 4.0 International License.