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# ELECTRICITY PRODUCTION FROM HYDRO-ELECTRIC SOURCES IN NIGERIA: A HISTORIO-TECHNICAL PERSPECTIVE

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## ABSTRACT

*The electric power generated by hydro-electric source is critical to maintaining the reliability of the Nigeria's electricity supply. Hydro power generation, transmission and distribution are addressed below due to the fact that adequate power supply is an unavoidable prerequisite to Nigeria's development and are capital-intensive activities requiring huge resources of both funds and capacity. Factors affecting them and advantages of hydro-electric source are also discussed. In the prevailing circumstances in Nigeria where funds availability is progressively dwindling, creative and innovative solutions are necessary to address the power supply problem. There are three types of hydroelectric power plants: conventional, pumped storage, and diversion facilities. The focus of this work is on the conventional hydroelectric facilities, which are the most common type of hydroelectric power plant.*

**KEYWORDS:** Electricity Generation, Transmission, Distribution, Dam, Reservoir.

## INTRODUCTION

Hydropower is critical to the Nigeria's economy and the overall energy reliability because it is:

1. the least expensive source of electricity, as it does not require fossil fuels for generation;
2. An emission-free renewable source.
3. Able to shift loads to provide peaking power (it does not require ramp-up time like combustion technologies); and
4. Often designated as a black start source that can be used to restore network interconnections in the event of a blackout.

Hydroelectric power is derived from the force of moving water. It is considered a 'renewable source' because the water on the earth is continuously replenished by precipitation.

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A typical hydro plant serves multiple functions and consists of three parts: a power plant where the electricity is produced, a dam that can be opened or closed to control water flow, and a reservoir where water can be stored. The water behind a dam flows through an intake and pushes against blades in a turbine, causing them to turn and produce electricity. The amount of electricity that can be generated depends on how far the water drops and how much water moves through the system. Furthermore, hydropower serves an essential purpose of enhancing electric grid reliability. Hydropower provides (black start) capability to help restore power during a blackout event. Black start capability is defined as the ability to start generation without an outside source of power. With black start capability, hydropower facilities can resume operations in isolation without drawing on an outside power source and help restore power to the grid.

## MATERIALS AND METHOD:

- Electricity generation
- Electricity generation method
- Electricity transmission and
- Distribution

**Electricity generation in Nigeria:**

In the year 1896, first electricity generating plant in Nigeria was installed in Lagos. Installation of the plants was done at isolated units owned and operated by Native Authorities in Ibadan and Kano, also by the public works departments in Warri and Port-Harcourt. The first electricity generating plant to be commissioned in Nigeria was Ijora 'B' Power station (Lagos) in 1956 by the head of British Common Wealth and the Queen Elizabeth. There are two methods of generating electricity namely; conventional method and non-conventional method. The conventional method makes use of prime movers such as petrol engine, diesel engine, steam turbine, while non-conventional methods

do not use prime movers. This includes Magneto Hydro Dynamic (MHD) generators, solar cells, fuel cells, wind, thermoelectric generators etc. Most of electricity generators are three phase-ac generators known as synchronous generators or alternators.

**Electricity generation methods**: Several generating methods are discussed below

**Dams (Conventional):**

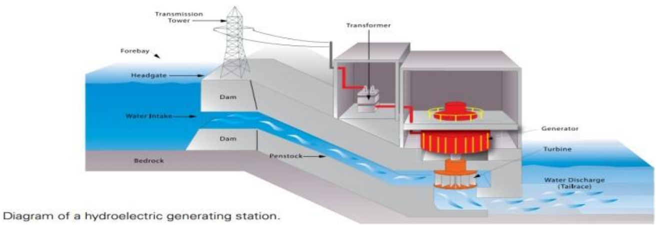


Figure 1: hydroelectric generation station

The oldest and cheapest method of power generation is that of utilizing the potential energy of water. The energy is obtained almost free of running cost and is completely pollution free. It involves high capital cost because of the heavy civil engineering construction works involved. Hydroelectric stations are designed, mostly as multipurpose projects such as river flood control, storage of irrigation drinking water and navigation. Most hydroelectric power comes from the potential energy of dammed water driving a water turbine and generator. The power extracted from the water depends on the volume and on the difference in height between the source and the water's outflow. This height difference is called the head. A large pipe (the "penstock") delivers water from the reservoir to the turbine.

