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Micro Hydro Power Plant for Sustainable Energy in Rural Electrification: A Case Study in Cameroon

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Abstract

The state of Cameroon, faced with the situation the electricity deficits, is promoting the development of renewable energies in general and to meet rural electrification needs in particular. The purpose of this work is to study the feasibility of the MHP of Batcheu, to show its contribution to sustainable development in this locality and to prove that it is a profitable project. After study, it appears that the waterfall of Batcheu is favourable to the establishment of a MHP with an installed power of 260 kW with an operating diagram corresponding to a Francis turbine. Given that it is a renewable energy that can supply more than 800 households in rural areas, its contribution to sustainable development is obvious. Its investment cost is estimated at 171,465,396 FCFA. It is a profitable project with a payback time of 7 years and 2 months.

Keywords

Micro Hydro Power, Sustainable Development, Rural Electrification

1. Introduction

In 2016, the access rate to electricity in Cameroon was around 91% for urban households while in rural areas 23% of households had access [1] [2]. The low rate of access to electricity in rural areas in Cameroon is the cause of several problems such as: rural exodus, under-schooling of children and very minor health actions. Under these conditions, it is very difficult to envisage projects in a perspective of sustainable development. The State of Cameroon has lot of strategies to growth this rate as soon as possible with renewable energies by promoting their development. Recall that Cameroon has one of the greatest potentials in MHP in Africa south of the Sahara that is untapped. A study carried out on the exploited and exploitable potentials of the MHP of some of these countries as Angola, Centrafric, RD Congo, R Congo, Sao Tome et P, … But the others countries are already making efforts in MHP while in Cameroon exploitation is almost naught despite its privileged potential in the field [1] [3] [4].

A contribution to the sustainable development of in rural areas in Cameroon is to supply the electricity from renewable sources to the population, and more precisely through the development of the Micro Hydro Power (MHP), because not only advantages in the production of electricity for isolated sites are proven but also, Cameroon has a large network of small rivers that make up the country's waterfalls [1] [3]. It is also proved that hydroelectrical system has an efficiency of 90%, a high-capacity factor of 60% and slow rate of change (due to the water flow varies gradually from time to time) [5]. In Cameroon, large power plants are often developed and energy issued is transferred trough interconnected networks which don't cover lot of localities mainly in rural areas. The development of MHP is very relevant to satisfy the needs of electrification in these remote rural areas [2]. According to the sustainable development objectives, in hydro power area, just small hydro power projects are considered as suitable to produce renewable energy [6]. It is clear that the development of the MHP in rural areas would allow to improve the income-generating activities (agriculture, livestock etc.), the conditions of studies of young people (schooling rate), the creating of healthy centers and the quality of life in these localities having as consequences a vision in a perspective of sustainable development [7] [8].

The objective of this work is firstly, do the feasibility studies of waterfall of Batcheu in view to set up a MHP. Secondly, prove that the development of MHP can contribute to the sustainable development in that village and finally show that it is a profitable project.

2. Materials and Methods

2.1. Study Site and Materials

Batcheu is a river in Penka Michel subdivision, Menoua division and West Region of Cameroon. Located in between 5˚26'54"N, 10˚18'49"E [5]. The following **Figure 1** represents a photo of waterfall.

As materials, a length meters, some hydrological data, an electronic laser level, a software Mass-hydro and computing accessories of feasibility studies and several other documents has been used.

2.2. Methods

2.2.1. Site Recognition and Topographic Evaluation

The survey team in recognitions visits did the gross Head measurement using an electronic laser level and obtain the gross waterfall height. Lots of data information about waterflow and topography were collected. The following **Figure 2** presents the image of the team in recognition and gross measuring the head. Let's mention that 25% of the gross head is lost as friction in the penstock. Then, the net head is obtained by reducing 25% from the gross Head. Therefore, the net Head equals to the gross head multiplied by 0.75 [4].

$$H_n = 0.75 H_g \quad (1)$$

with H_n: the net Head, H_g: the gross Head.

