FEDERAL UNIVERSITY OF AGRICULTURE ABEOKUTA NIGERIA

64TH INAUGURAL LECTURE

ELECTRICITY, MAN AND DEVELOPMENT: THE COMPLEXITY OF THE DISTRIBUTION SYSTEM MANAGEMENT IN A POWER NETWORK.

by

PROFESSOR ISAIAH ADEDIJI ADEJUMOBI

(Professor of Power Systems Engineering)

Department of Electrical and Electronics Engineering
College of Engineering (COLENG)
Federal University of Agriculture Abeokuta, Nigeria

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Professor Felix Kolawole Salako, FSSSN
B.Agric (UNN), Msc, Ph.D (Ibadan)

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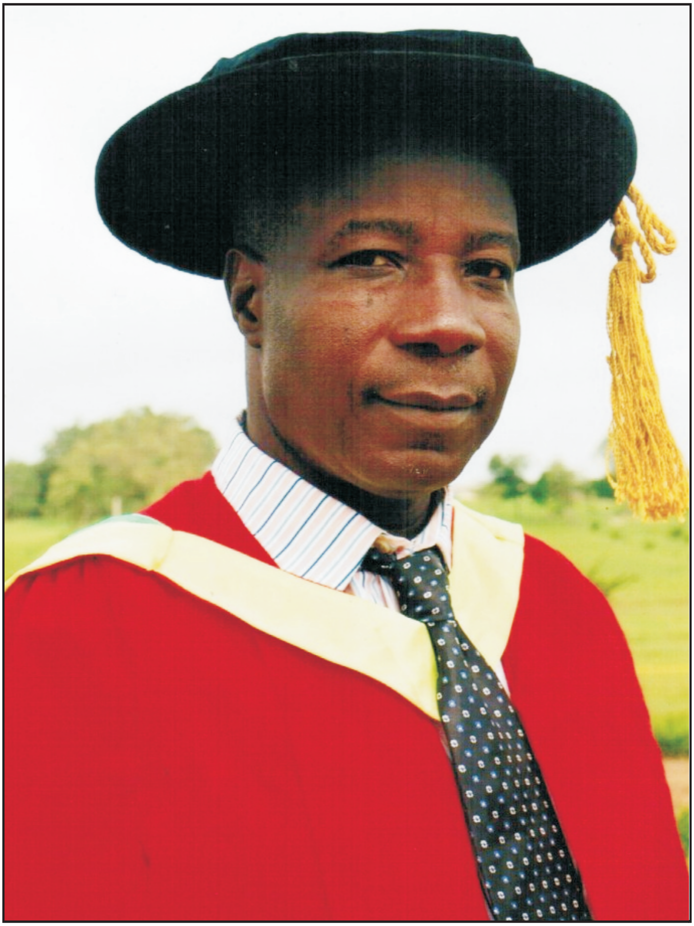

Professor Isaiah Adediji Adejumobi
B.Eng., M.Eng., Ph.D (Unilorin), MNSE, R.Eng
(Professor of Power Systems Engineering)
Department of Electrical and Electronics Engineering
College of Engineering (COLENG)

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Distinguished Ladies and Gentlemen
Great FUNAABITES!

1.0 Preamble

I am indeed delighted to stand before you today to present this Lecture. It is a privilege and grace by God and I thank God for it. If not for Him, the dream wouldn't have been realized. This Inaugural is the 64th in the Federal University of Agriculture, Abeokuta, 6th Inaugural in the College of Engineering, and 1st in the Department of Electrical and Electronics Engineering.

Mr. Vice-Chancellor, Sir, I feel honored today to give my

Inaugural Lecture titled " Electricity, Man and Development: The Complexity of the Distribution System Management in a Power Network". The lecture gives an account of my academic stewardship of about 30 years in the University System. The topic for this Lecture emanated from my passion for the management and quality operation of the power distribution system, which is a major link between electricity supply and end-users of electricity. Electric power is one of the essential factors for man's survival on the planet, a major source of energy for man's development and industrial revolution. Hence, this inaugural lecture being delivered today is coming at the right time when globally, and most especially in Nigeria, there is an energy crisis and everyone desires a stable, reliable, and quality power supply system for the domestic, commercial, academic, and industrial needs.

2.0 Introduction

Electricity is one of the necessities of modern life. With society in all works of life becoming more dependent for its successful functioning on a good supply of electric energy; the link between the source and the consumer, the distribution systems, assumes an ever significant role. Food, shelter, clothing, and energy are the four essential factors required for man's existence on the planet. Among these, electric power plays a vital role in our daily living because it integrates other factors. Electricity also has an irreplaceable feature in the driving of technological innovations, socio-economic growth, and the development of humanity.

Hence, it has a direct and optimistic correlation with economic growth and the standard of living of inhabitants of any nation, either developed or developing.
The history of the Nigerian electricity market dated back to about 1896, when electricity was first produced in Lagos to serve the Colonial Masters. The years 1929, 1946, 1951, 1962, and 1972 were major milestones in the evolvement of the electricity market in Nigeria (Ukoha and Agbaese, 2018). The Nigeria Electricity Supply Company (NESCO) commenced operations as an electric utility company in 1929 with the construction of a hydro-electric power station at Kura 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 (Akpan, 2006).

The Electricity Corporation of Nigeria (ECN) was established in 1951, while the construction of the first 132 kV line took place in 1962, linking Ijora Power Station to Ibadan Power Station. The Niger Dams Authority (NDA) was as well established in 1962 with a mandate to develop the hydropower potentials of the country. The authority was also responsible for the construction and maintenance of dams and other works in the River Niger and elsewhere, generating electricity using water power, improving navigation, and promoting fishing and irrigation. The electricity produced by NDA was sold to ECN for distribution and sales at utility voltages.

In 1972, ECN and NDA were merged to form the National Electric Power Authority (NEPA) ECN was mainly responsible for distribution and sales while NDA was created to build and run generating stations and transmission lines. The main reasons for merging the two organizations were to ensure the production and the distribution of electric power supply throughout the country by one organization and also to ensure effective and efficient utilization of the human, financial and other resources available to the electricity supply industry throughout the country. The new organization known as NEPA had the mandate to manage, maintain and oversee electricity production in Nigeria. NEPA had the statutory monopoly to generate, transmit, distribute and supply electricity throughout the federation, with its responsibilities also cutting across the Nigeria territorial borders as it was responsible for the supply of electricity in the neighboring countries of Chad and Benin.

Despite the various efforts of the state-owned utility, NEPA, which operated as a monopoly to manage the electricity market to provide efficient service delivery, it became clear by the late 1990s that the utility was failing to meet the power needs of the Nigerian populace. Hence, the National Electric Power Policy of 2001 kicked off the power sector reform in Nigeria, leading to several other reforms over the last decade.

Nigeria's electricity crisis is a long-standing issue that has become an endemic problem that has witnessed both public and private sector interventions over the years. Government efforts in the past led to the institutionalization of Nigeria Electric Power Authority (NEPA) as Power Holding Company of Nigeria (PHCN) for generation, transmission, and distribution of uninterruptible power to the Nigerian populace. However, this produced little success as constant and uninterrupted power supply was a mirage.

In 2013, President Goodluck Jonathan led Government introduced reforms which allowed private sector participation and gave room for private individuals to own more than 60% of Government asset in the power sector (Latham and Watkins, 2011). The power supply chain was unbundled and decentralized with the emergence of Generation companies (GenCos), Transmission Company of Nigeria (TCN), and Distribution Companies (DisCos) and are saddled with the responsibilities of ensuring continued power supply and meeting the ongoing Sustainable Development Goals (MDGs). Figure 1a is a complete power supply system, while Figure 1b is the Gantry of a power station.

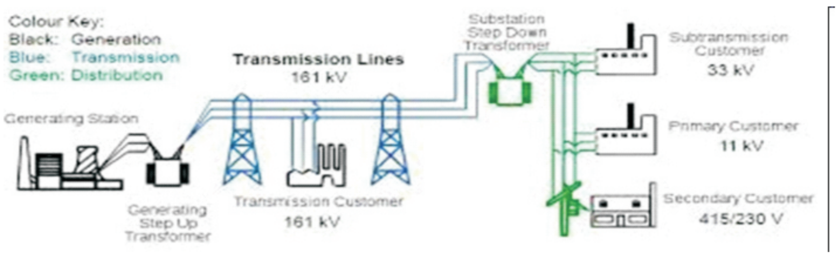


Figure 1a: A typical Power Supply System comprising Generation, Transmission, and Distribution systems.

Figure 1b: Power Station Gantry for incoming and outgoing lines

2.1 Power Generation in Nigeria

Nigeria is the largest economy in sub-Saharan Africa, endowed with large oil, gas, hydro and solar resources that have the potential to generate more than 12,522 megawatts (MW) of electric power from existing power plants. Electricity in Nigeria is generated through thermal and hydro power sources. Nigeria has 23 power generating plants connected to the national grid with the capacity to generate about 12,000 MW of electricity. These plants are managed by generating companies (GenCos), National Independent Power Providers (NIPP), and Niger Delta Holding Company.

Currently, Nigeria uses four different types of primary energy sources: Natural Gas, Oil, Hydro, and Coal. The energy sector is heavily dependent on petroleum as a basic raw material for electricity production which has slowed down the development of alternative forms of energy. Three out of the four resources used for energy production in Nigeria indicated earlier, are linked with increasing greenhouse gas emissions: coal, oil, and natural gas, with coal emitting the worst of the three.

The main source of electricity generation comes from fossil fuels, especially gas, which accounts for about 86% of the electricity generation capacity in Nigeria with the remainder generated from hydropower sources (Solynta, 2020). Current electricity generated in Nigeria is inadequate to meet the needs of households and businesses. The electricity sector of Nigeria generates, transmits, and distributes megawatts of power that is significantly less than the demand by the domestic, commercial, and industrial consumers of electricity. For the past few years, the sector has been struggling to distribute power with its peak ranging between 4000MW and 5000MW, the values which are much less than the 40000-Megawatts estimates required to sustain the basic needs of the Nigerian economy. Table 1 shows peaks of electricity generation between 2010 and 2019.

Table 1: Maximum and Minimum Power Generation in Megawatt (Mw) between 2010-2019

YEAR	MAXIMUM (MW)	DATE	MINIMUM (MW)	DATE
2010	3804.3	05/08/2010	23.0	06/02/2010
2011	4089.3	24/12/2011	15.0	16/07/2011
2012	4517.6	23/12/2012	18.3	31/10/2012
2013	4747.0	01/03/2013	20.0	24/05/2013
2014	4326.0	28/12/2014	9.0	22/06/2014
2015	4747.0	01/09/2015	1785.4	26/12/2015
2016	4996.5	03/02/2016	186.3	17/05/2016
2017	4816.20	30/10/2017	113.6	26/04/2017
2018	4821.4	28/02/2018	1963.2	10/05/2018
2019	5079.3	09/05/2019	1963.2	10/05/2019

SOURCE: TCN, 2019

Constant electricity supply is the hallmark of a developed economy. The Nigerian Electric Power Sector Reform Act of 2005 was designed among others, to move the electricity sector in Nigeria from Government control, a heavily subsidized system to a privatized, largely market-based endeavor. This reform was to encourage private companies to invest in electricity generations to have enough electric power for individual and corporate companies. As part of efforts and initiative to key into this power reform Act, some private and government-private owned companies came on board to produce power in addition to already existing ones. Table 2 is the generating capacities at various plant locations in the country. The generation sub-sector presently includes about 25 grid-connected generating plants in operation with a total installed capacity of 13,625.8 MW (available capacity 4,286.4 MW) with a thermal based generation having an installed capacity of 11, 689 MW (available capacity of 3,216.4 MW) and hydropower having 1,936.8 MW total installed capacity with an available capacity of 1,070 MW (Kayode et al, 2018). The available capacity falls significantly below the power demand in the country.

Table 2: Installed and Available Power Generating Capacities in Nigeria

S/N	STATIONS	TURBINE	NO. OF UNITS INSTALLED	INSTALLED GENERATION CAPACITY (MW)	NO. OF AVAILABLE UNITS	INSTALLED CAPACITY OF THE AVAILABLE UNITS (MW)	GENERATION CAPABILITY OF THE AVAILABLE UNITS (MW)	CAPACITY OF UNITS ON BAR (MW)
1.	Egbin	STEAM	6	1320	4	880	677	677
2.	Kanji	HYDRO	8	760	3	340	260	260
3.	Jebba	HYDRO	6	576.8	4	385.6	360	360
4.	Shiroro	HYDRO	4	600	3	450	450	450
5.	Sapele	STEAM	6	1020	2	75	68	68
6.	Afam IV-5	GAS	8	977	1	70	50	0
7.	Transcorp	GAS	6	972	6	465	320	320
8.	Geregu I	GAS	3	414	3	435	435	290
9.	Omotosho	GAS	6	450	6	252	186.4	186.4
10.	Olorunsogo	GAS	8	335	7	294	186.4	186.4
11.	Kwale Okpai	GAS	3	480	3	460	460	460
12.	Afam VI	GAS	4	642	2	315	315	315
13.	Ibom Power	GAS	3	190	1	115	52.1	52.1
14.	AES Barge	GAS	9	270	0	0	0	0
15.	Omokun II	GAS	6	150	2	50	40	33
16.	Trans-Amadi	GAS	4	136	4	100	80	80
17.	Rivers IPP	GAS	1	180	1	180	160	160
18.	Aba	GAS	3	140	3	140	140	140
19.	Geregu II	GAS	3	414	1	145	145	145
20.	Sapele	GAS	4	450	1	112.5	112.5	0
21.	Alaoji	GAS	4	1074	0	0	0	0
22.	Olorunsogo II	GAS	6	675	0	0	0	0
23.	Omotosho II	GAS	4	500	1	120	120	0
24.	Ihovbor	GAS	4	450	1	112.5	110	0
25.	Azura	GAS	3	450	3	459	454	454
			TOTAL	**13625.8**		**5350.6**	**4286.4**	**4176.9**

SOURCE: Kayode et.al, 2018

2.2 Challenges Facing the Nigeria Power Sector

When the issue of privatization of the Nigerian power sector came onboard in 2005,there were expectations that the electricity supply in the country was going to improve. However, the situation is yet to yield appreciable results. A few of the challenges are enumerated below:

a. Aging power infrastructures: both the old and new power operations are currently facing the challenges of aging facilities. Substantial amounts of investment are required to upgrade and expand power infrastructures;
b. Lack of fund: the dwindling income due to unstable global oil prices is creating a bottleneck for the finance of the power sector;
c. Incapacity of the existing transmission network to handle more load than the current peak of electricity production;
d. Poor electricity billing system. It has been very difficult for the administration to convince the frustrated electricity consumers of the need to increase the tariff;
e. Shortage of gas supply to the gas power plants;
f. Poor planning
g. Obsolete substation equipment;
h. High incidences of vandalism;
i. Community and Right of Way issues during project execution;
j. Inadequate coverage of transmission infrastructure, as well as weak infrastructure to evacuate existing generation

serving DisCo load demand;

k. Lack of effectiveness in managing system reliability and inability to perform real-time operations;

l. Government interference in the operations of the power sector.