**Reservoir (Pumped-storage):**

This method produces electricity to supply high peak demands by moving water between reservoirs at different elevations. At times of low electrical demand, the excess generation capacity is used to pump water into the higher reservoir. When the demand becomes greater, water is released back into the lower reservoir through a turbine. Pumped-storage schemes currently provide the most commercially important means of large-scale grid energy storage and improve the daily capacity factor of the generation system. Pumped storage is not an energy source, and appears as a negative number in listings.

**Run-of-the-river:**

Run-of-the-river hydroelectric stations are those with small or no reservoir capacity, so that only the water coming from upstream is available for generation at that moment, and any oversupply must pass unused. A constant supply of water from a lake or existing reservoir upstream is a significant advantage in choosing sites for run-of-the-river.

**Tide**:

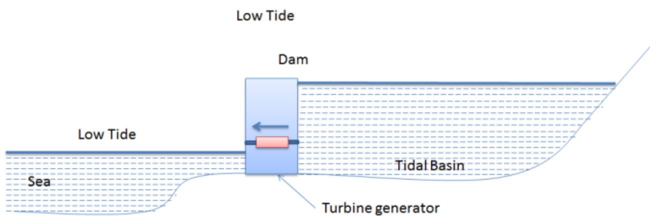


Figure 2: Tidal power station

A tidal power station makes use of the daily rise and fall of ocean water due to tides; such sources are highly predictable, and if conditions permit construction of reservoirs, can also be dispatchable to generate power during high demand periods. Less common types of hydro schemes use water's kinetic energy or undammed sources such as undershot water wheels.

**Electricity transmission and distribution:**

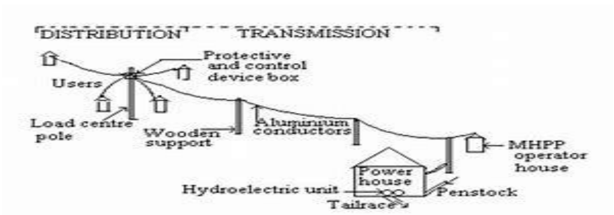


Figure 3: electricity transmission and distribution

In the early days of electricity distribution, direct current (DC) generators were connected at loads at the same voltage. The generation, transmission and loads had to be of the same voltage because there was no way of changing DC voltage levels. Low DC voltages were used since that was a practical voltage for incandescent lamps, which were the primary electrical loads then. The adoption of alternating current (AC) for electricity generation dramatically changed the situation. Power transformers, installed at power stations, could be used to raise the voltage from the generators, and transformers at local substations reduced it to supply loads. Increasing the voltage reduced the current in the transmission and distribution lines and hence the size of conductors and distribution losses. This made it more economical to distribute power over long distances.

Distribution network are typically of two types: radial network and interconnected network. A radial network leaves the station and passes through the network area with no normal connection to any other supply. This is a typical of long rural lines with isolated load areas. An interconnected network has multiple connections to other points of supply. These points of connection are normally open but allow various configurations by the operating utility by closing and opening switches. Operation of these switches may be by remote control from a control centre or by a lineman. The benefit of the interconnected model is that in the event of a fault or required maintenance, a small area of network can be isolated and the remainder kept on supply. Generated power cannot all be utilized at the generating stations and its immediate environment. Therefore, it must be distributed at suitable voltage to points and consumers. Distribution involves primary and secondary transformation of high voltage to the standard medium and low voltage by the appropriate transforming equipment. The distribution system is an important part of the total electric supply system and provides the final link between a utility's bulk transmission system and its ultimate customers (consumers). It has been reported in many technical publications that over eighty percent of all customer interruptions occur due to failures in the distribution systems. The problem of distribution system planning consists of determining the optimum numbers and locations of the distribution substations and the optimum way of connecting the load nodes to these substations through the interconnection of feeders.