2.2.2. Installed Power and Energy

Before obtained the installed power, data about discharge must be collected, treated and then plotting the curve of the classified discharges [9]. After that, the installed power could be calculated as the following formula:

$$P = \eta \cdot \rho \cdot g \cdot H_n \quad (2)$$

where P is installed power of plant in kW, Q is discharge in m^3/s, g is gravity acceleration constant (=9.81 m/s^2), H_n = net head (m) and η is turbine efficiency (=80% - 90%) [5].

Figure 1. The waterfall of site survey.

Figure 2. Image of the team in recognition and measuring the head.

The producible or the annual Energy is can be obtained by the following formula.

$$P_E = P \times 8760 \tag{3}$$

where P_E is the producible or the annual Energy in kWh and 8760 is the annual time in hour.

2.2.3. Technical Equipment of MHP

The main technical components of MHP are: The Weir, the water intake, the feeder canal, the fore bay, the penstock, turbine, electromechanical components and power house dimensions are the main technical equipment [10]. In Cameroon, there is a software (Mass_Hydro) successfully developed by a research team.

2.2.4. Turbine

The Sulzer-Escher Wyss diagram is an efficiency particular technique to choose the turbine and generator. The nominal discharge Q_n and the net head H_n are necessary to use it [3] [5]. Its diagram is presented in the following **Figure 3**.

2.2.5. Financial Analysis

The net actual value (NAV) of the project is given by the following formula:

$$\text{NAV} = \sum_{i=1}^{n} \frac{SR_i - S_i}{(1+y)^i} - I_1 \tag{4}$$

where the initial investment cost is I_0; discount rate is "y"; for years 1, 2, n, Cash-flows and Operating costs can be respectively represent by: R_1, R_2, …, R_n; S_1, S_2, …, S_n; The net actual value (NAV) of the project is given by the following equation:

The project is profitable if NAV ≥ 0.

The costs equipment necessary for the MHP implantation depend on many local constraints. A MHP can usually operate during around 60% to 80% of time per year, and the operating costs represent generally 30% of the cash-flow [6].

3. Results

3.1. The Head and the Flow Rate

The gross head obtained is 17 m after lot of measurement. Then according to Equation (1), the net Head is equal to:

$$H_n = 0.75 \times 17 = 12.75 \text{ m}.$$

About the flow rate, the Batcheu waterfall is on the same river that feeding the waterfall of the Metchié which had been followed 35 years ago. The average annual flow is 9.3 m^3/s. The flow rate exceeds 12.5 m^3/s with a frequency of 30% over the year. The average daily flows rate resulting from the station mentioned above made it possible to plot the curve of the classified discharges presented in the following **Figure 4**:

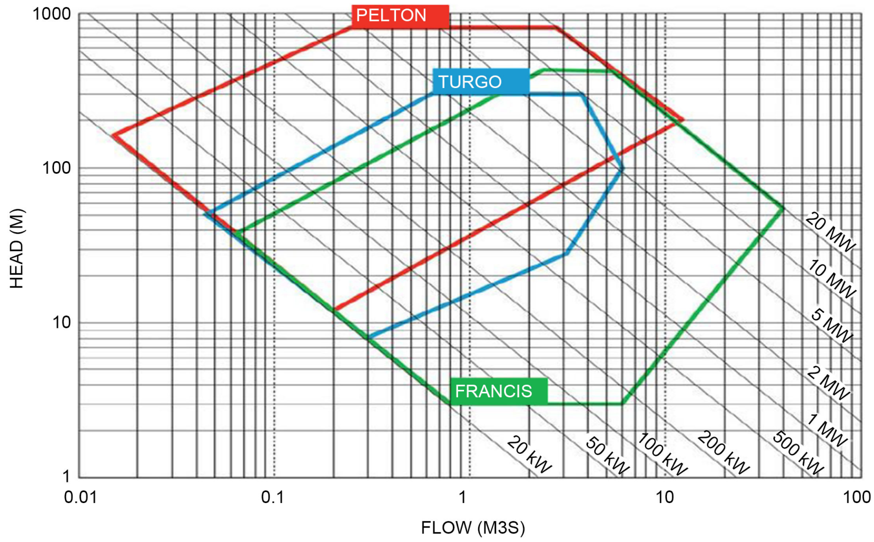

Figure 3. Turbine selection.

