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Evaluation of the Hydroelectric Potential of the Tokounou Waterfall, Kankan Prefecture, Guinea

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Abstract: This study is a continuation of the work of evaluation and valuation of the hydro power potential of Small hydropower plants in Guinea. With a total hydroelectric potential estimated at 6000 MW, Guinea generally suffers from a lack of electrical energy, especially in rural areas where nearly 70% of the populations live and less than 15% of this population is connected to the grid. Electricity of the country, which has the negative consequence of the misuse of wood as a source of energy. Hence the need for this study, which aims to assess the hydroelectric potential of the Tokounou waterfall in Kankan prefecture. The main results obtained relate to : the turbine flow rate, the net head, the useful power, the dimensions of the loading basin, the characteristics of the penstock and the choice of turbine. Proposals for the use of the estimated hydroelectric potential have been made, which could improve the energy needs of the locality.

Keywords: Hydroelectric, Rating, Potential, Power and Waterfall.

1. Introduction

The need to provider a power supply system is be coming more and more pressing everywhere in the world. The national policy in the energy sector in Guinea aims to increase the supply of electric power so as to reduce the excessive dependance on traditional non-renewable energy sources, and ensure the global coverage of demand. energy of the country. More specifically, it is about achieving access to electrical energy for 65% of the population by 2025 [1].

To achieve this vision, it is planned to develop hydroelectricity through the more intensive exploitation of the national hydroelectric potential in order to reduce the consumption of polluting fossil fuels, promote the development of renewable energies.F

Hydroelectricity is the production of electrical energy from rivers. This is an old technique, based on a very simple principle: the dam built on the stream creates a large water reservoir. The water level is then higher upstream than downstream. Through an opening at the base of the dam, water is allowed to escape into the pipe called the inlet channel or flow channel. The water passes at high speed and drives turbines coupled to alternators or electric generators that produce electricity. The flow of water can be increased or decreased, depending on the amount of electricity you want to generate. The higher the water retention, the greater the power of the dam. This transformation of hydraulic energy into electrical energy is carried out by the hydroelectric power station [2].

Hydroelectricity has several advantages: it is a renewable energy source. It allows energy storage and the modulation of electricity production, thus making an appreciable contribution to the stability of the electricity system. Finally, it does not produce greenhouse gases or other polluting gases.

Hydroelectric production also significantly reduces greenhouse gas emissions. By way of comparison, the hydraulic production of 1000 kWh represents compared to the same quantity of electricity produced by an oil-fired power station, a saving of 0.220 tonnes of oil equivalent and avoids the emission of 690 kg of CO_2. Hydroelectricity, when combined with a reservoir (lake, dam, etc.), is the only renewable energy that can be modulated, with the additional possibility of increasing the electrical power produced very quickly. It plays a crucial role in the safety and balance of our electrical system [3].

According to the International Union of Producers and Distributors of Electric Energy, hydroelectric power stations are classified according to the installed power: small power plant (2,000 kW to 10,000 kW, mini-power plant (500 kW to 2,000 kW), micro-power plant (20 kW to 500 kW) and pico-power plant less than 20 kW. In addition, structures (power plants) are classified according to their height of fall: high falls (greater than 100 m), medium falls (15 to 100 m) and low falls (less than 15 m) [4]. There are two important types of work for the construction of a small hydroelectric power station: civil engineering works and electrical and mechanical equipment [5].

The Tokounou sub-prefecture is an important agricultural production area. The rural communities of this locality, very far from the city of Kankan, are, like other rural entities, faced with the recurring problem of supplying energy resources. However, it has a hydroelectric site which has not yet been developed and operated. The general objective of this study is to assess the characteristics of the hydroelectric potential of the Tokounou waterfall, which are essential for the construction of a hydroelectric dam.

