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Factors Affecting the Power Outage in Nigeria (A Case Study of Kainji Hydro Power Station)

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ABSTRACT
Nigeria was faced with a chronic electricity crisis that has resulted in the crippling of most sectors of the economy. It is estimated that only 40% of Nigerians are connected to the national grid and the connected population is exposed frequently to power outages. Nigeria`s electricity grid is mainly powered by hydro and depleting hydrocarbon resources. Fossil-based electricity generation contributes not only to an increase in carbon footprints but also exposes the country to changes in the price of petroleum resources and political instability in the oil-producing region of the country. The country is blessed with abundant renewable energy resources (RESs) that have not been fully exploited; these renewable resources have the potential to change power generation and consumption in the country. The availability of RESs in all parts of Nigeria has been demonstrated in several studies. This contribution aimed to fill this gap by focusing on the current status and prospects of RE in Nigeria as well as identifying the key challenges confronting full-scale RE development in the country. We discussed the existing government policies, and legislation, and proposed others that can help speed up the adoption of RE in Nigeria. The study also compared RE development in Nigeria with that of four sub-Saharan African countries. It is hoped that this study will stimulate future research on how to address the energy crisis in Nigeria using RE.
Keywords: Power outage; Factors; Power System; energy crisis, renewable energy sources.

1. INTRODUCTION

Power outages have been a persistent issue in Nigeria, impacting economic development, industrial growth, and the daily lives of its citizens. One of the critical power generation facilities in Nigeria is the Kainji Hydro Power Station, located on the Niger River. Despite its potential to contribute significantly to the national grid, the station has faced numerous challenges that impede its efficiency and reliability. Understanding the factors affecting power outages at Kainji Hydro Power Station is essential for formulating effective strategies to enhance its performance and stability. This study delves into various elements such as infrastructural deficiencies, environmental influences, operational management, and policy frameworks, all of which play crucial roles in the station's operational challenges. By examining these factors in detail, this research aims to provide a

comprehensive overview of the underlying issues and propose actionable solutions to mitigate power outages, thereby contributing to the broader objective of achieving a stable and reliable power supply in Nigeria [1].

1.1 Background of the Study

Nigeria, the most populous country in Africa, has long grappled with the challenge of providing a reliable and consistent power supply to its citizens. The country's power sector has been characterized by frequent outages, which significantly hinder economic growth, industrial development, and the overall quality of life. Despite having abundant natural resources, including significant hydroelectric potential, the nation's power infrastructure struggles to meet the growing demand.

One of the key players in Nigeria's power generation landscape is the Kainji Hydro Power Station, situated on the Niger River. Commissioned in 1968, Kainji was Nigeria's first hydroelectric plant and has a design capacity of 760 MW. It plays a vital role in the national grid, providing a significant portion of the country's electricity. However, over the years, the station has faced numerous challenges that have compromised its ability to operate at full capacity and maintain a stable supply of electricity.

The factors contributing to power outages at Kainji Hydro Power Station are multifaceted. Infrastructural deficiencies, such as aging equipment and inadequate maintenance, have led to frequent breakdowns and inefficiencies. Environmental influences, including seasonal variations in water levels and the impacts of climate change, also pose significant challenges to the station's operation. Moreover, operational management issues, such as insufficient training and capacity building among staff, further exacerbate the situation. Additionally, the policy and regulatory framework governing the power sector in Nigeria often lacks the necessary support and investment to address these challenges effectively.

Electricity plays a vital role in modern society. It is about the greatest innovation of man. A country like Nigeria have to suppose a 24 hours power supply. There is no excuse for power failure because it is possible to have uninterrupted power supply as we have in several countries in the world (both in developed and developing). Nigerian power sector operates well below its estimated capacity with the power outage being a frequent occurrence., most substation and electric network in Nigeria were established in the early 50's and 60's. these networks with some upgrades are still functional today with their attendant with poor performance and epileptic power delivery, which has now become the of power utilities [2]. Nigeria operates a grid system known as the Nigeria National Grid. There are many benefits of this grid system. The National power system operates on a nominal frequency of 50 Hz +0.2 [3]. The function of a power system is to generate and transmit power to load centers at specified voltage and frequency levels. The generator in the system generates either 11 kV or 16 kV [4]. These voltages are stepped up to either 330 kV or 132 kV for the purpose of transmission. The high voltages levels are then stepped down to load centers. The 330 kV is then stepped down to 132 kV and this is further stepped down to 33 kV which is the primary distribution voltage [5] ([6]. The nominal voltage level is further stepped down to 11 kV. As the system load changes, the resulting changes in real and reactive power demand cause variations in the network voltage and frequency levels. Frequency stability is a major concern in power system networks as the power system nowadays operates very close to its stability limit. A power system is said to be in a state of instability when a disturbance causes a gradual and uncontrollable decline in voltage.

This study aims to delve into these factors in detail, providing a comprehensive analysis of the various elements contributing to power outages at Kainji Hydro Power Station. By understanding the root causes of these outages, the research seeks to propose actionable solutions that can enhance the station's performance and reliability. Ultimately, addressing these issues is crucial not only for improving the power supply from Kainji but also for contributing to the broader objective of achieving a stable and reliable power sector in Nigeria.

1.3 Importance of Reliable Power Supply

A reliable power supply is the backbone of economic development and societal well-being, serving as a critical component for the functioning of modern economies. In Nigeria, the importance of a consistent and dependable electricity supply cannot be overstated, given its direct impact on various sectors and the overall quality of life for its citizens [7].

i. Economic Development and Industrial Growth

A stable power supply is essential for the growth and sustainability of industries and businesses. In Nigeria, frequent power outages result in significant economic losses as industries and businesses face production downtimes, increased operational costs due to the need for alternative power sources, and decreased competitiveness in the global market [8]. For instance, manufacturing industries rely heavily on uninterrupted power to maintain continuous production lines. When power is unstable, these industries must invest in costly generators and other backup systems, which raises their production costs and reduces their profit margins. Thus, a reliable power supply from facilities like the Kainji Hydro Power Station is crucial for fostering industrial growth and attracting both domestic and foreign investment [9].

ii. Improvement in Healthcare and Education

Reliable electricity is vital for the health and education sectors. Hospitals and clinics depend on a steady power supply to operate medical equipment, store medicines, and provide emergency services. Power outages can disrupt critical medical procedures, leading to adverse health outcomes. Similarly, educational institutions require a consistent power supply to facilitate learning through digital tools and resources. Inadequate power can hinder educational activities, affecting the quality of education and limiting opportunities for students. Ensuring a stable power supply at the Kainji Hydro Power Station can significantly enhance the functioning of these essential services, contributing to better health and education outcomes [10].

iii. Enhancement of Daily Life and Social Well-being

The daily lives of Nigerians are deeply affected by the reliability of the power supply. Stable electricity allows for the smooth operation of household appliances, provides lighting, and supports communication technologies that connect people. Frequent power outages disrupt these activities, leading to discomfort and a lower quality of life. Furthermore, reliable power is crucial for public safety, as it ensures that streetlights and security systems operate effectively, reducing crime and enhancing community safety. By improving the performance and reliability of the Kainji Hydro Power Station, the overall quality of life for the populace can be significantly improved.

iv. Promotion of Sustainable Development

Sustainable development relies on the efficient and environmentally friendly generation and use of energy. Hydroelectric power, such as that generated by the Kainji Hydro Power Station, is a renewable energy source that contributes to reducing greenhouse gas emissions compared to fossil fuel-based power generation. A reliable hydroelectric power supply supports Nigeria's commitment to sustainable development goals by promoting clean energy use and reducing the environmental impact of energy production.

In conclusion, the importance of a reliable power supply in Nigeria is multifaceted, affecting economic development, healthcare, education, daily life, and sustainable development. Addressing the factors that lead to power outages at the Kainji Hydro Power Station is essential for harnessing its full potential and ensuring a stable and dependable electricity supply. This, in turn, can drive the nation's progress and improve the overall well-being of its citizens [11].

1.4 Overview of power sector issues in Nigeria

The Nigerian power sector has long been fraught with numerous challenges that have significantly hindered its ability to provide a reliable and consistent supply of electricity. These issues are multifaceted, involving infrastructural, managerial, financial, and regulatory dimensions. This overview highlights the key problems facing the sector, which are crucial for understanding the factors affecting power outages at the Kainji Hydro Power Station.

i. Infrastructural Deficiencies

One of the most pressing issues in Nigeria's power sector is the state of its infrastructure. Much of the country's power generation, transmission, and distribution infrastructure is outdated and poorly maintained. Power plants, including hydroelectric stations like Kainji, often operate below their installed capacities due to equipment failures, lack of spare parts, and inadequate maintenance practices. Additionally, the transmission network suffers from high technical losses, frequent breakdowns, and limited capacity, preventing efficient electricity delivery from power plants to end-users .

ii. Inadequate Generation Capacity

Despite having substantial natural resources, Nigeria's power generation capacity remains insufficient to meet the demand of its growing population and economy. The country's installed generation capacity is often not fully utilized due to technical and operational inefficiencies. Furthermore, the reliance on a mix of hydroelectric and thermal power generation creates vulnerabilities, especially during periods of low water levels or fuel supply disruptions.

iii. Financial Constraints

Financial challenges also plague the Nigerian power sector. Many power companies struggle with financial sustainability due to issues such as poor revenue collection, tariff inadequacies, and high operating costs. The lack of investment in upgrading and expanding infrastructure exacerbates the situation. Additionally, the financial instability of power distribution companies (DisCos) affects their ability to pay for the power they purchase, leading to a liquidity crisis that cascades through the entire supply chain.

iv. Policy and Regulatory Challenges

The policy and regulatory environment in Nigeria's power sector has been inconsistent and often lacks the necessary clarity and support to drive improvements. While there have been reforms aimed at privatizing and liberalizing the sector, the implementation has been slow and fraught with challenges. Regulatory oversight is sometimes weak, leading to issues such as tariff disputes, inadequate enforcement of regulations, and slow progress in infrastructure development projects.

v. Operational Inefficiencies

Operational inefficiencies are another significant problem. These include poor management practices, inadequate training, and lack of skilled personnel. The inefficiencies result in prolonged downtime during outages, slow response to faults, and generally suboptimal performance of power plants and distribution networks. For hydroelectric stations like Kainji, these inefficiencies can be particularly detrimental given the technical expertise required to manage water resources and generate power effectively [12].

vi. Environmental Factors

Environmental factors also play a critical role in the challenges faced by Nigeria's power sector. Climate change has led to unpredictable weather patterns, affecting water levels in rivers and reservoirs that hydroelectric stations depend on. Droughts can significantly reduce the power generation capacity of hydro plants, while extreme weather events can damage infrastructure.

vii. Energy Theft and Vandalism

Energy theft and vandalism are rampant issues that further complicate the power supply situation. Illegal connections, meter tampering, and vandalism of power infrastructure led to significant revenue losses and increase the burden on the already strained power supply system. These activities not only disrupt the distribution network but also pose safety hazards and increase the cost of electricity for legitimate consumers.

In essence, the power sector in Nigeria faces a complex array of issues that contribute to frequent and prolonged power outages. Addressing these challenges requires a holistic approach that includes infrastructural upgrades, financial stability, effective regulatory frameworks, improved operational practices, and measures to mitigate environmental impacts. Understanding these overarching issues is essential for analysing the specific factors affecting power outages at the Kainji Hydro Power Station and developing targeted interventions to improve its performance and reliability [13], [14].

1.5 Aim and Objectives of the Study

The study was aims to investigate and analyse the underlying causes of frequent power outages at one of Nigeria's critical hydroelectric power stations. The specific objectives of the study are as follows:

1. This study investigated the factors affecting (causes of) the power outage in the Kainji hydroelectric power generation plant, Kainji to Birnin Kebbi Transmission line and Distribution Branches in Birnin Kebbi.
2. The study recommended the easy steps for solving /resolving the power outage issues in Nigeria.
3. The study explored alternative sources of energy and used them to reduce the nation's overdependence on gas.
4. The study drew the government's attention to the issues of corruption, vandalism, and providing security for generation, transmission, and distribution levels of power systems.

These objectives aim to provide a comprehensive understanding of the factors contributing to power outages at the Kainji Hydro Power Station and offer actionable insights to enhance its performance and reliability.

1.6 Significance of the Study

Electricity as a source of energy plays a vital role in the growth and development of any economy. Its significance arises from the impact it has on infrastructure, a range of socio-economic activities, and consequently on the country's standard of living. This means that transportation, communication, construction, and other facilities depend on electricity to function effectively [15]. Electricity has continued to play a significant role in the development process. In the Nigerian situation, the reverse appears to be the case because power outages have continued to affect the country's economy and development. Some have argued that privatizing the electricity supply through the unbundling of the power generation arm of the National Electric Power Authority (NEPA).

1.7 Problem Statement

Nigeria has been plagued by frequent power outages, which significantly hinder economic growth and the quality of life for its citizens. The Kainji Hydro Power Station, one of Nigeria's key hydroelectric power stations, is a critical component of the national grid, yet it has been unable to consistently provide reliable power.

Nigeria is currently facing a significant electricity shortage despite its abundant natural resources. The country has over 20 generating plants that contribute to the national grid, including hydro plants at Kainji, Jebba, Shiroro, Zungeru, and Dadin Kowa, and 11 thermal (gas/steam) plants. Although the total installed capacity of these plants exceeds 7,000 MW, the actual available capacity is less than 5,000 MW. Seven of the fourteen power stations are over 20 years old, resulting in an average daily power generation far below the national demand, leading to widespread load shedding. Despite ongoing renovations and upgrades, technical issues such as weak transmission lines continue to hinder the reliable supply of electricity. Nigeria's power network, with a maximum capacity of around 4,000 MW, is very weak, and the distribution network is plagued by technical problems and high technical losses. There is an urgent need to upgrade the power transmission and distribution infrastructure, starting with the distribution subsector, to efficiently manage current and future power generation [16].

The electric industry, being the largest and most complex utility sector globally, faces numerous challenges, varying by country based on technological advancement and government effectiveness (International Energy Agency, 2022). Nigeria's power sector is beset by technical, financial, and governance issues [17]. Voltage collapses frequently lead to transmission line tripping and subsequent power blackouts (Machado, 2014). These collapses can result from technical or non-technical faults, including a radial grid system, faulty protection and governor systems, vandalism, natural accidents, poor maintenance, human error, corruption, political interference, and inadequate investment [18], [9].

A detailed analysis of Nigeria's power system reveals a fragile grid network with only one complete ring network (Benin-Ikeja-West-Aiyede-Oshogbo-Benin), which forces power to flow in one direction over a large portion of the grid, causing instability during faults due to a lack of [19]. Transient stability issues arise from large, sudden disturbances such as line faults, sudden switching, load changes, and the loss of major generating [20]. To prevent these collapses, regular maintenance, at least annually, is crucial along Nigeria's transmission lines (Kundur et al, 2010).

This study investigates the multifaceted factors contributing to these outages, including infrastructural deficiencies, environmental and climatic influences, operational management challenges, policy and regulatory issues, financial constraints, and the impact of energy theft and vandalism. Despite its potential, the Kainji Hydro Power Station's performance is undermined by aging equipment, inadequate maintenance, and outdated technology, which collectively reduce its operational efficiency.

