Development of Small Hydropower Base Distributive Power System in Nigeria

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Abstract - *Distributive Power Generation is an emerging highly efficient and effective system for distributing power close to the consumers with the capacity to enhance the performance and mitigate the numerous challenges currently besetting the Nigeria power transmission and distribution grid in case of grid interconnection. The paper establishes the basis for the development of a Small Hydropower (SHP) base Distributive Power System (DPS) to enhance electricity availability to the Nigeria populace, provide the essential spinning reserve and strengthen the grid resilience to issues facilitating national grid power failure. The technical requirement and methodology for the implementation of an SHP base DPS were developed. A case study analysis indicates that River Orle Auchi fulfilled the requirement of a model of SHP - DPS with an average power output of 10 MW and peak power potential of 18.567 MW at 70% flow exceedence. The implementation of the study SHP - DPS model will significantly improve access to electricity across Nigeria, minimize transmission and distribution losses, provide the essential spinning reserve and strengthen the national grid resilience to disturbance and grid failure.*

Key words: *Distributive, power, small, hydropower, Auchi, power, grid*

I. INTRODUCTION

Traditional Power Generation and Transmission System employs a central grid power supply to transmit and distribute power to electricity consumers. In this system the generation and end use points may be thousands of kilometers apart [1].The grid power system is customarily a large and intricate engineering system that is vital to industrial and socioeconomic development of nations.

The operation of the power grid in Nigeria is associated with a number of challenges which includes large scale power transmission losses, voltage instability and collapse, vandalization of power transmission facilities, power transmission facilities traversing rugged, remote and environmentally unfriendly terrain [2]. In the Nigerian context some of these challenges lead to frequent national power outage with severe implication to the economic development and security of the nation. According to the Centre for the Study of the Economies of Africa (CSEA) power issues in Nigeria also include inadequate power generation, poor capacity factor utilization and expansion of power infrastructure in line with Nigeria population increase [3].

The Nigerian Power Grid has experienced frequent system collapse over the years [2].It has witnessed frequent power collapses in 2020 with the Transmission Company of Nigeria disclosing that subsequent collapse of the National Power grid cannot be totally avoided due to zero spinning reserve system [4], instability originating from system disturbances and frequent vandalization of grid power lines. The Power Grid is weak, highly stressed, long and radial in nature hence lacking flexibility [5]. It is also highly prone to partial system collapse which occur when power flow is sustain in some part of the grid while a certain section is in a black out.

The reliance on thermal power plants as the major power generation base and the national power grid for transmission of power has not provided the magnitude of sustainable power supply to drive the Nigerian economy [6]. Incessant power outage as a result of low generation base, structurally weak and instability prone national power grid has negatively imparted on the Nigeria economy. It has significantly increased the cost of doing business, product manufacturing and poor availability of utility services. Many major manufacturing firms and business entities have exited the country while others have closed down, generating large scale unemployment [5]. It is imperative that a complimentary generation and distribution system be developed to augment and enhance power delivery to electricity consumers in Nigeria.

Distributive Power System (DPS) is an emerging technology that has the capacity to augment grid power supply challenges [7]. It uses a modular power base to supply power close to the user point without the use of an elaborate, expensive and voltage instability prone power grid. Popular power supply base of DPS are solar, wind, biogas and thermal generators.

Decentralization of the electricity system has been recognized as one means of achieving efficient and renewable energy provision, as well as addressing concerns over ageing electricity infrastructure and capacity constraints. DPS is one of the new trends in power systems used to support the increased energy demand due to increase in population and economic advancement [8].

The DPS could form mini power grids of various dimensions and could be made to discharge into the national power grid when there is surplus power generation. Their success, efficiency and cost effectiveness has warranted the extension of the power sources. Mini power grid in Nigeria presently consist mostly solar power systems with some application of thermal generators.

Small Hydro Power (SHP) technology due to its versatility, environmental friendliness, reliability and cost effectiveness constitute a suitable, effective and conducive technology to power the distributive power system in Nigeria [9]. The SHP has a strong capacity to feed and contribute to the stability of the national power supply in situation of surplus power generation in the raining period thereby serving a dual purpose.

