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Hydropower Potential of Nigeria

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ABSTRACT: *The quest for economical growth and development coupled with the need to have a secured environment necessitated the adoption of alternative energy technologies, one of which is hydropower technology. This paper brings to fore the hydropower resources, dams and river basins of Nigeria. It touches on the hydropower challenges and possible ways out of the problems associated with our hydropower dams. Corporate analysis of per capital electricity consumption worldwide is discussed as it concerns the subject matter. Basic design considerations of hydro dams are also highlighted.*
Keywords: *Hydropower, electricity, resources, environment, Station.*

I. INTRODUCTION

The earth as a planet is majorly covered with water. Two-third of it according to the geographers is water filled. Nigeria as a country is not exempted in this opportunistic discovery, the water resources sector in Nigeria holds enormous potentials which can be harnessed for rapid socio-economic development of the country. The Nigeria land is well drained by perennial rivers, streams and springs. Water power from flowing rivers and streams can be harnessed by building dams to hold the water which can be used to generate electricity through the use of turbines. In the mid 19th century the first effective water turbine was discovered, however, today the modern turbines are compact, highly efficient and are capable of turning at a very high speed to deliver the expected output. Hydropower is a proven technology, renewable, eco-friendly and can integrate easily with irrigation and township water supply project (Sule B.F 2010). The National Water Resources Master Plan estimates about $267.3 \times 10^9 m^3$ of surface water and about $52 \times 10^9 m^3$ of ground water per year (FMWR), (Imo E. 2012). It appears very little has been done to exploit these abundant resources and other sources of renewable energy, their technologies and their development through Research and Development (R&D) have not been given priorities by the previous successive Governments.

Nigeria is currently embarking on and proposing the construction of large hydropower dam projects such as Zungeru (950MW), Beji (240MW), Mambila (2,600MW), Kashim Bila (30MW), Gembu (130MW), Gurara Dam (30MW) and a number of thermal plants. The expectation of Nigeria to be among the top twenty economically viable countries by the year 2020 popularly known as 20:2020 to be realistic, a drastic approach and actions that will ensure reliable and sustainable energy through power supply has to be taken. All hands must be on deck.

Hydropower Categorization

The hydropower sources can be classified according to their sizes and a particular consideration must be given to the technological ability of the region where the categorization is been carried out for proper classification to be done. The classification varies from region to region. As far as a developing country like Nigeria is concerned, the classification below can be acceptable according to UNIDO;

- Large Hydropower: Hydropower Dam with output electricity potential of not less than **10MW.**
- Small Hydropower: Hydropower Dam with output electricity potential between 1-10MW.
- Mini Hydropower: Hydropower Dam with output electricity potential between 100-1,000kW.
- Micro Hydropower: Hydropower Dam with output electricity potential which is less than 100kW.

The developed world's categorization of the hydropower sources is as stated below;

Large Hydropower	More than **50MW**
Medium Hydropower	30MW to 50MW
Small Hydropower	100kW to 30MW
Micro Hydropower	3-5kW to 100kW
Pico-hydropower	3-Less than 5kW.

Global Overview of Hydropower

The African Continent is endowed with enormous hydropower potential that needs to be harnessed. Despite this huge potential which is enough to meet all the electricity needs of the continent, only a small fraction has been exploited. This could be due to the major technical, financial and environmental challenges that need to be overcome for the development of this resource base (Sirte, 2008). Hydropower currently makes about 20% contribution to the global electricity supply, second to fossil fuel. It is anticipated that the global demand for electricity will increase steadily and the growth for hydroelectricity is projected at 2.4% – 3.6% from 1990 – 2020. A large number of hydropower development projects with a total capacity of around 100,000MW are currently on-going globally. The greatest contribution to current hydropower development is coming from Asia (84,000MW). The contributions from the other regions are as follows: South America (14,800MW),

Africa (2,403MW), Europe (2,211MW) and North & Central America (1,236MW) (Bartle, 2002).
Energy security and access challenges are the main issues to address in terms of the developmental agenda of Africa for the attainment of the Millennium Development Goals (MDGs). Hydropower has a great role to play in solving Africa's energy security and access issues. Small hydro is attracting worldwide attention due to its short gestation period. Of all the non-conventional energy resources, small hydro represents the highest density of resource. Global installed capacity of Small hydro is around 50,000MW against the estimated potential of 180,000MW (Baidya, 2006). SHP plays a crucial role in remote off-grid hydropower development. Asia and particularly China is set to become the leader in SHP development. By the end of 2007, China's SHP installed capacity was 47,380MW from 50,000 SHP stations. Canada with a long tradition in using hydropower is currently developing SHP to replace diesel generation. Australasia-Oceania region makes the least contribution to global hydropower capacity. In countries such as Australia and New Zealand, present developments are focusing on SHP plants (Sirte, 2008). Africa countries are also directing efforts toward the development of both the Large and Small Hydro Power (LSHP) schemes.