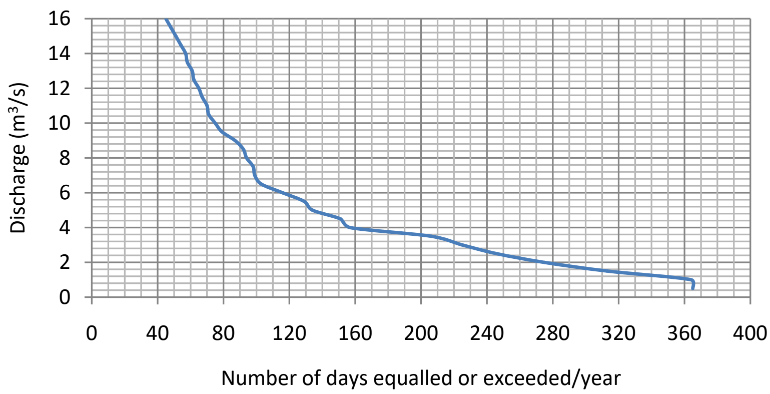

Figure 4. Graded flow curve.

3.2. Population Participation

Present the findings of the survey to the community at an open meeting to which local government staff and local development organisation. That is why a local committee to participate in the project and to manage the operation will be create. For the success of the project, that committee must be rich in skills such as: representatives of the community according to cultural varieties, council representant, farmers, breeders and fishermen etc. [7].

3.3. Installed Power and Energy

Considering that the net Head H_n = 12.75 m. Also, from the classification curve of water flow in **Figure 4**, and using the software Mass_Hydro, the flow rate of equipment (nominal flow rate) equals 2.6 m³/s, and the installed power is 260 kW. This is done applying formula (2).

P = 260 kW. So, the producible or the annual Energy is:

$$P_E = 260 \times 8760 = 2,279,012 \text{ kWh} = 2279 \text{ MWh} .$$

3.4. Technical Components of the Installation

Technical components for that MHP are proposed by our software Mass_hydro. The characteristics of the main are:

- **The turbine and generator**: According to the Sulzer-Escher Wyss the suitable turbine is Francis turbine with a synchronous generator functioning in conventional frequency;
- **The penstock**: The length of the penstock is 18 m, considering an angle of 45˚ between the penstock and gross Head [6]. Then for the PVC material, D_p = 0.69 m. The diameter of the pipe of 0.70 m and the the minimum thickness of penstock t_p = 2.47 mm.

The following Table 1 presents the results of feasibility study of Batcheu waterfall for MHP projection.

Table 1. Results of the study.

Elements	*Values*
Site characteristics	
Gross head	17 m
Mean flow rate	9.3 m^3/s
Derivation elements	
Feeding canal	$\Phi \approx 1.2$ m
Section of fore bay	7.2 m^2
Penstock	L ≈18 m, $\Phi \approx 0.7$ m; t_p = 2.4 mm
Power house	L =14
Turbine	
Type	Kaplan
Rotation speed	375 tr/min
Net head	12.75 m
Nominal flow rate	2.6 m^3/s
Nominal power	260 kW
Alternator	
Type	Synchronal
Tension	380/220V
Frequency	50 Hz
Interconnection/ distribution	
Type of grid	Isolate
Production of electricity	
Producible	**2279 MWh**

3.5. The Legal Regime of Batcheu MHP

According to the law No. 022/2011 for electricity sector [11], the generation of electrical energy in a rural electrification from hydroelectric plant with an installed power of 5 MW or less than, need for legal regime just a simple letter issue by the Electricity Sector Regulatory Board (ARSEL) for the development. The MHP of Batcheu will have the same legal regime because its installed power (260 kW) is less than 5 MW.