**Primary Distribution System:**

These consist of high voltage (11 and 33 KV) networks from primary and sub-primary substations. These substations are interconnected with high voltage transmission lines. In most cases, large industries consumers like cement factories, refineries, breweries, flour mills, steel rolling mills and so on take supply at primary distribution system with associated transformers, switchgears and breakers.

**Secondary Distribution System:**

These consist of low voltage feeder networks from the secondary transformers that are constructed along main roads and streets. Service connections are made to individual consumers by service cables from these networks feeder lines. The various system of alternating current distribution for domestic consumers includes:

Single-phase 2-wire system

Single-phase 3-wire system

Three-phase 3-wire system

Three-phase 4-wire system

In all, the single phase 2-wire and the three phase 4-wire system are the most widely used in Nigeria. The discussion so far, refers to alternating current distribution system. The direct current distribution, which is rarely used, has areas of application. Alternating current is usually converted into direct current by rotary converters. Direct current (DC) is supplied to substation bus bars and distributed locally by feeders, distributors and service lines. Usually DC is distributed by single phase 2-wire system at 230 volts and three-phase 3-wire at 460/230 volts (Sambo, 2008).

**Results and discussion:**

**Historical overview and current state of the sector**

**A. Historical Overview.**

The history of electricity production in Nigeria dates back to 1896 when electricity was first produced in Lagos, fifteen years after its introduction in England. The total capacity of the generators used then was 60KW. In other words, the maximum demand in 1896 was less than 60 kW. The Nigeria Electricity Supply Company (NESCO) commenced operations as an electric utility company in Nigeria in 1929 with the construction of a hydroelectric power station at Kurra, near Jos.

In 1946, the Nigerian government electricity undertaking was established under the jurisdiction of the public works department (PWD) to take over the responsibility of electricity supply in Lagos State. The Electricity Corporation of Nigeria (ECN) was established in 1951, while the first 132KV line was constructed in 1962, linking Ijora Power Station to Ibadan Power Station.

However, there was another body known as the Niger Dams Authority (NDA), which was established by an act of parliament. The Authority was responsible for the construction and maintenance of dams and other works on the River Niger and elsewhere, generating electricity by means of water power, improving navigation and promoting fish brines and irrigation. The electricity produced by NDA was sold to ECN for distribution and sales at utility voltages.

Also, Niger Power Review (1985) stated that in April 1972, the operation of ECN and NDA were merged in a new organization known as the National Electric Power Authority (NEPA). Since ECN was mainly responsible for distribution and sales and the NDA created to build and run generating stations and transmission lines, the primary reasons for merging the organizations were:

1. It would result in the vesting of the production and the distribution of electricity power supply throughout the country in one organization which would assume responsibility for the financial obligations.

2. The integration of the ECN and NDA should result in the more effective utilization of the human, financial and other resources available to the electricity supply industry throughout the country.

Okoro and Madueme (2004) stated in their research, that since the inception of NEPA, the authority expands annually in order to meet the ever-increasing demand. Unfortunately, majority of Nigerians have no access to electricity and the supply to those provided is not regular. It is against this backdrop that the federal government embarked on aggressive power sector reforms with the intention of resuscitating NEPA and making it more efficient, effective and responsive to the yawning of the teeming populace. NEPA as a result of unbundling and the power reform process was renamed Power holding Company of Nigeria (PHCN) in 2005.

Again, according to Sambo (2008), the Nigerian power sector is controlled by state-owned Power Holding Company of Nigeria (PHCN), formerly known as the National Electric Power Authority (NEPA). In March 2005, President Olusegun Obasanjo signed the Power Sector Reform Bill into law, enabling private companies to participate in electricity generation, transmission, and distribution. The government separated PHCN into eleven distribution firms, six generating companies, and a transmission company, all of which were to be privatized. Several problems, including union opposition, delayed the privatization, which was later rescheduled for 2006.

