

THE DEVELOPMENT OF MICRO-HYDROPOWER PROJECT: A CASE STUDY OF RIVER AWERE, OSUN STATE, NIGERIA

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ABSTRACT: Nigeria, with a population of about 180 million, needs more energy to survive the increasing population of citizens. It is very pertinent to develop the renewable resources in large quantities to complement the existing non-renewable resources (fossil fuels). It is necessary to develop River Awere in Konta community of Osun State to generate electricity because of insufficient power supply and incessant power outage owing to technical problem and a host of other challenges. River Awere is a run-of-river (with several days' storage) and can be developed as a Micro-Hydro Power (MHP) project. Research conducted revealed that the total technically exploitable hydropower potential of River Awere is estimated to 32.37 kW. The flow rate recorded during the feasibility study was 0.25 m³/s while the peak head measured was 2.2 m on the deepest section of the river. A total of 12 deep sections across the river were counted within Konta community. Although the water resource of the river has not been harnessed at all to generate electricity but the water can be developed with solar energy as a hybrid system to cater for low power supply from the river during the dry season. This paper reports the feasibility of such MHP in alleviating the identified problems of electric power supply at Konta community in Osun State, Nigeria using River Awere as a case study. The results obtained are adequately presented in the report.

Key words: River Awere, MHP, Flow rate, Head, Hybrid system, Konta community.

1. INTRODUCTION

Hydropower is a renewable source of energy that is suitable for both rural and urban electrification. In Nigeria, despite the cluster of small rivers in virtually all the states, only 30 MW of small hydro power (SHP) has been developed out of an estimated 734.2 MW [8] while large hydro power installed capacity is about 1936 MW out of an estimated 10,000 MW of hydropower potential of Nigeria's river system. This indicates that energy from water resource has not been fully harnessed for small hydropower development. Hydropower system is accessible in terms of sustainability and affordability. It is a clean, renewable and reliable energy resource. Hydropower system uses the natural, hydrologic cycle to generate electricity. Hydropower system has high capacity factor; has high level of predictability and it is a long-lasting and robust technology-system that can readily be engineered to last for 50 years or more. The objectives of this study are: to develop an indigenous technology to harness the renewable energy in run-of-river to generate electricity for Konta community; to promote the establishment of decentralized energy supply scheme which is cost effective and environmentally friendly; to enhance the quality of life of dwellers in Konta through independent community energy development programmes.

1.1 Hydropower in Nigeria

The large proportion of power production in Nigeria was from coal as the source of fuel for thermal power system before 1960. Construction activities on the first hydropower station in Nigeria started in 1964 at Kainji on River Niger. The dam was commissioned in 1968 with an installed capacity of 320 MW, and by 1978, the station had 8 plants with capacity of 760 MW. Later on, the tail water from Kainji Dam was used to generate 540 MW at Jebba Dam, which is 97 km downstream of Kainji Dam. The third hydro-electric power (HEP) station, the Shiroro Dam was commissioned in 1990 with 600 MW installed capacity. The total installed capacity of HEP of the three major hydropower stations (Kainji, Jebba and Shiroro) is about 1900 MW [7]. There are some small hydropower stations, such as 3 MW plant in Bagel, 8 MW plant in Kura and 8 MW in Lere, 2 MW Station at Kwall fall on N'Gell

river (River Kaduna), 6 MW station at Tiga and 3 MW at Bakalori. The cumulative capacity of hydropower stations (small and large) is about 2000 MW. This accounts for 32% of the total installed capacity of hydro, thermal and gas power stations in Nigeria. The development of 2500 MW Mambilla hydropower station is in progress and the country still has potential for about 6000 MW hydropower stations. Nigeria has just developed 23% of her feasible hydropower [15]. This percentage is very low compared to other African countries such as Lesotho which has developed 50% of her hydropower potential; Burkina Faso developed 46%, while Kenya has developed 34% of her hydropower potential [11]. Research conducted recently disclosed that the total technically exploitable hydropower potential (a renewable source of energy) of Nigeria's river system is estimated to be around 10,000 MW of which about 1966 MW is currently being tapped. Large hydro power installed capacity is about 1936 MW while small hydro power (SHP) installed capacity is about 30 MW. Thus, the energy from water resource has not been fully harnessed to generate electricity.