2. Material and Method

2.1 Material

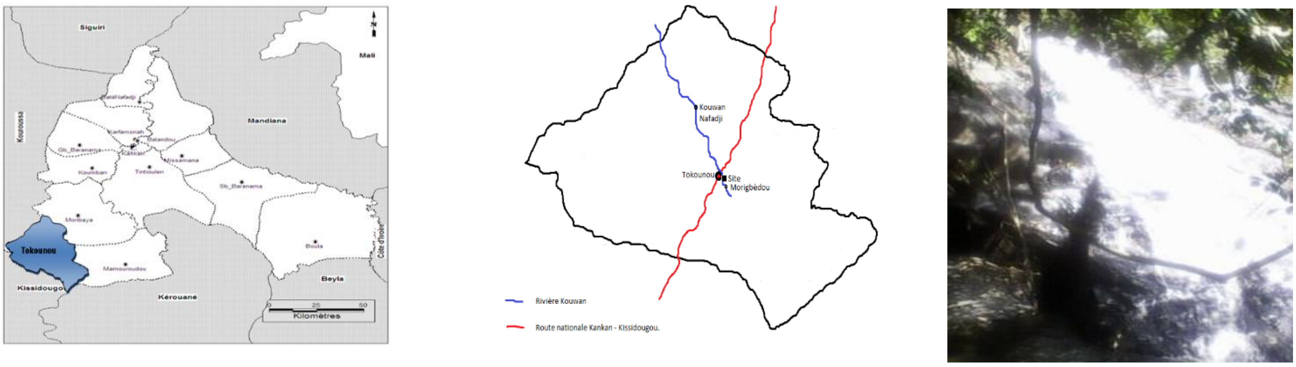
2.1.1 Presentation of the Study Area

Tokounou is one of the twelve (12) sub-prefectures of Kankan prefecture, it is located 120 km from the Kankan Urban Commune. Tokounou has a tropical climate. It is characterized by the alternation of two (2) seasons of approximately equal duration : the rainy season (from May to October) and the dry season (from November to April). The average annual rainfall is 116.02 mm. Solar irradiation varies from 5 kWh / m2.d in August and 6.03 kWh / m2.d in March, the annual average is 5.58 kWh/m^2.d, which offers this area of Guinea the greatest solar energy potential. The annual average temperature of the site is 25.5 ° C. The hottest month of the year is April with an average temperature of 28.5°C [6].

The dominant soils are of the ferralitic type with a sandy clay texture, sometimes gravelly. The Tokounou sub-prefecture has an area of 215 km2 and an estimated population of 32,807 inhabitants at the start of 2014. Its density is therefore approximately 153 inhabitants per square kilometer. It has 18 districts divided into 68 sectors. The village of Tokounou alone has a population of 4568 inhabitants unevenly divided into 360 households [7].

Like most rural areas, Tokounou's main activities are: agriculture, commerce, animal husbandry and crafts. In the village there are: five welding workshops, a health center, a youth center, five video clubs, ten sewing workshops, two grinding machines, four mosques, four primary schools, a high school and buildings administrative. Two generators of 30kVA and 20kVA belonging to individuals serving the population cannot cover all the electricity needs, hence the need for a reliable and less expensive source of energy for the locality (Tokounou).

The Tokounou waterfall site is located east of the Rural Commune on the Kouwan River 2 km away. This river takes its source 4 km behind the district of Morigbèdou. It has an irregular seasonal regime, due to the variation in rainfall with three (3) months of low water. Thus, it can be used effectively to operate a micro hydroelectric power station using a reserved flow during the low water period. The proximity to the village and the need for energy make this site one of the most important sites in Upper Guinea. Figure 1 show the position of Tokounou in Kankan prefecture and the photo of the Tokounou waterfall.



a) Map of Kankan prefecture b) Location of the site in relation to Tokounou c) Tokounou waterfall

Figure 1. Presentation of the study area

2.1.2 Equipment and Work Tools

This study required the use of the following equipment and materials: a float, a chronometer, a graduated rule, a decameter, two current and propeller currentometers, a GPS (Global Positioning System), a clisimeter, a level, a compass and telescope on tripod.

2.2 Method

The feasibility stages of a micro hydroelectric power station involves studies of the meteorological, hydrological, geological, topographical, socioeconomic parameters of the area, the sizing and design of the structures.

2.2.1 Site Meteorological Parameters

The meteorological parameters of the site were assimilated to those of the prefecture of Kankan, they were generated in the RETScreem software and from data from the meteorological station of the region.

2.2.2 Topographic

To measure the gross height of the Tokounou fall, two methods were used: the topographic method and the GPS (Global Position System) method. The gross height is the difference between the height measured upstream and the height measured downstream [8].

$$H_b = H_{amont} - H_{aval} \qquad (1)$$

2.2.3 Equipment Sizing

The sizing of the micro-plant is carried out according to the hydroelectric potential and the energy potential, which also make it possible to calculate the profitability of the micro-plant. These potentials come from the turbinable flow, itself given by a hydrological study of the site from which the reserved flow is subtracted.