1.8 Limitation and Scope of the Study

This study is limited to the Generation, Transmission, and Distribution Companies of Nigeria. It analysed and investigated the factors affecting the supply of electricity in Nigeria, which include poor maintenance and government negligence on electricity. And the scope of the study focused only on one generating station (Kainji hydroelectric power station, in Niger state), one Transmission Company (Birnin Kebbi transmission line), and a Distribution Company in Kebbi State. (Kaduna Electricity Distribution Company, Kebbi State branch). The findings from Kainji Hydro Power Station may not be fully generalizable to other power stations in Nigeria due to unique local factors. Time constraints may limit the ability to capture all relevant changes and trends, particularly recent developments. The study's environmental analysis is limited to the scope of available data and does not include detailed climatic studies. Additionally, operational transparency may be restricted due to confidentiality concerns, and comprehensive financial analysis might be hindered by limited access to financial records. Despite these limitations, the study aims to provide a realistic and practical analysis of the factors affecting power outages at Kainji Hydro Power Station and offer actionable insights for improving its performance and reliability.

2. LITERATURE REVIEW

2.1 Classification of Outages

The following are types of outages that are classified under the following heading [19], (PHCN, 2012):

1. **Forced outages**: it could also be a result of overloading in a particular branch of the network that the relay is overseeing;
2. **Emergency outage**: As the name implies this type of power interruption is initiated by qualified personnel under emergencies to avert any danger that may be as a result of the temporary removal of load
3. **Planned outage**: These are power interruptions that are initiated to carry out maintenance work on their equipment or to connect new extensions to the existing ones; similarly, in transmission stations, the bulk transformers, circuit breakers, isolators, protective and communication equipment often time scheduled to be overhauled to enhance their efficiency.

The faults that can lead to maintenance, reconstruction, or repairs to be carried out in the network are [21], (PHCN, 2012):

i. Changing of broken wooden cross arm involving High Tension (H.T.) lines;
ii. Vegetation online;
iii. Changing of broken or collapsed wooden or reinforced concrete poles;
iv. Replacement of shattered disc or pot insulators, lightening arresters, etc;
v. P-D fuse that was ill-fitted;
vi. Faulty underground cable;
vii. Mending of broken-up riser cable ends
viii. Extension of H.T. overhead lines;
ix. Mending of jumper cuts, among others
x. Construction of substations;
xi. Installation of RMU and so on.

Faults on high-voltage feeders can be classified into two main groups. These are:

1. Earth fault
2. Over-current fault

According to (NEPA, 2012), these factors affecting the power outages in Nigeria are uncountable including the government's inconsistent and misguided power reform policies. Like inefficiently power generation, transmission, distribution, and consumption, and the incompetent workforce of energy companies, other includes

1. Weak and broken transmission and distribution network;
2. Inadequate power generating capacity;
3. Poor maintenance;
4. Corruption;
5. Vandalism;
6. Shortage of skilled workers;

7. Overloading of transformer and electrical equipment;
8. Illegal connections;
9. Shortage of gas.

2.2 Review of existing research on Power Outage History in Nigeria

Over the years, many studies have been done and papers written by scholars who have decried the poor state of the Nigerian electricity sector. Research has shown that many households are not able to access electricity despite its existence in the country for over a century since 1886, thus highlighting the need for effective reforms in the sector (Oseni, 2012). The technical state of the nation's electricity distribution infrastructure has also been studied (Chinwuko, 2011) but most of the previous works analysed the country's energy problem as that of inadequate generation (Mulugetta et al, 2011). Further stating that for the country to transform from a low-income economy to (at least) a middle-income industrializing one over the next 15 years, the electric power generation will have to rise from the present capacity of less than 10 GW to over 160 GW. This would give the country an electricity consumption of 5000 kWh per capita as compared to its present 155 kWh/capita consumption (Adenikinju, 2007).

A review of empirical literature reveals that studies on electricity outages, corruption, and firm performance have occupied a substantial body of energy and industrial economics literature in recent times. Several studies have been carried out on the relationship between electricity outages and firm performance for both single and cross country in which their findings agreed with each other. For example (Adenikinju, 2015) investigated the impact of electricity failure in developing countries using Nigeria as a case study of Nigeria, He reported that frequent power outages affect business firms negatively but the impact is severe on Small and Medium Scale Enterprises (SMEs). Similarly, a more recent study (Arlet, 2017) examined the impact of electricity tariffs, and power outages on firm performance using firm-level survey data from all the states of this great country, which was done in over 190 countries around the world. The study found power outages to have a negative impact on firm performance across the globe. However, the impact is severe on small and medium-scale enterprises. Other studies in the literature, for example (Mensah et al., 2016), also found electricity outages to have a negative impact on firm performance and business activities related to electricity. On the other hand, studies on corruption and firm performance reveal mixed findings. Some studies, for example (De Rosa et al., 2010), found corruption to have a negative impact on firm performance for both single and cross-country analyses. In contrast, (Vial and Hanoteau, 2010) found corruption to have a positive effect on the firm performance in Indonesia. Their findings endorse the "grease to the wheels" hypothesis, where firms that give higher financial inducements have improved performance. Empirical studies on corruption and electricity are very scarce and recent. The only study so far, to the best of our knowledge, by (Pless and Fell, 2017) on the effect of bribery on electricity reliability.

2.3 Historical Emergence of Power System Components in Nigeria and Consumption

The history of electricity generation in Nigeria dates back to 1886 when the first electricity-generating machine was installed in Lagos; 24/25 Marina Road fifteen years after its introduction in England (Joseph and Adebayo, 2012). In 1962, another body known as the Niger Dams Authority (NDA) was established by an act of parliament. The Authority was responsible for the construction and maintenance of dams and other works on the River Niger And elsewhere generating electricity utilizing water power, improving navigation, and promoting fish brines and irrigation. The energy produced by NDA was sold to ECN for distribution and sales at utility voltages. In April 1972, the operation of ECN and NDA were merged into a new organization known as the National Electric Power Authority (NEPA) (Joseph and Adebayo, 2012).

NEPA as a government agency was plagued with inefficiency which is usually the characteristic of almost all government monopolies in developing countries and as such, there is constant power outage and blackout all over the country; (Adenikinj, 2013). This problem led to the federal government's consideration of the privatization of this corporation in the year 2005. This privatized company was renamed Power Holding Company of Nigeria (PHCN) PLC and was broken into 18 independent units which included the transmission company of Nigeria (TCN), 6 generating companies, and 11 distributing companies. Each of these companies is to be privatized despite this privatization move; the constant power outage remains a problem to the Nigeria economy (Joseph and Adebayo 2020).

2.4 Review of Fundamentals

The fundamental concept regarding this project work is power generation, transmission, distribution and other sources of electricity.

2.4.1 Generation of Electrical Power

Basically, power is generated between 10 kV to 25 kV at 50 Hz which is stepped up to through a step-up transformer to 330 kV to suite long distance transmission line and to minimize the effect of high-power loss on the transmitted power.

2.4.2 Transmission of Electrical Power

Electrical power is transmitted at a very high voltage in both primary and secondary stages of transmission (330 kV and 132 kV) at 50 Hz on overhead lines using towers, bare aluminum conductors and strain disc insulators of various size, capacity and as well as power transformers. The very high voltage is stepped down through a step-down transformer at the receiving end (330 kV to 132 kV) or (132 kV to 33 kV) depending on the power sub-station voltage requirement capacity.

2.4.3 Distribution of Electrical Power

At this very stage, Electrical power is being used at a voltage range of 33kV, 11kV and 415kV and is distributed using distribution transformers of different KVA ratings for stepping it down for industrial, commercial and domestic consumers.

2.5 Other Sources of Generating Electricity

Electricity comes from many sources. Some of these sources like fossil fuels are disappearing because there is such a big demand for them. Scientists are researching new ways of generating electricity, so that if fossil fuels run out, there will be other sources. None of these alternative sources is ideal, but they all have they reconstruct the sentence represent one another and act as back-up (Warwick and Diog, 2004). The most popular sources of electricity as explained below:

2.5.1 Solar Energy

Solar energy is the energy that comes from the sun. We captured and harnessed solar energy by the use of solar Panels. This energy produces no pollution; also, it does not spoil anything. 22 million barrels of oil of solar energy hits the United States alone per day. This might sound like the perfect energy but it is costly and besides, you cannot be sure that the sun will shine brightly without cloud cover everywhere in the country every day. It can last for 20-25 years.

2.5.2 Fossils Fuel

Fossil fuel is a material that can be burned and that comes from the fossil remains of animals and plants, such as long-dead dinosaurs. Some examples of fossil fuels are coal, natural gas, and petroleum. This source is currently available and it is not dependent upon the weather. Some of the problems of fossil fuel use are that it causes pollution, it is a non-renewable resource, and it needs to be mined from the earth. In addition, it causes acid rain, which destroys life in lakes.

2.5.3 Hydroelectric Energy

Hydroelectric energy is produced when water falls from a high place to a low place. A turbine at a hydroelectric power plant is powered by water from a dam falling into it. The generator is powered by the turbine. This energy source does not harm the water and produces little pollution. There are still other uses for the water. The cost of hydroelectric power is comparable to that of fossil fuels. Another benefit is the abundance of lakes and rivers where dams can be constructed to generate electricity. The fact that fish, like salmon, cannot scale the dam is a drawback because it alters the environment. Another drawback is that when a dam is built, a large area is flooded to create a lake, which causes the water to displace the inhabitants and other animals.

2.5.4 Nuclear Power

This energy is made by a nuclear fusion reaction or fission. It is produced in the reactor of a nuclear power station. The energy turns water into steam, which drives a turbine that powers a generator. Nuclear power produces lots of energy and can be used to power major cities. This energy, unlike other sources, produces lots of radioactive waste. If that waste gets released, it could cause devastation in a large area. In addition, it warms its wastewater, so fish in the nearby lake might lay their eggs at any time of year in the warmed spot. Some fish, such as trout, cannot live in warm water.

2.5.5 Wind Power

Wind power is produced by the wind turning a turbine. Wind power, through using windmills has been known for many centuries. This source of energy produces almost no pollution, and it is easy to capture in many parts of the country. Some people think that the fields of windmills ruin the beauty of the land, and some other people are bothered by the noise generated by the windmills. In addition, to be effective the wind speed at a power site has to be over 12 kilometers per hour. Finally, this source of power is costly and requires special equipment and maintenance.

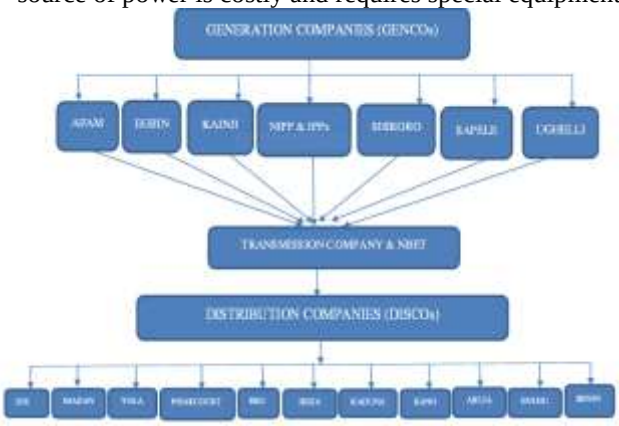

Figure 2.1: Structure of Nigerian power system components (Source: NERC, 2016)

According to the World Bank (2015), the average outage intensity in Nigeria is 32 times in a typical month, which is adjudged to be the highest rate (Alby et al., 2012). Poor electricity supply is one of the major obstacles to economic growth and development in Nigeria. It is responsible for the loss of output amounting to US$ 470 billion (N71 trillion) measured in terms of Gross Domestic Product (GDP) between 1999 and 2015 (Iwayemi, 2018).

Also, poor access to electricity has been identified to be a major obstacle to business operations in Nigeria. For example, about 35.5% of firms reported to have identified electricity outages as a major setback to their business performance (WBES, 2014). The unreliable electricity supply in Nigeria is linked to poor power infrastructure facilities [22], (Iwayemi, 2018). However, improving the electricity supply from the grid does not entirely rest on investing in physical electrical infrastructures. The problems are much deeper which go beyond the electricity industry and may be closely linked to areas such as corruption, political institutions and the government's inability to maintain, upgrade, and protect the system (Pless & Fell 2017).

Adequate and reliable power supply is fundamental to the rapid and sustainable socio-economic development of a people or nation. A good infrastructural service, especially electricity, is a prerequisite to the rapid and sustainable socio-economic growth of any country. However inadequate and unreliable access to electricity services has been a regular feature in the Nigerian power sector (Adedukun, 2010). Any power outage, even of the shortest duration in Nigeria has a severe economic impact on Business and social activities the country is becoming rapidly more dependent on electricity and there is no likelihood that the potential impacts of power outages on industries would abate in the nearest future. The high cost of power outages has inspired a lot of studies into the power sector of the economy over the years. Various researchers (Iwayemi, 2018) have investigated the different aspects of the cost of Power outage to the economy. In particular, established a variation in the outage costs of electricity among consumers and noted that though the residential outage costs are lower than those of commercial and industrial consumers, the difference between industrial outage costs and the commercial costs is not very significant. As noted, (Adenikinji, 2015), [23], besides causing prolonged blackouts, power outages result in factory closure, health problems, and loss of life and properties with the subsequent hampering of economic development. The erratic electricity supply in Nigeria can hinder industrial growth unless these sectors are activated using some radical public-private sector participation strategies. Nigeria is currently faced with an acute shortage of electricity despite the availability of vast natural resources in the country (Iwayemi, 2018).

The country has 28 be specific about the number of generating plants, which supply electric energy to the national grid. Three of these plants are hydro located at Kainji, Jebba, and Shiroro and some are thermal (gas/steam) situated at Afam, Sapele, Ogorode (Delta), Egbin, and other parts of the country. The total installed capacity of the generating plants is above 7000MW, but the available capacity is 4,000MW. Presently, seven of the fourteen power stations are over 20 years old causing the average daily power generation output to come far below the demand and forcing the nation to experience massive load shedding always.

2.6 Historical Blackout in the World

Examining historical blackouts globally provides crucial insights into the multifaceted factors that can contribute to power outages, which is particularly relevant for understanding the challenges faced by the Kainji Hydro Power Station in Nigeria. One of the most significant blackouts occurred in 2003 in the Northeastern United States and Canada, affecting approximately 50 million people. This blackout was initiated by a software failure in a control room, leading to cascading grid failures. Another major event was the 2012 blackout in India, the largest in history, impacting over 620 million people due to excessive demand, insufficient grid infrastructure, and poor management. Additionally, in 2019, Venezuela experienced a prolonged blackout that lasted several days, caused by a combination of neglected infrastructure, lack of investment, and political instability. These examples highlight the importance of maintaining robust infrastructure, effective operational management, and resilient policies. They underscore the necessity for Kainji Hydro Power Station to address its infrastructural deficiencies, operational inefficiencies, and environmental vulnerabilities to mitigate the risk of similar large-scale power outages in Nigeria.