Figures 2a-g are a few of the problems militating against the smooth operation of the power supply system in Nigeria

Figure 2a: Fallen poles and disjointed wire-cut

Figure 2b: Electric poles fallen on infrastructures due to rust base of the electric poles and weaken pole.

Figure 2c: Weeds covering power transformers

Figure 2d: Trees fell on conducting overhead distribution cables due to bush burning and storm.

Figure 2e: Burnt Transformers due to sparks and poor earthing

Figure 2f: Abandoned Hydro-Plant project

Figure 2g: One of the gigantic power stations in Nigeria, struggling to restore it after a major fault

2.3 State of Transmission System in Nigeria

The transmission grid is an integral part of the electricity value chain. The operation of the Nigerian electricity transmission network is vested in the Transmission Company of Nigeria (TCN), one of the successor companies unbundled from the Power Holding Company Ltd.

Just like in the generation system, the transmission system also faces technical challenges. These include transmission line congestion, interconnections of the transmission system, voltage limit violations, system stability loss, and high impedance which leads to high transmission line losses, etc. (Adepoju et al., 2017). Nigeria's transmission infrastructure is made up of approximately 6,680 km of 330 kV lines, 7,780km of 132kV lines. The average transmission loss (line losses) is about 9 percent. Though, since privatization began, TCN has been able to achieve significant improvements in its operations, system reliability, and efficiency, it is however still plagued with high non-technical loss and low infrastructure coverage. There are ongoing reinforcements of existing 330 kV and 132 kV lines and substations across the country to enable the efficient wheeling of more electricity as less than 40 percent of the country is covered by the existing transmission infrastructure.

2.4 State of Power Distribution System in Nigeria

The distribution system being the major link between the consumers of electricity and the power supply system is the last value chain in the power sector and its actions and inactions determine the consumers/end-users perception of the power sector as a whole. The power sector in Nigeria was partially privatized and unbundled in the year 2013 with the hope of improving service delivery and efficiency. However, this has not been achieved. Electricity distribution companies in the country are currently faced with myriad challenges among which are:

- **Obsolete equipment and Infrastructure constraints-** Some circuit breakers, transformers, and other components of the distribution system are as old as the history of electricity in Nigeria, not performing their vital roles optimally some not serviceable.
- **Liquidity crunch**: The tariffs/pricing passed to end-users by DisCos is not cost-reflective and it is one of the major reasons for revenue gap or liquidity issue in the distribution value chain. The Federal Government is responsible for payment of the shortfall in tariff in form of Electricity subsidy.
- **Indebtedness by Ministries, Departments, and Agencies MDAs**: DisCos have constantly cried out of huge amounts of money owed by Federal Ministries, Departments, and Agencies (MDAs).
- **Lack of Investment in Technical Operations:** The business owners in distribution companies see it as a

commercial entity with little or no investment in the Technical aspect of the value chain. Technical staff in most cases are deprived of standby operational vehicles for prompt and effective patrolling of faulty feeders (which was not so at pre-privatization era), causing high mean time between when a feeder is declared faulty and when the fault is cleared. Personal Protective Equipment (PPE) is hardly provided for new technical staff and worn-out PPE for old staff are not replaced.

- **High Aggregate Technical, Commercial, and Collection (ATC&C) Losses**:

  High ATC&C losses are pointers to lack of investment in electricity distribution networks or its expansion, energy theft, vandalization of cables and other substation materials, low and inefficient cash collection drive, and customers not willing to pay for energy consumed, etc.

2.5 Effects of Incessant Power Failure on Socio-Economic, Industrial Development of Nigeria

Electricity supply involves creating a balance between Generation, Transmission, and Distribution. Its availability is important for both economic development and quality of life in modern society. Huang and Yang (2012) related regular power supply of power as an important factor that could improve the economic growth of developing countries. Charles (2017) showed that the World Bank report of 2015 stated that about 75 million Nigerians lacked access to adequate electricity with Nigeria being among the countries with the highest electricity deficit. Joy (2017) avowed that poor electricity supply was a major stumbling block to Nigeria's economic growth.

Nigeria's electricity crisis is a long-standing issue that has become an endemic problem that has witnessed both public and private sector interventions over the years. Government efforts in the past led to the institutionalization of Nigeria Electric Power Authority (NEPA), Power Holding Company of Nigeria (PHCN) for the generation, transmission, and distribution of uninterruptible power to the Nigerian populace. However, this only produced little success as constant and uninterrupted power supply was an uncommon phenomenon. Eight years after the reform introduced by President Goodluck led government in 2013, private sector participation seems not to be yielding expected outcome as technical losses, system losses, the inability of the DisCos to invest and distribute maximum power from GenCos are still the challenges that hinder the progress of the sector. Hence, lengthy hours of power outages due to load shedding or system failure are recurring occurrences in the country.

Nigeria's industrial sector is faced with multi-faceted problems, top of which is the incessant power outage. Most industries in

Nigeria barely have power supply from the National grid and therefore, run on generator / renewable sources for long hours. Many power firms, information technology companies, and food processing companies largely run on generators or renewable sources to power routers, switches, and terminal equipment. The cost of producing power via alternative sources constitutes more than 30% of the total cost of production (Ahmed & Mallo,2015) in many companies resulting in higher cost of production, higher cost of goods and services, and reduction in the profit margin of companies.

The telecommunication industry has also been affected by poor electricity supply in the country. Poor power generation has increased the operational costs of telecommunication service providers in Nigeria. Mobile system operators and Internet service providers are some of the largest consumers of diesel in Nigeria. The poor power supply is a direct cause of poor services like drop calls, poor internet services, undelivered messages, and user inaccessibility from mobile communication providers. It has been noted that "The greatest factor undermining the growth of telecom and information technology sectors is the unreliable power supply and only elimination of the rots in the power sector could successfully eradicate poor service challenges" (Malakata, 2015). Off-grid supply in rural areas and operational costs of new base stations reduce penetration to rural areas and limit accessibility to telecommunication. Due to unreliable power supply in Nigeria, Mobile network providers have over the years failed to meet the National Communication Commission (NCC) standard of network availability every time of the day. This failure attracts fines imposed by NCC.

The growth of Small and Medium Enterprises (SMEs) in Nigeria has also been hampered by the unusual and un-assuring power supply. It kills the business instincts of budding entrepreneurs who could not afford generators for start-ups and undermines the efforts of the Government to achieve economic growth and development. Artisans like welders, barbers, plumbers, and so on, have forsaken their main work and turn to 'Okada' riding or looked for other means as a source of livelihoods; few could afford to buy generators for their work. Those that could bear the cost of generators charge higher rates for their services. Customers now pay through their noses for services that ordinarily should not cost much.

Incessant power supply has led to the winding up of companies in Nigeria. Firms that could not cope with business terrain in the country have closed down or relocated to neighboring African countries for safe havens. Typical examples are those companies such as Leventis, Michelin, and Dunlop, etc. Many have relocated to sister countries thereby increasing the unemployment rate in the country.

Nigeria's prevalent electricity crises are also having their toll on the health sector and tertiary institutions such as hospitals, universities, polytechnics, colleges of education, etc. To compete favorably with the rest of the world, most institutions in Nigeria have wittingly resulted in the use of alternative energy sources for research and academic purposes. A case in perspective is this university, Federal University of Agriculture, Abeokuta, Nigeria which runs on generators for several hours a week. Frequent use of generators raises sundry expenses and increases net expenses.

The importance of electricity in our social lives is not debatable and in that regard, a lot of homes, hotels, and brothels have surrendered to the use of generators for lighting which not only puts pressure on their slim resources but also poses dangers to humans. It is read everyday in national dailies the sad and alarming reports of Nigerians who lost their lives to generator fumes. Poisonous exhaust from generators seems to be the second cause of unnatural death after natural disasters and insurgency in Nigeria. There is no doubt that Nigeria is running a generator economy that is risky and grossly inadequate to meet the daily demand of electricity.

2.6 The Complexity of the Distribution System Management

The delivery of electric energy from the generating plant to the consumer may consist of several, more or less distinct parts that are somewhat interrelated. Nigeria's power sector consists of three major subsectors including generation, transmission, and distribution systems, the distribution being the last stage of the process. The part considered as "distribution" forms the bulk supply substation to the meter at the consumer's premises and can be conveniently divided into two subdivisions:

(i) **Primary distribution** carries the load at higher than utilization voltages (33kV or 11kV) from the substation (or other sources) to the point where the voltage is stepped down to the value at which the energy is utilized by the consumer. Primary distribution feeders are usually in Radial or Loop connections. Though, complex and requires more cost to manage, loop connection provides a safer and stable electric power supply.

(ii) **Secondary distribution** includes that part of the system operating at utilization voltages (415V, 240V), up to the meter at the consumers' premises.

Several problems abound in distribution systems that undermine regular power supply to many consumers in Nigeria. These include incompetent personnel, insufficient investment, energy theft, and distribution or technical losses. Many of the organization's technical staff lack the required technical expertise to improve the distribution system, which affects power delivery in the country. In some cases, the distribution network connections are not effective enough to deliver electric power to consumers efficiently.

The pre-privatization days witness insufficient funds for infrastructural facilities and good maintenance. This trend continues as DisCos are not willing to invest massively in the sector. Obsolete equipment that predates the privatization is still in existence which not only affects the growth of the power sector but also undermines the quality power supply in the country.

Nigeria's distribution sector lacks a sophisticated and advanced energy tracking system to identify and prevent illegal connections. There are no sufficient predicting tools to see into the future; to know how much energy will be demanded in the nearest future, and how much equipment will be needed for system smooth operations.

Nigeria's distribution management has no control over the types and sizes of cables being used to connect at the consumer end. Different sizes of cable are seen connecting supply to consumers premises. Poor conductor sizing causes high distribution losses, and there are lots of unsound or obsolete equipment which greatly affects the electricity supply. Due to the complexity of the distribution network, the technical analysis of its operational behaviors is increasingly more difficult. There are insufficient operational data. It is therefore very difficult to manage power distribution systems, and hence, to provide essential and quality services to consumers.

3.0 Government Intervention

In an attempt to ensure quality electricity services in Nigeria, the

Government has not relented in her efforts to enhance performance within the three sectors of the electricity market in Nigeria. Few of the government involvements are briefly discussed below.

3.1 Electricity Act Reform

The Nigeria Electric Power Sector Reform Act of 2005 was designed to among others move the electricity sector in Nigeria from Government control, a heavily subsidized system to a privatized, largely market-based endeavor. This reform was to encourage private companies to invest in electricity generation to have enough electric power for individual and corporate companies. Since 2005, the electricity reform Act has been a challenging one for Nigeria Government. However, the process of implementing the reform Act was revitalized when the Government under the leadership of President Goodluck Jonathan established the presidential task force on power and published a roadmap for power sector reform in August 2010, which potentially opened door to significant private investments in the Nigeria power sector. In 2013, President Goodluck Jonathan introduced reforms which allowed private sector participation and gave room for private individuals to own more than 60% of Government asset in the power sector.

3.2 The Power Sector Recovery Implementation Plan

The Federal Executive Council on March 22, 2017, approved a power sector recovery and Implementation Plan, which was prepared in consultation with the World Bank Group. The Plan was a set of policy actions, operational and financial interventions to be implemented by the Federal Government of Nigeria to attain financial viability of the power sector. The objectives of the Implementation plan include among others, the elimination of the payment deficit which had accumulated in 2015 and 2016, a commitment to fund the deficit, ensuring performance and implementation of credible business continuity plans by the electricity distribution companies and the Transmission Company of Nigeria, ensuring that cost-effective tariffs are achieved over five (5) years and increasing electricity access by implementing off-grid renewable power solutions. The implementation is ongoing.

3.3 Issuance of the Mini-Grid Regulations 2016 by NERC

The National Electric Regulation Commission (NERC) issued a draft on "**Mini-Grid Regulations**" in draft form in 2016 which was subsequently adopted on May 24, 2017 (NERC, 2017). The Mini-Grid Regulations is the first legal framework for the establishment and development of mini-grids in Nigeria and it provides for, among other things the regulatory framework for all mini-grids in Nigeria. A mini- grid as defined under Section 3(1) of the Mini-Grid Regulations is, "*any electricity supply system with its power generation capacity, supplying electricity to more than one customer and which can operate in isolation from or be* *connected to a distribution licensee's network.*" The Mini-Grid Regulations also restrict the definition of the term to "*any isolated or interconnected mini-grid generating between 0kW and 1MW of generation capacity*". The issued Regulations were meant to (1) accelerate electrification in areas without existing distribution infrastructure (**Undeserved Areas**) as well as areas with existing but poorly electrified or non-functional distribution facilities (**Underserved Areas**); and (2) act as a catalyst for stimulating the desired improvements along the electricity value chain.