The present study aims to develop a model for the development of a small hydro base distributive power system in Nigeria for the mitigation of the Nigeria National Power Grid challenges to enhance power transmission and availability for sustainable national development.

II. Materials and Methods

A. Features and Configurations of Grid Power Transmission

The power grid consists mainly of large synchronous alternating current (AC) power grids, with all the interconnected systems maintained at the same precise electrical frequency [10]. The primary requirement of the system to the electrical power consumers are as follows;

i. To cover required territory to deliver power.
ii. Possess adequate capacity to meet peak demand.
iii. Supply highly reliable power.
iv. Supply stable and quality voltage

In meeting the above requirements the power transmission line are designed for stability of operation. There is a strong electrical correlation and synchronization between the power generators and the power grid. This stability of operation enables the system to operate evenly as the load fluctuates and to smoothly pick up load in the event of any generator failure. The stability of operation is the main focus of the grid power supply. Its compromise results to grid power transmission disruption and failure.

Despite the immense benefits of the grid power supply system there exist some technical complication and risk in its operations in sustaining the synchronous operation of the system.

B. General Requirements for AC Interconnection

1) ***Sustaining Synchronous Operations:*** To operate synchronously at a minimum, the systems must have the same nominal frequency of 50 Hz or 60 Hz at a common voltage level. This balance must be managed at a narrow range to sustain the synchronism. To do this requires a high degree of technical compatibility and operational coordination, which grows in cost and complexity with the scale and inherent differences of the systems involved [11]. Operational synchronism is the product of extensive planning studies, computer modeling, and exchange of data between the interconnected systems. The grid is sensitive and vulnerable to disturbance generated from any section of the interconnection. Disturbances in one location are quickly propagated to other locations. The occurrence of major blackouts in North America and Europe in 2003 established that large-scale disturbances can propagate through interconnections and cascades outages

staggering system collapse. Long distance interconnections with long transmission lines have potentially greater stability problems than is the case for shorter lines.

Many systems that have undergone electricity liberalization have experienced large increases in transmission capacity utilization reducing reserve margins [11]. To minimize the likelihood of interconnected system experiencing such problems as voltage collapse, dynamic and transient instability, or cascading outages due to propagated disturbances requires careful planning and well-coordinated operation.

C. Power Grid Protection Systems

Protection systems are an extremely important part of any power system. Their primary function is to monitor, detect and eliminate faults. Short circuits faults between system components at different voltage are inadvertent in electrical connections. The goal of protection systems is to isolate and de-energize faults before they can cause harm to personnel and cause serious damage to equipment [12]. The key mechanism of protection systems are circuit breakers, device transformers, and relays. Circuit breakers are operated by routine relays that sense faults or other undesirable system conditions.

D. Communications, Monitoring, and Control Systems

Grid power system operations take place within geographically well-defined control areas. The system operation is coordinated by a central control center with the responsibility of keeping the entire system running safely and reliably [12]. This entails continuously monitoring system conditions and deploying system resources to manage the system effectively.

Traditionally, monitoring and control have been conducted semi-manually, with a heavy reliance on telephone communications with plant operators and field personnel. Modern power grids are automated with Supervisory control and data acquisition (SCADA) systems which combine remote sensing of system conditions and system elements operations. SCADA systems control key generators through automatic generator control (AGC), and can change the topology of the transmission and distribution system by remotely opening or closing circuit breakers [13]. This monitoring and control is enabled by dedicated fiber optic based phone systems, microwave radio or power line carrier signals.

E. Technical Issues for AC Grid Operation

1) ***Thermal limits:*** The capacity of transmission lines, transformers, and other equipment is determined by temperature limits. If these limits are exceeded, the equipment can be damaged or destroyed.

2) ***Stability limits*****:** The stability limit of a transmission line is the maximum amount of power that can be transmitted for which the system will remain synchronized if a disturbance occurs.

3) Voltage Regulation: Utilities generally maintain system voltages within 5-10 percent of nominal values in order to avoid the risk of voltage collapse, which can lead to a major interruption of service. Power system voltages are primarily governed by reactive power flows. Voltage collapse can be triggered when reactive demand is high and systems are operating near their stability limits, and then undergo a disturbance that triggers a quick downward spiraling of the system.