However, when the administration of President Umaru Musa Yar'adua came on board, the privatisation issue was suspended. He therefore, unveiled a mission, setting an agenda of industrializing Nigeria by 2020. The conference was therefore one of the highest and administrative governing structures that was considered to proffer practicable solutions to the power supply problems in order to achieve this priority goal of the Nigerian government. Unfortunately, he was unable to accomplish the mission, due to ill health which eventually took his life.

In Nnaji (2011), a new Power Sector Roadmap was officially launched by Mr. President, Goodluck Jonathan, on 26th August, 2010. The Presidential Action Committee on Power (PACP) was created to remove "red-tape", achieve policy consistency and cut-through bureaucracy indecision making by key stakeholders in power and the Presidential Task Force on Power (PTFP) was created for day-to-day planning, developing and driving forward the Reform Plan for the Nigerian Power sector which was the Electric Power Sector Reform Act (EPSRA) enacted in 2005.

This Act was to drive the reform processes as follows:

- Transfer NEPA's assets to PHCN and subsequent unbundling into: A transmission company, TCN, 6 generating companies, GenCos, 11 distribution companies, DisCos.
- NELMCO to take over PHCN stranded assets and liabilities.
- Establish a bulk trader of power as a broker between power producers and DisCos.
- Establish an independent sector regulator: (Nigeria Electricity Regulatory Commission (NERC) charged with the responsibility of tariffs regulation and monitoring of the quality of services of the PHCN.
- Provide for a consumer assistance fund
- Develop competitive electricity market
- Licensing of IPPs and ring-fence distribution companies
- Establish a rural electrification agency, (REA).

**B. Current state of the sector:**

In accordance with the Electricity Power Sector Reform Act 2005, the privatization of PHCN was finally established in 2013. PHCN was subsequently unbundled into a transmission company, TCN, 6 generating companies, Gen-Cos, and 11 distribution companies, Dis-Cos.

The Federal Government retains the ownership of the transmission assets. Manitoba Hydro International (Canada) is responsible for revamping TCN to achieve and provide stable transmission of power without system failure. Currently, the transmission capacity of the Nigerian Electricity Transmission system is made up of about 5,523.8 km of 330 KV lines and 6,801.49 km of 132 KV lines (Sambo, 2008). However, the generation and distribution sectors were fully privatised and owned by private individuals.

The operating environment is such that the DisCOs can purchase power from Gen-COs of their choice while Gen-COs are allowed to optimize production cost and hence make competitive offers for sale of power. The Trans-CO on the other hand is an independent power Operator (IPO), as well as, an energy carrier with the responsibility of ensuring bilateral contracts exist between Dis-COs and GenCOs with additional responsibility of issuing operational guidelines for efficiency of the system

**Structure, deregulation and liberalization of the electricity industry**:

According to NPSG, the structure of the Nigerian Power Sector is made up of 3 major subsectors as depicted below: Generation, Transmission and Distribution

**Generation:** There are currently 23 grid-connected generating plants in operation in the Nigerian Electricity Supply Industry (NESI) with a total installed capacity of 10,396.0 MW and available capacity of 6,056 MW. Most generation is thermal based, with an installed capacity of 8,457.6 MW (81% of the total) and an available capacity of 4,996 MW (83% of the total). Hydropower from three major plants accounts for 1,938.4 MW of total installed capacity (and an available capacity of 1,060 MW).

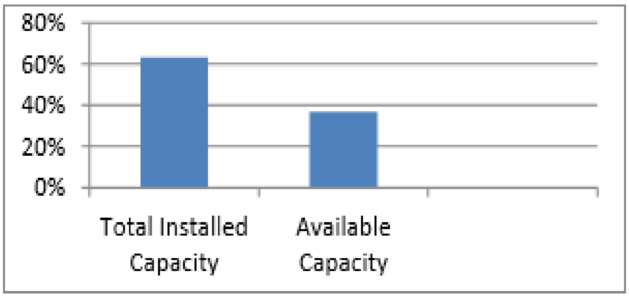


Figure 4: Installed Capacity and Available Capacity in Nigeria

According to IEA, total installed electricity net generation in Nigeria was majorly on the Gas Thermal Plant with 64%, Hydro with 23% and Steam Thermal Plant with 13%.