The shortcomings on Mini-Grid Regulations are: (1) potential cumbersome process for the application of a permit, particularly the requirement that developers of an interconnected mini-grid must execute a tripartite contract with a community connected to the Disco and the incumbent Disco; and (2) generators with a stranded capacity of more than 1MW are restricted from participating under the scheme. In addition, a developer of an isolated mini-grid needs to ensure that a Disco has no plans to extend its network to its project site, and the isolated mini-grid will be required to convert to an interconnected mini-grid operator or transfer all assets to the Disco. This may serve as a deterrent to investors willing to construct isolated mini-grids.

3.4 The liberalization of power generation and distribution between the Federal and State Governments

The Minister of Power on August 14, 2017, affirmed the right of

State Governments in Nigeria to generate their power independent of the GenCos, DisCos, the TCN, and other operators in the Nigerian Electricity Supply Industry (NESI). This was aimed at underpinning the free-enterprise stance of the Reform Act and liberating the power business in the country from the grip of an inefficient supply monopoly. While the affirmation has no force of law, it is expected that National Electric Regulation Commission (NERC) will treat applications from state governments who have the financial wherewithal to generate their power for the development of power projects, more favorably. Lagos, Oyo, and some others States have started the process of cueing into the scheme.

3.5 Siemens (German Energy Company)-Nigeria Agreement

Since August 2018, the Nigerian government signed a six-year power deal with the German energy company in an attempt to fix the country's unreliable electricity grid. The deal was expected to result in the production of at least 25,000 megawatts of electricity by the year 2025. When signing the agreement, President Muhammad Buhari declared "We all know how critical electricity is to the development of any community or indeed any nation "… whilst we are blessed to have significant natural gas, hydro and solar resources for power generation, we are still on the journey to achieving reliable, adorable and quality electricity supply necessary for economic growth, industrialization, and poverty alleviation." By this deal, Siemens is expected to work alongside the Transmission Company of Nigeria to achieve 7,000 megawatts and 11,000 megawatts of reliable power supply by 2021 and 2023 respectively, before the contract lapses.

4.0 Scholars Contributions to securing solutions to Electric Power Problem in Nigeria

Currently, Nigeria's Electricity Grid system consists of about 25 generating stations (3 hydro and 22 thermal) with a total installed capacity of about 13,625.8 MW. However, the available power output is far below the installed capacity, mostly a little above 4000MW at peak period. Several factors account for the disparity between installed capacity and available power and efforts to address the problems created by those factors have spanned several decades.

Several researchers have focused attention on unraveling the rationale behind poor electricity supply in Nigeria, as well as proffering solutions to those problems, some of which are discussed below:

4.1 Generation System

Madueme (2002) carried out an investigative study on the culture of maintenance at Afam Power Generating Station from 1993-1997 and it was revealed that ineffective maintenance culture, and delays in making funds available for maintenance purposes accounted for the poor performance recorded in those years.

Idigbe and Igbinovia (2010) and Onohaebi and Lawal (2010) identified problems confronting power generation in Nigeria to include lack of energy mix, poor electricity pricing, obsolete facilities, poor policy on Natural gas as well as poor funding. Ohajianya et al (2010) observed that inconsistent energy policy, uncoordinated workforce, obsolete equipment were issues that needed to be addressed to boost electric power production.

Sule (2010) further pointed out that the absence of good research, pipeline vandalism, gas flaring, seasonal drought, poor plant maintenance, bribery, and corruption are factors behind poor power generation in Nigeria.

Oyedepo and Fagbenle (2011) on the other hand examined the impact of preventive maintenance schedules on the available units of the Egbin power plant. Analytical results showed among others, that generation improved significantly when preventive maintenance activities were properly implemented on the available six units of Egbin power plant.

Ebukanson *et al* (2017) presented a statistical analysis of electric power generation in Nigeria using the Multi-linear regression model and Box-Jenkin's auto-regression model of order 1 [AR(1)] and the results indicated that the former predicted power generation reliability from 2012-2014 better than the latter.

Emovon and Samuel (2017a) for example, utilized a tool based on the integration of statistical variance and Vlsekriterijumska

Optimizacija Ikompromisno Resenje (VIKOR) to rate problems confronting power generation in Nigeria. It was shown that poor maintenance of power generation infrastructure is the most critical problem confronting power generation in the country.

Emovon and Samuel (2017b) presented Multi-Criteria Decision Making (MCDM) tool for prioritizing solutions to power generation problems. It was realized in his work, that Reliability Centered Maintenance (RCM) and diplomatic approach are the tools necessary for averting downtime.

Emovon and Nwaoha (2018) employed Multi-Objective Optimization based on Ratio Analysis (MOORA) and Analytical Hierarchy Process (AHP) techniques for prioritizing problems affecting power generation. The work revealed that poor maintenance of power generation infrastructure, militant activities, and corruption are the most important issues causing poor power generation in Nigeria.

4.2 Transmission System

Jokojeje *et al*. (2015) worked on the application of Static Synchronous Compensator (STATCOM) in improving power system performance using the Nigeria 330 kV electricity grid as a case study. Evidence from the study revealed that STATCOM application on the Nigeria electricity grid will stabilize the system's voltage and reduce the overall transmission active power loss thereby releasing spare capacities to cater for more consumers.

Melodi *et al* (2016) proposed a probabilistic load forecast algorithm for long transmission expansion planning of the Nigerian transmission network. A developed solution technique consists of an artificial neural network and Monte Carlo simulations, considering predominant driving factors of the location, population, and GDP growth in Nigeria. The results obtained from the analysis showed a better improvement in power transmission over the existing network. However, the uncertainty in the accuracy of the forecast technique may lead to wrong decisions.

Adebisi *et al.* (2017) examined the effect of the application of Static Var Compensator (SVC) for voltage stability enhancement and power loss reduction in power systems, networks. Findings from the work showed that SVC as a compensating device is capable of enhancing voltage profile and reducing power loss if incorporated in power system networks.

Adebisi *et al.* (2018) worked on performance improvement of power system networks using Flexible Alternating Current Transmission Systems Devices (FACTS) using the Nigerian 330 kV electricity grid as a case study. The FACTS employed for the study was SVC. The results showed that SVC is not only capable of improving and maintaining the system voltage profile within an acceptable limit but will also reduce power loss and in effect improve the power transfer capability of the system when deployed.

Ogundare and Adejumobi (2019) studied transmission expansion planning using the Power Transfer Distribution Factor Index (PTDFI) and considering the **Nigeria 330kV 30-bus grid system as a case study**. The objective of the research work was to identify transmission lines within the Nigeria Grid system that were overloaded above the rated capacities, and those critically loaded. Results from the work revealed that six lines were critically loaded. To mitigate the effects of the overloaded networks, the work proposed twelve new transmission lines for maximum evacuation of generated power from the power generation stations and further suggested the possible locations of the new lines that would stabilize the entire system.

4.3 Distribution System

Uhunmwangho and Okedu (2009) worked on the state of power distribution in Nigeria, using Akwa-Ibon State as a case study. Data on the loadings and states of distribution facilities at sub-distributions areas of Uyo, Ikot Ekpene, and Eket were collected and analysed qualitatively to determine the reliability of the system. Factors such as broken poles, damaged straps, broken cross arms, broken insulators, damaged feeder pillars, leaking and overloaded transformers, were some of the major defects identified as the cause of poor power distribution in the study areas.

Chinwuko *et., al* (2012) worked on modeling and optimization of electricity distribution system using dynamic programming techniques, a case study of Power Holding Company Awka, Nigeria. A primary information of sub-distribution locations and network configuration and arrangement was used as input variables to optimize system performance. A huge amount of energy losses and high investment costs were discovered before optimizing. Through reconfiguration and optimization of the system component size, the energy loss and investment cost were reduced.

Jubril and Ekundayo (2013) researched on reliability assessment of 33kV Kaduna Electricity Distribution Feeders in the Northern Region of Nigeria using daily outages data on feeders for 16 months. The system experienced a high failure rate, and hence poor reliability values.

Uhunmwagho and Okedu (2014) worked on the issues and challenges facing the Nigerian Electricity Distribution Industry: a case of Benin Electricity Distribution Company, covering Edo, Delta, Ekiti, and Ondo state. A five-year data including the supply in feed to Benin Electricity Distribution Company, available average daily supply, transformer loading, fundings, etc were collected and statistically analyzed. The work discovered overloading of transformers, inadequate funding, and vandalization of equipment as part of factors militating against the quality operation of the distribution system.

Omonfoman's (2016) article on ”Electricity Distribution Companies: The challenges and way forward” noted that grid energy insufficiency, network infrastructure, poor tariff, poor metering system, low funding, and energy theft are some of the challenges facing power distribution in Nigeria. Capitalization of DisCos, access to long-term debt financing, implementation of a cost-reflective tariff and addressing fixed charges were some of the recommendations proposed in the article for quality performance of the distribution system.

Akintola and Awosope (2017) worked on reliability analysis of secondary distribution systems in Nigeria: A case study of Ayetoro 1 sub-station Lagos State. Quantitative techniques involving the collection of data and qualitative analysis of the data were used to determine the system's reliability. The work identified overloading of the transformers as the major factor contributing to poor distribution and low reliability of power distribution in Nigeria.

5.0 My Contributions

Distribution networks are the major links between the electricity supply authority and the consumer of Electricity. My passion for distribution system management and analyses began about twenty-four years ago during my Ph.D. program. While in Nigeria, the government was focusing much attention on electric power generation plants and transmission systems, electrical distribution systems received relatively little attention. Even in engineering schools, while series of software on the optimal generation of power was being developed every day, only a few researchers were interested in distribution system analyses. With the expansion in the use of electricity due to commercial, industrial and technological developments coupled with population growth, the demand for distribution systems became greater and more complex. Hence, a lot of problems emanate daily across distribution centers in Nigeria that require day-to-day attention.

A **distribution system management** is the application of designed techniques and initiatives to monitor and control the entire distribution system efficiently and reliably. The management is meant, among others, to improve the reliability and quality of service in terms of reducing outages, minimizing outage time, maintaining acceptable frequency and voltage levels as well as lowering the supply cost. For this lecture, three major areas were covered: System-configuration, System Management and Planning, and Economics. The Power Distribution Management Architecture based on my work is shown in Figure 3.

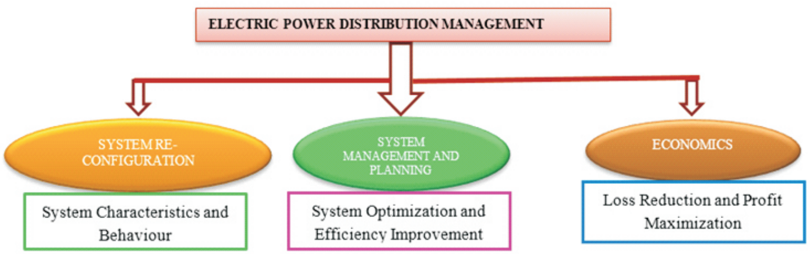


Figure 3: Power Distribution Management Architecture

5.1 Importance of Distribution System Management

Consumers of electricity cannot obtain satisfactory and efficient performance from electrically powered equipment operating on voltages or frequency outside the statutory values. Hence, the proper understanding of the behavior of distribution networks and the improvement techniques, through system management is very essential.

5.2 Distribution System Re-Configurations

Distribution systems are usually either radial or loop. Most times, the choice of connection is made based upon the type and characteristics of the load to be served and also the cost. Due to inadequacy in power generation in Nigeria, it has become imperative that efforts be made to use the available energy efficiently and to reduce losses when distributing it. The uneven load distributions in primary distribution feeders have been identified as one of the major causes of power losses in the distribution system. The auto-reconfiguration of a distribution network allows instant by instant transferring of loads between possible closed distribution feeders whenever there is load imbalance and the system variables statutory limits are violated.

Adejumobi and Opeodu (2011) developed a fast and reliable heuristic Visual Basic.Net-based algorithm capable of measuring and evaluating power flow, power losses on feeders, and voltage profile at the feeder buses. When load imbalance occurred, loads are transferred between possible closed distribution feeders to reduce power loss and improve voltage stability. When the technique was applied to the Ilorin Distribution network, the results showed that power losses on the critically loaded feeders reduced considerably and voltage profile at load buses improved close to limits of ±10% statutory value as shown in Figures 4a-d.