4) Available Transmission Capacity (ATC): An important measure of transmission capacity is transmission transfer capability (TTC), which is the maximum power flow that a line can accommodate at any given time and still be able to survive the loss of a major generator or transmission link elsewhere in the system.

5) **Flexible AC Transmission System (FACTS)**: Flexible AC Transmission System (FACTS) refers to a number of different technologies based on power electronics and advanced control technologies, which are used to optimize power flows and increase grid stability

6) ***Systems Issues*****:** Key technical systems issues that must be addressed in planning and implementing a grid interconnection include frequency regulation, coordination of operations, interconnections of power systems with weak grids, and aspects of interconnection that are associated with electricity market liberalization [11].

F. Power Grid Inertia

Inertia in power systems refers to the energy stored in large rotating generators and some industrial motors, which gives them the tendency to remain rotating. This stored energy can be particularly valuable when a large power plant fails, as it can temporarily make up for the power lost from the failed generator. This temporary response is typically available for a few seconds, allows the mechanical systems that control most power plants time to detect and respond to the failure [14].

Grid inertia contributes to the stability of the power grid. A power grid without inertia suffers from issues of power quality and is susceptible to blackouts. The primary mechanism for providing inertia is through the presence of heavy rotating equipment such as steam turbines and gas turbines driving generators and rotating generators [15].

In an electric system, the energy contained in generators and motors at power stations and industrial facilities provides inertia as they rotate at the same frequency as the electricity grid. This effectively acts as a buffer against rapid change. If demand for power goes up sharply, the frequency of the grid tends to decrease. Having a lot of rotating mass on the grid acts like a shock absorber and slows the rate of change, thereby contributing to the frequency stability [14].

When inertia decreases, sudden changes in incidence caused by a change in electricity use or production are faster and larger. This means that it is more difficult to keep the frequency within its normal range of variation.

G. The Nigeria National Power Grid

Nigeria's transmission network consists of 159 substations with a total transformation capacity of approximately 19,000MW and 15,022 km of transmission lines. Currently, transmission capacity is 5,300 MW and average operational generation capacity is about 4000MW [16], which is far below the total installed capacity of 12,522MW.

Nigeria has 23 power generating plants connected to the national grid. These plants are managed by generating companies (**Gencos**), Independent Power Providers (IPP) and Niger Delta Holding Company.

Figure: The Nigeria Grid Network

H. Frequency Control and Operating Reserve

In the Nigeria Power Grid Frequency operation is obtained by the System Operator using Operating Reserve. Operating Reserve is additional active power output provided from generation plants, or a reduction in consumer demand, which must be realizable in real time operation to contain and correct any potential power system frequency deviation to an acceptable level.

According to the Nigeria Electricity Regulatory Commission (NERC), there are two types of Operating Reserve namely Quick Reserve and Slow Reserve. Quick Reserve is the reserve that can respond within ten seconds and be fully active within 30 minutes of activation. This Reserve is routinely used for balancing of supply and demand, and to restore frequency to nominal values following a disturbance. Quick Reserve consists of Spinning Reserve and Emergency Reserve [17].

1) ***Spinning Reserve*****:** Spinning reserve is the additional output from a synchronized generating unit, which must be realizable to respond to any frequency deviation to contain and restore the frequency to an acceptable level in the event of a loss of generation or a mismatch between generation output and demand. The Nigeria Power Grid has zero spinning reserve [4].

2) Frequency Limits: The frequency of the system is maintained at 50 Hz. The National Control Centre endeavors to control the System Frequency within a narrow operating band of ± 0.5% (49.75 – 50.25 Hz) from 50 Hz, at least 97 % of the time during Normal Conditions [17].

3) ***Frequency Control*****:** During normal conditions, frequency control will be exercised utilizing the Spinning Reserve. The Nigerian Power System requires a minimum spinning reserve that is sufficient to cover the largest credible trip in order to secure the network. The largest credible trip is the largest loss of power inflow that could be caused by a single trip, which will normally be the largest generating unit synchronized to the system. As at 2012 the largest generating unit on the system is 220MW[17].