Table 2.1 below represents a summary of some major blackouts previously experienced in the world. Amongst the previous outages, only the incident in the Philippines was caused by a factor similar to the main cause of power outages in Africa. While the causes of major outages in Europe and North America had been attributed to natural disasters or technical faults, the massive blackouts in the Philippines (1992-1994) were caused by inadequate generating capacity. The inadequate capacity brought by poor implementation of energy planning and obsolete power plants resulted in a daily average duration of 12 hours of outage time. This resulted in economic losses ranging from US$600million-US$800 million yearly average [24]. Like that of the Philippines, the major cause of power outages in Africa is inadequate installed and generating capacity which resulted from poor planning and implementation. Due to inadequate installed capacity, electricity generation is always low and subsequently causes supply to fall below demand. Inadequate generation results in low power supply and constant blackouts [9].

Table 2.1 Examining historical blackouts globally which provided valuable insights into the factors affecting power outages, which are particularly relevant to the Kainji Hydro Power Station in Nigeria. These events highlight the critical need for robust infrastructure, effective operational management, and comprehensive policy frameworks to prevent and mitigate the impact of power outages, underscoring the importance of addressing similar issues at the Kainji Hydro Power Station [10], [9], [12], [13], [14].

Table 2.1: Historical blackouts in the world (Source: Bialek, 2004; US-Canada Power System Outage Task Force 2003, 2004) [25]–[30]

Table 2.2 gives major blackout that occurred in the world depicting the location, date and the reason for blackouts of the Understanding the factors affecting power outages at the Kainji Hydro Power Station in Nigeria can be informed by examining major blackouts and grid collapses worldwide. These lessons are particularly relevant for addressing the challenges at Kainji Hydro Power Station, emphasizing the need for improved infrastructure, effective management practices, and proactive policy measures to prevent similar occurrences in Nigeria.

Country/Year	**Type of incident**	**Consequences in the Power System**	**Number of End Users Interrupted**	**Strip. Duration, Energy Not Supplied**	**Estimated Costs to whole Society in 2010 Prices**
Sweden/ Denmark 2003	Disconnect or short circuit followed by double bus bar short circuit	Loss of all lines and generation separation of Southern Sweden/Denmark Voltage collapse	1.6 million in Sweden and 2.4 million in Denmark	2.1 hours, 18 GWh	(US$ 206.22-256 million)
France, 1999	Two consecutive Storms, extreme wind	Extensive outages, 0.4% of the total network length damaged	1.4-3.5million	2 days to 2 weeks, 400 GWh	(US$ 14.13 billion)
Italy/Switzerland 2003	Overloading lines between Switzerland and Italy	Collapse of the entire Italian electric power system	55 million	18 hours	N.A
Sweden, 2005	Storm Gudrun, extreme wind	Extensive damage of overhead lines in Southern Sweden	0.7 million	1 day –5 weeks, 111 GWh	(US$ 526 million)
Central Europe 2006	Bus bar fault at substation in Germany	Disturbances in the whole interconnected grid in Europe	15 million households	Less than 2 hours	N.A
London, 2003	Poor Protection of Relays	Disturbances of 720 MW in South London	410,000 people	37 minutes	N.A
Philippine, 1992-1994	Insufficient generation capacity	Interruption in Country wide electricity supply	Entire country	12 hours daily	US$ 1.89 - 2.52 billion per annum
US/ Canada, 2003	Tree flashovers	Disturbances in interconnector grid in North America	50 million people	16 hour –1 week	US$ 8.3 - $ 11.9 billion

Table 2.2: Major Blackouts/Grid Collapses Occurrences in the World [10], [9], [12], [13], [14]

S/ N	The year it happens	Location & date	Reason for blackout
1	9th November, 1965	Canada and USA	Failure in setting of a protective relays on the transmission lines
2	March-June 1999	Brazil	A lightning strike in the substation
3	2nd January, 2001	India	Grid collapse after substation failed due to inadequate transmission facility
4	7th April, 2001	Luzon Blackout Philippines	Tripping of the multiple Power Plant
5	21st May, 2002	Luzon Blackout Philippines	Flashover of the transmission cable
6	28th September, 2003	Italy blackout	Sagging conductor causes transmission line flash over
7	14th-28th August, 2003	Canada and USA	A software bug in the alarm system of the control room
8	18th August, 2005	Indonesia Java Bali Blackout	Cascading transmission line failure caused substation shut down
9	10th -20th November, 2009	Brazil and Paraguay	Meteorological events
10	30th -31st July, 2012	India Blackout	Weak inter regional power transmission route loading due to faulty protective devices.
11	1st November, 2014	Bangladesh blackout	Substation overloading reduces the frequency to 45Hz causing electrical surge
12	26th January, 2015	Pakistan blackout	Due to the breakage of the power transmission line
13	31st March, 2015	Turkey blackout	Overload of power line due to maintenance
14	13th March, 2016	Sri Lanka	Transmission technical failure
15	4th -5th August, 2019	Indonesia	Disruptions in gas turbines of generating stations
16	16th June, 2019	Argentina, Paraguay and Uruguay	Failure in electrical interconnection system
17	March 7th -July 23rd 2019	Venezuela blackout	Mismanagement by using electricians to operate substation
18	9th January,2021	Pakistan blackout	Cascading effect and shutdown of a power plant
19	April,2014	Nigerian blackout	Voltage instability contributes to large extent to the system collapses or blackouts
20	March, 2021	Nigerian blackout	Tripping of lines on account of faulty equipment or increase in load than the available supply
21	January, 2016	Nigerian blackout	power failures caused by natural weather phenomena such as lightning, rain, snow, ice, wind, flood and earth tremor

2.6.1 National Grid Collapse in Nigeria for 37 Years

Over the past 37 years, Nigeria has experienced numerous national grid collapses that have significantly disrupted the country's power supply. These collapses are often caused by a combination of factors including aging infrastructure, insufficient maintenance, and operational inefficiencies. Frequent grid failures have highlighted the vulnerability of Nigeria's power system, exacerbated by inadequate investment and a lack of modern technology [31]. The consequences of these collapses have been severe, affecting millions of end users, hampering economic activities, and contributing to social unrest. For instance, major collapses have led to prolonged blackouts, paralyzing industries, businesses, and essential services. These recurrent issues underscore the critical need for comprehensive reforms and upgrades in Nigeria's power sector. Analyzing these historical collapses provides valuable insights into the systemic weaknesses and emphasizes the urgency of addressing infrastructural and managerial deficiencies at key power stations like Kainji Hydro Power Station to improve reliability and stability in the national grid.

Table 2.3: National Grid Collapse in Nigeria for 37 Years [31], [32]

YEAR	FULL COLLAPSE	PARTIAL COLLAPSE	TOTAL COLLAPSE
1987	20	13	37
1988	13	8	21
1989	10	6	16
1990	14	0	14
1991	5	1	6
1992	0	1	1
1993	5	14	19
1994	2	4	6
1995	1	10	11
1996	2	8	10
1997	7	13	20
1998	5	13	18
1999	4	5	9
2000	5	6	11
2001	14	5	19
2002	9	32	41
2003	14	39	53
2004	22	30	52
2005	21	15	36
2006	20	10	30
2007	18	9	27
2008	25	15	40
2009	19	20	39
2010	22	20	42
2011	13	6	19
2012	16	8	24
2013	22	2	24
2014	9	4	13
2015	6	4	10
2016	16	6	22
2017	15	9	24
2018	12	1	13
2019	9	1	10
2020	4	0	4
2021	2	2	4
2022	4	2	6
2023	2	0	2

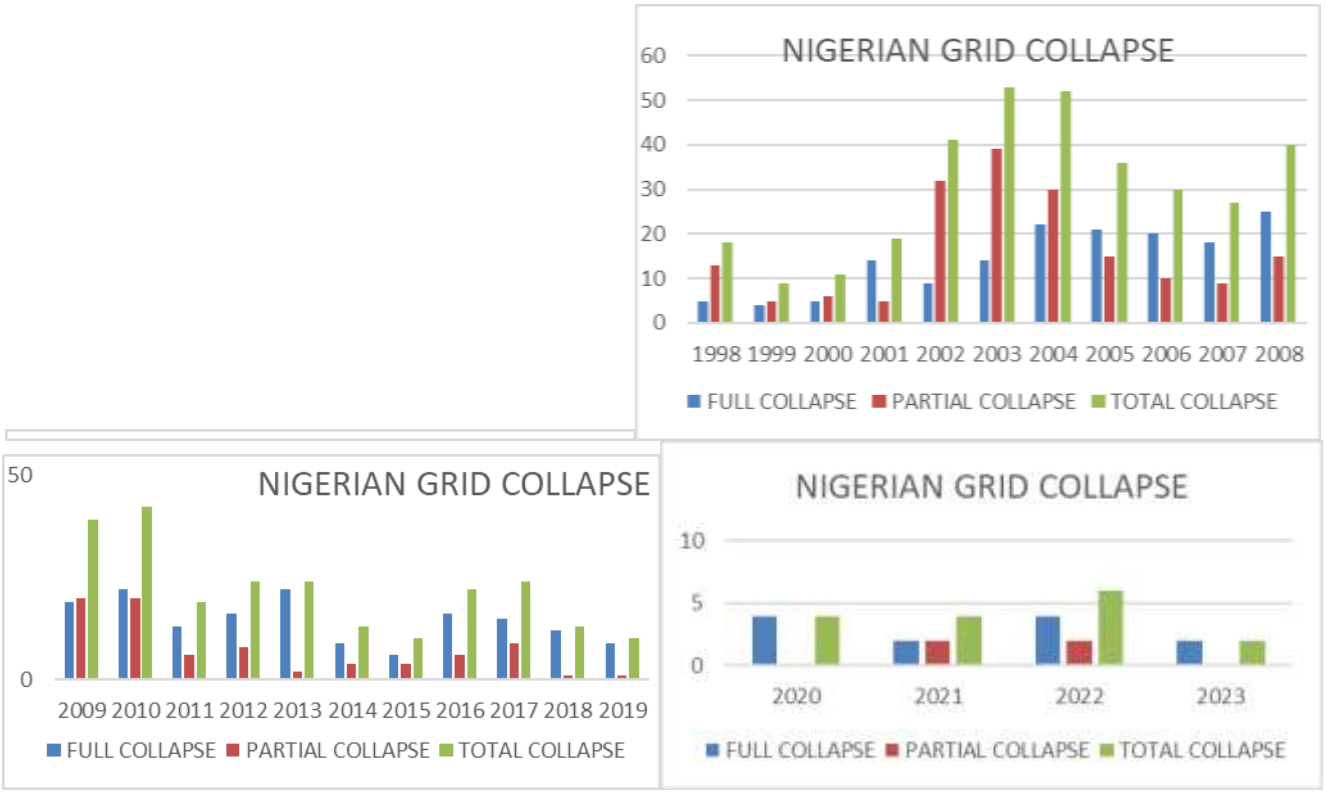

Figure 2.2: Grid Collapse in Nigeria for 37 years

2.6.2 Effect of Power Failure on Households

Power failure impacts on the households in various ways. Its impact varies from the experience of a dark night to a lot of damage being caused to household requirements. Many households have their fridges, television sets, video sets, and a host of household equipment damaged due to frequent power failures. Also, what the households would have purchased in bulk (perishable goods) and kept in refrigerators is bought in bits. According to [33], studies have shown that infrastructure like improvement in road transport, electricity, and sanitation as well as better communications has led to more enrolment and better attendance of children in schools. Improved Electricity also leads to having better teachers. It has also been highlighted as one of the factors that lead to improvement in learning, by allowing children to spend more hours reading and using of electronic devices like computers and hence be able to access more information on their learning. The availability of electricity is essential for the functioning of hospitals and the delivery of health services. This is because surgical operations can be done and vaccines can be refrigerated (Agenor and Moreno, 2006). According to air pollution from the burning of solid fuels kills over 1.6 million people a year. More efficient electricity stoves would reduce this death. Thus, households pay more for what they would have bought cheaply if purchased in bulk [34], [35]. Also, some richer households buy generators which they operate when there is a power outage. This is an additional burden to such households; apart from the cost of the generator they buy diesel or petrol to operate them. Poorer households that cannot afford the cost of generating sets buy lanterns and candles. All these lead to additional expenses for the households. Apart from this, the use of these back–ups expose the households to a threat like five outbreaks and health hazards. According to [21] confirm that households purchase back up electricity to ease the Problem they usually encounter as a result of shortages.

2.6.3 Effect of Power Failure on the Commercial Sector

The commercial sectors also are affected by the impact of frequent power failure. Their Consumption of electricity ranges from usage as a source of light to usage in cold rooms for selling perishable things. Some use computers and electric typewriters to transact their business. When there is a frequent erratic power supply, these cannot be used and it may even cause damage to both their wares and the equipment. Big commercial enterprises like the Leventies and others use it to power their lift elevator. With power failure, their business will be at a standstill since people will not be able to move in and out of their shops. Some use it to power their air conditioning and fans. When there is a power failure, these will stop and there will be a reduction in their efficiency.

2.6.4 Effect of Power Failure on the Industrial Sector

The industrial sector suffers a lot from frequent power failures. In the words of [36] the problem of unreliability ranks high among issues in the business environment. [37] reported in their survey that electricity outages in small firms fall among their top four constraints to expansion. Also [38] reported that in Columbia, rationing of power was estimated to reduce overall economic output by almost 1 percent of GDP in 1992. All these are due to the frequent power failure which always affects these industries negatively. Evidence is provided by (Reinikka and Stevenson, 2002) in Uganda, they also emphasized how inadequate public infrastructure may adversely affect private investment. According to (Sambo, 2005), the major factors contributing to the above unreliability and inefficiency in the power sector are Frequent breakdown of generating plants and equipment due to inadequate repairs and maintenance; Lack of foreign exchange to purchase needed spare parts on time; Obsolete transmission and distribution equipment which frequently breakdown; Lack of skilled manpower; as well as Inadequacy of basic industries to service the power sector [24], (Oshodi and Oloni, 2006). Also confirms that the erratic power supply in Nigeria can lead to slow growth in industry unless the sector is revitalized using any of the Public-Private participation strategies.

2.7 Brief Discussion on National Control Center (NCC)

The National Control Centre (NCC), Osogbo is responsible for all TCN grid operations, monitoring, and control within the transmission network. It is equipped with state of art Supervisory Control and Data Acquisition (SCADA) which is an energy management system, Tele-control interfaces, Human-machine interfaces, communication equipment, and system planning tools, etc. functionally, NCC supervises all the regional control centers in the grid network.

The Regional Control Centers (RCC) are as follows:

1. Regional Control Center (RCC), Benin;
2. Regional Control Center (RCC), Ikeja West;
3. Regional Control Center (RCC), Shiroro.

The Regional Control Centers (RCC) are responsible for monitoring grid operations in the 330 kV and 132kV transmission networks under the Regional Operations Coordinating units (ROC).

2.8 Brief Discussion on Kainji Hydro Power Station

Kainji Dam is located in Borgu LGA of Niger State. Kainji Dam comprises the civil dam structure, the gated spillway, the hydroelectric turbine and generators, and a navigation lock, with monitoring and control systems for all these.