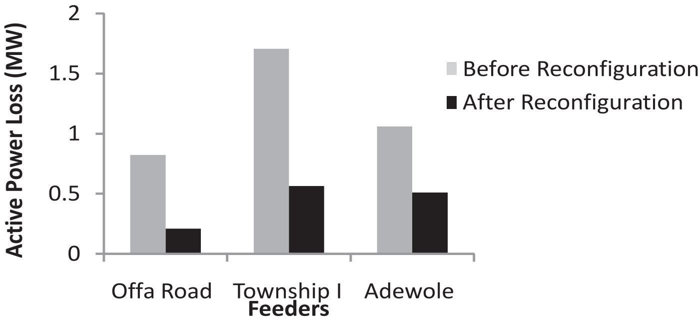


Figure 4a: Active Power Losses on Selected Feeders in Ilorin Distribution Network

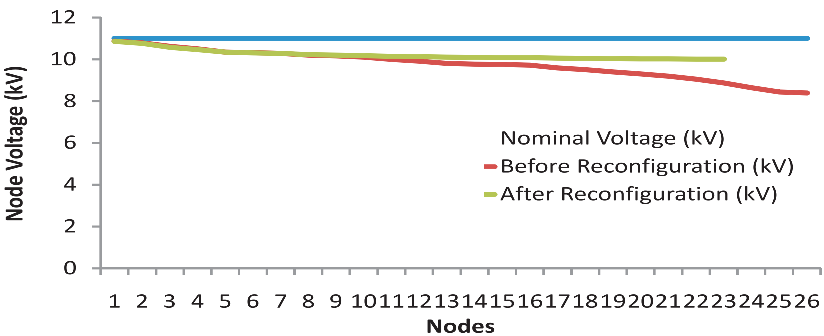
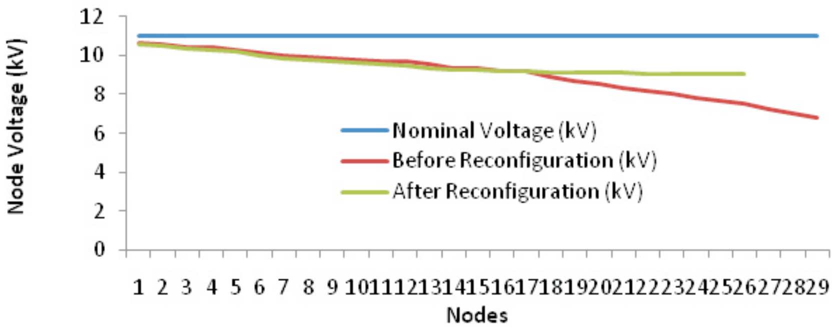


Figure 4b: Voltage Profile for Offa Road Feeder



: Voltage Profile for Township I Feeder

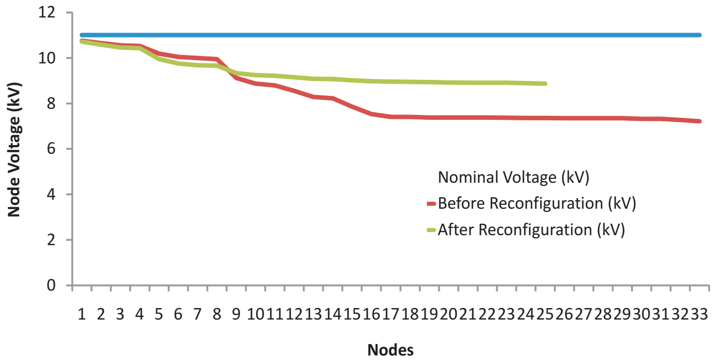


Figure 4d: Voltage Profile for Adewole Feeder

Similarly, Adebanji and Adejumobi (2011) developed a Civanlar based heuristicradial distribution network configuration algorithm for minimizing power loss, using Ekiti 33kV distribution network as a case study. Using the MATLAB package, the power flow and losses before and after the network was reconfigured were simulated. The results of the analysis showed that the loss on the Ekiti 33kV reduced from 3280kW to 2843kW, the system's overall voltage profile improved with the voltage deviation index reduces from 0.010 to 0.002. The results were as presented in Figures 5a & b.

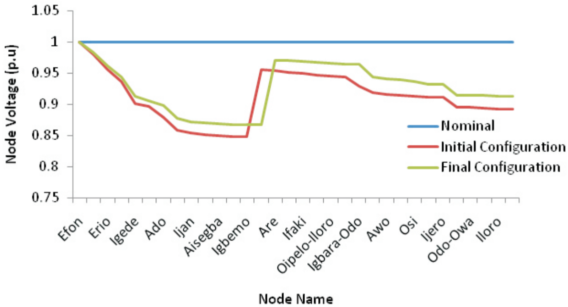


Figure 5a: Voltage Profile for Ekiti Distribution Network

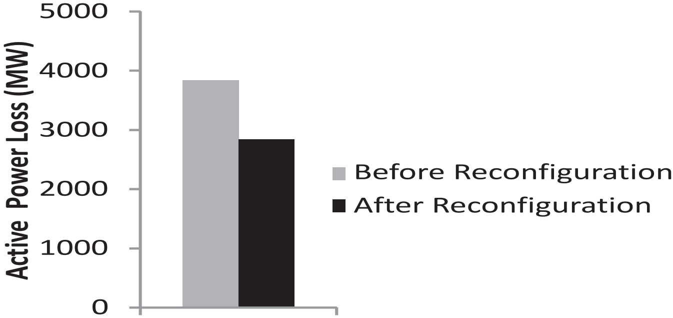


Figure 5b: Active Power Loss on Ekiti Distribution Network

Adejumobi and Adebisi (2012) considered the application of tap changing transformer technique on selected primary feeders with the sole objective of minimizing distribution network losses and voltage drops, using piece-wise power equations, with the basic assumption that voltage drop on any selected feeders should be within the statutory limit of $\pm 10\%$. Using the Abeokuta distribution network in Ogun state as a case study, a developed optimal tap selector program was used to analyze three selected feeders within the Abeokuta metropolis. The results were as presented in Figures 6a and b. The transformer voltage drops reduced by 0.3, 0.1, and 2.5% respectively for Camp, Obantoko, and Ibara feeders. Similarly, power losses for the three feeders were reduced by 13, 10.81, and 21.81% respectively for Camp, Obantoko, and Ibara.

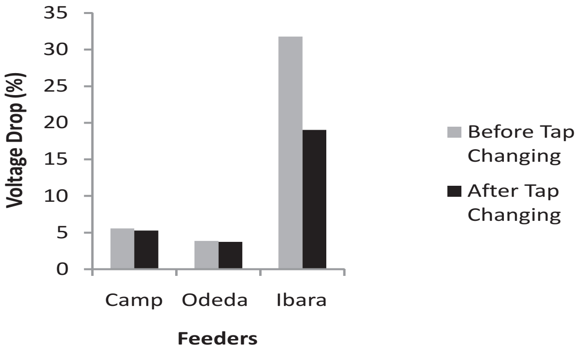


Figure 6a: Percentage Voltage Drops for Selected Feeders in Abeokuta

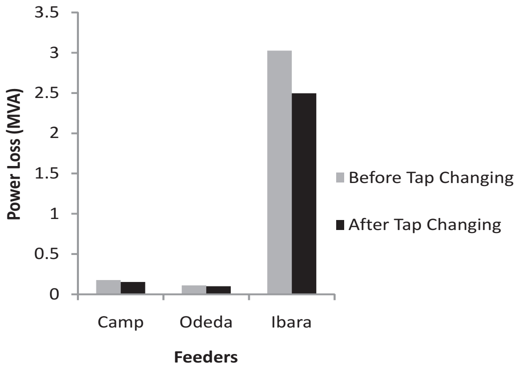


Figure 6b: Power Losses for Selected 33kV Feeders in Abeokuta

The Nigerian power distribution system is characterized by high power loss arising from excessive overloading of the distribution feeders. Consequently, poor quality power is delivered to the consumers. To solve the problem, Adejumobi and Opeodu (2012), using the Ilorin Distribution network, developed an algorithm coded with Visual Basic.Net to provide a simple and flexible task in determining optimal capacitor sizing and placement on the distribution feeder for voltage stabilization and power loss minimization. The results of three selected heavily loaded distribution feeders from about seven feeders on the network showed a percentage power loss reduction of 43.22, 45.38, and 44.91 %respectively for Adewole, Township I and Township II as presented in Table 3. These reductions would allow spare for more load to be added to the supply system from consumers.

Table 3: Feeder Losses with Capacitor Size and Placement

Feeder Name	No of nodes	Power Loss Before Capacitor Placement (MVA)	Power Loss After Capacitor Placement (MVA)	Power Loss Reduction (%)	Capacitor Size (MVar)	Optimal Capacitor Placement Node
Adewole	33	1.955	1.11	43.22	2.344	16
Township I	29	1.633	0.892	45.38	3.362	13
Township II	22	1.011	0.557	44.91	3.154	9

Adejumobi (2009) presented the quality assessment of transformer insulating oil. The breakdown voltage, dielectric, and acidity tests were electrically and chemically carried out on sixteen samples of transformer insulating oil which were strategically collected from various serving distribution transformers in Ilorin Metropolis in Nigeria, through the supply authority. The samples were collected at different distribution substation locations in Ilorin Metropolis in Nigeria. The collections were randomly done based on old, fairly old, and new 11kV and 33kV distribution transformers. The results of the tests were used to determine the dielectric strength and acidity of the selected samples. The authenticity of the obtained results was ascertained by comparing the experimental values with the recommendations from the American Society for Testing and Materials (ASTM) and the British Standard (BTA705). For 33kV and 11kV distribution transformers, minimum Breakdown Voltages are 45kV and 25 kV respectively. Similarly, the maximum allowable acidity (in MgKOH/g) present in transformer insulation oil irrespective of voltage rating should not be more than 0.2.

Table 4: Result of dielectric and acidity test

Oil Sample	Transformer Type (kV)	Transformer Rating (kVA)	Breakdown Voltage (kV)	Dielectric Strength kV/min	Total Acidity MgKOH/g of oil	Remark
A	33/11/0.415	300	49.8	19.20	0.00	In good condition
B	33/11/0.415	300	41.3	16.52	0.06	To be reconditioned
C	11/0.415	100	33.3	13.3	0.06	In good condition
D	33/0.415	200	37.5	15.0	0.10	To be reconditioned
E	11/0.415	100	14.5	5.80	0.20	To be replaced
F	11/0.415	250	27.2	6.90	0.30	To be replaced
G	11/0.415	100	36.6	5.50	0.35	To be reconditioned
H	11/0.415	100	27.8	11.12	0.10	In good condition
I	11/0.415	100	8.3	3.30	0.45	To be replaced
J	33/0.415	300	28.7	11.50	0.45	To be replaced
K	33/0.415	500	49.8	19.90	0.00	In good condition
L	11/0.415	300	30.0	12.0	0.06	In good condition
M	11/0.415	300	27.2	10.88	0.11	To be reconditioned
N	33/0.415	300	9.80	3.92	0.45	To be replaced
O	11/0.415	200	13.8	5.52	0.35	To be replaced
P	33/0.415	500	44.5	18.95	0.30	To be reconditioned

When Adekoya and Adejumobi (2017) applied the same tests to another thirty (30) selected samples from Jericho Distribution Network, Ibadan in Oyo state, the results indicated that ten 10 out of the 30samples (33% of the sample data) failed the tests.

The overall economic implication of the result in Table 4 is that the affected transformer insulations will be broken down and hence, result in interruption of electricity supply to consumers. When a transformer breaks down, unavailable foreign exchange must have to be sought but the masses suffer eventually and the economy is negatively affected. Preventive maintenance and routine checks will prolong the life span of the power transformers and provide quality service to consumers of electricity.

5.3SYSTEM MANAGEMENT AND PLANNING

System Management and Planning involves system optimization and efficiency improvement of the distribution systems. It includes load (demand) growth predictions, assessment of distribution systems reliability, system stability, voltage drops, and power loss assessments.

An uninterrupted and reliable electricity supply is undoubtedly one of the most important prerequisites for the growth and development of any nation. Reliability is an important concept in power systems and is one of the basic measures of effectiveness with which an electrical distribution network achieves its objective of distributing electric energy to various consumers. It is essential in the planning, designing, operating, and maintenance of electrical power systems. The reliability of a system can be defined as the probability that the system will operate to an agreed level of performance for a specific period, subject to specified environmental conditions.

Accurate and efficient electrical energy demand forecasting is an inevitable prerequisite for electrical power distribution system planning and operation as it can result in cost savings and high returns on investment in the power industry. Forecasting is a decision-making tool that deals with past events, present status, and prediction/projection of future occurrences. It is an intelligent prediction of past and current load demand patterns to ascertain satisfactory reliability and accuracy of the anticipated load growth (Okoye and Madueme, 2016), The proper presentation and use of forecasting techniques to help in budgeting, planning, and estimating future growth in terms of quantity and quality is vital (Andersen *et, al*, 2013). When the energy forecast is too conservative, there is a tendency for the generating capacity to fall below the consuming capacity, resulting in restrictions on the power supply which can be detrimental to the socio-economic growth of the nation. Likewise, too optimistic forecasting may lead to the creation of excess generating capacity without commensurate returns on investment (DeLurgio, 1998).

Conversely, one percent (1%) error in energy demand forecast can result in hundreds of millions of Naira loss (Awosope 2014; DeLurgio, 1998).

Adejumobi (2003) worked on distribution system load demand growth prediction using the least square regression approach. The least-square regression, one of the quantitative forecasting techniques for load demand prediction was used with the assumption that the dependent variable of interest will be affected by one or more factors. Five-year (1997-2001) data of monthly peak loads in MVA from six injection sub-stations from the Ilorin Distribution network were collected and used to project for another five years (2002-2006).The best line of fit was done on plotted scatter diagram of the data and analysis of variance (ANOVA) tables were computed using statistical model equations. The adequacy of the model equations was assessed by comparing the values of the calculated F-ratio with the standard F-statistical table. The adequacy of the forecast modeled equations was further assessed by comparing the value of calculated correlation (r) with standard r-statistical tables at the appropriate degree of freedom.

The results showed that three injection sub-stations (T1, T2, and T5) would be overloaded beyond rated capacities five years into the forecast period while the remaining (T3, T4, and T6) would be operating close to critical load points as shown in Figures 7a and b.