1.2 Fossil Fuels and Environmental Pollution

The environmental pollution associated with the extraction and production of fossil fuels is very significant and detrimental to human health and animals. Also, the flaring of gas in Nigeria results in the release of associated gases which have been linked to global warming and climate change [12]. The release of greenhouse gases, particularly methane and carbon dioxide during flaring continues to contribute to climate change and its attendant impacts. [13] stated that 'the burning of fossil fuel, mainly coal, oil and gas greenhouse gases; has led to the warming up of the world and is projected to get much worse during the course of the 21st century, according to the Intergovernmental Panel on Climate Change (IPCC)'. The proportion of emitted greenhouse gases that is contributed in Nigeria is larger when compared with that of the total combined sources from sub-Saharan Africa; the problems resulting from global warming are very grave indeed. This necessitates the need for the development of small hydropower (renewable energy) that is devoid and free of environmental pollution unlike non-renewable energy sources in Nigeria.

1.3 World Small Hydropower Development

In the global SHP sector, China is the major player, driven by long-standing rural electrification programmes from the government. The International Network on Small Hydropower (INSHP) latest figures reveals an installed SHP capacity of 31,200 MW in 43,000 stations; China alone has developed more than half of the world's small hydro capacity and represents the bulk of installed capacity in developing countries. Growth in the Chinese SHP sector remains strong at 9% per year and there are plans to develop a further 10,000MW in the next decade. Other developing countries with large SHP capacity are India (1,694MW), Brazil (859MW), Peru (215MW), Malaysia and Pakistan (both 107MW), Bolivia (104MW), Vietnam (70MW), the DR Congo (65MW), Sri Lanka (35MW) and Papua New Guinea (20MW), while Russia and the Central Asian states also have significant amounts installed (totaling 639MW). In the last 30 years, China, Nepal, Vietnam and many South American countries have seen a large number of micro and pico hydro projects developed that are providing electrification to many thousands of households. Chinese villages have developed the most micro-hydro with 100,000 very small capacity units installed, amounting to 188.5MW and rural families in Vietnam have installed 130,000 pico-hydro systems (usually 200 Watts) in the last 15 years on a purely commercial basis. Currently, small hydropower plants with a capacity of 10 MW exist in 148 countries or territories worldwide. The findings of World Small Hydropower Development Report (WSHPDR 2013) reveal that small hydropower potential globally is approximated at almost 173 GW. The figure is arrived by totaling data from a wide range of sources with potential compromise of data integrity to varying degrees [9]. For instance, research data on economically feasible potential were more readily available in developed countries than those in the least developed or developing countries. More than half of the world's known hydropower potential is located in Asia, around one third can be found in Europe and the Americas. It is possible in the future that more small hydropower potential might be identified both on the African and American continents. The installed small hydropower capacity (up to 10 MW) is estimated to be 75 GW in 2011/2012.

1.4 Existing Small Hydropower Scheme in Nigeria

There are few small hydropower plants currently in operation in Nigeria that have been constructed simply because they constitute, among other competing alternatives, the most cost-effective means of providing cheap and reliable electricity for the intended end uses. Table 1 depicts such existing small hydropower plants. Table 2 depicts small hydro potentials in surveyed states of Nigeria while Table 3 shows the small hydro potential sites in some south-western states of Nigeria.

Table 1 Existing Small Hydropower Plants in Nigeria [14]

No.	Location	River	Design Head & Flow rate		Installed Capacity (MW)
			Head (m)	Flowrate (m ³ /s)	
1.	Plateau	Bangel I	60	1.7	1.0
2.	Plateau	Bangel II	60	3.4	2.0
3.	Plateau	Kurra	115	7.09	8.0
4.	Plateau	Lere I	85	4.80	4.0
5.	Plateau	Lere II	85	4.80	4.0
6.	Sokoto	Bakalori	19	15.4	3.0
7.	Kano	Tiga	28	20	6.0
8.	Plateau	Oure	60	3.2	2.0

Table 2 Small Hydro Potentials in Surveyed States (pre1980) of Nigeria, [2]