The Kainji hydropower plant (Kainji HPP) was constructed in 1968. The Kainji HPP dam creates a reservoir 136km long, holding approximately 15 billion m^3 of water. The main dam is 550m long with a height of 64m. It comprises the water intake, the flood evacuator, and the abutments. The powerhouse is located downstream of the dam, on the right side of the river bank, and has an installed capacity of 760MW comprised of eight turbine-alternator groups that include four Kaplan type 80MW, two turbines also Kaplan type rated 100MW and two propeller turbines rated at 120MW. In the original design, there was a provision to further accommodate four turbines, but this has not materialized. The dam is equipped with a spillway and a powerhouse with a water inlet. The powerhouse is equipped with six turbines with a 96.4 MW capacity each, resulting in a total installed power of 578 MW. Currently, the available capacity of the plants is substantially below their installed capacity due to poorly functioning equipment.

2.11 Kainji – Birnin Kebbi Transmission Line Circuit (K3R)

Birnin Kebbi town has its transmission and distribution through the tertiary winding of the 150MVA power transformer, while Sokoto and Republic of Niger are through the secondary winding of the transformer. All along the line there are protective devices, such as circuit breakers, isolators, fuses, reactors, and so on.

The existing system for electric power transmission system in Kebbi State, from the National Grid, covers a distance of 315km. The 330KV transmission line is being emanated from the Kainji power generation switchyard. In 1975 two transformers (90MVA) 330/132/13.8KV and 400KVA get the actual rating were installed to receive the incoming voltage (330KV) from Kainji. In 1996 a 15MVA 132/33KV transformer (T6) and dedicated to the state capital consumers which included areas such as G. R.A, Tudun Wada, Bulasa, and Nasarawa. In 2002 a new 30MVA 132/33KV transformer (T7) was installed to boost power supply to the rural areas of Kebbi State such as Aliero, Jega, Argungu, Gwandu, Old Gaya, and new Gaya.

2.12 Brief Discussion on Kaduna c (KEDCO), Birnin-Kebbi Branch.

Kaduna Electricity Distribution Company (KAEDCO) Birnin Kebbi, Kebbi State Branch Area Office, is one of the branches operating under the umbrella of Kaduna Electricity Distribution Company (KAEDCO) [39]. It is one of the 18 successor companies created following the unbundled and subsequent privatization of the defunct power holding company of Nigeria plc. Kaduna Electric is one of the 11 downstream operators in the Nigerian electricity market. It is responsible for the retail distribution and marketing of electricity in Kaduna, Kebbi, Sokoto, and Zamfara States.

The company has 8 area offices and 147 customer service centers across the four states, with a customer population of about 490,000. Kaduna Electric is the 7th largest Disco in the Distribution Companies (DisCos). Kaduna Electric is strategically located and uniquely positioned to be among the best three (3) distribution companies if the abundant potentialities at the disposal of the company are harnessed and effectively utilized in line with the Nigerian Electricity Reform Act 2004.

2.13 Trends in Renewable Energy

Renewable energy is energy generated from natural resources such as sunlight, wind, rain, tides, and geothermal heat. It is derived from natural processes that are constantly replenished [40]. Each of these renewable sources has unique characteristics which influence how and where they are used. Globally in 2012, about 19% of total energy consumption came from renewable, with 9% coming from traditional biomass like fuel wood, and 10% from modern renewable such as biomass for heat production and vehicle fuel, geothermal, biofuel, solar, wind and hydropower. The share of renewable in electricity generation at the end of 2015 was around 23.7 % with 16.6% coming from hydropower, 3.7% from wind, and 3.4% from another new renewable [41].

To date, fossil fuels, majorly coal, oil, and natural gas have been the principal sources of energy worldwide. For instance, more than three-quarters amounting to 78.4% of total world energy demands in 2012 were fulfilled by fossils [42]. Still, the report shows that the demand for these fuels grows in absolute terms through 2035. However, burning of fossil fuels has been identified to create two adverse effects on our environment; (i) it produces greenhouse gas (GHG) emissions that cause global warming, and (ii) the by-products of burning, such as Sulphur dioxide, and soot, and ash that are responsible for global dimming by changing the properties of the clouds. Therefore, the need to conserve our environment from these pollutants led to a global search for alternative clean energy sources (Akorede and Hizm, 2012).

2.14 Current Renewable Energy Scenario in Nigeria

According to (Oyedepo, 2012) Nigeria is a rich country blessed with fossil fuels such as crude oil, natural gas, coal, etc., and renewable energy resources like solar, wind, hydro, and biomass. Details of this are shown in Table 1 constructed with data obtained from the Nigerian National Petroleum Corporation, Renewable Energy Master Plan, and Ministry of Mines and Steel Development. It is seen from the table that Nigeria has a reserve of 36.22 billion barrels of crude oil, 187 trillion Standard Cubic Foot (SCF) of natural gas at standard temperature and pressure (60 degrees and sea level), and 2.374 billion tons of coal and lignite of which virtually nothing has been tapped. Nigeria's reserve for large hydropower is estimated at 11,250 MW and 3,500 MW for small hydropower. Nigeria has a reserve of 11 million hectares of forest and woodland and 72 million hectares of agricultural land wasteland. Based on the available statistics, Nigeria produces about 227,500 tons of fresh animal waste daily. If fully utilized, this quantity is equivalent to 6.8 million m3 of biogas production every day [43].

Despite this abundance of energy resources in Nigeria, the country is currently facing an energy crisis due to the country's grossly inadequate energy supply that is incapable of meeting the ever-growing demand. Essentially, the major energy-consuming activities in Nigerian households are cooking, lighting, and use of electrical appliances. Based on estimates carried out, cooking accounts for about 91% of household energy consumption, lighting uses up 6% and the remaining 3% goes to the use of basic electrical appliances such as television and pressing iron [44].

According to [20], the national energy supply in Nigeria is entirely dominated by fossil fuels. Renewable energy resources are grossly underutilized in the country despite their availability in reasonable quantities. According to the Central Bank of Nigeria (CBN), the report shows the primary energy consumption by type. It is apparent from the table that while coal has over a long period been neglected; petroleum has constituted over 80% of the commercial primary energy consumed in the country. However, it is paradoxical to say that despite Nigeria's rich oil and gas sector, 58% of the population does not have access to electricity which is a secondary form of energy fuelled by the petroleum with which Nigeria is richly endowed.

Nigeria has three main hydropower plants. These plants are located at Kainji, Jebba, and Shiroro power stations with installed capacities of 760 MW, 560 MW, and 600 MW respectively; totalling 1,900 MW. These three hydropower plants contribute about 35.6% of power to the National Grid, thus making hydropower the country's largest renewable energy source [45].

3.1 METHODOLOGY

The growth of any country is heavily dependent on the effectiveness of its power sector. Voltage collapse, a precursor to system blackout, is a significant concern for power system operations. Over the past 12 years, the Nigerian National Grid has experienced an average of 28 system collapses annually. This paper investigates the incidences of power system voltage collapse, analysing the underlying causes and proposing potential solutions. The research methodology includes data collection and analysis, focusing on the series of voltage collapses in Nigeria's power network. The data, analysed and simulated using Microsoft Excel, reveal that the highest number of total system collapses occurred in 2003 with 53 incidents, while the lowest was in 2014 with 9 incidents. Although there was a reduction in collapses in 2015, there are concerns that the frequency may be increasing again. In the first half of 2017, the grid recorded 12 total collapses and 2 partial collapses, with another 12 collapses in 2019. The study underscores the urgent need for a comprehensive overhaul of Nigeria's power system to mitigate the economic impact of frequent system collapses.

3.2 Method of Data Collection

The methodology for this research involved a combination of data collection techniques, including telephone and face-to-face interviews with personnel from Generation, Transmission, and Distribution sectors. Both numerical and theoretical data were gathered, focusing on the series of voltage collapses in the Nigerian power network. The collected data were analysed and simulated using Microsoft Excel. This analysis illustrated the variations and frequency of occurrences, covering both partial and total system collapses. Graphical representations and frequency incidences of voltage collapses were generated, with

simulations of total system collapses over the years conducted in Excel. Table 1 presents the statistical data for both partial and total collapses in the Nigerian National Grid.

3.2.1 Data collected from the National Control Center (NCC)

Nigeria operates a grid system known as the Nigeria National Grid, which offers numerous benefits. The national power system functions at a nominal frequency of 50 Hz (Abdul-Ganiyu, 2013). The primary role of the power system is to generate and transmit electricity to load centres at specified voltage and frequency levels. Generators in the system produce electricity at either 11 kV or 16 kV (Machado, 2017). These voltages are then stepped up to either 330 kV or 132 kV for efficient transmission. The map below illustrates the transmission network linked to the National Grid and their locations throughout Nigeria (NCC, 2017).

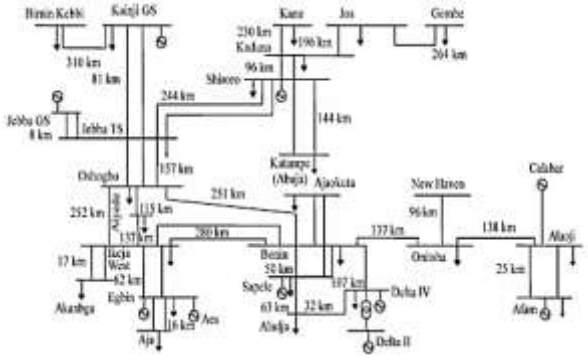

Figure 3.1: one-line Diagram of Nigerian 330-kV Transmission Network Source, (NCC, 2017)

Causes of voltage collapse in Nigeria According to (NCC, 2016) Whenever there is the occurrence of a voltage collapses, it brings about the tripping of transmission lines resulting in a power blackout or brownout in some areas or all areas of the network. The causes of system collapse may either be due to technical or non-technical faults. Generally, system collapse may arise due to any of the following reasons; radial grid system, weak system inertia, faulty protection system, defective governor, vandalism, natural accident, poor maintenance, human error, corruption, neglect of government by politicizing the sector and lack of adequate investment. A careful study of Nigeria's power system network shown in Fig. 2 reveals that the Nigeria grid network comprises only one ring network. Hence, exposing the grid to severe collapse because power has to flow in one direction only in a large portion of the grid thus, exposing the grid to great instability during fault conditions because of lack of redundancy in transmission lines. Transient stability problems deal with the effects of large, sudden system disturbances such as; Line faults, sudden switching of lines, sudden application or removal of loads, and loss of a major generating unit. The grid has a table recorded with stochastic collapse data from 2000 to 2019, which will be shown in Table 3.1.

Table 3.1: Statistical Data of Both partial and total collapse on the Nigerian National Grid from 2000 to 2019 Source, (NCC, 2019), [46]

Year	Partial collapse	Total collapse	Total system collapse
2000	6	5	11
2001	5	14	19
2002	32	9	41
2003	39	14	53
2004	30	22	52
2005	15	21	36
2006	10	20	30
2007	9	18	27
2008	15	25	40
2009	20	19	39
2010	20	22	42
2011	6	13	19
2012	8	16	24
2013	2	22	24
2014	7	2	9
2015	2	10	12
2016	6	4	10
2017	2	12	14
2018	7	5	12
2019	5	6	11

3.2.2 Capacity of Electricity Generation Stations in Nigeria

Nigeria uses three types of electricity generation stations namely Hydro generating stations, Steam turbine generation stations, and gas turbine generation stations.

Each generation station in Nigeria has a specific megawatt (MW) contributing to the national grid. Table 2 shown below gives the locations and ratings of electricity generating stations used in Nigeria.

Table 3.2: Electricity Generation Stations, Ratings, and their Locations in Nigeria.

S/NO.	NAME	LOCATION (STATE)	TYPE	INSTALLED CAPACITY
1.	Kainji power station	Niger state	Hydro	760MW
2.	Jebba power station	Niger state	Hydro	576.8MW
3.	Shiroro power station	Niger state	Hydro	600MW
4.	Egbin thermal power station	Ikorodu, Lagos	Gas	1320MW
5.	Sapele power station	Delta state	Gas	1020MW
6.	Transcorp ughelli power station	Delta state	Gas	972MW
7.	Afam 1-4 & 5 power station	Rivers state	Thermal	977MW
8.	Geregu power station	Kogi	Gas	414MW
9.	Omotosho power station	Ondo state	Gas	335MW
10.	Papalanto (olorunsogo) power station	Ogun state	Gas	335MW
11.	Kwale okapi power station	Delta state	Gas	480MW
12.	Afam vi power station	Rivers state	Gas	642MW
13.	Ibom power station	Akwa-ibom	Gas	500MW
14.	Ase barge	Lagos state	Gas	270MW
15.	Omoku power station	Rivers state	Gas	150MW
16.	Trans amadi power station	Rivers state	Gas	136MW
17	Rivers (IPP)	Rivers state	Gas	180MW
18	Aba power station	Abia state	Gas	140MW
19	Geregu II power station	Kogi state	Gas	434MW
20	Sapele power station	Delta state	Gas	1074MW
21	Olorunsogo II power station	Ogun state	Gas	675MW
22	Aloaji power station	Abia state	Gas	1074MW
23	Omotosho II power station	Ondo state	Gas	450MW
24	Omoku II power station	Rivers state	Gas	225MW
25	Ihovbor power station	Benin	Gas	450MW
26	Egbema power station	Imo state	Gas	338MW
27	Calabar power station	Cross-rivers state	Gas	561MW
28	Gbarain power station	Bayelsa state	Gas	225MW

Table 3.3: Power stations in Nigeria under construction/proposed (**Source:** NCC, 2019)

S/NO.	NAME	LOCATION (STATE)	TYPE	INSTALLED CAPACITY
1.	Mambila power station	Taraba state	Hydro	3050MW
2.	Itobe power station	Kogi state	Coal	1200MW
3.	Azura thermal power station	Benin city	Gas	450MW
4.	Kano power station	Kano state	Hydro	100MW
5.	Qua iboe power station	Akwa ibom	Thermal	540MW
6.	Zungeru power station	Niger state	Hydro	700MW
7.	Kaduna power station	Kaduna state	Gas/Diesel	215MW
8.	Gurara power station	Kaduna state	Hydro	40MW
9.	Dadin kowa power station	Gombe state	Hydro	29MW
10.	Okapi	Delta state	Gas	480MW

In Nigeria, the electricity generating stations are interconnected in radial form with a single National Control Centre (NCC) in Oshogbo. This has led to a low-reliability index of the Nigerian National Grid. The Nigerian government has awarded the contract for the generation, transmission, and distribution of 6000MW with a completion date of December 2010. This seems impossible if you look at the electric power scorecard of the government that the installed capacity of electricity generating stations in Nigeria is 5000MW, but only 2, 900 MW has been generated as of November 2019 due to major factors affecting electricity generation, transmission, and distribution in Nigeria to be mention in this project.

3.2.3 Hydro Electric Power Stations Hydrological Water Balance Analysis

The in-flow and outflow of water at Kanji hydropower stations have affected the generation of electricity and this is to say, the higher the level of water head, the higher the generating output capacity. Meanwhile, the monthly hydrological water balance on the Kanji reservoir operation for 2018 is shown in the table below.