As at February 2020, the Nigeria power grid operation has zero spinning reserve which makes normal frequency control of the grid system very difficult [4].

I. Nigeria Power Grid Transmission Challenges

1) Limited transmission coverage: The existing transmission network comprises mostly 300kV circuits and substations. There are approximately 32 work centres spread across the country. The transmission grid covers only 45% of the country. This is a limitation that constitutes a significant growth barrier for the power sector in Nigeria.

2) ***Power Supply disruptions*****:** Supply disruptions due to violence are an additional challenge observed across the power value chain in Nigeria. Militant groups recognize the impact of disruptions on the economy to negotiate for their demands as evident through rampant violence targeted at oil and gas pipelines in the north and south of Nigeria, which in turn impacts power generation. This development has cautioned investment in getting involved in the development of Nigeria power generation and transmission network

3) Low Transmission Capacity: Nigeria currently has installed power generation capacity of almost 13,000MW. It is noteworthy that, the national grid is only able to evacuate approximately 6700 MW which is about 54% of the installed power generation.

It is of recent that a study was done to determine the actual evacuation capacity of the grid and the areas that require enhancement in the short, medium and long terms.

4) ***Poor Maintenance and Vandalism of Transmission Lines*****:** The challenge with the grid operation is exacerbated by issues such as vandalism and poor maintenance. Transformers deployed are overloaded in most service areas with inadequate spare parts for urgent maintenance. The grid management is plagued by poor technical staff recruitment, capacity building and training programme [5]. This ineffective maintenance and poor system management contribute largely to partial or total system collapses.

5) ***Transmission and Distribution Losses*****:** At an average 7.4%, transmission losses across the network are high compared to emerging country benchmarks of about 2 - 6%. Distribution losses across the system are at an average of 12%, amounting to total losses of about 19.4% [18]. These reflect the critical infrastructure and operational challenges. Power losses result in lower power availability to the consumers, leading to inadequate power availability.

6) ***Frequent Power Outages*****:** Nigeria ranks first both in electrical outages per month and average outage duration in Africa with average of 33 power outages per month, each averaging 12 hours in 2014. The situation has compelled 71% of companies to use generators to compensate for the grid’s deficiency. Increased power demand pushes the power transmission and distribution networks to their upper limits and beyond, resulting to shortening of the life span of the network or total collapse. The system operator has attempted to manage the situation by selective isolation of the load demand of sections of the grid creating partial black outs.

I. Mini Power Grid

Mini grids are modern, localized, small-scale grids as opposed to the traditional, centralized electricity grid. Some mini grids are connected to the central power for the transfer of excess power. In this arrangement they help strengthen grid resilience, and mitigate grid disturbances. The mini grid has increasingly employed a mixture of different distributed energy resources such as solar hybrid power systems.

1) Mini Power Grid Application in Nigeria: Early operators developed off-grid generation because the main grid neither extended to isolated areas nor met electricity demand reliably. Less than 15% of the population is connected to the main grid in most Nigerian states.

Mini grids offer a moderately more expensive but far more reliable service than the main grid. Mini grid customers pay on average twice the average tariff of the main grid. The relatively low tariffs are the result of government subsidies. Mini grids typically supply electricity for a time period two to three times longer than the main grid.

2) Mini Grid Generation in Nigeria: Mini grid generation in Nigeria evolved from fossil to renewable sources of energy over the past two decades. From the 1990s until the end of the 2000s, almost all mini grids were diesel-fired. Today, all of Nigeria's 11 mini grids use renewable sources, with solar PV as the dominant technology in combination with batteries. Ajima Farms in Rije of 20kW capacity uses biogas, hybrid solar PV and diesel systems. Pilot projects in collaboration with Schneider Electrics of France and Philips Electronics of Netherland have already been commissioned in rural communities of the Federal Capital Territory (FCT) of Nigeria [19].