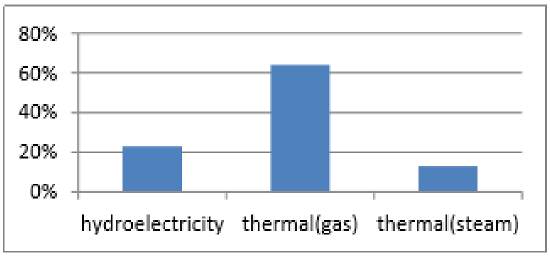


Figure 5: Total installed electricity net generation in Nigeria.

There are 6 successor Gen-Cos in Nigeria.

Table 1: Names and installed capacities of the Gen-Cos

| S/n | Generation Company | Plant Type | Capacity (MW) |
|---|---|---|---|
| 1 | Afam Power Plc (1-V) | Thermal | 987.2 |
| 2 | Egbin Power Plc | Thermal | 1320 |
| 3 | Kainji/ Jebba Hydro Electric Plc | Hydro | 1330 |
| 4 | Sapele Power Plc | Thermal | 1020 |
| 5 | Shiroro Hydro Electric Plc | Hydro | 600 |
| 6 | Ughelli Power Plc | Thermal | 924 |

Source: Nigerian Electricity Regulatory Commission

**Transmission:**

The Transmission Company of Nigeria (TCN) is a successor company of PHCN, following the unbundling of the sector, and is currently being managed by a Management Contractor, Manitoba Hydro International (Canada). Manitoba is responsible for revamping TCN to achieve providing stable transmission of power without system failure. Currently, the transmission capacity of the Nigerian Electricity Transmission system is made up of about 5,523.8 km of 330 KV lines and 6,801.49 km of 132 KV lines. The TCN is made up of two major departments: System Operator and Market Operator. The Market Operations (MO) is a department under TCN charged with the responsibility of administering the wholesale electricity market, promoting efficiency and where possible, competition. The system operator is focused on system planning, administration and grid discipline. Furthermore, one of the major areas of focus of Manitoba Hydro International is to reorganise TCN and ensure that the Market Operator and the System Operator become autonomous.

**Distribution:**

There are 11 electricity distribution companies (discos) in Nigeria.

Table 2: Key information about the 11 discos

| S/N | DISCOs | Percentage Load Allocation |
|---|---|---|
| 1 | Abuja Distribution Company | 11.50% |
| 2 | Benin distribution company | 9% |
| 3 | Eko Distribution Company | 11% |
| 4 | Enugu Distribution Company | 9% |
| 5 | Ibadan Distribution Company | 13% |
| 6 | Ikeja Distribution Company | 15% |
| 7 | Jos Distribution Company | 5.50% |
| 8 | Kaduna Distribution Company | 8% |
| 9 | Kano Distribution Company | 8% |
| 10 | Port Harcourt Distribution Company | 6.50% |
| 11 | Yola Distribution Company | 11.50% |

Source: Monthly Energy Balance Sheet, October 2013, Transmission Company of Nigeria (TCN)

**Existing power plants, IPPS and NIPPS:**

**A. Independent Power Producers (IPPs)**

According to NPSG, IPPs are power plants owned and managed by the private sector. Although there are Independent Power Producers (IPPs) existing in Nigeria prior to the privatisation process, the Nigerian Electricity Regulatory Commission (NERC) has recently issued about 70 licenses to Independent Power Producers in order to improve the power situation in the country. The existing IPPs include Shell – Afam VI (642MW), Agip – Okpai (480MW) and AES Barges (270MW).

**B. National Integrated Power Projects (NIPP):**

The National Integrated Power Project ('NIPP') is an integral part of Federal Government's efforts to combat the power shortages in the country. It was conceived in 2004 as a fast-track public sector funded initiative to add significant new generation capacity to Nigeria's electricity supply system along with the electricity transmission and distribution and natural gas supply infrastructure required to deliver the additional capacity to consumers throughout the country [9]. There are 10 National Integrated Power Projects (NIPPs), with combined capacity of 5,455 MW, scheduled for completion (for ongoing projects) and privatization in 2014.

