Micro-Hydroelectric Power Generation from Water Falls: A case Study of Erin-Ijesha water falls, Osun State, Nigeria

Gabriel.A. Adegboyega

Electrical, Electronics and Computer Engineering Department,Bells University of technology, Ota, Ogun State, Nigeria.

ABSTACT--Energy is the key stimulus for rapid industrial development of all sectors of the economy. In fact, the availability of electricity (power) is of paramount importance for the economic and industrial development of a nation. The aim of this paper is to study Erin-Ijesha Water-falls as an initiative for harnessing electric power from micro-hydro production. It is established that the obtainable head and flow rate available during the year round, Erin-Ijesha water falls should be sustainable for micro-hydro power plant. The effect on the ecosystem is very less, the ecotourism will attract visitors and the living standard of the people in the area will improve after commissioning of a micro-hydroelecric power station. Hence, the problem of in-adequate electric power production would be improved by using sustainable technology.

Keywords: Erin- Ijesha Water Falls, micro-hydroelectric, flow rate, dam head.

I. Introduction

Energy is one of the most fundamental elements in the world. Energy is used for operating machine, light homes and cities, power vehicles, trains, aeroplanes, musical equipment, television and other home appliances. Energy is a necessity for human survival in the universe. Nigeria is seriously facing energy demand predicament and the bad-state of power has been the major bane of it's under development [1]. The demand for electricity is increasing day by day for large population as well as for industries. In view of the crucial energy situation, it is necessary to find alternative sources of generating electric power. Erin-Ijesha town is very close to Efon-Alaye mountain which is full of hills, streams,rivers, springs and waterfalls. A small scale hydro-electric power station can be set up across these rivers, springs and stream from the hills. Erin-Ijesha waterfalls also known as Olumirin waterfall is situated within latitude $7^{0}30^{1}$and 8^{0} 45^{1} North and Longitude 4^{0} 3^{1} and 5^{0} East [2].

Figure1 shows Erin-IjeshaGeographical characteristics while Figure 2 shows Erin-Ijesha water fall and Figure 3 shows first level of Erin-Ijeshawater fall. The river has about seven stages and three major falls. The area is evergreen and cool. The water does not overflow its banks. It does not dry off, even during the typical dry season.

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Figure 1: Photograph of Erin-Ijesa Top Fall

Figure 2: Photograph of First Level of Erin-Ijesha Waterfall

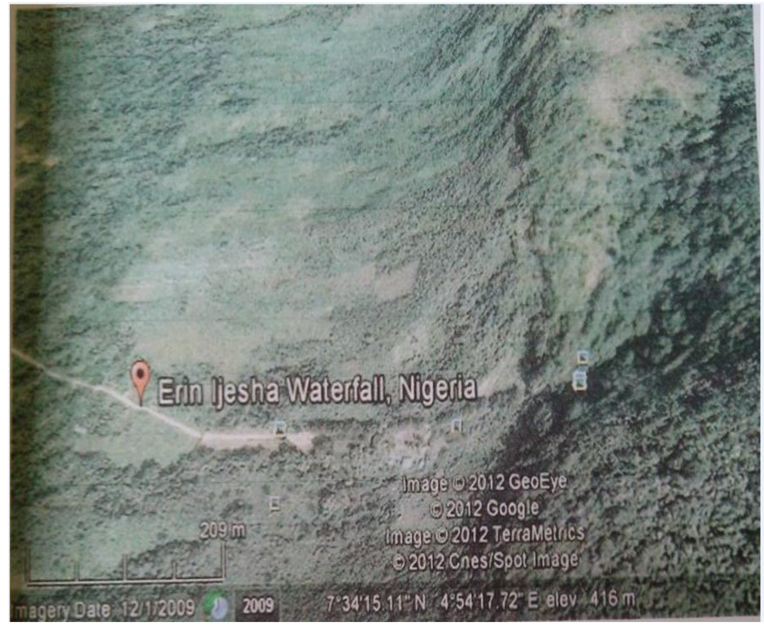

Figure 3: Geographical Location of Erin-Ijesha

Nigeria is facing energy predicament which could be improved if renewable energy is used as a primary source of energy. Hydroelectric power generation may be potential energy source for hilly areas such as Efon-Alayemountain in Ekiti state, Plateau hills and Mambila mountain in Nigeria.

Hydropower has been used in many ways over the ages and installing mini-hydro power can increase production of electric power. The Nigerian Electricity Supply Corporation (Nigeria) Limited (NESCO) was set up in 1929 to develop the hydro-electric power available from Kurra falls, utilizing the water of the Tenti and Sanga Rivers and a fall of some 235 metres to build the initial 4MW capacity all season power station to supply mining prospecting machines and equipment in the mining areas of Jos Plateau, Nigeria [3]. The system capacity was raised to 6MW in 1930 and by 1936 a further 4MW of plant was installed at Kurra falls power station bringing the system's total

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capacity to 10MW. Work was also commenced downstream of the Kurra power house at the jekko falls utilizing a head of some 200metres and the Jekko I power station of 4MW capacity was commissioned in 1938 [4,5]. Mining and public supply load demands from NESCO system was extended to Jos town in 1936 and work was undertaken on increasing the dry season water storage capacity of Kurra system. Jekko II power station was built and commissioned in 1954 with a capacity of 4MW.