J. Distributed Power Systems (DPS)

Distributed generators are small, self-contained electric generating plants that can deliver power for residential, business and industrial purposes. It can be used to provide an alternative and an enhancement of the traditional electric grid power system. DPS are commonly fueled by fossil fuel powered sources. Recent development has diversified the fuel to include renewable energy sources such as solar and wind power, small hydro power, geothermal and biomass. Distributed power systems are decentralized, modular, and more flexible technologies that are located close to the electrical load, having capacities of about 10 megawatts (MW). There is the increasing use of DPS in electrical power distribution to consumers. In the event of surplus power generation the DPS is arranged to transfer power to the traditional power grid. Distributed generation and storage enables the collection of energy from many sources and may lower environmental impacts and improve the security of supply. Distributed resources can either be grid connected or independent of the grid [20].

The development of DPS arose out of the following factors;

i. Concerns over perceived externalized costs of central plant generation, particularly environmental concerns.
ii. The increasing age, deterioration, and capacity constraints relating transmission and distribution of electrical power.
iii. The increasing relative economy of mass production of smaller appliances over heavy manufacturing of larger units and on-site construction.
iv. Along with higher relative prices for energy, higher overall complexity and total costs for regulatory oversight, tariff administration, metering and billing.

Other factors favoring their deployment include the capacity of DPS to reduce the amount of energy lost in transmitting electricity. This also reduces the size and number of power lines that must be constructed. They also have low maintenance, low pollution and high efficiencies.

It has been realized by power investors that right-sized resources, for individual customers through mini grids offer important but little-known economic advantages over central plants. Smaller units offered greater economies from mass-production than big ones could gain through unit size. These increased value of DPS as a result of improvements in financial risk, engineering flexibility, security, and environmental quality more than offset their apparent initial cost disadvantages.

K. **Small Hydro Power (SHP) Technology**

Small Hydro Power classification varies according to countries and agencies, US Directorate of Energy (DOE) consider SHP to be between the range of 1 – 30 MW [21]. There is currently no common consensus among countries and hydropower associations regarding the upper limit of small hydropower plant capacity. The growing awareness to protect the environment and ecology of different species as well as the corresponding authority's incentives caused small hydropower to emerge as an important source of renewable energy. SHP possess some characteristic which make them particularly adaptable to DPS application.

1) *Environmental Compatibility of Operation*: The CO_2 reduction targets imposed by many countries and associated funding incentives to boost renewable technology has promoted small hydro power plants as prime technology for power generation in locations where sustainable water resources exist [22]. Research results have indicated that a well-designed small hydroelectric power system is easily adaptable to its surroundings to produce minimal negative environmental impacts compared to large hydropower projects [23].

2) *Promotes Sustainable Development*: SHP contributes to sustainable development by being economically feasible, respecting the environment and allowing decentralized production for the development of dispersed populations.

3) *Adaptation to Distributive Power Generation*: Building SHP plants helps create a more diversified electricity system**,** providing production of electricity in smaller distribution systems when the main grid is disrupted. Furthermore, since SHP is a decentralized energy source located close to the consumers, transmission losses can be significantly reduced.

4) Economy of Operation: Small hydro power benefit in terms of cost and simplicity from different approaches in the design, planning and installation than those which are applied to larger hydro power. Recent advances in small hydro technology have made it an economic source of power even in very poor and inaccessible places [24].

5) *Prime Technology for Rural and Remote Power Supply*: Assessments of the feasibility of small hydropower in rural areas have shown that even if population density is sparse, micro- and pico- hydropower may be cost-effective solutions due to the low cost of distribution and minimal effects on the environment.

6) *Flexibility of operation of hydropower generation*: Hydropower is a flexible source of electricity; power output can be quickly adjusted up and down very quickly to adapt to changing energy demands. Hydro turbines have a start-up time of the order of a few minutes [25]. It takes around 60 to 90 seconds to bring a unit from cold start-up to full load; this is much shorter than for gas turbines or steam plants [26]. Power generation can also be decreased quickly when there is a surplus power [27].