S/N	State	River Basin	Sites	Total MW
1	Bauchi	Upper Benue	20	42.6
2	Benue	Lower Benue	19	69.2
3	Borno	Chad	28	20.8
4	Kaduna	Niger	19	59.2
5	Kano	Hadejia-Jamaare	28	46.2
6	Kastina	Sokoto-Rima	11	8
7	Kwara	Niger	12	38.8
8	Gongola	Upper Benue	38	162.7
9	Niger	Niger	30	117.6
10	Plateau	Lower Benue	32	110.4
11	Rivers	Cross River	18	28.1
12	Sokoto	Sokoto-Rima	22	30.6

Table 3 Small Hydro Potential Sites in Some South-West States of Nigeria [8]

S/N	States	Sites	Cumulative Estimated Power (MW)
1	Ekiti	6	1.2472
2	Ogun	13	15.610
3	Ondo	1	1.300
4	Osun	8	2.622
5	Oyo	3	1.062
Total		31	21.8412

1.5 Hydropower System of River Awere

The objective of this study is to utilize surface water abstraction for the development of mini-hydropower project for the inhabitants of Konta community. It includes the preliminary and feasibility studies of the adequacy of 'River Awere' for micro-hydropower project. River Awere is situated at a distance of about 30m from Konta motor garage and about 20m from the railway terminal in Okuku community. Also, River Awere flows across the borderline between Okuku community and Konta community. The length of the river is 1.2km with a breadth of 4.1m. A total of 12 sections/sites were counted across the river with the peak heads of 2.2m each measured on the deepest sections of the river. The flow rate recorded during the feasibility study was 0.25m³/s. The development of the project will involve construction of dam (civil works) on the river, installation of turbines and fittings, transmission and distribution systems/lines, poles and transformers. The project area is Konta community. It has an approximate area of 8.96 km² (3.2km x 2.8km).

1.6 Population

The population estimate of Konta community at the time of this study year 2014-2015, is 8,500 people and this has been projected to be 12,000 by year 2025.

1.7 Climate and Vegetation

The climate is tropical. The rainy season is from March to November (9 months) with a short break in August. The dry season is from December to February (3 months). The average monthly rainfall varies from 42mm to 230mm. The temperature is usually hot and uniform at 33°C ± 2 throughout the year. The relative humidity is 93% in wet season and 44% in dry season. The rate of evaporation is estimated at 1522mm per km² per day.

1.8 Geology

The form of the river valley is similar to a dominant north – south geological pattern. The sections contain rocks which consist of gneiss complex of sedimentary source and older intrusive rocks lay in the gneiss.

2. METHODOLOGY

2.1 The Development of Small Scale Hydropower

From the classifications of various hydro schemes provided in Table 4, the small, mini and micro hydro schemes referred to as small scale are of specific interest for the task of meeting part of the energy requirements of some rural communities.

Table 4 Classification of Various Hydro Schemes, [1]

Scale of Hydro Scheme	Capacity Range (MW)
Large	100
Medium	> 50-100
Intermediate	10-50
Small	1-10
Mini	0.5-1.0
Micro	< 0.5

2.2 Planning a Micro-Hydropower (MHP) Scheme

The final implementation of a MHP plant is the result of a complex and interactive process, where consideration is given to both environmental impacts and different technological options as evaluated from the economic perspective. The list of the studies that should be undertaken include topography and geomorphology of the site, evaluation of the water resource and its generating potential, site selection and basic layout, hydraulic turbines and generators and their control, environmental impact assessment and mitigation measures, economic evaluation of the project and financing potential, institutional framework and administrative procedures to attain the authorizations [4].

2.3 Hydrological Data of River Awere

The topological survey of the dam site was used to determine the effective water head. Hydrological data (head and flow rate) were collected daily for a period of 9 months (March-November, 2017). Before a hybrid system can be developed, it is important to know the daily characteristics of solar radiation parameters such as sunshine hours; insolation; cloudiness index etcetera.