In 1962 work began on the construction of a third dam at Ankuli on the Tenti River to provide increased water storage capacity and also work was put in hand to build two power stations of 1MW and 2MW capacity at Ankwil falls utilizing heads of 47 metres and 94 metres respectively [6]. In 1963 further studies of the Kwall and Jekko systems were undertaken and work began on a second power station at Kwall of 4MW capacity which was commissioned in 1967. Furthermore, in 1968 work commenced on the construction of fourth power plant on the Sanga River at Jekko falls of 4MW capacity. The main civil work was completed which included a new canal system and pipeline for this project. NESCO, now operates seven small hydro-electric power stations of a total capacity of 25MW from hydro-electric sources [7].

According to Obasanjo Reforms (2004) the Federal Government of Nigeria encouraged the participation of Independent Power Producers (IPP) in the electricity industry. Under this initiative, the IPP could build power station and sell electric power to utility companies. Hence, policy directions for power sector, where the private sector was expected to play a key role in power sector development activities,private sector financing will be utilized for power generation from small hydro power plants. The main objectives of this paper are to study and find proper location for micro-hydroelectric power generation, to measure the available height, flow rate and estimate possible power output from generation plant [7].

Pico-hydroelectric and Micro-hydroelectric plants are the smallest type of hydroelectric energy systems capable of generating between hundred watts up to one kilowatts of power (Micro Hydro Systems, 2007). Micro hydro system is well –Known principle of using water to drive a turbine and generate electricity. Infact, not only that Micro hydro is non-polluting energy source, but also it is much more efficient than the burning of fossil fuels for electricity generation. Coal fired power station which is the most common energy is not as efficient as micro hydro power. Efficiency of micro hydro units range from 60% to 90% while modern coal fired units are from 43% to 60% efficient.(Beckett et al,2006).

Hydro power is the generation of electrical energy by harnessing water’s Kinetic energy due to gravity. Hydro power is centered on the efficiency of the energy converting process power to electrical energy. In hydro power, the kinetic energy of the water depends on two aspects, head and flow. The head refers to the vertical distance the water travels and the flow refers to the volume of water that passes through the turbine in a given amount of time.(Beckett et al, 2006). The head of a site is the vertical distance from the source surface to the point of the water outflow. (Energy Efficiency and Renewable Energy, 2007)

The flowing water moves through the converting system and pushes the turbine to rotate. The rotation of the turbine is turned into electricity by the

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generator whose shaft is coupled to the turbine shaft.Micro hydro power is a site-specific type of renewable energy. As a result of this, each different site requires a separate evaluation in order to determine the energy output.A summary of small hydro power potential Distribution in Nigeria [8].

II. Theoretical Power Produced in a Hydro Plant

Let mkg of water be stored at an altitude in metres above the turbine position. If acceleration due to free fall is g/ms^2 then the potential energy E_p of the water at that altitude is given by

$$E_P = mgh \quad \text{Joules} \quad (1)$$

Since density d, of a substance is the ratio of the mass to the volume V,

That is,

$$D = \frac{m}{V} \quad kgm^{-3} \quad (2)$$

$$\text{Then} \quad m = Dv \quad (3)$$

Substituting equation (3) into (1) yields

$$E_P = dvgh \quad \text{Joules} \quad (4)$$

Since density of water is 1000 kgm^{-3}

$$E_P = 1000vgh \quad \text{Joules} \quad (5)$$

But power is Energy per unit time

$$\text{Therefore,} \quad P = \frac{1000\,vgh}{t} = 1000\frac{v}{t}gh \quad \text{Watts} \quad (6)$$

Where $\frac{v}{t}$ is the flow rate q of water in m^3s^{-1} as it runs through the penstock towards the turbine.

$$\text{Therefore,} \quad P = 1000qgh \quad \text{Watts} \quad (7)$$

If turbine/ generator assembly efficiency is taken into consideration and represented by a constant ɳ, the power is given by

$$P = 1000\eta ghq \quad \text{Watts} \quad (8)$$

When both the head and the flow data are measured, the potential power can be obtained using Equation (9) [9]

$$P = 9.81 \times Q \times H \quad (9)$$

Where P is the potential Power in Kilowatts, Q is the flow in m^3s^{-1} and H is the head in metres.

III. Materials and Method

When rain water falls over the earth's surface, it possesses potential energy relative to sea or ocean towards which it flows. As the water falls through a certain vertical height, its potential energy is converted into Kinetic energy and this kinetic energy is converted to the mechanical energy by allowing the water to flow through the hydraulic turbine runner. This mechanical energy is utilized to run an electric generator which is coupled to the turbine shaft (Raja et al, 2006).