The construction of the dam and the installation of the Tokounou micro-power plant requires a diversion of the river (inlet and tailpipe channel), as well as sufficient space for access, the installation of the technical room.

✓ Flow velocity in the supply channel

In the head channel, the speed of water flow is slightly different from its speed in the river bed which can be determined using the float method. In uniform conditions, the flow velocity is calculated by the Manning-Strickler relationship, (formula 2).

$$V = K_S \cdot R^{\frac{2}{3}} \cdot J^{\frac{1}{2}}$$

$$\text{Ainsi : } V = K_S \cdot \left[\frac{(L+l)\cdot h}{2(l+2X)}\right]^{\frac{2}{3}} \cdot J^{\frac{1}{2}} \qquad (2)$$

Where : J is the slope of the pipe (its value is set according to the distance between the dam and the penstock); Ks the Strickler coefficient (it depends on the nature of the supply channel). The wetted section Sm and the wetted perimeter Pm depend on the shape of the penstock [9].

✓ Flow in the channel (free surface flow).

The QV flow passing through the channel is calculated by multiplying the average flow velocity by the section of the channel (formula 3).

$$Q_V = V \cdot S_m \qquad (3)$$

✓ Nominal diameter of the penstock

Two criteria must be taken into consideration in the dimensioning of the penstock (the value of admissible pressure drops 6 to 10% of the gross height and the critical speed in the penstock). The diameter D_N of the penstock is determined by formula 4.

$$D_N = 2 \cdot \sqrt{\frac{Q_v}{\pi \cdot V}} \qquad (4)$$

✓ Dimensions of the Loading Basin

The loading basin supplies the penstock. It is equipped with a settling tank and a grid, a drain channel and a valve. The dimensions of the loading basin are : width (5. DN), length (8. DN) and height (3. DN).

✓ Net height of fall.

The net height is the gross height minus all the pressure drops, it is calculated by formula 5.

$$H_n = H_b - \sum pertes \qquad (5)$$

✓ Pressure losses

The height loss in the supply channel is the product of the slope observed by the length of the pipe. The height losses in the penstock are made up of linear and singular losses. The linear loss depends on the standardized value of the penstock. The abacuses are used for its determination.

✓ Useful electrical power

The real (useful) electrical power that can be recovered depends on the losses in the system : the hydraulic head losses (net height of fall and the efficiency of the machines through which this power will pass for use. useful P_u is expressed by relation 6.

$$P_u = 9{,}81 \cdot \eta \cdot Q_V H_n \text{ où } \eta = \eta_t \cdot \eta_g \cdot \eta_a \quad (6)$$

With (η: Overall efficiency, η_t: Turbine efficiency, η_g : Generator efficiency, η_a : Efficiency of couplings).

$$n_S = n \cdot P_{mec}^{\frac{1}{2}} \times H_n^{-\frac{5}{4}} \text{ et } P_{mec} = \frac{P_u}{\eta_g \cdot \eta_a} \quad (7)$$

✓ Securing the control unit

Penstock pipes are subject to overpressure, which to some extent can lead to the bursting of the piping (eg water hammer). In order to avoid this unfortunate situation, it is recommended to choose from the market pipes that can withstand a pressure greater than the pressure corresponding to the gross height of fall.

✓ Valve closing time

It should be noted that these overpressures result from the opening / closing maneuvers of the turbine flow regulator and that of the components by relation 8.

$$t_{fv} \geq \frac{2.L.V}{g.\Delta H} \quad (8)$$

With : t_{fv}: minimum closing time; L : Length of the penstock in meters; V : Maximum flow velocity ; g : Acceleration of gravity (9.81m/s²) ; ΔH : Permissible overpressure.

✓ Cable cross section

The choice of the section of the cables is governed by the Charts. These charts relate the power P of the plant in kW, the intensity I in Amperes, the distances between the plant and the distribution station in meters and the section of the cable in mm2. Thus, the calculation of the current delivered (in three-phase) by the plant is given by relation 9.

$$I = \frac{P_a}{3.U} \quad (9)$$

With: $P_a = P_u \cos\varphi$: Apparent power ; $\cos\varphi = 0{,}8$: Power factor ; $U = 400V$: Nominal voltage.

3. Results and Discussions

3.1 Meteorological Parameters

The annual variation of certain meteorological parameters of the site (temperature and precipitation) is shown in figure 2.