L. SHP Potentials in Nigeria

Small rivers and streams exist within the present arrangement of the country into eleven river basin authorities. It has been established that Nigeria possesses potential hydro-energy resources along her numerous river systems consisting of a total of 70 micro dams, 126 mini dams and 86 small sites [28]. The total exploitable potential of the country's large hydropower is estimated to be about 11,250 MW while the small hydropower stands at 3500 MW.A survey of SHP potentials in 13 states of the Federation shows that SHP potentials in two hundred and seventy-seven locations in the country could contribute approximately 734MW of electricity to the national grid. Therefore, SHP has a very large prospects when the whole country is considered.

M. SHP and Economy of power Generation

Assessment of SHP sites has underscored the site specific nature of small hydro developments. Some considerations for economic development of SHP has been identified as follows;

i. Development of heads in excess of 10 metres is most likely to prove economically sustaining.
ii. The higher the power output, the better the prospect of cost-effective development.
iii. Power outputs as low as 10 kW can only be developed economically if a direct labor approach is adopted to reduce labor costs.
iv. On-site demand for electricity should be capable of fully utilizing hydro production.

v. To be economical, energy consumers need to be located near to the hydropower scheme.

Table 1 indicates the adapted application of hydro power to domestic, small scale industry, community and national electricity supply.

Table1: Classification of Hydro Power Application

Type	Power Output	Applicability
Large	> 100 M W	Large urban population centres
Medium	10 – 100 MW	Medium urban population centres
Small	1 – 10MW	Small communities with possibility to supply electricity to regional grid.
Mini	100 kW – 1MW	Small factory or isolated communities.
Micro	5 – 100kW	Small isolated communities.
Pico	<5kW	1 – 2 houses.

Source: [2]

N. Technical Requirement for Hydro base Distributive Power System

i. Presence of a river with suitable site, head and adequate all-round the year flow volume
ii. A minimum head of 10 m
iii. An average power output of 10 MW
iv. A small dam to optimize and stabilize power supply
v. Adequate rainfall amount for present and future power production
vi. Target small to medium urban centers for adequate return on investment
vii. Community to possess sufficient economic resources to dispose power utility bills
viii. Power demand for plant output to be fully utilized

O. Formulation of Methodology for the Development of Small Hydro Power Base Distributive Power Generation

i. Reconnaissance mission to identify suitable sites with adequate hydrological characteristics suitable for distributive power system implementation
ii. Feasibility assessment to determine the annual hydro power profile of the selected river
iii. Determination of reservoir and penstock characteristics and power output optimization
iv. Materials and equipment selection in line with the hydrological characteristics of the river and power potentials
v. Determine the volume and annual rainfall characteristics of the SHP catchment area
vi. Determine the requirement, magnitude and characteristic of electrical load of the communities or urban settlement
vii. Evaluation of the economic status and activity of the community in relation to their capacity to dispose utility bills.

P. A Case Study of River Orle, Auchi

Table 2: shows the hydrological and hydro power characteristic of River Orle, Auchi Etsako West Local Government of Edo State, Nigeria suitable for implementation for an SHP base DPS.

Table 2: Hydrological and Hydro Power Characteristic of River Orle

	Minimum	Maximum	Average
Velocity (m/s)	0.462	0.564	0.513
Flow rate (m^3/s)	8.067	68.035	19.283
Power (MW)	3.957	33.374	9.348
Head (m)	-	50	-

Source: [9]

III. ANALYSIS OF FINDINGS

The primary requirement of the power grid is to supply stable quality highly reliable power to consumers over a service territory with high availability in a network with a strong electrical correlation and synchronization. To sustain the grid operation to meet its primary requirements requires a high degree of technical compatibility and operational coordination through functional circuit breakers operated by automatic relays, instrument transformers and communication, monitoring and control systems.

The Nigeria power grid which is radial in structure and transverses 15,022km has a transmission capacity of 6,700 MW which is about 54% of installed generation capacity of 12,500. The power grid covers only 40% of the country and is vulnerable to power supply disruption due to poor maintenance and vandalism. The system is plagued by poor surveillance, control and communication equipments. It has zero spinning reserve for frequency stabilization and poor protection facilities to monitor and isolate fault zone before it manifest into a disturbance and system failure.