Table 3.4: Hydrological monthly water balance on the operation of kanji Reservoir in 2019 (Source: Operation Dept., kanji Dam 2019)

Months	Average In-Flow (Billion M^3)	Average Out-Flow (Billion M^3)	Average Evaporation (Billion M^3)	Reservoir Level At The End Of The Month (Billion M^3)	Storage Balance at the End of The Month (Billion M^3)	Water Used for Power Generation (Billion M^3)	Energy Generated (MW)
JANUARY	1026	824.84	92.52	141.17	11.309	2.2092	207,773.00
FEBUARY	522	1062	89	139.73	8.54	2.5684	232,948.00
MARCH	200	995	87	137.57	9.619	2.665	229,645.00
APRIL	63	839.27	82.33	135.24	7.2692	2.1754	178,106.00
MAY	25	551	55	133.46	5.0417	1.4748	144,740.00
JUNE	79	362.57	28.27	132.6	3.1475	0.9398	72,122.00
JULY	424	311	14	132.72	2.8677	0.8331	62,899.00
AUGUST	877	309	20	133.46	2.9597	0.8276	61,943.00
SEPTEMBER	1587	291	22	137.33	3.955	0.754	58,205.00
OCTORBER	1310	496.52	39.35	138.77	77.0388	1.3299	109,875.00
NOVEMBER	1298	651	48.63	139.58	9.448	1.686	145,279.00
DECEMBER	1373.7	632	49.07	140.48	10.48	1.6896	147,999.00
						19,153	**1,621,534.00**

Table 3.5: Kanji Reservoir Annual Computed In-Flow (2001 To 2018)

YEAR	IN-FLOW (BILLION M^3)
2001	28.10
2002	31.20
2003	30.40
2004	30.30
2005	31.40
2006	28.90
2007	30.60
2008	27.60
2009	25.90
2010	35.40
2011	33.20
2012	30.80
2013	29.70
2014	32.10
2015	26.90
2016	30.70
2017	29.60
2018	30.40

However, the intake level or quantity of water into the hydropower generating stations differs. It varies concerning the position of the hydropower stations and the prevailing seasons experienced at a particular point in time.

3.2.4 Causes of power outage at Generation station

Water Head: This is to say, that whenever the head of water goes low, the generation capacity will be low, and whenever the head of water is high, the generation capacity will be high. This means that the higher the head of water, the higher the generating output capacity and power produced, and vice versa when the head of water is low [9], [47].

In Kainji hydropower station, an excess inflow of water is expected at the early end of September and full in November, December, and January (end of the rainy season). But anytime between February and March, we are in dry season, and the head will go down. That is why, anytime from March to July, serious load-shedding is experienced in some parts of Nigeria, especially Kebbi, Sokoto, Niger, and the Zamfara States of Nigeria and the Niger Republic, since their supply is from Kainji between locations.

Water at the Kainji Dam was collected from different catchment areas and different locations which include Kebbi, Sokoto, Niger States of Nigeria, and the Niger Republic. The river is also called the Rima River.

Generator failure: This is the inability of the generation plant's generator to generate electricity despite the availability of water in the reservoir or dam. Failure in the generator can be due to damage from the generator's spare parts, like bad belts, dead batteries, lack of fuel, bad fuel, sludge in the fuel tank or lines, low coolant, no coolant, or lack of oil, which causes overheating and broken pistons. All these can cause catastrophic engine (generator) failure.

In the Kainji power station, there are eight (8) generators, namely: 1G12, 1G11, 1G10, 1G9, 1G8, 1G7, 1G6, and 1G5, with an installed capacity of 760 MW. Out of these generators, only four (4) are currently working in the generation plant as of 2019/2020, and they contribute 440 MW to the national grid using only those four generators, which are 1G12, 1G11, 1G6, and 1G5. As of 2020, generator 1G7 is under rehabilitation, and all the remaining generators from 1G4, 1G3, 1G2, and 1G1 are expected to be installed by their manufacturers before 2023. This is to say, whenever one of the generators fails, the generating capacity will go down, and if care is not taken, this will lead to a serious power outage.

System frequency: frequency can either be under or over. Under-frequency can result when the result generator is overloaded; over-frequency is when there is a sudden outage of a major consumer for example if a company consuming 200 MW goes out without notice, the frequency will go high. The same thing is true in the case of under-frequency: when a major consumer comes to the system without notice, the system frequency will go down, and this situation is known as under-frequency. Whenever the system frequency goes down, if it is not restored to its normal (tolerance) value, there must be an outage, which is usually an emergency outage.

Reactive Power: Reactive power is the parameter that determines the quality of the generating voltage. If the reactive power in the generating voltage becomes high without necessary action being taken, the system can trip, which will result in an outage [48], [48], [49].

If the voltage drops too low, some generators will disconnect automatically to protect themselves. Voltage collapse occurs when an increase in load or less generation in transmission facilities causes dropping voltage, which causes a further reduction in reactive power from capacitor and line charging, and still their further voltage reduction continues, these will cause additional elements to trip, leading to further reduction in voltage and loss of the load. Therefore, at the generation delivery station reactive power (VARs) is required to maintain the voltage and to deliver active power (watts) through the transmission line up to the distribution and final consumers.

System Imbalance: when the angle between the phases (3-phases), i.e., red, yellow, and blue (R.Y.B.), is altered by 120 degrees, an increase or decrease in the phase angle will lead to an outage. This can be caused by system relay malfunctions, aging equipment, phase angle overloading, and faults, whether symmetrical or unsymmetrical [50].

System Voltage (weak or high): whenever the generating voltage goes higher or beyond the tolerance value, for example, in the case of 330 kV, when it reaches 315 kV downward, the system voltage is said to be weak. Likewise, when it reaches 345, the system voltage is said to be high.

If the generating voltage goes beyond the generating value of the generating station, it will be regarded as under voltage and will lead to a power outage. When the system voltage goes high, there will be an outage after many types of equipment have been damaged.

Generally, other causes of outages from Kainji hydropower station also include planned or scheduled outages outage, unplanned or unscheduled outages, and emergency outages.

3.*2.5 Causes of Power Outage at Transmission Stations*

At the transmission station, we deal with two lines, which are the 33 kV line and the 330 kV line. Outages can be found due to problems on these lines and other problems in the transmission substation [47].

The transmission on the 33kVKainji-Birninkainji-Birnin Kebbi line, there are two main causes of power outages, which are overcurrent and earth fault.

Overcurrent in an electric power system, or excess current, is a situation where a larger than intended electric current exists generation through a conductor, leading to excessive generation of heat, and the risk of fire or damage to equipment. Possible causes of overcurrent include: exists

Short circuit;

i. Excessive load;
ii. Incorrect design;
iii. Arc fault;
iv. Ground (symmetrical or unsymmetrical) fault, phase-to-phase fault, and 3-phase fault
v. Overcurrent protection mechanisms include the use of:
vi. Fuses;
vii. Circuit breakers; and

viii. Current limiters.

An earth fault is an inadvertent fault between the live conductor and the earth. When an earth fault occurs, the electrical system gets short-circuited, and the short-circuited current flows through the earth or any electrical equipment, which damages the equipment. Also, an earth fault can be explained as any failure that allows the unintended connection of power circuit conductors with the earth. Such faults can cause objectionable circulating currents or may energize the housing of equipment at a dangerous voltage.

Earth faults can be caused by the following:

i. The line to a ground fault;
ii. Two lines to ground fault;
iii. 3-phase ground fault.

The causes of the faults listed above could be due to wind action. Conductor cuts, accidents (falling off poles, and other emergencies).

3.2.6 Causes (problems) found within the transmission substation:

Within the transmission substation, a fault in the equipment also causes an outage. The equipment found in transmission substations is:

i. Transformers' faults can be due to loss of insulation between the two turns windings to the main tank, or replacement of silica gel, transformer oil, or tap-changing, which on some transformers cannot be done on-load.
ii. Circuit breaker faults can be due to operating mechanism problems, shattering of insulation due to a high-magnitude high magnitude fault, or improper contact latching.
iii. Conductors: most of the problems with conductors in transmission substation substations include the use of small weak (undersized) (size) conductors, hotspots due to found on termination clamps, and improper tightening of joints, bolts, and nuts. All the above-mentioned factors can contribute to faults and energy losses.

On the 330 kV Kainji-Birnin Kebbi line, faults are due to:

i. Broken insulators;
ii. Arching due to relay tripping, wind, wire overload;
iii. Equipment aging;
iv. Unqualified personnel working on the line contribute to a lack of good jumper positioning and improper tightening of bolts and nuts.
v. Erosion on towers;
vi. Wildlife activities;
vii. Human activities on towers

Generally, in transmission station overcurrent, most of the faults are earth faults and overcurrent. Earth faults occupy more than 60%, while overcurrent occupies just 40%. Likewise, in transmission stations, outages are classified based on planned or scheduled, forced, and emergency outages, as explained in Chapter 1 of this paper.

3.2.7 Causes Power Outages at Distribution Station

i. Natural phenomena.
ii. Technology failures.
iii. Human errors.
iv. Scheduled interruption.
v. Forced interruption.
vi. Emergency interruption.

1. Natural phenomena are the natural conditions that can cause the outage of electricity, which include;

a) Wind;
b) Lightning;
c) Rain;
d) Wild life;
e) Tree branches.

2. Technology failures are failures of equipment that either originated from the manufacturer or occurred within the operation period. Although distribution equipment is rigorously maintained, some technical issues cannot be avoided, such as problems with conductors (cables), insulators, transformers, switchgear, relays, switches, and many other types of equipment that can fail and accidentally trigger an outage. switchgear

3. Human errors are errors made by personnel or other people outside of the operator. They can be intentional (like vandalism) or unintentional, Human beings can accidentally cause a power outage while working with a too-long antenna or ladder close to the power line, hitting a buried cable while digging, while cutting trees, and traffic accidents.

4. Scheduled Outage (interruption): these are intentional interruptions of service to carry out maintenance or repair work that cannot be safely handled any other way, but they are occasional. We always keep these scheduled interruptions to a minimum and attempt to schedule them for the least inconvenient time. Scheduled interruption can be used to achieve the following activities:

i. Shifting;
ii. Maintenance (Annual or non-annual);
iii. Tree cutting;
iv. Equipment replacement, e.g., conductors (wires and cables), insulators, poles, jumper wires, transformer oil, silica gel, etc.

5. A forced interruption, also known as a forced outage, is caused by some external forces and occurrences due to the following factors:

i. Lightning;
ii. Heavy wind;
iii. Sudden failures in the operation of electrical equipment like relays, switch gears, fuses, jumper wires, bird's action, earth faults, overcurrent, etc.

6. An emergency interruption, also known as an emergency outage, occurs due to the presence of emergency factors in the operations of the system that cause a sudden interruption of the service. An emergency outage at the distribution level can be found due to the following factors:

i. Outage from Transmission or Generation
ii. Heavy wind;
iii. sudden erosion; sudden failure of equipment; we need to be replaced urgently.

4. RESULT AND DISCUSSION

In this chapter, results and their charts, details, and a discussion of the work done are presented.

4.2 Power Outage at Kainji-Birnin Kebbi line

In the table below, you will see the causes of the outage at the Kainji-Birnin Kebbi line, i.e., from generation to transmission station.

Table 4.1: Power Outage at K3R Kainji-Birnin Kebbi Line (Source: Generation Field Survey Logbook, 2020)

S/NO.	DATE	FEEDER	CAUSES	TIME	POWER LOSS	OUTAGE CLASS
1.	03/01/2020	Circuit K3R	Line maintenance	9 Hours	10.0 MW	Planned
2.	17/01/2020	Circuit K3R	System collapse	1 day	12.0MW	Emergency
3.	26/01/2020	Circuit K3R	Under frequency	15 Hours	7.0 MW	Emergency
4.	30/01/2020	Circuit K3R	Transformer maintenance	5 Hours	5.7 MW	Planned
5.	09/02/2020	Circuit K3R	Line maintenance	8 Hours	0.1 MW	Planned
6.	19/02/2020	Circuit K3R	Transformer maintenance	2 Hours	10.2 MW	Planned
7.	27/02/2020	Circuit K3R	Insulator breakdown	10 Hours	10.6 MW	Emergency
8.	07/03/2020	Circuit K3R	Under frequency	5 Hours	6.9 MW	Emergency
9.	19/03/2020	Circuit K3R	Transformer maintenance	8 Hours	6.1 MW	Planned
10.	29/03/2020	Circuit K3R	Transformer maintenance	2 Hours	18.0 MW	Planned
11.	15/04/2020	Circuit K3R	Line maintenance	2days	6.0 MW	Planned
12.	25/04/2020	Circuit K3R	System collapse	8 Hours	6.1 MW	Emergency

13.	30/04/2020	Circuit K3R	Free working space for TCN	9 Hours	8.4 MW	Planned
14.	17/05/2020	Circuit K3R	Insulator breakdown	7 Hours	18 MW	Forced
15.	29/05/2020	Circuit K3R	Under frequency	8 Hours	6.2 MW	Emergency
16.	06/06/2020	Circuit K3R	System collapse	23 Hours	8.5 MW	Emergency
17.	21/06/2020	Circuit K3R	Free working space for TCN	5 Hours	7.2 MW	Planned
18.	28/06/2020	Circuit K3R	Line maintenance	8 Hours	10.4 MW	Planned
19.	14/07/2020	Circuit K3R	Free working space for TCN	2 Hours	9.5 MW	Planned
20.	23/07/2020	Circuit K3R	Free working space for TCN	11 Hours	9.5 MW	Planned
21.	28/07/2020	Circuit K3R	System collapse	5 Hours	21.8 MW	Emergency
22.	02/08/2020	Circuit K3R	Insulator breakdown	8 Hours	10.7 MW	Forced
23.	14/08/2020	Circuit K3R	Free working space for TCN	10 Hours	6.1 MW	Planned
24.	26/08/2020	Circuit K3R	System collapse	15 Hours	9.1 MW	Emergency
25.	28/08/2020	Circuit K3R	Line maintenance	8 Hours	3.3 MW	Planned
26.	30/08/2020	Circuit K3R	Insulator breakdown	9 Hours	5.4 MW	Forced
27.	03/09/2020	Circuit K3R	Free working space for TCN	7 Hours	7.0 MW	Planned
28.	15/09/2020	Circuit K3R	Insulator breakdown	8 Hours	10.8 MW	Forced
29.	17/09/2020	Circuit K3R	Under frequency	2 Hours	12.4 MW	Forced
30.	30/09/2020	Circuit K3R	Over frequency	8 Hours	10.5 MW	Forced
31.	06/10/2020	Circuit K3R	Insulator breakdown	9 Hours	8.2 MW	Forced
32.	17/10/2020	Circuit K3R	Over frequency	5 Hours	4.1 MW	Forced
33.	24/10/2020	Circuit K3R	Line maintenance	8 Hours	8.1 MW	Planned
34.	31/10/2020	Circuit K3R	Over frequency	2 Hours	9.9 MW	Forced
35.	08/11/2020	Circuit K3R	Insulator breakdown	11 Hours	9.5 MW	Forced
36.	30/11/2020	Circuit K3R	System collapse	8 Hours	8.5 MW	Emergency
37.	04/12/2020	Circuit K3R	Line maintenance	9 Hours	4.5 MW	Planned
38.	16/12/2020	Circuit K3R	Line maintenance	7 Hours	7.5 MW	Planned
39.	28/12/2020	Circuit K3R	Free working space for TCN	6 Hours	8.0 MW	Planned
40.	31/12/2020	Circuit K3R	Line maintenance	9 Hours	9.5 MW	Planned
				Total=307	**Total=288.51**	**Total=40**

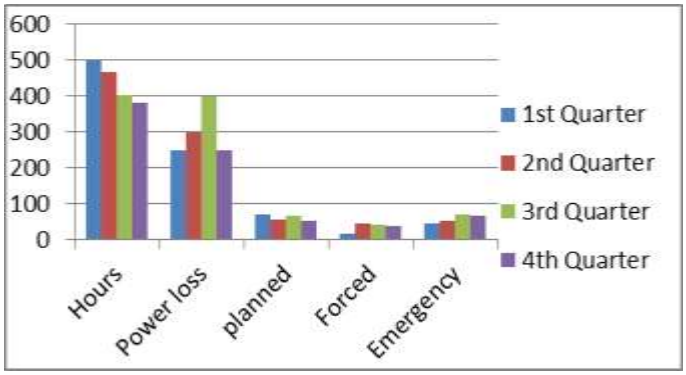

Figure 4.1: Chart for Data Obtained from Generation Field Survey Logbook, 2020.