Table 3: The NIPPs and their capacities

| S/N | NIPPs | Capacity (MW) | Expected completion date |
|---|---|---|---|
| 1 | Alaoji Generation Company Nigeria Limited | 1,131 | Jun-14 |
| 2 | Benin Generation Company Limited | 508 | Dec-13 |
| 3 | Calabar Generation Company Limited | 634 | Jun-14 |
| 4 | Egbema Generation Company Limited | 381 | Jun-14 |
| 5 | Gbarain Generation Company Limited | 254 | Jun-14 |
| 6 | Geregu Generation Company Limited | 506 | Jun-13 |
| 7 | Ogorode Generation Company Limited | 508 | All units commissioned |
| 8 | Olorunsogo Generation Company Limited | 754 | All units commissioned |
| 9 | Omoku Generation Company Limited | 265 | |
| 10 | Omotosho Generation Company Limited | 513 | All units commissioned |

Source: Niger Delta Power Holding Company Limited, Transaction Review Conference, Completion Status of NDPHC Generation Companies

**Factors affecting electricity generation, transmission and distribution in Nigeria**:

There are many factors that affect electricity generation in Nigeria, they are listed below,

1. Lack of water management in Nigeria
2. Vandalization of oil and gas pipe lines, oil gas exploration and exploitation facilities.
3. The kidnapping of foreign and indigenous professionals that manned oil and gas facilities in Nigeria resulting into abandoning of oil and gas exploration.
4. The inability of Nigeria government in collaboration with oil companies to utilize fully the gas, due to gas flaring.
5. Low level of annual rainfall in Nigeria due to global warming which leads to global climate change that affects water level at hydro generation stations.
6. The absence of research and development in Nigeria which focus on hydroelectric generation, transmission and distribution.
7. Non diversification of existing electricity generating potentials in Nigeria. Nigeria only utilizes oil, gas and dams for electricity generation.
8. There is poor planned maintenance culture, in which fixed-time maintenance is not carried out regularly.
9. Pushing down of electricity transmission and distribution lines by winds as well as vandalization of these lines by thieves, fluid, soil erosion.

**Advantages of hydro electricity generation**

- Hydropower is fueled by water, so it's a clean fuel source, meaning it won't pollute the air like power plants that burn fossil fuels, such as coal or natural gas.
- Hydroelectric power is a domestic source of energy, allowing each state to produce their own energy without being reliant on international fuel sources.
- The energy generated through hydropower relies on the water cycle, which is driven by the sun, making it a renewable power source, making it a more reliable and affordable source than fossil fuels that are rapidly being depleted.
- Impoundment hydropower creates reservoirs that offer a variety of recreational opportunities, notably fishing, swimming, and boating. Most

water power installations are required to provide some public access to the reservoir to allow the public to take advantage of these opportunities.

- Some hydropower facilities can quickly go from zero power to maximum output. Because hydropower plants can generate power to the grid immediately, they provide essential back-up power during major electricity outages or disruptions.
- In addition to a sustainable fuel source, hydropower efforts produce a number of benefits, such as flood control, irrigation, and water supply.
- Reservoirs created by hydroelectric schemes often provide facilities for water sports, and become tourist attractions themselves.

**CONCLUSION:** Since the amount of electricity that can be generated on hydro-electric source depends on how far the water drops and how much water moves through the system. It necessary that to ensure adequate maintenance in the three stages (generation, transmission and distribution) of electricity to consumers, putting much consideration on the turbine blades, penstocks, tunnels, power house, transformers, and the reservoir of the generating stations we have in Nigeria. Furthermore, to improve the delivery of electricity to consumers in Nigeria the civil liberty organizations, the Non-governmental organizations and ordinary citizens have to cooperate and work together for good maintenance culture and good governance.

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