The site (waterfall) of Tokounou is characterized by 6 months of low water (January, February, March, April, November and December), the other months from May to October (period of the rainy season) are favorable to the proper functioning of the hydroelectric power station. The climatic data of this region show the need to provide for another energy source (solar, thermal or wind) during the low water period. The monitoring of the variation of these parameters makes it possible to carry out a precise study of the feasibility of the hydraulic and solar energy systems.

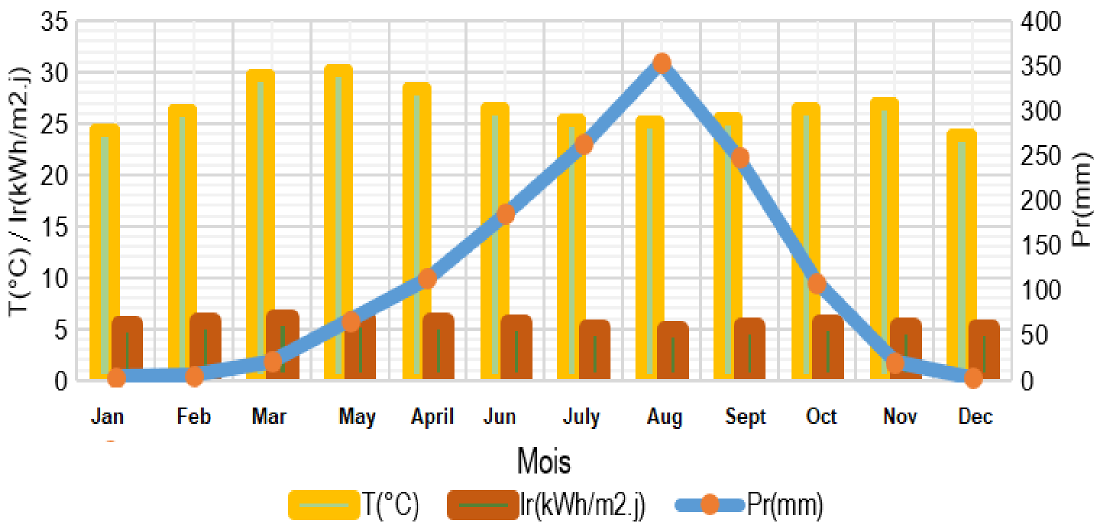


Figure 2. Annual variation in temperature, irradiation and precipitation

Table 1. Hydroelectric characteristics of the Tokounou waterfall

Designation	Symbol	Value	Unit
Gross drop height	H_b	19	m
Net height of fall	H_{nette}	18,23	m
Wetted section	S	0,6	m^2
Flow velocity	V	0,49	m/s
Flow rate	Q	290	m^3/s
Nominal diameter of the penstock	D_{CF}	0,868	m
Length of the penstock	L_{CF}	85	m
Loading Basin Width	l_{BMC}	2,17	m
Longueur du Bassin de Mise en Charge	L_{BMC}	3,47	m
Loading Basin Height	H_{BMC}	1,30	m
Volume of the Loading Basin	V_{BMC}	7,75	m^3
Electric power	P	31,4	kW
Turbine type	T_{Turb}	Francis ou Banki	-
Three-phase current output	I	38	A
valve closing time	t_{fv}	5,58	s

3.2 Construction Parameters of the Hydroelectric Power Station

The calculated hydroelectric characteristics of the Tokounou fall are shown in Table 1.

The technical characteristics of the micro-hydroelectric power station of the Tokounou site determined represent a first of the feasibility studies for the realization of the construction project. The electrical power estimated at 31.4 kW electricity production can be used in the locality for lighting, supplying water points, setting up a cold room at the health center, and operating a welding station.

The Tokounou dam can produce several tens of kilowatt of electricity to supply several energy consumption units in the sub-prefecture. The dam can also retain water reserves that can be used for irrigation of rice plains. It hardly produces any waste and emits very little carbon dioxide.

4. Conclusion

This research has led to important results, the enhancement of which would lead to sustainable development. These results are mainly: mastery of the dimensioning method used; the determination of the main parameters of the fall (flow rate, net height of fall, useful power); the sizing of the structures (charging basin, the supply channel, the technical room, the area where the dam is located) and the proposals for the use of the electrical energy assessed.

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Conflict of interest

The authors have no conflicts of interest to declare that they are relevant to the content of this article.

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