Installed Large Hydropower in Some African Countries

Country	Sub-Region	Capacity
Egypt	North Africa	2 810
DRC	Central	2 440
Mozambique	Southern Africa	2 180
Nigeria	West Africa	**1 938**
Zambia	Southern	1 634
Morroco	Northern Africa	1 205
Ghana	West Africa	1 072
Total		**13 279**

Source: International Journal on Hydropower & Dams, 2004

Review Of Hydropower Systems In Nigeria

Before 1960, the bulk of power production in Nigeria was from coal as the source of fuel for thermal power system. Construction activities on the first hydropower station in Nigeria commenced in 1964 at Kainji on River Niger. The dam was commissioned in 1968 with an installed capacity of 320MW, and by 1978, the station had 8 plants with capacity of 760MW. Later on, the tail water from Kainji Dam was utilized to generate 540MW at Jebba Dam, 97 km downstream of Kainji Dam. The third Hydro-Electric Power (HEP) station, the Shiroro Dam was commissioned in 1990 with an installed capacity of 600MW bringing the total installed capacity of Hydro Electric Power (HEP) in Nigeria to 1900MW. There are a number of small hydropower stations, such as 3MW plant in Bagel, 8MW plant in Kura and 8MW in Lere, 2MW Station at Kwall fall on N'Gell River (River Kaduna) and 8MW station at Kurra fall. The cumulative capacity of hydropower stations (small and large) is about **2000 MW**. This accounts for 32% of the combined installed capacity of hydro, thermal and gas power stations in Nigeria. The development of 2500MW Mambilla hydropower station is in progress and the country still has potential for about 6000MW hydropower stations. Nigeria has just developed 23% of her feasible hydropower. This 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 (Opanefe and Owolabi, 2002, Zarma, 2006, Jimoh O.D, 2009).
There are over 278 unexploited hydropower sites with total potentials of around 734.3MW. So far about eight (8) small hydropower stations with aggregate capacity of 37.0MW have been installed in Nigeria by private company and the government.

Nigeria River Basins Identified Hydropower Potential Sites

Organization	Potential site	Status	Capacity
Upper Benue River Basins Development Authority	• Jada Dam • Monkin Dam • Kiri Dam • Waya Dam • Dandinkowa Dam	Pre-feasibility level	5MW 500kW 1083kW 61.8kW 33kW
Owena Benin River Basin Development Authority	• River OWENA • Ele River • River Okhuanwan	Pre-feasibility level	1.3MW 1.29MW 600kW
Anambara–Imo River Development Authority	• River Igwu • Imo River • Ivo River	Identified	7.55 kW
Chad Basin Development Authority	• Biu site • Janga Dole Dam site • Majeekin Dam site	Identified	
Ogun-Oshun River Basin Development Authority	• Oyan River Dam • Ikere Gorge Dam • Lekan Are Dam • Oke-Odan • Eniosa • Ofiki I • Ofiki II • Sepeteri I • Sepeteri II • Okuku • Igbojaiye	Pre –feasibility level	9MW

ECN Publications 2009.

The Hydropower Dam Potential Estimation.

The potential of a typical dam site can be estimated using the formula below, where P is the Power in kW, Q is the discharge for Power generation (Flow Rate) that has a value which varies from river to river but for Asa dam (Sample) of 12.09m^3/s, H is the Net Head, ρ is the density of water, E_t is the Turbine Efficiency and E_g is the Generator Efficiency.

$P=9.81\times Q\times H\times E_t\times E_g$.

For **Asa Dam** Potential, we have:

H=25m, E_t=80%, E_g=95% (Hydrological Data)

Therefore;

P=9.81×12.09×0.8×0.95=2253.4kW=**2.25MW**

Relevant Details of the Asa Dam

S/N	Item	Details
A	**Dam Details**	
1	Overall Length	597m
2	Storage Capacity	43Mm3
3	Extent of Lake	18km

B	**Earth Embankment**	
1	Length	402m
2	Crest Width	6m
3	Maximum Height	27m
4	Slope	1:3 upstream, 1:2.5 downstream.
5	Earth Fill	250,000m3
C	**Non Overflow Concrete Section**	
1	Length	130m
2	Crest Width	6m
3	Maximum Height	11m
D	**Spillway**	
1	Length	65m
2	Height	14m
3	Discharge (Max)	79,000m3

Source: Kwara State Water Board, Ilorin.

Design and design requirements for hydropower dam.