The peak head (H) measured was 2.2m

Flow rate (Q) was $0.25 \text{ m}^3/\text{s}$

Number of sections/sites = 12

2.4 Production of Electricity by MHP Plant of River Awere

The basic principle of hydropower is to transform the potential energy of water into mechanical energy available at a turbine shaft and afterwards into electricity through a generator. Water can be piped from a certain higher level to a lower level. Then the resulting water pressure and kinetic energy can be used to do some useable work. The main requirement is to have a 'head' so that water, diverted through an intake channel or a pipe (the penstock) into a turbine, discharges back into the river downstream. It is normal to achieve optimum energy conversion efficiencies with all types of hydraulic turbines in the range of 80 up to over 90%. The potential power that can be generated will be calculated from the theoretical power (P), Flow rate (Q), Head (H) and Gravity (g). Where Q is in cubic metres per second, H in metres and $g = 9.81 \text{ m/s}^2$ [5]. Power will also be lost in the pipe carrying the water to the turbine, due to frictional losses. By careful design, this loss can be reduced to only a small percentage. A rough guide used for small systems of a few kW rating is to take the overall efficiency as approximately 50% [6]. The theoretical power will then be compared with the experimental results when measurements of mass, flow rate and head are recorded after installation and testing. In order to use the electricity produced by the MHP plant it should be transmitted to the final user through the transformer and the grid.

$$P = 9.81 \times Q \times H \quad \text{kW}$$

However, energy is always lost when it is converted from one form to another. Small water turbines rarely have efficiencies better than 80%. Power will also be lost in the pipe carrying the water to the turbine, due to frictional losses. By careful design, this loss can be reduced to only a small percentage. A rough guide used for small systems of a few kW rating is to take the overall efficiency as approximately 50% [6]. Thus, the theoretical power is multiplied by 0.50.

$$Q = 0.25 \text{ m}^3/\text{s}, \quad H = 2.2 \text{ m} \quad g = 9.81 \text{ m/s}^2 \text{ (hydrological data from Awere River).}$$

$$P = 9.81 \times 0.25 \times 2.2 \times 0.5$$

$$P = 2.69775 \text{ kW, for 12 sections of the river, } P = 12 \times 2.69775 = 32.37 \text{ kW}$$

From the theoretical power calculation, the estimated power is 32.37 kW.

After the installation of turbine, pipes and network, fittings, generator and control equipment; measurement of mass of 'runner and shaft' will be recorded. Angular speed of the Francis turbine shaft and radius of the turbine shaft will also be measured and recorded.

Mass of runner and shaft, m (kg),

radius of the turbine shaft, r (m),

Angular speed of the turbine, w (rad/s) , [10].

$$Power(P) = Force (F) \times Velocity (V) \quad P = m \times g \times w \times r \text{ (since } F = mg \text{ \& } V = wr) \\ 2$$

$$Turbine \text{ efficiency} = \frac{Power \text{ output}}{Power \text{ input}} \times 100 \%$$

During the dry season of each year, the average rotational speed of the turbine shaft will be measured and recorded as well.

3. RESULTS AND DISCUSSION

Instrumentation

The hydraulic head was measured using topographical survey instrument (Fiberglass measuring tape-100'/30m and metal poles) while flow meter was used to measure the flow rate of the river.

Advantages of SHP Plants over Large Hydropower Plants

China has long discovered that SHP has benefits that cannot be achieved through large or mega hydro stations, for instance SHP construction results in fewer environmental impacts and does not require the displacement of people. In addition, SHP technology is simple and can be easily understood and transferred to a variety of communities. Since most SHP stations have their own supply areas and local grids, they can supply electricity to local people as well as connect to larger grids. This enables these

Table 5: Hydrological Data of River Awere

Number of sections/sites	Head (m)	Flow rate (m ³ /s)
1	2.2	0.25
2	2.2	0.25
3	2.2	0.25
4	2.2	0.25
5	2.2	0.24
6	2.2	0.25
7	2.2	0.25
8	2.1	0.25
9	2.2	0.25
10	2.2	0.25
11	2.2	0.25
12	2.2	0.25
Total (12 sections)	Peak head = 2.2	Average flow rate = 0.25

stations to maximize profits by purchasing electricity from the large grid in times of low generation and sell it back when there is surplus generation capacity according to European Small Hydropower Association [3]. These benefits will equally be achieved in greater percentage if SHP plants are funded and developed in large quantities in Nigeria, especially in remote community like Konta community for rural electrification.

From the theoretical power calculation, the estimated power is 32.37 kW.

4. CONCLUSION

Micro-Hydropower (MHP) project at River Awere is a renewable energy source and suitable for rural electrification in Konta community. It is a proven technology that can be connected to the main grid, used as a stand-alone option or combined with irrigation systems. This renewable MHP project will help decrease carbon dioxide gas emissions, contribute to climate change mitigation; contribute to poverty alleviation and economic development.