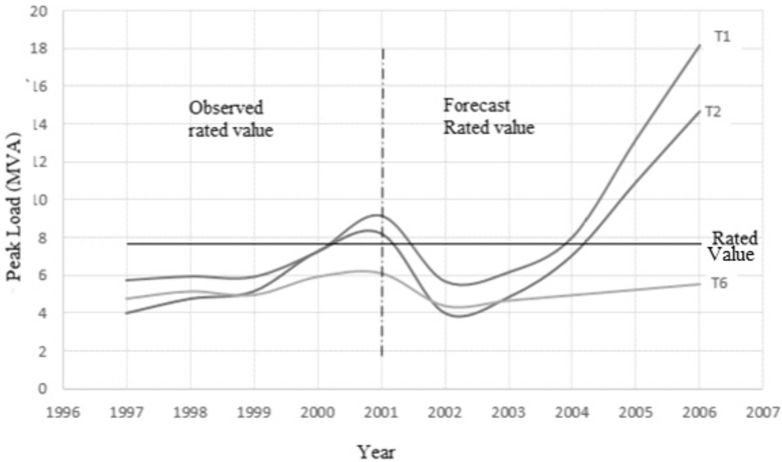


Figure 7a: Ilorin distribution system yearly load growth rate for 7.5 MVA injection transformers T1, T2, T6. Observed value (1997-2001), Forecast (2002-2006)

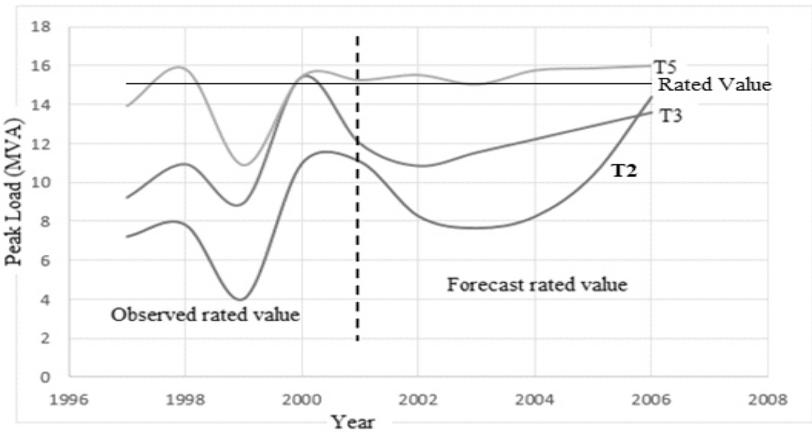


Figure 7b: Ilorin distribution system yearly load growth rate for 15 MVA injection transformers T3, T4, T5. Observed value (1997-2001), Forecast (2002-2006)

Still, on system planning, Adejumobi (2005a) assessed the distribution system reliabilities using Ilorin and Dugbe (Jericho Undertaking) distribution networks as a case study. The ten-year

(1991-2001 and 1992-2002) monthly fault data collected from the respective two stations were qualitatively modeled and used to forecast for another ten (2002-2011 and 2003-2012) years using Box-Jenkins time series methodology. Selected models were based on the plots of Sample Auto Correlation (SAC) and Sample Partial Auto Correlation (SPAC). From the observed and forecast values, the failure rates were determined and used to calculate the reliability of the system as years progressed as shown in Figures 8a and b. The adequacy of the chosen model was also determined by comparing the computed chi-square with the standard statistical table. The results showed that the reliabilities of both distribution systems for Ilorin and Ibadan (Jericho Undertakings) decreased with time to 12.5% and 21.7% by the years 2011 and 2012 respectively.

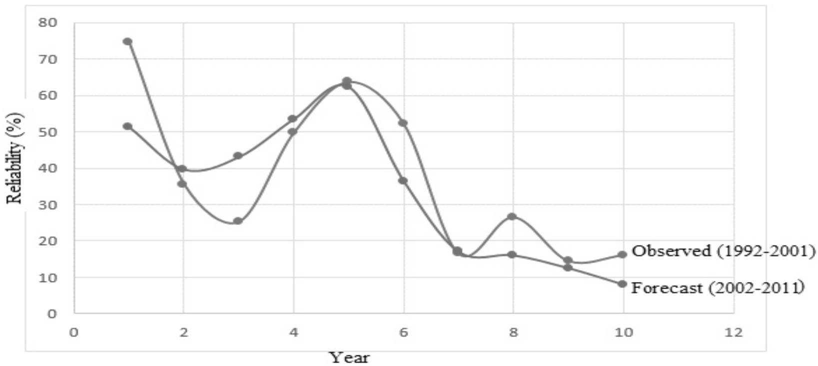


Figure 8a: Ilorin Distribution System Reliabilities:1992-2001(observed);2002-2011(forecast)

Figure 8b: Dugbe Jericho Undertaking Ibadan, Distribution System Reliabilities: 1993-2002 (observed); 2003-2012 (forecast)

Similarly, Adebisi *et al.* (2016) assessed the reliability of the electrical distribution network using the least square regression approach. Regression analysis is a mathematical technique that provides a trend equation that best fits empirical or experimental data and for predicting the value of a dependent variable based on the known value of an independent variable for a given set of data points. Using the Federal University of Agriculture, Abeokuta (FUNAAB) 33 kV distribution network in Abeokuta, Ogun State as a case study, the available five years (2010-2014) fault data were used to determine the forecast model for the network. The appropriateness of the model equations was diagnostically checked using the minimum sum of the error square (and coefficient of determination (R^2). Where the model equation fails to satisfy R^2 conditions, R^2 adjusted was used.

The results obtained from the study which showed the observed reliability between 2010 to 2014 and forecast reliability between 2015 to 2019 were shown in Figure 9.

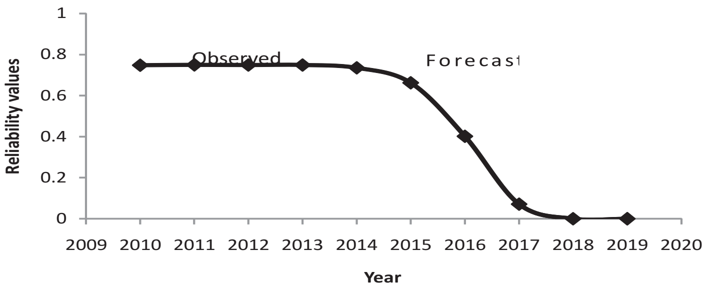


Figure 9: Reliability values of FUNAAB 33 kV feeder from 2010 to 2019

Figure 9 revealed that the reliability of the FUNAAB 33 kV electricity distribution feeder declined over time. Within the period under study (2010 - 2014), the feeder experienced gradual decline in reliability. Over the forecast period (2015 - 2019), the feeder recorded a very steep decline in reliability from 66.22% in 2015 to an approximately zero value in 2019. Experiences have shown that when an electric distribution network is subjected to overloading, lack of adequate maintenance or necessary upgrading which may be due to administrative or technical challenges, the performance level of such a network depreciates fast. An incessant fault due to excessive overload for instance reduces system reliability. Results from this work suggest that necessary precautionary measures must be put in place. These may include system upgrades or replacements of some system components.

5.3.1 The Use of Appropriate Statistical Model and Mathematics Equations

The heart of distribution system planning is forecasting. A reliable forecast can only be realized if correct and adequate forecast models are used. The authenticity of the correct forecast model is ascertained when it is subjected to rigorous diagnostic tests using standard statistical test tools. Adejumobi (2005b) applied the Box Jenkins forecasting models to a ten-year (1991-2001) fault data to determine the reliability of the Ilorin Distribution Network. The choice of forecasting model was made by comparing the graph from the computed sample autocorrelation and partial auto-correlation of the data with the theoretical auto-correlation graph. The adequacy of a chosen model was further confirmed by diagnostic check; that is by comparing the calculated Chi-square Q with the standard statistical value x^2 at appropriate confidence level. The selected model is adequate only if the calculated Q is less than x^2 The results in Table 5showed that the developed forecasting models for single-phase, three-phase, and component faults agreed with the theoretical models while the developed models for two-phase faults and wire cut faults proved otherwise when diagnostic checking was applied. When a researcher encounters this difficulty, further research is required. If a researcher is not patient enough, he/she may select the inappropriate model to forecast.

Table 5: Test of the adequacy of the forecast models autocorrelation and diagnostic checking

	TYPES OF FAULT				
	SINGLE PHASE FAULTS	TWO-PHASE FAULTS	THREE-PHASE FAULTS	COMPONENT FAULTS	WIRE -CUT FAULTS
NEAREST BEST FORECAST MODEL FROM AUTOCORRELATION PLOT- (SAC) & (SPAC)	ARMA(2,0) d=0	ARMA (1,0) d=0	ARMA (0,1) d=0	ARMA (1,0) d=0	ARMA (2,0) d=0
CALCULATED CHI SQUARE (Q)	19.68	149.89	19.8	14.8	147.96
DEGREE OF FREEDOM (df)	28	29	29	29	28
STANDARD STATISTICAL VALUE (□^{2})	22.7	23.6	23.6	23.6	22.7
CONFIDENCE LEVEL	0.75	0.75	0.75	0.75	0.75
REMARKS	MODEL IS ADEQUATE	CONTRADICTORY	MODEL IS ADEQUATE	MODEL IS ADEQUATE	CONTRADICTORY

Adejumobi (2005c) carried out the analytical assessment of distribution system power quality comparing the effect of using approximate and exact power equations for voltage drop calculations on primary distribution feeders using Ilorin NEPA distribution network as a case study. Often, analysts base voltage drop calculations on approximate formulae. However, the approximate formulae do not produce the exact identities of the states of systems being analyzed especially when considering long and heavily loaded distribution feeders. Hence, the approximate formula causes calculation errors. When applied the two formulae to the sample study, the results in Table 6 showed that some primary feeders experienced voltage drop above limits of +10% statutory values. Meanwhile, the application of the exact voltage drop formula has revealed that a significant error occurred when the approximate formula was applied, most especially for heavily loaded distribution networks. When an error of this type occurs, it may lead to a wrong decision being taken by the management when planning.

An approximate formula for voltage drop V_{drop} between two nodes RI_p-XI_q

$$V_{drop_{approximate}} = RI_p + XI_q = |V_s| - |V_r| \quad \text{------ (A)}$$

$$V_{drop_{exact}} = RI_p + XI_q + \frac{0.5(XI_p - RI_q)}{|V_r| + RI_p + XI_q} \quad \text{------ (B)}$$

$$\%\ Error = 100\left(\frac{B - A}{B}\right)$$

$$Nominal\ value = 11kV$$

Table 6: Voltage drop calculation on feeders using an approximate and exact formula with a nominal voltage of 11kV

SN	Feeder	No of substations	Load Capacity (MVA)	Voltage Drop				Approximation error %
				Approximate		Exact		
				kV	%	kV	%	
1	Industrial Feeder	15	5.75	0.318955	2.9	0.32166	2.92	0.84
2	Adewole Feeder	33	10.05	1.20441	10.95	1.26942	11.54	5.12
3	Offa Feeder	26	5.90	0.15807	1.43	0.15899	1.45	0.58
4	Airport Feeder	20	5.50	0.6681	6.07	0.6945	6.31	3.80
5	Township Feeder I	29	8.915	0.81957	7.45	0.84134	7.65	2.59
6	Township Feeder II	22	7.216	2.24	20.36	2.49394	22.67	10.18
7	GRA Feeder	56	19.57	4.48628	40.78	6.01201	54.65	25.37

5.3.2Assessment of Small Hydro Power (SHP) Potential for Rural and Sub- Urban Electrifications to enhance Power Distribution.

Over 65% of the Nigerian rural dwellers are not connected to the national grid. As such, most of the rural dwellers depend on fossil fuel-based generators (especially petrol and diesel) with no consideration for their environmental effects. The increasing awareness of the environmental effects of such generators and the quest for increasing access to electricity made Adejumobi *et al.* (2007) carry out a study on the identification of small hydropower sites and their potentials in Nigeria to supply electric power to rural and suburban communities across the country. Hydrological data obtained from River Basin Authorities were collected and fundamental energy equations were applied to determine the theoretical output capacity, based on the selected turbine for small hydropower (SHP) schemes. Some of the identified SHP sites from selected communities across the country are presented in Table 7.

Table 7: Identified Small Hydro Power Sites in Nigeria

S/N	Name of Site	Site Location	Site State	Hydro Source	Average Water Head (m)	Suggested Turbine Set	Theoretical Plant Generating Capacity kW
1	Ayiba	Ayiba	Osun	Dam	11,58	Crossflow	122.4
2	Erinle	Ede	Osun	Dam	10.50	Crossflow	110.94
3	Otin	Eko-Odo	Osun	Dam	13.70	Crossflow	140.75
4	Osun	Esa-Odo	Osun	Dam	11.30	Crossflow	120
5	Erinle	Nelo-Erinle	Osun	Dam	28.00	Peltori	285.8
6	Tage	Kishi	Oyo	Dam	11.00	Turgo	116.2
7	Olupo	Igbeti	Oyo	Dam	9.00	Turgo	95.0
8	Fofo	Shaki	Oyo	Dam	14.60	Crossflow	148.26
9	Osune	Asejir	Oyo	Dam	26.22	Pelton	270.0
10	One	Eleiyele	Oyo	Dam	14.60	Crossflow	148.26
11	Oyo	Awon	Oyo	Dam	13.00	Crossflow	130.3
12	Oba	Oba	Oyo	Dam	13.50	Crossflow	139.2
13	Opeki	Opeki	Oyo	Dam	12.00	Turgo	126.8
14	Esinowu	Irawo	Oyo	Dam	10.00	Turgo	105.6
15	Iconsi	Igboho	Oyo	Dam	10.00	Turgo	105.6
16	Okugba	Ayete	Oyo	Dam	10.00	Turgo	105.6
17	Ibu	Ajura	Ogun	River	2.00	Propeller	21.13
18	Yewa	Yara-Mata	Ogun	River	2.60	Turgo	28.0
19	Ona-Nla	IdiAyanra	Ogun	River	1.50	Propeller	15.84
20	Oshun	Ijebu-Igbo	Ogun	River	2.10	Propeller	22.20
21	Yewa	Eggua	Ogun	River	1.85	Propeller	16.70
22	Oni	EffonAlaye	Ekiti	Dam	6.25	Turgo	60.06
23	Ero	Ikun Ekiti	Ekiti	Dam	24.50	Pelton	250.96
24	Ele	Itapaji	Ekiti	Dam	25.10	Pelton	264.0
25	Little Ose	Egbe Ekiti	Ekiti	Dam	25.0	Pelton	262.25
26	Erita	Igbara-Odo	Ekiti	Dam	3.50	Turgo	37.0
27	Tagwai	Tagwai	Niger	Dam	15.70	Crossflow	165.95
28	Agboh2	Agboh	Niger	River	6.10	Turgo	64.48
29	Mfum 2	Mfum	Niger	River	7.00	Turgo	79.28
30	Belle	Baata	Kwara	Dam	72.60	Pelton	719.0
31	Onitsha	Onitsha	Anambra	River	7.50	Turgo	79.28
32	Itu	Itu	Cross River	River	3.50	Turgo	37.0

5.3.3Determination of Small Hydro Energy Capacity using Opeki River in Ogun State as a case study.