3.6. Financial Analysis

- **Investment cost**

Establish the source of key components particularly the turbine-generator and controller Determine the range of head/flow/power outputs of available equipment. Obtain approximate cost of total scheme from turbine generator supplier and/or other schemes. Considering the others similar projects studied in the same subdivision, as MHP of KEMKEN and Bakassa river and another work about local material there some good basis of cost evaluation [5] [7] [12]. Table 2 presents prices of different section of project and give total investment cost.

- **Cash flow**

Batcheu and environing villages are rural areas, households should pay electrical energy in social range which is 50 FCFA/kWh in Cameroon [5]. In that evaluation, we consider that the using rate of the MHP is 60% [5] [13]. Since the global producible is equal to 2279 MWh, Then, the Cash-flow is CF = 68,328,000 FCFA.

- **Operating charges**

Generally, operating charges in MHP equals to the 35% of the cash-flow. Credit rate in Cameroon I about 12.5%. The inflation rate in Cameroon in 2019 was about 3% [5] [14].

Table 2. The investment cost in FCFA*.

No.	Component of the MHPP	Total Prices (FCFA)
1	Civil engineering works: Total 1 = T1	**69,215,133**
2	Metal building: Total 2 = T2	**6,000,000**
3	Turbo-generator group: Total 3 =T3	**44,762,500**
4	Equipment for transmission and supply of electricity Total 4 = T4	**22,900,000**
	Others cost (*administration and legal fees*): Total 5 = T5	**13,000,000**
	Total = T1 + T2 + T3 + T4 + T5	**155,877,633**
	Contingences 10% = I	**15,587,763**
	Grand Total	**171,465,396**

*1 Euro = 656 FCFA.

- **Profitability**

- **Net present value NAV**

The deadline of this kind of project is generally around 20 years, NAV of that project is equal to: NAV = 84,900,239 FCFA ≥ 0. The project is profitable under our hypothesis.

- **Payback period (PBP)**

The calculation of the payback period is: PBP ≈ 6 years + 11 months.

4. Discussion

The development and establishment of a MHP in Batcheu could be a driver of development in this locality. An increasing in agricultural production, livestock, fishing, and any other related activity. Given that the provision of more clean energy to the populations makes the area attractive to investments. The farmers will thus be able to better preserve their products too. Activities will generate more income, lighting and appliances for small vital needs (telephones, televisions, radios, computers, refrigerators, etc.) will no longer have enough power problems. This makes it possible to improve the quality of life there and promote the sedentarization of the populations and consequently even fight against the rural exodus which is at the origin of many social problems in the big cities.

For our study, we made several assumptions, each time considering the most unfavorable situations. With a closer look, the installed power could be raised.

Considering that it is possible to feed around one hundred households (in rural area) with 30 kW as according to Lomé and Katmandou conferences in 1979 [6] [14] [15], with the Batcheu MHP (260 kW) it will be possible to supply more than 800 households in rural areas.

However, it should be remembered that this is a complex project and other problems and constraints may arise during implementation and even during operation. Financing could also experience some difficulties in a fairly tense economic environment. The project is profitable in any case.

5. Conclusions

It was question in this work to study the feasibility of the MHP of Batcheu, to show its contribution to sustainable development in this locality and to prove that it is a profitable project. A methodology and software (Mass_hydro) previously developed in some of our works have been used.

After the study, it appears that the fallshed of Batcheu is favourable to the establishment of a MHP with an installed power of 260 kW, with an operating diagram corresponding to a Francis turbine. Given that it is a renewable energy that can supply more than 800 households in rural areas, its contribution to sustainable development is obvious.

Its investment cost is estimated at 171,465,396 FCFA. It is a profitable project with a payback time of 7 years 2 months.

The solar irradiation not being weak in this locality, a system of electricity production from two hydro and solar sources would be more efficient.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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