A high level carefulness is desirable in the design and construction of hydropower dams and of course, certain requisite conditions must be met before a sustainable and long lasting hydro power stations can be put in place. Design simplification and adoption of alternate technologies can offer saving in costs. Design does not go all alone, in the process planning and construction have to be in consideration while the design is going on.

Design

The following are some of the necessary conditions and studies that have to be carried out for a standard design of hydropower dam;

- Topography and geomorphology studies of the sites.
- Evaluation of the water resources and their generating potentials (hydrological study)
- Site selection and basic layout
- Hydraulic turbines and generators and their control (Choice)- Cross flow is versatile, {Pelton and Turgo for High Head}, {Kaplan and Francis for Low Head}
- Environmental Impact Assessment (EIA) and mitigation measures
- Economic evaluation of the projects and financing potentials
- Institutional framework and administrative procedures to attain the authorization.

Planning

The planning should among other things include;

– Optimization of schemes considering optimum development of a particular basin

– Optimization of civil component structures during planning phase

– Cost reduction in civil structures in Hydropower plants to be ensured based on cost optimization or power optimization

– Planning and implementing of hydropower schemes as MP project linking them with other areas such irrigation, fishery, drinking water, flood control, tourism and environment**.**

II. CONSTRUCTION

Though the construction work takes the rear position in the execution of hydropower project, nevertheless, the way and manner to carry it out should be included in the planning and design processes.

Before award of works, all requisite clearances and land acquisition should be obtained so that time overruns can be reduced. While developing Hydropower Schemes particularly the small hydro, it would help very much if cluster approach is adopted, in which couple of projects are taken up in a geographical area together, so that cost on technical supervision, machinery deployment, man power utilization would get shared to make it more cost effective. Through effective construction planning and management, time over runs can be reduced.

Nigeria dams and dam sites.

Nigeria is blessed with hundreds of rivers that could be dammed to serve the dual purposes of township water supply (for domestic and industrial uses) and electricity generation. Below are the tables that show both the already constructed and potential dam sites.

Existing Hydropower Dams in Nigeria

S/N	Hydropower Station	Year Commissioned	Installed Capacity(MW)	River Dammed	Remarks
1.	Kainji Dam	1968	760	River Niger	Main/Most Active
2.	Jebba Power Station	1984	640	River Niger	Located 100km downstream of Kainji
3.	Shiroro Dam	1990	600	River Kaduna	Major Tributary of River Niger
4.	Kwall Falls	1923	2	N'Gell	Operational. NESCO
5.	Kurra Falls	1911	8	Tenti	Operational. NESCO.
TOTAL INSTALLED CAPACITY			**2010**		

Source: Challenges of Hydropower Development by Engr. Imo E. Large Dams (ICOLD) 2012.

Hydro Installed Plants in the Grid

Plant	Age (Years)	No of Units	Installed Capacity (MW)	Current Nos of Available Units	Capacity Available (MW)	Operational Capability (MW)
Kainji	44	8	760	6	440	400
Jebba	25	6	640	4	385.6	300
Shiroro	22	4	600	4	600	300

Total		18	**2,000**	14	1431.6	**1,000**

Nigeria today is able to make a hydropower delivery of 1000MW only, which is being complimented by the thermal output of 2,589MW, aggregate of which is 3,589MW. This is available, though not consistent, to a population of people figured at 151Million. The balance of national energy requirement is sourced from the various sizes of electric generators individually. The Kwall and Kurra falls are privately owned plants and as such used privately by the owner company NESCO, though part of the generated power is sold to the grid.

Proposed Dams with Hydropower Potentials

S/N	Name of Project	Location (State)	Dam Completion Level %	Current Capacity (MW)
1.	Oyan	Ogun	100	9
2.	Ikere George	Oyo	100	6
3.	Bakolori	Sokoto	100	3
4.	Dadin Kowa	Gombe	100	34
5.	Tiga	Kano	100	6
6.	Kiri	Adamawa	100	20
7.	Jibiya	Katsina	100	3
8.	Challawa Gorge	Kano	100	6
9.	Owena	Ondo	100	3
10.	Waya	Bauchi	100	**0.150** UNIDO
11.	Ngbowo	Enugu	98	**0.125** UNIDO
12.	Zobe	Katsina	100	3
13.	Kampe	Kogi	100	2
14.	Mangu Dam	Plateau	20	2
15.	Jada Dam	Adamawa	15	3
16.	Cham Dam	Gombe	10	2
TOTAL				**96.275**

Source: Challenges of Hydropower Development by Engr. Imo E. Large Dams (ICOLD) 2012. /ECN Publication.

Potential capacities of some hydropower dam sites in Nigeria.

In the mid 1960s, about 142MW of hydropower electricity were being generated in Nigeria, however, in the 70s Nigeria as a country through the then National Electric Power Authority NEPA contracted a Canadian consultant, Motor Columbus, to carry out hydrological studies of our major rivers with hydropower potentials. The study captured only those rivers with potential above 100MW of electricity. Today we have in excess of thirty-two (32) potential hydropower sites already studied and surveyed.