Table 4.2: Power Outage at Birnin Kebbi Transmission Station (Source: Transmission Field Survey Logbook, 2020)

S/No	Day/Month/ Year	Feeders	Causes	Time (Out)	Time (In)	Power Loss In (MW)	Outage Class
1.	08/01/2020	Fadama 2	E/F	12:51	12:56	12.0MW	Forced
2.	14/01/2020	Fadama 2	OC/EF	10:24	10:53	7.0 MW	Forced
3.	28/01/2020	Fadama 2	O/C	16:15	16:35	5.7 MW	Planned
4.	03/02/2020	Fadama1	Annual maintenance	11:25	16:13	0.1 MW	Planned
5.	16/02/2020	Fadama 2	O/C	15:16	15:30	10.2 MW	Forced
6.	20/02/2020	Fadama 2	OC/EF	13:55	14:23	10.6 MW	Forced
7.	04/03/2020	Fadama 2	OC/EF	10:10	10:19	6.9 MW	Forced
8.	09/03/2020	Fadama1	OC/EF	16:28	16:48	6.1 MW	Forced
9.	12/03/2020	Fadama2	O/C	14:20	14:32	18.0 MW	Forced
10.	18/03/2020	Fadama1	E/F	06:28	06:31	6.0 MW	Forced
11.	26/03/2020	Fadama 2	OC/EF	10:02	10:44	6.1 MW	Forced
12.	06/04/2020	Fadama1	O/C	17:20	17:30	8.4 MW	Planned
13.	07/04/2020	Fadama 2	O/C	19:10	19:23	1861 MW	Planned
14.	09/04/2020	Fadama1	OC/EF	20:49	21:11	6.2 MW	Forced
15.	13/04/2020	Fadama 2	E/F	01:05	01:22	8.5 MW	Forced
16.	13/04/2020	Fadama 2	E/F	19:05	20:55	7.2 MW	Emergency
17.	13/04/2020	Fadama 2	E/F	19:05	19:55	10.4 MW	Emergency
18.	13/04/2020	Fadama1	O/C	0930	09:48	9.5 MW	Emergency
19.	16/04/2020	Fadama 2	O/C	16:53	17:04	9.5 MW	Forced
20.	23/04/2020	Fadama1	E/F	10:54	11:10	21.8 MW	Emergency
21.	24/04/2020	Fadama1	E/F	15:36	15:43	10.7 MW	Forced
22.	25/04/2020	Fadama 2	O/C	10:02	00:02	6.1 MW	Forced
23.	30/04/2020	Fadama 2	OC/EF	23:02	23:51	9.1 MW	Forced
24.	02/05/2020	Fadama 2	O/C	10:15	11:36	3.3 MW	
25.	03/05/2020	Fadama1	O/C	09:29	09:39	5.4 MW	Emergency
26.	04/05/2020	Fadama1	E/F	11:13	11:17	7.0 MW	Forced
27.	09/05/2020	Fadama1	O/C	09:56	11:21	10.8 MW	Forced
28.	09/05/2020	Fadama1	E/F	12:26	16:57	12.4 MW	Forced
29.	13/05/2020	Fadama 2	O/C	07:22	07:29	10.5 MW	Forced
30.	15/05/2020	Fadama1	E/F	11:58	12:58	8.2 MW	Forced
31.	17/05/2020	Fadama 2	O/C	09:20	09:29	4.1 MW	Forced
32.	17/05/2020	Fadama2	OC/EF	12:36	12:44	8.1 MW	Emergency
33.	17/05/2020	Fadama 2	E/F	18:17	18:26	9.9 MW	Forced
34.	31/05/2020	Fadama1	E/F	02:28	07:11	9.5 MW	Forced
35.	03/06/2020	Fadama1	OC/EF	02:28	02:55	8.5 MW	Emergency
36.	04/06/2020	Fadama2	Conductor replacement	20:28	20:45	4.5 MW	Planned
37.	04/06/2020	Fadama1	O/C	20:25	20:55	7.5 MW	Forced
38.	06/06/2020	Fadama1	To enable injection substation to replace jumper.	08:37	08:57	8.0 MW	Planned
39.	11/06/2020	Fadama2	OC/EF	12:13	12:52	9.5 MW	Forced
40.	12/06/2020	Fadama1	O/C	12:13	12:13	10.5 MW	Forced
41.	12/06/2020	Fadama2	O/C	12:13	13:13	5.5 MW	Forced
42.	16/06/2020	Fadama2	O/C	12:13	15:15	4.5 MW	Emergency
43.	16/06/2020	Fadama2	Safe working space for KEDCO personnel	12:13	12:53	11.5 MW	Planned
44.	20/06/2020	Fadama2	OC/EF	12:13	13:03	10.5 MW	Emergency
45.	20/06/2020	Fadama1	OC/EF	12:13	02:13	7.0 MW	Emergency
46.	20/06/2020	Fadama2	Transformer replacement	12:13	12:53	9.5 MW	Planned
47.	23/06/2020	Fadama1	Annual maintenance	14:51	16:26	0 MW	Planned
48.	24/06/2020	Fadama1	OC	14:15	07:37	5.5 MW	Forced
49.	03/07/2020	Fadama2	OC/EF	18:13	19:15	18.5 MW	Forced
50.	04/07/2020	Fadama2	OC	17:15	20:15	13.5 MW	Forced
51.	09/07/2020	Fadama2	OC/EF	12:19	14:15	14.5 MW	Forced

52.	15/07/2020	Fadama2	OC	11:11	14:15	15.5 MW	Forced
53.	17/07/2020	Fadama1	EF	07:18	14:15	12.5 MW	Emergency
54.	17/07/2020	Fadama1	Maintenance	10:15	12:12	2.5 MW	Planned
55.	22/07/2020	Fadama2	OC/EF	14:15	14:45	15. MW	Emergency
56.	27/07/2020	Fadama1	EF	14:15	16:18	11.5 MW	Emergency
57.	01/08/2020	Fadama1	OC/EF	01:10	01:40	19.0 MW	Forced
58.	03/08/2020	Fadama2	OC/EF	19:12	20:52	9.5 MW	Forced
59.	10/08/2020	Fadama2	Heavy wind	11:05	13:35	12.5 MW	Emergency
60.	13/08/2020	Fadama1	Heavy wind	06:12	10:22	13.5 MW	Emergency
61.	16/08/2020	Fadama1	OC/EF	08:17	08:47	10.5 MW	Forced
62.	18/08/2020	Fadama2	OC	14:16	14:56	11.5 MW	Forced
63.	22/08/2020	Fadama1	OC/EF	11:13	11:53	12.5 MW	Forced
64.	23/08/2020	Fadama2	Heavy wind	13:12	13:42	13.5 MW	Emergency
65.	26/08/2020	Fadama1	Heavy wind	14:11	14:31	6.5 MW	Emergency
66.	28/08/2020	Fadama2	OC/EF	13:12	13:52	10.5 MW	Forced
67.	30/08/2020	Fadama2	EF	12:13	12:43	11.5 MW	Forced
68.	31/08/2020	Fadama2	OC/EF	11:14	11:55	9.5 MW	Forced
69	03/09/2020	Fadama 2	OC/	14:15	16:18	11.5 MW	Forced
70.	05/09/2020	Fadama1	OC/	01:10	01:40	13.5 MW	Forced
71.	10/09/2020	Fadama 2	OC/EF	19:12	19:52	9.5 MW	Forced
72.	12/09/2020	Fadama 2	Heavy wind	11:05	11:35	10.0MW	Emergency
73.	16/09/2020	Fadama1	EF	06:12	06:22	11.0 MW	Forced
74.	21/09/2020	Fadama 2	EF	08:17	08:47	16.5 MW	Forced
75.	24/09/2020	Fadama1	EF	14:16	14:56	9.5 MW	Forced
76.	26/09/2020	Fadama 2	EF	11:13	12:53	13.5 MW	Forced
77.	28/09/2020	Fadama1	Heavy wind	13:12	14:42	15.5 MW	Emergency
78.	29/09/2020	Fadama 2	OC	14:11	16:31	17.0 MW	Forced
79.	30/09/2020	Fadama1	Maintenance	13:12	17:52	10.5 MW	Planned
80.	30/09/2020	Fadama 2	Maintenance	12:13	18:43	5.5 MW	Planned
81.	05/10/2020	Fadama 2	EF	11:13	12:53	13.5 MW	Forced
82.	08/10/2020	Fadama1	E/F	02:28	05:11	9.5 MW	Forced
83.	15/10/2020	Fadama1	OC/EF	02:28	03:55	8.5 MW	Emergency
84.	20/10/2020	Fadama2	Conductor replacement	20:28	21:45	4.5 MW	Planned
85.	28/10/2020	Fadama1	O/C	20:25	20:55	7.5 MW	Forced
86.	31/10/2020	Fadama1	To enable injection substation to replace jumper.	08:37	09:57	8.0 MW	Planned
87.	08/11/2020	Fadama2	OC/EF	12:13	13:52	9.5 MW	Forced
88.	04/11/2020	Fadama1	O/C	12:13	13:13	10.5 MW	Forced
89.	12/11/2020	Fadama2	O/C	12:13	13:13	5.5 MW	Forced
90.	22/11/2020	Fadama2	O/C	12:13	15:15	4.5 MW	Emergency
91.	26/11/2020	Fadama2	Safe working space for KEDCO personnel	12:13	13:53	11.5 MW	planned
92.	29/11/2020	Fadama2	OC/EF	12:13	13:03	10.5 MW	Emergency
93.	02/12/2020	Fadama1	OC/EF	12:13	02:13	7.0 MW	Emergency
94.	09/12/2020	Fadama2	Transformer replacement	12:13	12:53	9.5 MW	Planned
95.	11/12/2020	Fadama1	Annual maintenance	14:51	16:26	0 MW	Planned
96.	19/12/2020	Fadama1	OC	14:15	07:37	5.5 MW	Forced
97.	23/12/2020	Fadama2	OC/EF	18:13	19:15	18.5 MW	Forced
98.	27/12/2020	Fadama2	OC	17:15	20:15	13.5 MW	Forced
99.	29/12/2020	Fadama2	OC/EF	12:19	14:15	14.5 MW	Forced
100.	30/12/2020	Fadama2	OC	11:11	14:15	15.5 MW	Forced
			Total=	**1800**	**1950**	**560**	**100**

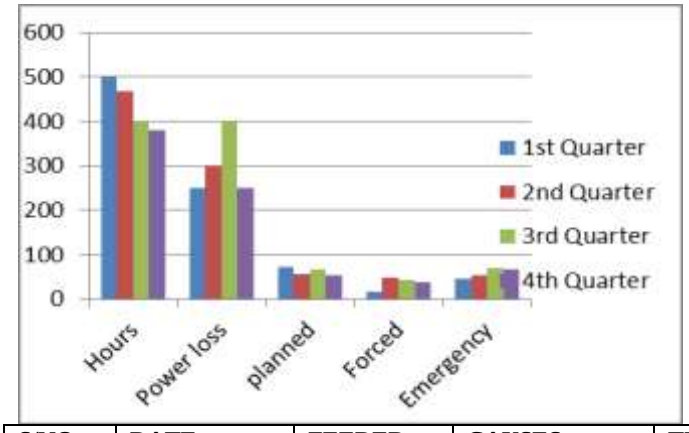

Figure 4.2: Chart for Data Obtained from Transmission Field Survey Logbook, 2020.

Table 4.3: Power Outage in Distribution Station (Source: Distribution Field Survey Logbook, 2020)

S/NO.	DATE	FEEDER	CAUSES	TIME (OUT)	TIME (IN)	POWER LOSS	OUTAGE CLASS
1	03/01/2020	G.R.A	T.C.N Outage	12:51	12:56	12.0MW	Emergency
2	07/01/2020	Kara	Jumper wire cut	10:24	10:53	7.0 MW	Emergency
3	10/01/2020	G/gaji	Accident on Pole	16:15	16:35	5.7 MW	Emergency
4	11/01/2020	T/wada	Shifting	11:25	17:13	0.1 MW	Scheduled
5	15/01/2020	Bulasa	Annual maintenance	15:16	15:30	10.2 MW	Scheduled
6	17/01/2020	Nasarawa	Earth Fault	13:55	14:23	10.6 MW	Forced
7	18/01/2020	G/gaji	T.C.N Outage	10:10	10:19	6.9 MW	Emergency
8	19/01/2020	T/wada	Shifting	16:28	16:48	6.1 MW	Scheduled
9	20/01/2020	Bulasa	Earth Fault	14:20	14:32	18.0 MW	Forced
10	20/01/2020	Nasarawa	Over Current	06:28	06:31	6.0 MW	Forced
11	21/01/2020	Kara	Jumper wire cut	10:02	11:44	6.1 MW	Forced
12	21/01/2020	G/gaji	Shifting	17:20	23:30	8.4 MW	Scheduled
13	22/01/2020	T/wada	T.C.N Outage	19:10	19:23	1861 MW	Emergency
14	22/01/2020	Kara	Annual maintenance	20:49	21:11	6.2 MW	Scheduled
15	23/01/2020	G.R.A	Accident on Pole	01:05	01:22	8.5 MW	Forced
16	24/01/2020	Kara	Earth Fault	19:05	20:55	7.2 MW	Forced
17	28/01/2020	G/gaji	Jumper wire cut	19:05	19:55	10.4 MW	Forced
18	28/01/2020	T/wada	Annual maintenance	0930	09:48	9.5 MW	Scheduled
19	28/01/2020	Bulasa	T.C.N Outage	16:53	17:04	9.5 MW	Emergency
20	30/01/2020	Nasarawa	Earth Fault	10:54	11:10	21.8 MW	Forced
21	02/02/2020	Bulasa	Shifting	15:36	20:43	10.7 MW	Scheduled
22	04/02/2020	Kara	Earth Fault	10:02	00:02	6.1 MW	Forced
23	06/02/2020	G/gaji	Jumper wire cut	23:02	23:51	9.1 MW	Forced
24	08/02/2020	T/wada	Accident on Pole	10:15	11:36	3.3 MW	Forced
25	09/02/2020	Bulasa	T.C.N Outage	09:29	09:39	5.4 MW	Emergency
26	11/02/2020	Nasarawa	Earth Fault	11:13	11:17	7.0 MW	Forced
27	15/02/2020	G.R.A	Shifting	09:56	11:21	10.8 MW	Scheduled
28	17/02/2020	Kara	T.C.N Outage	12:26	16:57	12.4 MW	Emergency
29	20/02/2020	G.R.A	Over Current	07:22	08:29	10.5 MW	Forced
30	22/02/2020	Kara	Transformer Replacement	11:58	12:58	8.2 MW	Scheduled
31	24/02/2020	G/gaji	Over Current	09:20	09:29	4.1 MW	Forced
32	25/02/2020	T/wada	Shifting	12:36	14:44	8.1 MW	Scheduled
33	27/02/2020	Bulasa	T.C.N Outage	18:17	18:26	9.9 MW	Emergency
34	28/02/2020	Nasarawa	Shifting	02:28	07:11	9.5 MW	Scheduled
35	09/03/2020	G.R.A	Annual maintenance	02:28	02:55	8.5 MW	Scheduled
36	15/03/2020	Kara	Accident on Pole	20:28	20:45	4.5 MW	Forced
37	18/03/2020	G.R.A	TCN Maintenance	20:25	23:55	7.5 MW	Scheduled
38	20/03/2020	Kara	Breaker fault	08:37	08:57	8.0 MW	Scheduled
39	21/03/2020	G/gaji	Shifting	12:13	18:52	9.5 MW	Scheduled
40	22/03/2020	T/wada	Breaker fault	12:13	13:13	10.5 MW	Scheduled
41	22/03/2020	Bulasa	T.C.N Outage	12:13	13:13	5.5 MW	Emergency
42	23/03/2020	Nasarawa	Over Current	12:13	15:15	4.5 MW	Forced
43	24/03/2020	Kara	Over Current	12:13	12:53	11.5 MW	Forced
44	24/03/2020	Bulasa	Jumper wire cut	12:13	13:03	10.5 MW	Forced