The remoteness and sparse nature of many rural communities in Nigeria made grid extension to most communities in the country an extremely difficult task. However, several rivers, streams, and dams whose potential could be harnessed for small hydropower (SHP) generation of capacities ranging from 1kW to 10MW to meet the energy needs of nearby rural and suburban communities are available in Nigeria. It was on this note that Adejumobi etal.(2014) assessed the small hydro energy potential of the Opeki river in Ogun State. In the assessment, the mean daily flow records obtained from the Ogun-Osun River Basin Development Authority were used to evaluate the medium range of head and establish a flow duration curve (FDC) for the river. Conventional power equations were adopted and modified to determine the rated power output (P_o), annual optimal operation period (T_o), and power duration curve (PDC) from which the annual energy production and capacity factor were projected.

The summary of the assessment result for the river with alternative turbine types is as shown in Table 8. With the average Exceedance Probability of rated flow of about 47% and annual optimum operation days of about 170days, the annual estimated energy productions (MWh) ranges from 57076 to 67332 were obtained with the selected turbines all operating at an average optimal capacity factor of about 75%.

Table 8: Summary of Assessment Result for Opeki River (Estimated Plant installed Capacity, P_c = 10205 kW; Estimated power output, P_k = 10000 kW

Alternative Turbine	Annual Maximum Plant Output (kW)	Annual Estimated Energy Production (MWh)	Optimal Capacity Factor (%)	Turbine Rated Flow (m^3/s)	Exceedance Probability of Rated Flow (%)	Annual Period of Optimum Operation (Days)	Turbine Rotational Speed (rev./min)
Kaplan	8110	66625	76.1	17.3	48.15	176	600
Propeller	9713	57076	65.1	17.21	48.38	177	600
Francis	8631	65109	74.3	17.66	47.36	173	429
Crossflow	8177	61190	69.9	19.99	43.11	157	111
1 Jet Pelton	7476	67332	77.3	17.35	48.01	175	61
2 Jets Pelton	7513	67017	76.5	17.47	47.75	174	88
3 Jets Pelton	7510	66938	76.3	17.53	47.63	174	107
4 Jets Pelton	7505	66711	76.1	17.57	47.55	174	125
5 Jets Pelton	7498	66613	76.1	17.6	47.49	173	136
6 Jets Pelton	7493	66533	75.9	17.63	47.43	173	150
1 Jet Turgo	7580	66502	76	17.92	46.81	171	125
2 Jets Turgo	7615	66176	75.6	18.06	46.5	170	176
3 Jets Turgo	7614	65990	75.4	18.12	46.35	169	214
4 Jets Turgo	7411	65860	75.2	18.16	46.26	169	231
5 Jets Turgo	7600	65759	75.1	18.2	46.19	169	273
6 Jets Turgo	7593	65676	75	18.23	46.12	168	300

5.3.4Optimal Selection of Hydraulic Turbine for a Sustainable Small Hydro-Electric Power Generation

The uncertainty in the level of available water head (h) and discharge (Q) is a major challenge to the realization of the effectively designed power output of any SHP site throughout a year. The water height (head) and stream flow (discharge) which are season-dependent along with turbine efficiency are the major determinants of the net annual energy production from the small hydropower (SHP) scheme. The above variables are responsible for the conflict being experienced year-round between the actual power delivery by small hydro plants and theoretical rated output. This calls for the optimum selection of turbines, which will match up with the available water flow rate (discharge) for sustainable power output throughout the year. To estimate the water potential that can effectively drive a turbine, one needs to know the variation of the discharge throughout the year. This annual discharge variation is called the flow duration curve. Hence, Adejumobi and Shobayo (2015) provided a platform for optimum selection of hydraulic turbines for SHP. Weibull energy optimization technique was used to derive a flow duration curve and calculate actual plant capacities of the selected site as shown in Figure 10. The curve was used to optimally select the turbine type that guarantees sustainable energy output all the year. The result of the analysis for the sampled hydraulic turbine types is as shown in Table 9. With the duration curve of the river as shown in Figure 11, detailed optimum annual estimated energy against flow duration curves for two of the Turbines; Francis and Kaplan were presented in Figures 11 and 12. It is observed in Figures 11 and 12 that though the annual estimated energy production in MWh when compared with Table 8, reduces to about 33%, there is assurance that there would be energy output throughout the year with an optimal capacity factor of 96.9% and exceedance probability ranges from 98.1% to 100%.

Table 9: Summary of Assessment Result for Opeki River using the developed Curve Flow Duration (Estimated Plant installed Capacity, P_c = 10205 kW; Estimated power output, P_k = 10000 kW)

Alternative Turbine	Annual Maximum Plant Output (kW)	Annual Estimated Energy Production (MWh)	Optimal Capacity Factor (%)	Turbine Rated Flow (m^3/s)	Exceedance Probability of Rated Flow (%)	Annual Period of Optimum Operation (Days)	Turbine Rotational Speed (rev./min)
Kaplan	0	21148	96.9	4.35	100	365	1500
Propeller	0	21151	96.9	4.33	100	365	1500
Francis	0	21146	96.9	4.44	100	365	1000
Crossflow	330	21127	96.8	4.98	98.1	358	214
1 Jet Pelton	0	21146	96.9	4.44	100	365	125
2 Jets Pelton	47	21145	96.9	4.47	99.9	365	176
3 Jets Pelton	56	21145	96.9	4.49	99.9	365	214
4 Jets Pelton	61	21145	96.9	4.5	99.9	365	250
5 Jets Pelton	67	21145	96.9	4.51	99.9	365	273
6 Jets Pelton	68	21144	96.9	4.51	99.9	364	300
1 Jet Turgo	84	21143	96.9	4.59	99.7	364	231
2 Jets Turgo	105	21142	96.9	4.63	99.6	364	333
3 Jets Turgo	119	21142	96.9	4.65	99.6	363	429
4 Jets Turgo	128	21142	96.9	4.66	99.6	363	500
5 Jets Turgo	131	21141	96.9	4.66	99.5	363	500
6 Jets Turgo	139	21141	96.9	2.05	99.5	365	1000

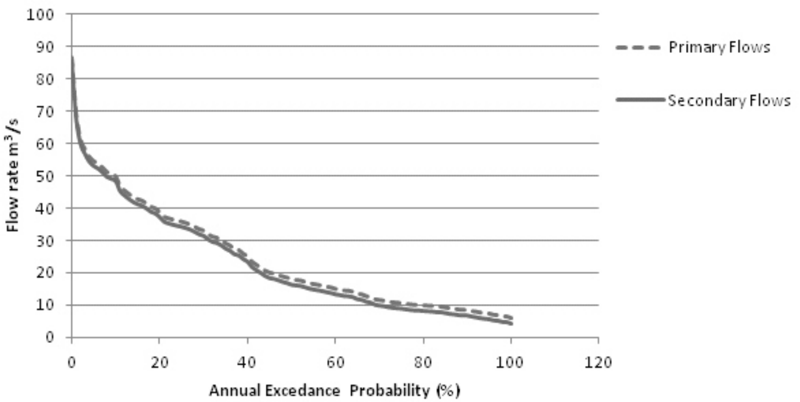


Figure 10: Primary and Secondary Flow Duration Curves for Opeki River

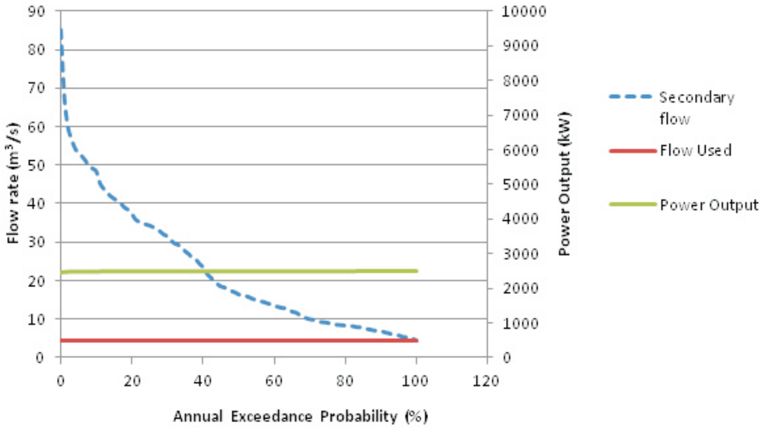


Figure 11: Flow Duration Curves (FDC) for Opeki River and Power Duration Curve (PDC) for a Plant having an Installed Francis Turbine of Rated Flow (Q_k), 4.44m^3/s.

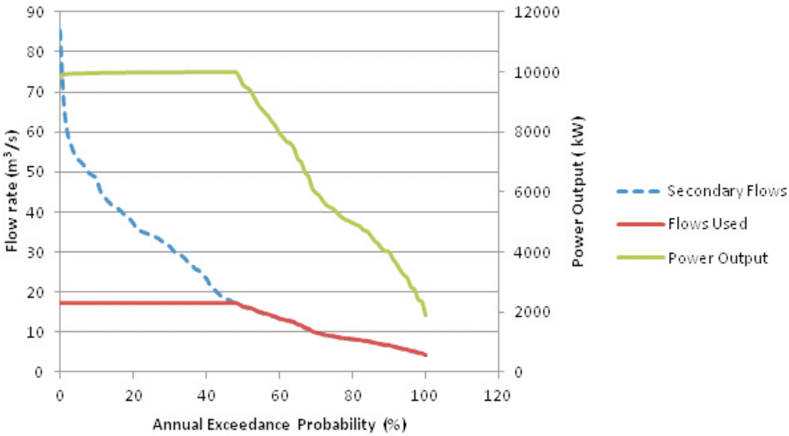


Figure 12: Flow Duration Curve (FDC) for Opeki River and Power Duration Curve (PDC) for a Plant Having an Installed Kaplan Turbine of Rated Flow (Q_k), 17.30m^3/s - 4.35m^3/s

5.3.5 Solar-Wind Hybrid Power System

Adejumobi *et al* (2011) designed a hybrid Solar-Wind power system capable of powering information and communication technology infrastructure and residential loads in an off-grid rural community. The work harnessed indigenous technology of a hybrid Solar-Wind power system that can provide renewable energy from the sun and wind to generate electricity for rural dwellers.

The DC energies produced from the hybrid sources were transported to a DC disconnect energy mix controller (a bi-directional controller) connected to a DC-AC float charging-inverter system that provides charging current to a heavy-duty storage battery banks and at the same time produces inverted AC power to AC loads as illustrated in Figure 13. About 10 years of wind speed data and average annual solar irradiance for the Abeokuta suburb were collected and used to simulate the hybrid energy system 1500W for a typical ten household-rural community.

While it is true that the initial cost of implementation may be high, the work showed that the rural community will enjoy a long-lasting energy supply with maximum efficiency if the system is embraced. The system is useful in complementing the power distributing in rural communities.

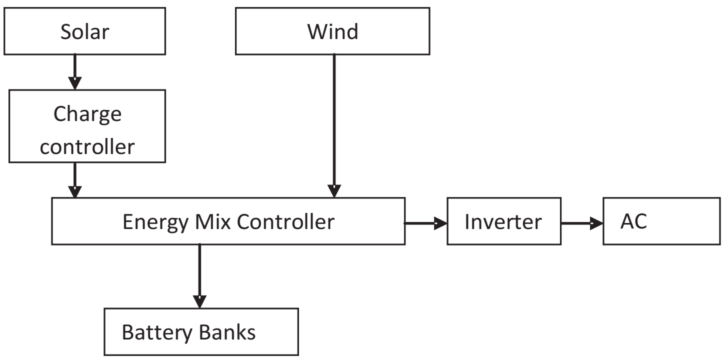


Figure 13: Solar-Wind Hybrid Power System

5.4. Power Distribution System Economics

Economics in the power system is a complex term that can be explained in many diverse ways because many things revolve around it. It is one of the basic considerations that must be critically analyzed to achieve success in the evolving electricity market globally. Simply put, economics contains three important concepts as its fundamental building block: policymaking, planning, and investment decision making. These concepts are integral for utilities, plant owners, operators, designers, investors as well as energy consumers to run at minimum operating cost and maximum efficiency; leading to profit maximization and reduced operational losses. For this inaugural lecture, my contributions in this research area are hereby presented.