Potential Capacities of 32 Hydropower Sites in Nigeria

S/N	Location	River	Average Discharge (m^3/s)	Maximum Head (m)	Potential Capacity (MW), (pf=0.5)
1	Donko	Niger	1650	17	225
2	Jebba	Niger	1767	27.10	500
3	Zungeru I	Kaduna	343	100.06	500
4	Zungeru II	Kaduna	343	97.50	450
5	Shiroro	Kaduna	294	95.00	300
6	Zurubu	Kaduna	55	40.00	20
7	Gwaram	Jamaare	75	50	30
8	Izon	Gurara	55	30	10
9	Gudi	Mada	41.5	100	40
10	Kafanchan	Kongum	2.2	100	5
11	Kurra I	Sanga	5.0	290	15
12	Kurra II	Sanga	5.5	430	25
13	Richa I	Mosari	6.5	400	36
14	Richa II	Daffo	4.0	480	25
15	Mistakuku	Kurra	2.0	670	20
16	Kombo	Gongola	128	37	35
17	Kiri	Gongola	154	30.50	40
18	Kramti	Kam	80	100	115
19	Beli	Taraba	266	79.2	240
20	Garin Dali	Taraba	323	36.60	135
21	Sarkin	Suntai	20	180	46
22	Danko	Donga	45	200	130
23	Gembu	Katsina Ala	170	45	30

24	Kashimbila	Katsina Ala	740	49	260
25	Katsina Ala	Benue	3185	25.90	600
26	Markudi	Niger	6253	31.40	1950
27	Lokoja	Niger	6635	15.25	750
28	Onitsha	Osse	80	50	30
29	Ifon	Cross	759	47	400
30	Ikom	Cross	1621	15.50	180
31	Afikpo	Cross	1704	10	180
32	Yola	Benue	790	35	350
TOTAL					**7,672**

Source: ECN Project Report (2009)

Corporate Analysis Of Per Capital Electricity Consumption Worldwide

The comparative analysis of the per capital consumption of electricity worldwide shows a gross inadequacy of Nigeria in the power sector, whereas some countries in the comparism have a history of economic development similar to that of Nigeria. This country can generate hydropower in the excess of **15,000MW** (ECN Project Report) if global best practice is adopted.

Comparative Analysis of the Per Capita Consumption of Electricity Worldwide.

S/N	Country	Population (Million)	Power Generated (Mw)	Per Capita Consumption (Kw)
1	Usa	250	813,000	3.2
2	Cuba	10.54	4,000	0.38
3	Uk	57.5	76,000	1.33
4	Ukrain	49	54,000	1.33
5	Iraq	23.6	10,000	0.42
6	South Korea	47	52,000	1.09
7	Egypt	67.9	18,000	0.265
8	Turkey	72	12,000	0.16
9	South Africa	44.3	45,000	1.015
10	**Nigeria**	150	Around 4,000	**0.03**

Source: Challenges of Hydropower Development by Engr. Imo E. Large Dams (ICOLD) 2012.

Challenges of hydropower system/scheme in Nigeria.

1. Hydrological challenge; Seasonal flooding due to inconsistent rainfall and obsolete civil works.
2. Financial challenge; Inadequate funding by the government and other stakeholders in the sector. Huge financial investments and Poor revenue collection.
3. Managerial challenge; Poor maintenance and spare parts, employment of mediocre to handle the technical departments of hydropower stations.
4. Political challenge; Unfavorable policy, institutional and legal frameworks that are not supporting the proper development of the hydropower projects.
5. Inadequate expertise/ Low Manpower; The poor and low level of manpower development cum ineffective collaboration with the foreign partners to secure the much needed skills and training which could aid rapid hydropower development with latest technologies. Lack of local capacity to manufacture hydropower equipment thereby relying on imported equipment
6. Significant environmental damage
7. Low and uneconomic tariff.

Way Foreward

- Government high level commitment is required to put necessary machineries in place to better the power sector, this is to solve both financial and managerial problems
- Improvement on the civil works of the existing and future hydro dams to address the hydrological problems
- Reactivation of the already constructed large hydro plants to assume their 100% working capabilities
- Concessioning of the large hydropower plants to private investors to be completed as soon as possible in compliance with the power road map.
- Manpower development which entails the recruitment, training and re-training of competent personnel to handle both the technical and administrative hydro works
- Fixing of acceptable and adoptable energy tariff that will sustain the power projects
- Adopting the global best practice in the execution of the hydropower project. This will take care of the possible environmental problems
- Favorable policies, institutional and legal framework to be made available by the government.

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