45	25/03/2020	T/wada	Over Current	12:13	02:13	7.0 MW	Forced
46	27/03/2020	Bulasa	TCN Maintenance	12:13	12:53	9.5 MW	Scheduled
47	03/04/2020	Nasarawa	Earth Fault	14:51	16:26	0 MW	Forced
48	04/04/2020	G.R.A	Earth Fault	14:15	07:37	5.5 MW	Forced
49	06/04/2020	Kara	Over Current	18:13	19:15	18.5 MW	Forced
50	11/04/2020	T/wada	Earth Fault	17:15	20:15	13.5 MW	Forced
51	14/04/2020	Bulasa	Over Current	12:19	14:15	14.5 MW	Forced
52	15/04/2020	Nasarawa	T.C.N Outage	11:11	14:15	15.5 MW	Emergency
53	17/04/2020	G.R.A	Earth Fault	07:18	14:15	12.5 MW	Forced
54	17/04/2020	Kara	Earth Fault	10:15	12:12	2.5 MW	Forced
55	18/04/2020	T/wada	Earth Fault	14:15	14:45	15. MW	Forced
56	19/04/2020	Bulasa	Over Current	14:15	16:18	11.5 MW	Forced
57	19/04/2020	Nasarawa	Over Current	01:10	01:40	19.0 MW	Forced
58	20/04/2020	G.R.A	Over Current	19:12	20:52	9.5 MW	Forced
59	23/04/2020	Kara	T.C.N Outage	11:05	13:35	12.5 MW	Emergency
60	23/04/2020	T/wada	Earth Fault	06:12	10:22	13.5 MW	Forced
61	23/04/2020	Bulasa	Over Current	08:17	08:47	10.5 MW	Forced
62	25/04/2020	Nasarawa	Earth Fault	14:16	14:56	11.5 MW	Forced
63	26/04/2020	Kara	Breaker fault	11:13	11:53	12.5 MW	Forced
64	28/04/2020	T/wada	Pole Replacement	13:12	13:42	13.5 MW	Scheduled
65	30/04/2020	Kara	Earth Fault	14:11	14:31	6.5 MW	Forced
66	01/05/2020	T/wada	Breaker fault	13:12	13:52	10.5 MW	Forced
67	02/05/2020	Bulasa	Over Current	12:13	12:43	11.5 MW	Forced
68	05/05/2020	Kara	Relay fault	11:14	11:55	9.5 MW	Forced
69	06/05/2020	G.R.A	Earth Fault	14:15	16:18	11.5 MW	Forced
70	08/05/2020	G.R.A	Over Current	01:10	01:40	13.5 MW	Forced
71	08/05/2020	G.R.A	Earth Fault	19:12	19:52	9.5 MW	Forced
72	09/05/2020	G/gaji	T.C.N Outage	11:05	11:35	10.0MW	Emergency
73	11/05/2020	T/wada	Earth Fault	06:12	06:22	11.0 MW	Forced
74	18/05/2020	Bulasa	Over Current	08:17	08:47	16.5 MW	Forced
75	19/05/2020	Nasarawa	Earth Fault	14:16	14:56	9.5 MW	Forced
76	20/05/2020	G/gaji	Over Current	11:13	12:53	13.5 MW	Forced
77	20/05/2020	T/wada	Jumper wire cut	13:12	14:42	15.5 MW	Forced
78	21/05/2020	Bulasa	T.C.N Outage	14:11	16:31	17.0 MW	Emergency
79	22/05/2020	Nasarawa	Over Current	13:12	17:52	10.5 MW	Forced
80	23/05/2020	G/gaji	T.C.N Outage	12:13	18:43	5.5 MW	Emergency
81	24/05/2020	T/wada	Earth Fault	12:51	12:56	12.0MW	Forced
82	24/05/2020	Bulasa	Over Current	10:24	10:53	7.0 MW	Forced
83	25/05/2020	G.R.A	Earth Fault	16:15	16:35	5.7 MW	Forced
84	26/05/2020	Kara	Over Current	11:25	16:13	0.1 MW	Forced
85	28/05/2020	G/gaji	Earth Fault	15:16	15:30	10.2 MW	Forced
86	29/05/2020	T/wada	Over Current	13:55	14:23	10.6 MW	Forced
87	29/05/2020	Bulasa	Earth Fault	10:10	10:19	6.9 MW	Forced
88	01/06/2020	Nasarawa	Over Current	16:28	16:48	6.1 MW	Forced
89	02/06/2020	Bulasa	Relay fault	14:20	14:32	18.0 MW	Forced
90	03/06/2020	Nasarawa	T.C.N Outage	06:28	06:31	6.0 MW	Emergency
91	05/06/2020	G.R.A	Pole Replacement	10:02	16:44	6.1 MW	Scheduled
92	06/06/2020	Kara	Earth Fault	17:20	17:30	8.4 MW	Forced
93	08/06/2020	T/wada	Jumper wire cut	19:10	19:23	1861 MW	Forced
94	08/06/2020	Bulasa	Annual maintenance	20:49	21:11	6.2 MW	Scheduled
95	09/06/2020	Nasarawa	T.C.N Outage	01:05	01:22	8.5 MW	Emergency
96	09/06/2020	Kara	Earth Fault	19:05	20:55	7.2 MW	Forced
97	10/06/2020	T/wada	Shifting	19:05	19:55	10.4 MW	Scheduled
98	11/06/2020	Kara	Earth Fault	0930	09:48	9.5 MW	Forced
99	13/06/2020	T/wada	Jumper wire cut	16:53	17:04	9.5 MW	Forced
100	14/06/2020	Bulasa	Relay fault	10:54	11:10	21.8 MW	Forced
101	14/06/2020	Nasarawa	T.C.N Outage	15:36	15:43	10.7 MW	Emergency
102	15/06/2020	G.R.A	Shifting	18:02	00:02	6.1 MW	Scheduled
103	16/06/2020	Kara	Birds	23:02	23:51	9.1 MW	Forced
104	17/06/2020	T/wada	Transformer Replacement	10:15	11:36	3.3 MW	Scheduled
105	18/06/2020	Bulasa	Pole Replacement	09:29	11:39	5.4 MW	Scheduled
106	19/06/2020	Nasarawa	Birds	11:13	11:17	7.0 MW	Forced

107	21/06/2020	Kara	Insulator Replacement	09:56	11:21	10.8 MW	Scheduled
108	23/06/2020	T/wada	Shifting	12:26	16:57	12.4 MW	Scheduled
109	25/06/2020	Bulasa	Relay fault	07:22	08:29	10.5 MW	Scheduled
110	01/07/2020	Nasarawa	Shifting	11:58	12:58	8.2 MW	Scheduled
111	04/07/2020	G.R.A	Birds	09:20	09:29	4.1 MW	Forced
112	06/07/2020	Kara	T.C.N Outage	12:36	12:44	8.1 MW	Emergency
113	09/07/2020	T/wada	Relay fault	18:17	19:26	9.9 MW	Scheduled
114	13/07/2020	Bulasa	Shifting	02:28	07:11	9.5 MW	Scheduled
115	14/07/2020	Nasarawa	Shifting	02:28	02:55	8.5 MW	Scheduled
116	15/07/2020	G/gaji	Faulty Breaker	20:28	21:45	4.5 MW	Scheduled
117	16/07/2020	Kara	Faulty relay	14:25	20:55	7.5 MW	Scheduled
118	17/07/2020	G/gaji	Shifting	08:37	14:57	8.0 MW	Scheduled
119	18/07/2020	T/wada	Transformer maintenance	12:13	15:52	9.5 MW	Scheduled
120	19/07/2020	Bulasa	Transformer maintenance	12:13	15:13	10.5 MW	Scheduled
121	20/07/2020	Nasarawa	Shifting	12:13	18:13	5.5 MW	Scheduled
122	21/07/2020	Bulasa	T.C.N Outage	12:13	15:15	4.5 MW	Emergency
123	21/07/2020	Nasarawa	Insulator Replacement	12:13	12:53	11.5 MW	Scheduled
124	22/07/2020	G.R.A	Shifting	12:13	13:03	10.5 MW	Scheduled
125	23/07/2020	Kara	Transformer Replacement	12:13	02:13	7.0 MW	Scheduled
126	23/07/2020	T/wada	Jumper wire cut	12:13	12:53	9.5 MW	Forced
127	25/07/2020	Bulasa	Tree cutting	14:51	16:26	0 MW	Scheduled
128	27/07/2020	Nasarawa	Shifting	14:15	07:37	5.5 MW	Scheduled
129	27/07/2020	Kara	T.C.N Outage	18:13	19:15	18.5 MW	Emergency
130	27/07/2020	T/wada	Tree cutting	17:15	20:15	13.5 MW	Scheduled
131	29/07/2020	Kara	Tree cutting	12:19	14:15	14.5 MW	Scheduled
132	30/07/2020	T/wada	Tree cutting	11:11	14:15	15.5 MW	Scheduled
133	02/08/2020	Bulasa	T.C.N Outage	07:18	14:15	12.5 MW	Emergency
134	03/08/2020	Kara	Tree cutting	10:15	12:12	2.5 MW	Scheduled
135	05/08/2020	G.R.A	Heavy wind	14:15	15:45	15. MW	Forced
136	07/08/2020	G/gaji	Tree cutting	14:15	16:18	11.5 MW	Scheduled
137	08/08/2020	G.R.A	Insulator Replacement	01:10	02:40	19.0 MW	Scheduled
138	09/08/2020	G/gaji	Tree cutting	19:12	20:52	9.5 MW	Scheduled
139	10/08/2020	T/wada	Heavy wind	11:05	13:35	12.5 MW	Forced
140	11/08/2020	Bulasa	Lightning	06:12	07:22	13.5 MW	Forced
141	13/08/2020	Nasarawa	Heavy wind	08:17	10:47	10.5 MW	Emergency
142	14/08/2020	G/gaji	Heavy wind	14:16	16:56	11.5 MW	Emergency
143	16/08/2020	Kara	Relay fault	11:13	12:53	12.5 MW	Scheduled
144	19/08/2020	T/wada	Jumper wire cut	13:12	13:42	13.5 MW	Forced
145	27/08/2020	Bulasa	Lightning	06:12	07:22	13.5 MW	Forced
146	28/08/2020	Kara	Erosion	13:12	13:52	10.5 MW	Emergency
147	28/08/2020	T/wada	Tree cutting	12:13	14:43	11.5 MW	Scheduled
148	01/09/2020	Bulasa	Heavy wind	11:14	12:55	9.5 MW	Emergency
149	02/09/2020	Kara	Heavy wind	14:15	16:18	11.5 MW	Emergency
150	04/09/2020	T/wada	Insulator Replacement	01:10	02:40	13.5 MW	Scheduled
151	06/09/2020	Bulasa	Lightning	06:12	07:22	13.5 MW	Forced
152	07/09/2020	Nasarawa	Insulator Replacement	11:05	15:35	10.0MW	Scheduled
153	09/09/2020	G.R.A	Transformer maintenance	06:12	09:22	11.0 MW	Scheduled
154	09/09/2020	Kara	Heavy wind	08:17	09:47	16.5 MW	Emergency
155	08/09/2020	T/wada	Transformer Replacement	14:16	19:56	9.5 MW	Scheduled
156	09/09/2020	Bulasa	Lightning	06:12	07:22	13.5 MW	Forced
157	09/09/2020	Nasarawa	Heavy wind	13:12	14:42	15.5 MW	Emergency
158	11/09/2020	Kara	T.C.N Outage	14:11	16:31	17.0 MW	Emergency
159	13/09/2020	T/wada	Working space	13:12	17:52	10.5 MW	Scheduled
160	15/09/2020	Kara	Transformer maintenance	12:13	18:43	5.5 MW	Scheduled
161	18/09/2020	T/wada	TCN Maintenance	12:51	14:56	12.0MW	Scheduled