Adejumobi *et al.* (2016) examined the economics of using energy-saving appliances for electrical services. One major practice these days for effective utilization of the available electrical energy is the use of energy-saving electrical loads. Due to the inadequacy and instability of the available power supply, the utility companies are faced with challenges of coping with ever-increasing electricity demand which has resulted in massive load shedding and low voltage at the consumers' end. More so, a large portion of industries, businesses, and households have been forced to rely on diesel and petrol generators as primary or backup sources of electricity. Hence, as a result of the electric power supply shortage in Nigeria, energy efficiency management schemes such as supply-side management, demand-side management among others (Yamba, 2006) have been advanced by various stakeholders to address this problem. Energy efficiency involves the utilization of energy in the most economical way for efficient service delivery, thereby reducing energy wastage and the overall consumption of the energy resources, and allows spare for other users.

Load audits and energy efficiency calculations for the two colleges within the Federal University of Agriculture, Abeokuta (FUNAAB) in Nigeria: College of Agricultural Management and Rural Development (COLAMRUD) and College of Engineering (COLENG) shown in Tables10a and b were used as sample cases for the study. Considering both conventional and energy-saving components for electrical services, the economic benefits of using the energy efficiency components were determined by using the Mean Absolute Percentage Saving (MAPS) of electrical energy consumption for the two considered cases. The results of the audited loads from the study are presented in Tables 10 c-d and Figures 14a-f.

Table 10a:: Load Auditing -Electrical; Loads for COLAMURUD

Load Description	Lighting	A/C Units	Incubators/ Refrigerators	Computers	Ceiling Fans	Printers	Photocopiers
Rated Wattage (Watts)	23238	112017.81	5710	8800	13000	4600	8450

Table 10b: Load Auditing- Electrical Loads for COLENG

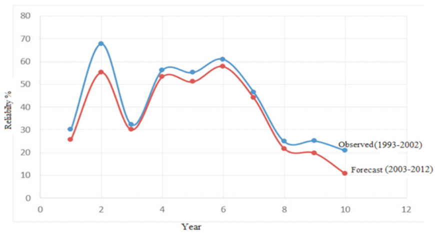
Load Description	Lighting	A/C Units	Incubators/ Refrigerators	Computers	Ceiling Fans	Printers	Photocopiers
Rated Wattage (Watts)	6600	36505	530	7200	4030	2400	4940

Table 10c: Comparison of Actual and Energy Efficient Load of COLAMRUD Using Mean Absolute Percentage Saving (MAPS)

	Lighting	**A/C**	**Fridge**	**Computer**	**Fan**	**Printer**	**Photocopier**
E_{actual} (kWh)	205.944	672.107	45.680	52.800	78.000	9.200	46.690
E_{ee} (kWh)	116.906	387.394	45.36	29.400	62.400	9.000	45.080
Energy Saved	89.038	284.713	0.320	23.400	15.600	0.200	1.610
% Reduction	43.23%	42.36%	0.70%	44.32%	20%	2.17%	3.45%
MAPS = 22.32%							

Table 10d: Comparison of Actual and Energy Efficient Load of COLENG Using Mean Absolute Percentage Saving (MAPS)

	Lighting	**A/C**	**Fridge**	**Computer**	**Fan**	**Printer**	**Photocopier**
E_{actual} (kWh)	55.440	219.030	4.240	43.200	24.180	4.800	25.720
E_{ee} (kWh)	35.200	102.961	3.680	25.200	19.500	3.600	19.600
Energy Saved	20.240	116.069	0.560	18.000	4.680	1.200	6.120
% Reduction	36.51%	53.00%	13.20%	41.67%	19.35%	25.00%	23.79%
MAPS = 30.36%							



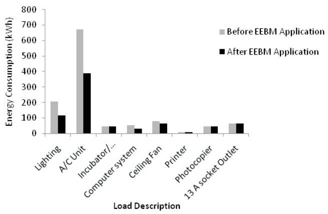


Figure 14a: Energy Consumption Chart for COLAMRUD

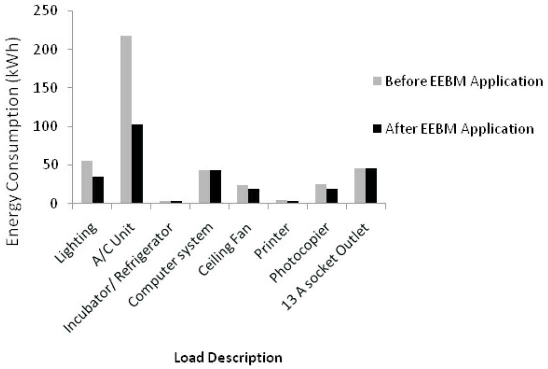


Figure 14b: Energy Consumption Chart for COLENG

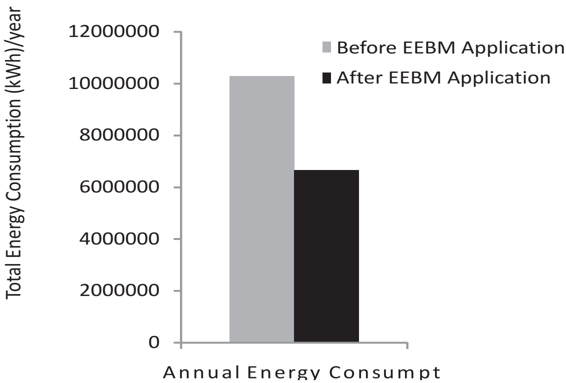


Figure 14c: Annual Energy Consumption Summary Chart for COLAMRUD

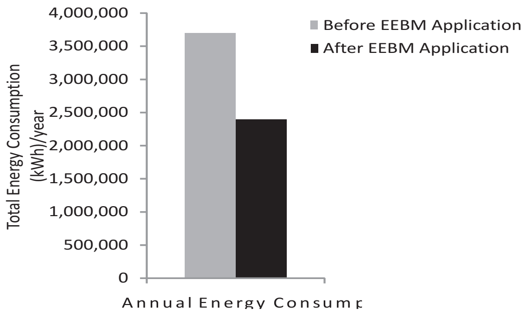


Figure 14d: Annual Energy Consumption Summary Chart for COLENG

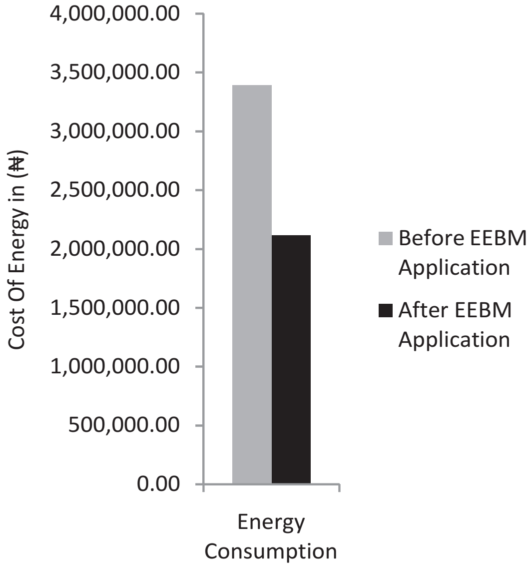


Figure 14e: Energy Cost Chart for COLAMRUD

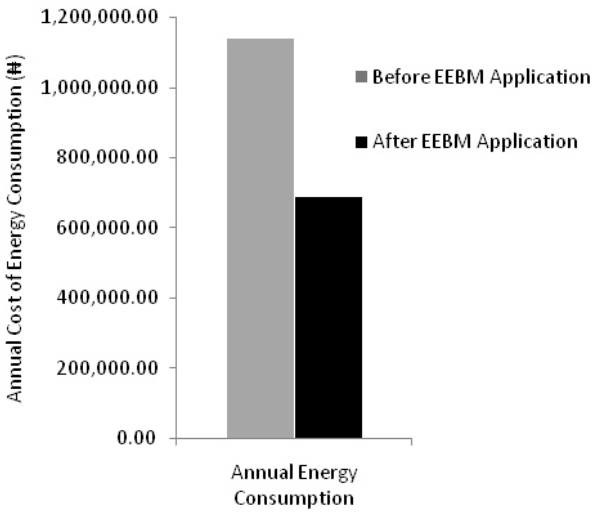
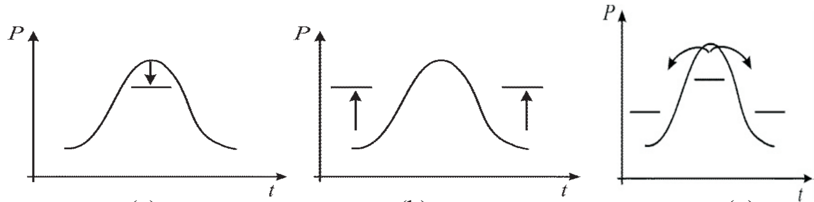


Figure 14f: Energy Cost Chart for COLENG

From the analyses in Figures 14 a-f, if all the loads are connected, the daily energy consumptions of COLAMRUD and COLENG were respectively computed as 1,175.431 and 422.330 kWh with the use of conventional electrical loads whereas with the use of energy-saving electrical appliances, daily energy consumptions of the two colleges reduced to 754.996 and 253.749 kWh respectively, giving percentage yearly energy saving for COLAMRUD as 37.62% and COLENG as 39.48%. on energy consumptions. The cost implication of this study is that FUNAAB would save ₦1,906,043.55 on COLAMRUD and ₦672,068.19 on COLENG of the annual electricity bill paid to the utility authority if the use of energy-saving loads is encouraged. This indicates that if the whole university is considered for this approach, a large sum of money would be saved.

Adejumobi and Adeoti (2019) also worked on the efficient utilization of industrial electric power using Demand Side Management (DSM) Approach. DSM is one of the recent technologies employed to manage the use of electricity in the face of insufficient electricity supply capacity, increasing fuel costs, and problems of environmental pollution. It involves programs and activities which reduce high load demand by the use of among others, dynamic pricing, advanced metering, and enabling technologies with various beneficial effects including mitigation of electrical system emergencies, minimization of blackouts, and improved system reliability (Gellings, 2017, UNIDO, 2017). The various available DSM techniques include peak clipping, valley filling, load shifting, strategic conservation, strategic load growth, and flexible load building (Logenthiran *et al., 2021* ; Alpana & Mana, 2016), samples of which are shown in Figures 15a, b, and c.



(a) (b) (c)

Figure 15:(a) Peak Clipping Technique (b) Valley Filling

Technique (c) Load Shifting Technique

The work adopted a mathematical algorithm to optimize system load factor, minimizing the peak load demand and energy cost of electricity consumers. The peak load reduction was achieved by peak clipping and load shifting techniques where some loads were shifted from peak load period to off-load period within operation hours. Using the available energy distribution profile of a Bottling Company in Nigeria as a case study, the Microsoft excel solver optimization tool was applied to respectively improve load factor, reducing energy cost and peak load demand. The industry has two production lines: bottling and content production (drinks). The activities in the two production lines involve chilling, counting, corking, sitting, blending, pasteurizing, carbonating, palletizing, and labeling. The main sources of energy for the company are the

Ibadan Electricity Distribution Company, IBEDC, and backup diesel generators. The industry operates with different machines and equipment such as motors, pumps, compressors, etc. and engaging in 24 hours operations.

The results obtained from the analysis as presented in Figures 16a-d.Figures 16 a and b are the obtained Bottling Company's load/energy demand curves before and after the application of DSM techniques (peak clipping and load shifting methods) for the company's total load and bottle washing section, while Figures 16(c & d) are the computed load factors and peak loads from Figures 16a and 16b respectively.

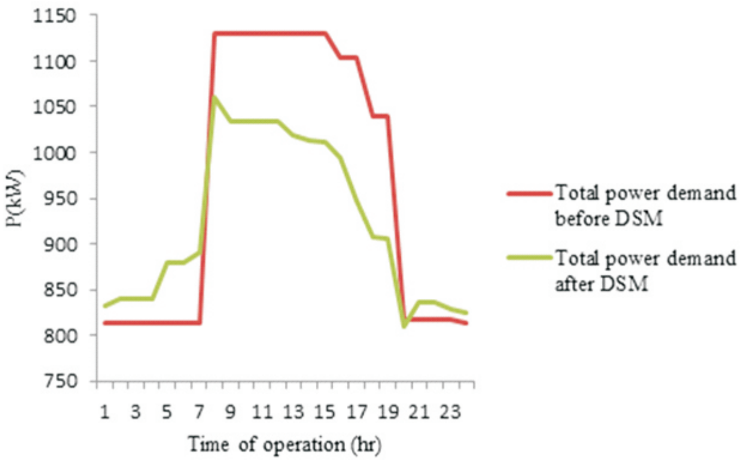


Figure 16a: Total load demand profile before and after application of DSM (Peak clipping and Load shifting) techniques

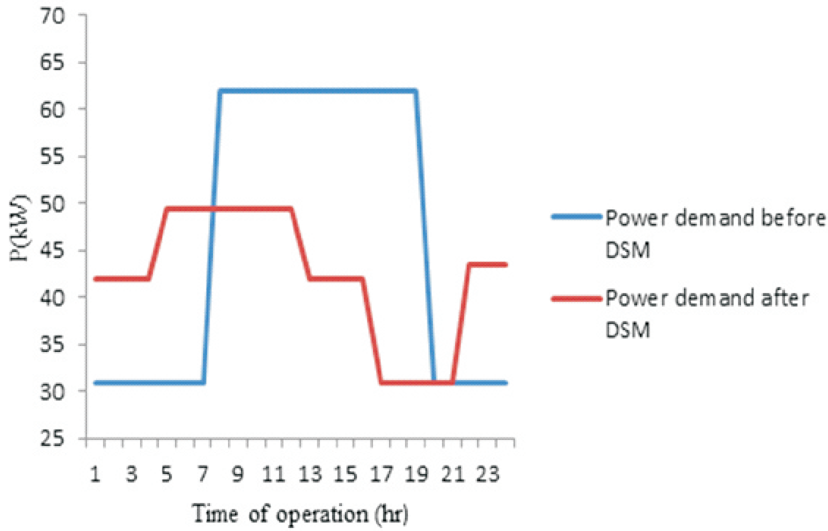


Figure 16b: Load demand profile before and after application of DSM (Peak clipping and Load shifting) techniques for bottle washing section of the company only