These challenges have led to about 209 grid failure in 10 years with its attendant operational setback and socio-economic implication to sensitive and vital aspect of the economy. There is the dire need to complement the ageing and weak grid operation with an independent, effective emerging power system that can easily mitigate the challenges inherent in the nation power grid operation through the use of hydro base distribute power system. The present mini grid operation in Nigeria operates on a shallow basis with Solar and diesel generators with very narrow scope of power generation. The consideration for the use of SHP in DPS will upgrade the power generation profile of the mini grid and could transfer the surplus power generation to the National power grid in the raining season. A case study of River Orle in Auchi Edo indicates its SHP output has an average power output of 10 MW and a range of 10% - 70% power exceedence of 18.567 MW– 5.266 MW which can supply power conveniently to Auchi and a substantial part of Edo North. This is indicated in Fig. 2: The production of 18.567mw could relieve the highly stressed National power grid and enhanced its operation.

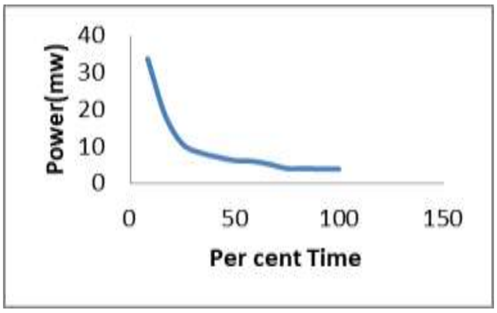

Fig 2: Power Duration Curve of River Orle, Auchi Nigeria
Source: [9]

The integration of renewable energy into the national grid is one of the most important areas for infrastructure upgrades [5]. SHP base DPS could best serve as operating reserve to the National Power Grid. A Minimum Spinning Reserve Capacity of 220 MW is required for the Nigeria National Power Grid. SHP satisfies the requirement of spinning reserve in that it can be brought into stable operating status within 60 - 90 seconds of start-up. The power output could be also varied quickly up and down which satisfy the requirement of operating reserve.

SHP produces power through rotating elements which possess the required inertia to stabilize frequency of the grid in the advent of a generator failure or sharp increase in demand. SHP could serve as an instrument of grid stability through the inertia of the rotating elements.

Nigeria is endowed with numerous small rivers across its length and breadth, the adoption of SHP base distributive power generation system will increase the national electricity coverage from 40% to higher significant figure. SHP base DPS is not constrained by remote access and fuel supply hindrance.
However, the SHP base DPS must target appropriate communities with the economic status to promptly dispose utility bill for quick and good return on investment. The system should possess a minimum head of 10m and an average power output of 10MW with a ceaseless annual flow volume.

IV. CONCLUSION

Analysis of the structure, operation and challenges of the Nigeria Power Grid in line with the development of a SHP base DPS to enhance the generation and availability of power for socio-economic consumption in Nigeria was carried out. The analysis revealed a structural weak and highly stress power grid with limited transmission coverage of the country of only 40%, high transmission and distribution losses of about 19%, zero spinning reserve, poor monitoring, communication and protection equipments. The grid vulnerability to power failure is high due very high demand for electrical power.

Assessment and feasibility studies indicate that DPS, an emerging trend in decentralize power supply, has the ability to enhance and compliment the grid power supply functions. A SHP base DPS has been identified as particularly conducive for the programme implementation due its flexibility, economy of operation and versatility with high compatibility of operation with the environment. A case study of River Orle as an SHP in Auchi indicates it can produce up to 18.567 MW at 70% flow exceedence and about 10 MW at 50% flow exceedence with the capacity to supply power to a significant part of Edo North.

The implementation of SHP base DPS in Nigeria will significantly increase the generation and availability of power to the Nigeria economy, relieve the power grid of operational stress, significantly reduce the high transmission losses and cost of electricity transmission and distribution, enhance management of the grid control, provide the essential spinning reserve and grid inertial to stabilize the operation of the grid.

The Federal Government of Nigeria is enjoined to put urgent measures in place for feasibility assessment of potential SHP with average power output of 10MW for the implementation of the SHP base DPS for small to medium urban communities with sufficient economic means for quick return on investment.

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