The power developed by this system is given as:

$$\text{Power} = WQH\eta \quad \text{Watts} \quad (10)$$

Where W is specific weight of water, N/m^3

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Q is the rate of water flow, m^3/sec.

H is the height of fall or head, m

ɳ is the efficiency of conversion of potential energy into mechanical energy.

The generation of electric energy from falling water is only a small process in the mighty power cycle known as Hydrological cycle or rain evaporation cycle.

Data on rainfall in the proposed pico/micro- hydro station area were collected for fifteen years from Nigeria Metrological Centre, Osogbo, Osun State. These data spans through the year 1998 to 2013, with a peak rainfall of 1697.8mm in 2010.

According to Osun State Tourism Board, the elevation of Erin- Ijesha waterfalls was measured to be 200 feet or 60.6 metres. The flow rate of water fall was measured with a bucket and using a stop watch for timing the period to fill the bucket. The time taken to fill 9 litres bucket ranges from 2.5 seconds to 6.2 seconds.

Power output = 1000 × Head × Flow × acceleration due to gravity. (11)

Using Ninelitres bucket and a stop watch, the flow rate was obtained using equation (12)

$$\text{Flow rate} = \frac{9\ litres\ \ m}{Time\ taken\ to\ fill\ up\ the\ bucket\ \ (seconds\ )} \quad (12)$$

IV. Results and Discussion

Flow rate can be calculated for each month in the dry and rainy seasons, that is November to March and April to October respectively, and power that could be generated was calculated using the highest figures and the values obtained are shown in Table 1

Table 1. Monthly Highest Flow rate andand Highest power generated at an instant.

Months	Flow Rate (m^3/s)	Power Output (Kwatts)
November	1.5	891.729
December	1.46	867.94
January	1.45	862.00
February	1.46	867.94
March	2.7	867.94
April	2.7	1605.1
May	2.73	1622
June	2.83	1664
July	2.89	1718
August	3.3	1783
September	3.5	1812
October	3.6	1863

Micro hydro will be major source supplying the short- fall of energy needs in the country by harnessing the water falls in various locations. From Figure 4, the minimum flow rate was m^3/s and the maximum flow rate was m^3/s while from Figure 5, the minimum power output was KW and the maximum power output was KW.

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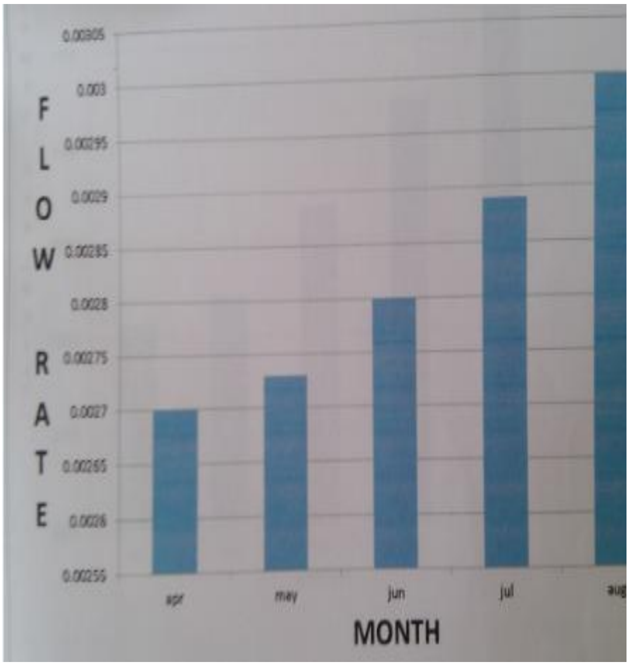

Figure 4: Monthly Variation of Flow Rate

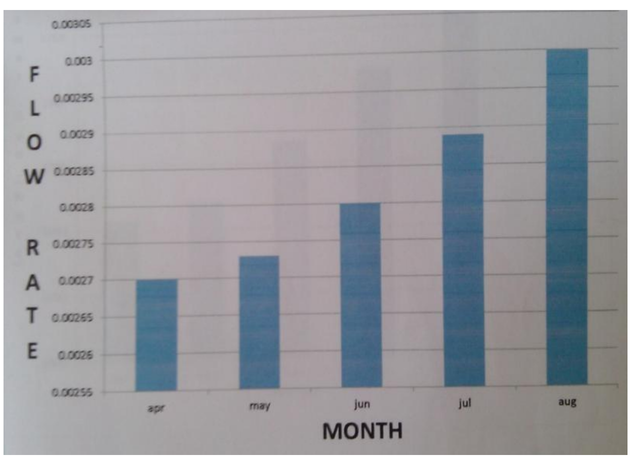

Figure 5: Monthly Variation of Power

V. Conclusion

Based on the results obtained, Erin- Ijesha water falls could be prospective sites for micro hydro generation for added immediate breakthroughs for energy needs necessary to meet electricity demand goal of the country. With the available head and flow rate a Kaplan Turbine or a water wheel will be the best for the electricity production and the generator should be flexible enough to cover the range 700- 2000 Watts .

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