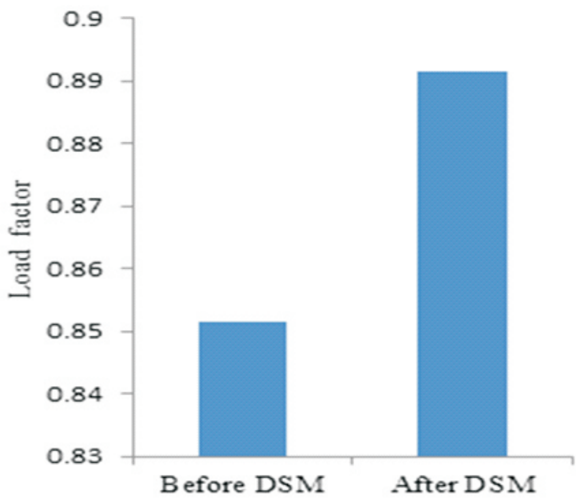


Figure 16c: Load factors before and after DSM

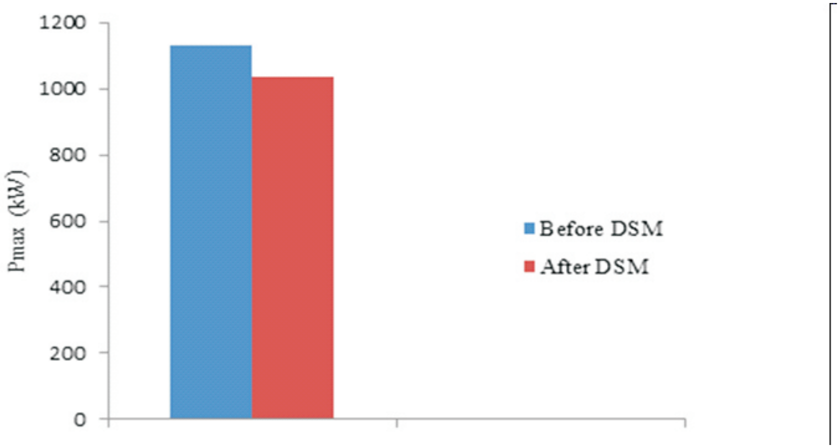


Figure 16d: Maximum Power demand before and after application of DSM techniques for the Company

From Figure16c, the Company's load factor improved from 0.8516 to 0.8915 and this in effect reduced the peak load demand from 1130.39 kW to 1034.75 kW with no reduction in the company production (Figure 16d). In monetary equivalent, the company's monthly energy bill decreased by₦11, 536,729.60 per annum using the kWh charge of ₦33.70 (NERC, 2019) at the time of this study. Hence, a 4.18% reduction in the energy consumption cost was obtained. When only the washing section was considered, the peak load reduced from 62 kW to 49.5 kWwith the application of DSM as shown in Figure 16b. The work, therefore, suggested that implementation of demand-side management techniques for industrial settings would go a long way giving opportunity for more users of electricity to benefit from the little available electric energy.

Similarly, Adeoti and Adejumobi (2019) worked on the application of load shifting and fuzzy logic to minimize industrial energy utilization using a non-alcoholic beverage-producing Bottling Company in Ilorin, Kwara State, Nigeria as a sample case. The growing electricity demand due to the continuous increase in human population and industrialization has necessitated the conservation of available insufficient generated electrical energy for meeting the users' needs.

This work employed load shifting and fuzzy logic techniques to optimize the system's load factor and energy consumption at different time instances. The formulated DSM optimization problems were implemented using Microsoft Excel Solver whereas, for the fuzzy logic, the inference system takes inputs (load and time), processes them based on the pre-specified rules to produce the outputs (desired demand).The primary sources of energy for the company is Ibadan Electricity Distribution Company (IBEDC) which connects the company through a 5000 kVA transformer and backup with four diesel generators of rating 500, 500, 1270, and 140 kVA respectively. The Company has two production lines: bottling and content (drink) production and engages in 24hours operations.

The obtained load curves comparing the energy consumption patterns of the sample network before and after the application of the load shifting technique using the DSM optimization model and

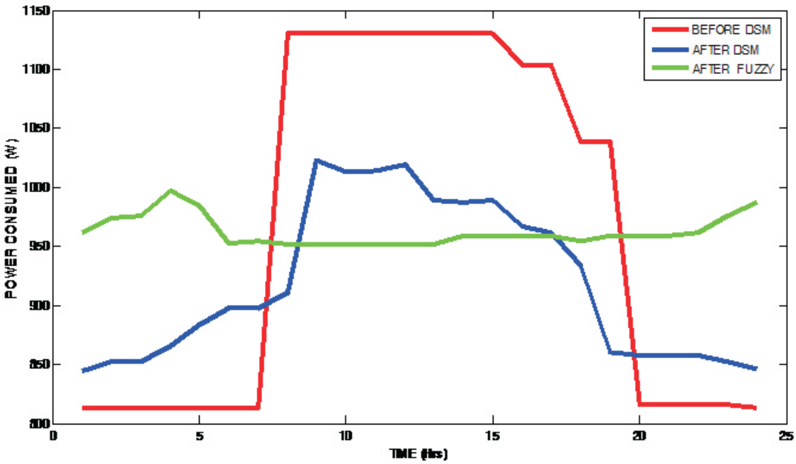


Figure 17: Load curves of sample network before and after load shifting using the DSM optimization model and the fuzzy inference system

Figure 17 revealed that without the use of any optimization model for enhancing the load factor of the considered Bottling Company, more power was consumed during the peak period between 08:00hr to15:00hrs than in the off-peak periods: 00:01hrs to 07:59hrs and 15:01hrs to 24:00hrs. When applied load shifting method, the maximum peak demand reduced from 1130.39 kW to 1022.5 kW by shifting the load demand from peak period to an off-peak period and therefore, improved the system load factor from 0.854 to 0.9413. The implication of this is that some factory production activities will be shifted from peak load period to off-load period.

When the fuzzy inference system was applied for shifting the load demand for the same period under study, the maximum peak demand reduced from 1130.39 kW to 987 kW and the system load factor increased from 0.854 to 0.975. Comparison of these results showed that the two optimization techniques adopted for shifting load demand led to improved energy utilization and consequently led to increased system load factor. However, the fuzzy inference system gave a good performance over DSM optimization since loads are almost evenly distributed as electricity requirement varies during the day. However, to achieve this, the factory workers' comfort may have to be compromised.

Adejumobi and Salaudeen (2019) developed a Home Energy Management System(HEMS) that incorporated a smart meter to manage household appliances' energy consumption. The system allows a considerable amount of energy-saving when using home appliances, reducing the cost of used energy, and at the same time, giving comfort to consumers. The system adopted the ATMEGA328 micro-processor as the control unit of the meter, and IC RTC DS1307 to provide a real-time clock to keep track of the date and time of the ON/OFF for electrical loads. The performance of the system was tested using a standard 3 bedroom bungalow as a case study. The individual load-rated capacities are presented in Table 11.

The results in Figures 18 a-c showed that by considering the total rated power consumption of the building appliances, the total monthly energy saving of 1445.79 kWh and saving the cost of N48,000.31 were realized when the home energy management system was applied.

Table 11: Rated power for the Electrical Services for a 3-Bedroom Bungalow

S/No	Description of Load	Rated power of the residential 3-Bedroom Bungalow (Watts)
1	Indoor Lighting	1992
2	Security Lighting	900
3	A/C Units	4847.05
4	Refrigerator	300
5	Water Heater	6000
6	Pumping Machine	745.7
	Total	13884.75

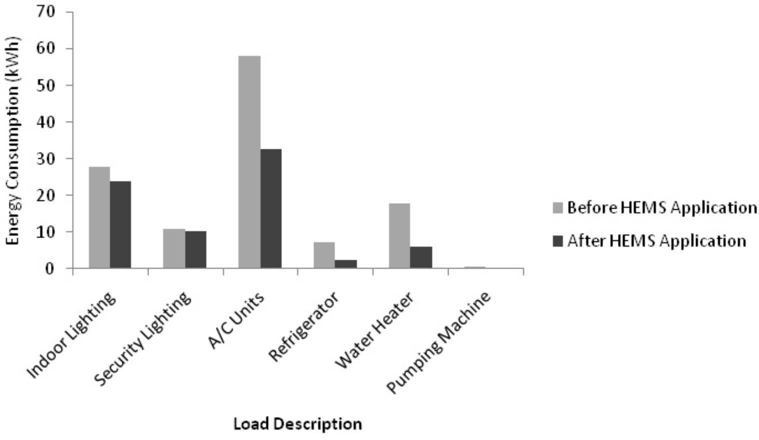


Figure 18a: Daily Residential Energy Consumption Chart before and after application of HEMS

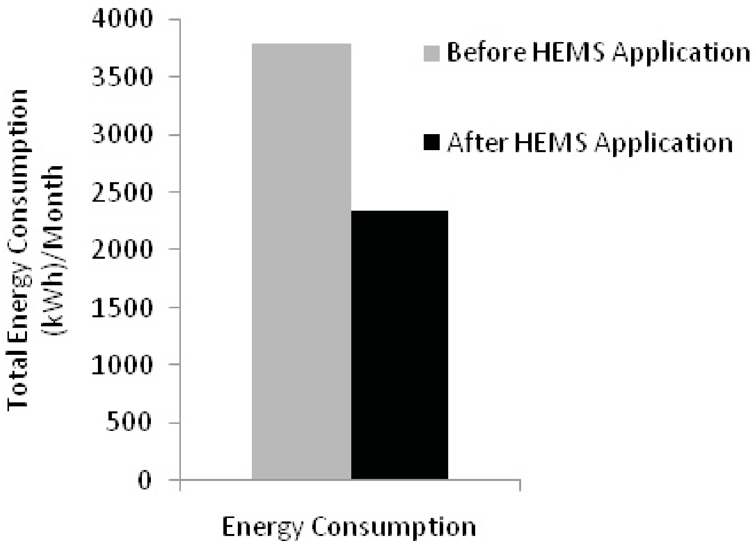


Figure 18b: Monthly Residential Energy Consumption Summary Chart before and after application of HEMS

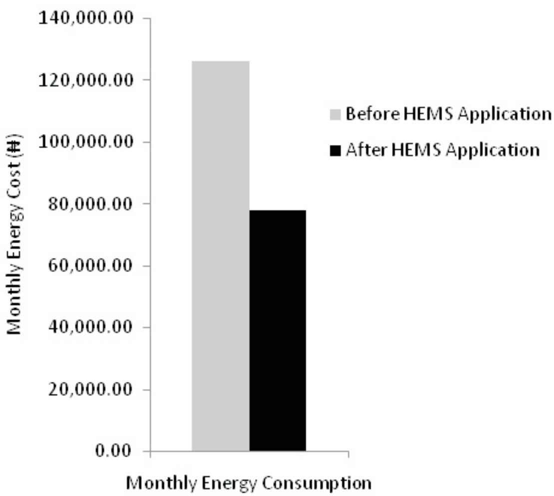


Figure 18c: Monthly Residential Energy Cost Chart before and after application of HEMS

5.5 Conclusion and Recommendation

Mr. Vice-Chancellor Sir, distinguished ladies and gentlemen, I have attempted in this lecture to present the importance of electric energy and the place of the power distribution system in providing stable, reliable, and quality electric power for the human and economic development of our nation. The electricity supply system in Nigeria is in a dilapidated state and the electric energy being produced is a far cry below electric power demands for domestic, commercial, and industrial uses in Nigeria.

Optimizing the management performance of the power distribution system, which is a major link between the electricity supply system and consumers of electric energy, will go along way in proffering solutions to the problem of erratic power being experienced in Nigeria. Step-by-step system re-configuration, good planning strategies, standard energy management, and efficiency technologies, and appropriate energy loss reduction techniques, will assist tremendously in improving the quantity and quality of electric energy being delivered to the consumers of electricity through power distribution utility. It is therefore very necessary for the researchers, the electricity utility, and the Government to rise to the challenges of poor and shortage of electric energy, showing more interest and concern for proper power distribution system management in Nigeria, for human development and socio-economic growth of the nation.

Recommendations

This lecture came at a time Nigeria as a country is in deep energy crises and needs urgent attention to prevent further decay in the Nigerian power system, especially in the distribution section. Thus, the lecture recommends that the:

i. government and other stakeholders should give urgent attention to the provision of new and modern equipment and replacement/upgrade of dilapidated infrastructures in the distribution network.

ii. authorities managing the distribution system should show a keen interest in preventive maintenance rather than corrective maintenance. For example, power transformers, circuit breakers, and other equipment and protective devices should be installed.

iii. establishment of Distributed Generations (DGs) at various locations within the Urban center, that will incorporate the use of renewable energy sources such as Wind and Solar will go along way to stabilize the distribution system in Nigeria.

iv. consumers of electricity including industrial, commercial, residential and some private individuals incorporate energy-efficient techniques on their power distribution layouts since there is insufficient energy supply from the generation station. Low energy consumption and appliances that would minimize the peak energy demand should be adopted.

v. state of art planning and forecasting tools should be developed for a sound and reliable power distribution network operation and maintenance. Day-to-day data recording of system operational activities and maintenance is very essential.
vi. adequate funding is provided for upgrading, maintenance, and operation of distribution systems in Nigeria by the stakeholders including government, consumers, and individual donors.
vii. adequate incentives should be provided for both technical and non-technical personnel in the distribution industries.
viii. there should be synergy between power distribution companies and reseachers

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