This paper gives a report of a case study and provides suggestions for the development of hydropower potential at River Awere to meet the energy requirements of Konta community in Odo-Otin Local Government area of Osun State, Nigeria. Also, this paper makes use of existing database on some viable rivers and streams in Nigeria. It is concluded that the development of hydropower potential at River Awere with an estimated power output of 32.37 kW for rural electrification scheme and other applications is very viable and can be developed as a hybrid system with solar energy to cater for low power production during dry season.

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REFERENCES

- [1] Aribisala, J. O. (2011). "Small Hydropower Project: A Case Study of River Elemi, Ekiti State". 'www.unilorin.edu.ng/nachrede/small.hydropower.project'.
- [2] Awogbemi, O. and Ojo, A. O. (2012). *Small Hydro Power for Rural Electrification in Nigeria*. American Journal of Science and Engineering, Vol. 1, No.2, 2012.
- [3] European Small Hydropower Association (ESHA¹). (2003). *Brochure of SHP for Developing Countries*, Renewable Energy House, 63-67 Rue d'Arlon-B-1040 Brussels, Belgium.
- [4] European Small Hydropower Association (ESHA²). (2003). *Hydropower Technology, Small Hydropower (SHP)*, Renewable Energy House, 63-67 Rue d'Arlon-B-1040 Brussels, Belgium.
- [5] European Small Hydropower Association (ESHA). (2004). *Guide on How to Develop a Small Hydropower Plant*. Renewable Energy House, 63-67 Rue d'Arlon-B-1040 Brussels, Belgium.
- [6] Intermediate Technology Development Group (ITDG). (2001). *MICRO-HYDROPOWER Practical Answers to Poverty*. Technical Brief. ITDG Publishing, IT Power, Stockholm Environment Institute.
- [7] Jimoh, O.D. (2006). *Operation of Hydropower Systems in Nigeria*. Department of Civil Engineering, Federal University of Technology, Minna, Niger State, Nigeria.
- [8] Kela, R., Usman, K. M. and Tijjani, A. (2012). *Potentials of Small Hydro Power in Nigeria: The Current Status and Investment Opportunities*. International Journal of Scientific & Engineering Research. Volume 3, Issue 5, 2012.
- [9] Liu, H., Masera, D. and Esser, L., eds. (2013). *World Small Hydropower Development Report 2013*. United Nations Industrial Development Organization (UNIDO); International Center on Small Hydro Power. 'www.smallhydroworld.org'.
- [10] Odesola, I.F., Atoyebi, M.O., Olatunbosun, A. and Zubair, A.R. (2012). *Installation and Testing of a 5kW Hydropower Turbine*. Journal of Natural Science, Energy and Technology, Vol.11, No. 2, Nigeria.
- [11] Okpanefe, P. E. and Owolabi, S. (2002). *Small Hydropower in Nigeria*. 2001 TCDC Training Workshop on SHP. SHP News, Spring 2002. <https://hrshp.org>
- [12] Oni, S.I. and Oyewo, M.A. (2011). *Gas Flaring, Transportation and Sustainable Energy Development in the Niger-Delta, Nigeria*. Department of Geography, University of Lagos, Lagos, Nigeria, Kamla-Raj 2011, J Hum Ecol, 33(1): 21-28 (2011).
- [13] Osuoka, A. and Roderick, P. (2005). *Gas Flaring in Nigeria: A Human Rights, Environmental and Economic Monstrosity*. A joint report written by the Environmental Rights Action/ Friends of the Earth, Nigeria and The Climate Justice Programme, Amsterdam: Press.
- [14] Thierno, A.D. (2007). *Small Hydropower (SHP) in Selected Countries in West Africa*. Synthesis of Country Papers presented during the Expert Group meeting on SHP Development in West Africa, United Nations Industrial Development Organization (UNIDO), 6-8 August, Abuja, Nigeria.
- [15] Zarma, I. H. (2006). *Hydro Power Resources in Nigeria*. Being a Country Position Paper presented at 2nd Hydropower for Today Conference International Centre on Small Hydropower (IC-SHP), Hangzhou, China 2006.