162	22/09/2020	Bulasa	Erosion	10:24	11:53	7.0 MW	Emergency
163	24/09/2020	Kara	Jumper wire cut	16:15	18:35	5.7 MW	Forced
164	26/09/2020	G.R.A	T.C.N Outage	11:25	16:13	0.1 MW	Emergency
165	27/09/2020	G.R.A	Lightning	06:12	07:22	13.5 MW	Forced
166	28/09/2020	G.R.A	Breaker	13:55	17:23	10.6 MW	Scheduled
167	29/09/2020	G/gaji	Transformer maintenance	10:10	13:19	6.9 MW	Scheduled
168	30/09/2020	T/wada	TCN Maintenance	10:28	14:48	6.1 MW	Scheduled
169	01/10/2020	Bulasa	Transformer Replacement	14:20	19:32	18.0 MW	Scheduled
170	02/10/2020	G.R.A	TCN Maintenance	10:28	12:31	6.0 MW	Scheduled
171	04/10/2020	Kara	Shifting	10:02	16:44	6.1 MW	Scheduled
172	06/10/2020	T/wada	TCN Maintenance	09:20	13:30	8.4 MW	Scheduled
173	06/10/2020	Bulasa	Shifting	19:10	23:23	1861 MW	Scheduled
174	09/10/2020	Nasarawa	Insulator Replacement	20:49	21:11	6.2 MW	Scheduled
175	11/10/2020	Kara	Shifting	01:05	06:22	8.5 MW	Scheduled
176	12/10/2020	T/wada	Transformer maintenance	19:05	21:55	7.2 MW	Scheduled
177	13/10/2020	Kara	Shifting	19:05	23:55	10.4 MW	Scheduled
178	14/10/2020	T/wada	Jumper wire cut	0930	09:48	9.5 MW	Forced
179	16/10/2020	Bulasa	Shifting	16:53	22:04	9.5 MW	Scheduled
180	19/10/2020	Kara	TCN Maintenance	10:54	11:10	21.8 MW	Scheduled
181	20/10/2020	Kara	Shifting	15:36	21:43	10.7 MW	Scheduled
182	24/10/2020	G.R.A	Insulator Replacement	10:02	12:02	6.1 MW	Scheduled
183	25/10/2020	G.R.A	Shifting	23:02	05:51	9.1 MW	Scheduled
184	27/10/2020	G/gaji	Jumper wire cut	10:15	11:36	3.3 MW	Forced
185	29/10/2020	T/wada	Shifting	09:29	15:39	5.4 MW	Scheduled
186	03/11/2020	Bulasa	T.C.N Outage	11:13	11:17	7.0 MW	Emergency
187	04/11/2020	Nasarawa	Insulator Replacement	09:56	11:21	10.8 MW	Scheduled
188	06/11/2020	G/gaji	Transformer maintenance	12:26	16:57	12.4 MW	Scheduled
189	08/11/2020	T/wada	Shifting	07:22	13:29	10.5 MW	Scheduled
190	10/11/2020	Bulasa	TCN Maintenance	11:58	12:58	8.2 MW	Scheduled
191	13/11/2020	Nasarawa	Shifting	09:20	15:29	4.1 MW	Scheduled
192	14/11/2020	G/gaji	Working space	12:36	14:44	8.1 MW	Scheduled
193	15/11/2020	T/wada	Shifting	18:17	23:26	9.9 MW	Scheduled
194	16/11/2020	Bulasa	T.C.N Outage	02:28	07:11	9.5 MW	Emergency
195	17/11/2020	G.R.A	Shifting	02:28	06:55	8.5 MW	Scheduled
196	18/11/2020	Kara	Working space	20:28	21:45	4.5 MW	Scheduled
197	20/11/2020	G/gaji	Fire Outbreak	20:25	21:55	7.5 MW	Emergency
198	21/11/2020	T/wada	TCN Maintenance	08:37	09:57	8.0 MW	Scheduled
199	22/11/2020	Bulasa	Transformer maintenance	12:13	14:52	9.5 MW	Scheduled
200	23/11/2020	Nasarawa	Working space	12:13	13:13	10.5 MW	Scheduled
201	25/11/2020	Bulasa	Working space	12:13	14:13	5.5 MW	Scheduled
202	27/11/2020	Nasarawa	T.C.N Outage	12:13	15:15	4.5 MW	Emergency
203	30/11/2020	G.R.A	Transformer Replacement	12:13	19:53	11.5 MW	Scheduled
204	05/12/2020	Kara	Shifting	12:13	16:03	10.5 MW	Scheduled
205	09/12/2020	T/wada	Working space	12:13	02:13	7.0 MW	Scheduled
206	11/12/2020	Bulasa	Shifting	12:13	18:53	9.5 MW	Scheduled
207	13/12/2020	Nasarawa	Insulator Replacement	14:51	17:26	0 MW	Scheduled
208	14/12/2020	Kara	Shifting	14:15	20:37	5.5 MW	Scheduled
209	15/12/2020	T/wada	Shifting	18:13	23:15	18.5 MW	Scheduled
210	16/12/2020	Kara	T.C.N Outage	17:15	20:15	13.5 MW	Emergency
211	18/12/2020	T/wada	Shifting	12:19	18:15	14.5 MW	Scheduled
212	20/12/2020	Bulasa	Working space	11:11	14:15	15.5 MW	Scheduled
213	20/12/2020	Kara	T.C.N Outage	07:18	14:15	12.5 MW	Emergency

214	22/12/2020	G.R.A	Shifting	06:15	12:12	2.5 MW	Scheduled
215	24/12/2020	Nasarawa	Shifting	14:15	20:45	15. MW	Scheduled
216	24/12/2020	G.R.A	Transformer maintenance	14:15	19:18	11.5 MW	Scheduled
217	25/12/2020	G/gaji	Shifting	01:10	08:40	19.0 MW	Scheduled
218	25/12/2020	T/wada	T.C.N Outage	19:12	20:52	9.5 MW	Emergency
219	25/12/2020	Bulasa	Transformer maintenance	11:05	13:35	12.5 MW	Scheduled
220	26/12/2020	Nasarawa	Transformer Replacement	06:12	10:22	13.5 MW	Scheduled
221	28/12/2020	G/gaji	TCN Maintenance	08:17	20:47	10.5 MW	Scheduled
222	29/12/2020	T/wada	Insulator Replacement	14:16	14:56	11.5 MW	Scheduled
223	31/12/2020	Bulasa	T.C.N Outage	11:13	11:53	12.5 MW	Emergency

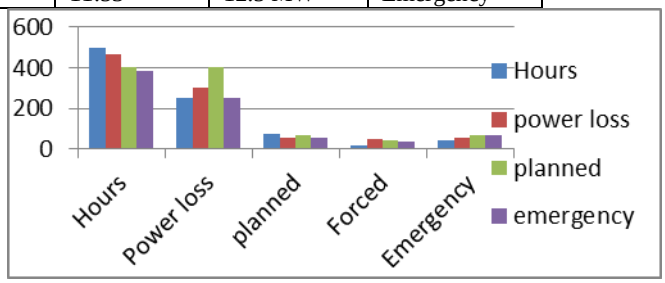

Figure 4.2: Chart for Data Obtained from Distribution Field Survey Logbook, 2020.

Regression analysis of data obtained from the Generation, Transmission and Distribution.

SUMMARY OUTPUT

Regression Statistics

Multiple R	0.049075223
R Square	0.002408378
Adjusted R Square	-0.023844034
Standard Error	7.901112411
Observations	40

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	5.727061539	5.72706154	0.091739	0.76362948
Residual	38	2372.247938	62.4275773		
Total	39	2377.975			

	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95.0%*
Intercept	9.346765984	1.271546563	7.35070681	8.29E-09	6.772654542	11.92087742	6.772654542	11.9208774
X Variable 1	-0.001308226	0.004319216	-0.30288494	0.763629	-0.010052022	0.007435571	-0.01005202	0.00743557

RESIDUAL OUTPUT

Observation	*Predicted Y*	*Residuals*
1	9.333683728	-0.333683728
2	9.331067277	14.66893272
3	9.337608405	5.662391595
4	9.339309098	-4.339309098
5	9.346635161	-1.346635161
6	9.333422083	-7.333422083
7	9.332898793	0.667101207
8	9.337739227	-4.337739227
9	9.338785808	-1.338785808
10	9.323217923	-7.323217923
11	9.33891663	38.66108337
12	9.338785808	-1.338785808
13	9.335776889	-0.335776889
14	6.912158222	0.087841778
15	9.338654985	-1.338654985
16	9.335646066	13.66435393
17	9.337346759	-4.337346759
18	9.333160438	-1.333160438
19	9.334337841	-7.334337841
20	9.334337841	1.665662159
21	9.318246666	-4.318246666
22	9.33276797	-1.33276797
23	9.338785808	0.661214192
24	9.334861131	5.665138869
25	9.342448839	-1.342448839
26	9.339701565	-0.339701565
27	9.337608405	-2.337608405
28	9.332637147	-1.332637147
29	9.330543987	-7.330543987
30	9.333029615	-1.333029615
31	9.336038534	-0.336038534
32	9.341402259	-4.341402259
33	9.336169356	-1.336169356
34	9.33381455	-7.33381455
35	9.334337841	1.665662159
36	9.335646066	-1.335646066
37	9.340878968	-0.340878968
38	9.336954292	-2.336954292
39	9.336300179	-3.336300179
40	9.334337841	-0.334337841

4.3 DISCUSSION

The results obtained from the charts presented above, we realized that most problems are from distribution followed by transmission and are found in the generation. Similarly, most of the outages occur at first quarter of the year which happens to be the dry season as explained in chapter three of this.

The data collected as represented in the above tables, a total number of systems collapses against the year is plotted using Micro soft word application to compare the frequency of the collapses in the years. System collapse was on the increase between the year 2001 and 2013 resulting in insecurity and unreliability of the entire power system network. This was caused majorly by different line tripping due to many reasons. In the year 2000, 11 systems collapses were recorded; all of these were caused by faults from the transmission section of the power system. From the simulation, the highest number of system collapse was recorded in 2003 with a total number of 53.

This frequent collapse of the power system has caused many industries to close down during this period because of the high cost of running diesel generators. Small businesses and heavy machinery manufacturers are severely affected by the abysmal performance of the power industry. In addition, the entire population is also affected socially, psychologically and physically due to inadequate and unstable power supply. The Nigeria Electric system experienced the least number of system collapse (partial system collapse) in the year 2014 within the period of the study.

From table 3.4,

$$\textit{the total water used for power generation} = 19.153 \times 109 m^3$$

$$\textit{Total energy geneated} = 1{,}621{,}534 MWh$$

$$\textit{Amount ofwaterconsmed per energy generated} = \frac{\textit{total water used}}{\textit{total energy generated}}$$

$$= \frac{19.153 \times 109 m^3}{1{,}621{,}534 MWh}$$

$$= 1.181165 m^3/MWh$$

Therefore, to generate 1MWH of electricity, the hydro power station consumes about 11,811.65 m^3 of water.

The inflow and outflow of reservoir can also determine the amount of electricity that generation plant will produce per year. As observed, in rainy season the amount of electricity produced is greater compared to dry season, likewise the amount of outage recorded varies.

The amount of power received from water (Hydro) is too low compared to other sources. Therefore, Nigeria should use the abundance natural resources to generate electricity such as wind and solar.

From figure 4.1, the data in chart described the time in which outage last in one year, is 307 hours and total megawatts lost which is 288.51MW and the percentages of plan outage is 60%, forced outage is 40% and 50% represents the emergency outage.

Similarly, figure 4.2 represents the data obtained from transmission station. In this, hours that outage covers and power loss is much greater compared to that in generation. The plan and emergency outage have the same percentage of 40% respectively, and 20% is for forced outage.

In figure 4.3, the percentage of hours and power loss remain the same, while planned outage occupies 45%, 30% for emergency and 25% for forced outage.

The regression explains the relationship between the dependent variable of x and y in which x is outage time in hours and y is the power loss recorded in one year.

Where df= degree of freedom

Ss= sum of squares

Ms= mean square error

F= intercept

5. CONCLUSION AND RECOMMENDATIONS

5.1 Summary

Rephrase is all about the factors affecting the power outage in Nigeria causes, analysis of data obtained from different power components in Nigeria and some recommendation that shows the way-out.

5.2 Conclusion

Power system should have the ability to maintain stability during and after faults. The number of collapses is perturbing and has led to system blackouts and of so many generating companies. This has led to decrease in economic. There is need for contingency analysis evaluation which permits systems to be operated defensively. Modern computers are equipped with contingency analysis programs that model possible system troubles before they arise. System monitoring is another security measure that provides the operators of power system with up-to-date information on the conditions of the power system.

Nigeria power system needs total overhauling so as to reduce the economic impact of the high incidence of system collapse in the country. Also, the case of adequate security of power system substations equipment against vandals should be treated with utmost concern.

5.3 Recommendations

This frequent collapse of the power system has caused many industries to close down during this period because of the high cost of running diesel generators. Small businesses and heavy machinery manufacturers are severely affected by the abysmal performance of the power industry. In addition, the entire population is also affected socially, psychologically and physically due to inadequate and unstable power supply. The Nigeria Electric system experienced the least number of system collapse (partial system collapse) in the year 2014 within the period of the study.

This study affirms that power outage is a great hindrance to the sustainable socio-economic growth of that certain factors are majorly responsible for the persistence of the phenomenon. The most severe of these factors as reflected in this project are: Inadequate power generating capacity, shortage of Gas, weak transmission and distribution network, inadequate infrastructural facilities, vandalism, wasteful use of electricity etc. This researcher, therefore, makes the following recommendations towards the improvement of electricity supply to the area:

1. There should be frequent inspection and planned maintenance programmed for all electrical installations and facilities. The high voltage transmission lines should be closely monitored and regularly inspected to avoid trees growing under and bridging the high tension (H.T.) lines.
2. There should be an immediate upgrade of the power transmission and distribution infrastructures beginning with those at the distribution sub-sector to ensure that they can efficiently distribute the amount of electrical power being generated currently and in the foreseeable future. The number of powers generating stations should be increased also to meet the ever-increasing demand for electricity. It is both important and necessary to avoid overloading of transmission lines and distribution transformers. In the same vein, the daily energy allocation to Port Harcourt should be increased in view of the City's current high-level demand for electricity.
3. There should be an immediate and comprehensive power generation planning programme that would determine the country's maximum load demand when the suppressed loads are added to the national grid.
4. The on-going deregulation of the power sector should be fully implemented and the new distribution companies (DisCos) should be adequately funded to enable them overcome some of the inherent problems and also guarantee their smooth take-off.
5. Government should legislate against people who vandalize electrical installations and those prides in making illegal connections to electrical infrastructures. Persons who connive with distribution companies (DisCos) staff to avert/circumvent payment of electricity bills should equally be made to suffer stiff penalties for such offence (s).
6. Nigeria should emulate Ghana and Niger republic and legislate on energy conservation and efficiency policy that would encourage consumers to use electric gadgets and devices that do not consume much current. For instance, incandescent bulbs should be outlawed to give way for LED bulbs in order to save some energy.
7. Nigeria should consider entering into an agreement with neighboring African countries for a power pool programme that would enable them share electrical energy sources commonly among themselves.
8. Distributed generation should be encouraged so that more and more power plants can be installed especially at locations were fuel such as gas and coal are available. This would help determine the maximum energy demand not only for Port Harcourt but for Nigeria as a whole.
9. Alternative sources of energy must be fully explored and used in order to reduce the nation's over-dependence on gas. Government must review its current policy on domestic gas supply and ensure increased investment in gas infrastructures so that gas can be readily available for local use.
10. Efforts should be expedited to make pre-paid meters available to every electricity consumer. This would help checkmate power wastages and exploitation of unsuspecting customers by dubious staff of electricity distribution companies (DisCos).
11. There should be programs to enlighten the public and especially electricity users on how to use the energy economically and efficiently and on the need to safeguard electrical installations and equipment in their domains from being vandalized. The populace should also be taught the danger of burning bushes near electrical infrastructures and under high tension transmission lines. In the same vein, they must be told of the legal implications of illegal use of electricity.
12. There should be regular and proper policing of electrical installations, equipment and gas pipelines by the relevant security agencies. Government should as matter of urgent national interest make vandalism an illegal business by ensuring that suspected vandals are promptly prosecuted. Proper street lighting of areas where these installations are located too will reduce the activities of the vandals. The relevant agencies of government should liaise with community leaders to sensitive their people and help in policing electrical installations in their areas.
13. Utility companies' workforce should be overhauled from time to time to ensure that only qualified and technically competent persons drive the new efficient and sustainable electric power system. There should be in place also, regular

on-the-job training and retraining of staff of the electricity supply companies to keep them abreast of latest developments in the power system world.

Declaration of Competing Interest

The authors declare that they have no known financial or personal conflicts of interest that could have influenced the work reported in this paper.

Credit Authorship Contribution Statement

Abba Muhammad Adua: Conceptualization, Methodology, Software. **B. G. Danshehu**: Data curation, Writing- Original draft preparation. **A. I. Araga**: Visualization, Investigation. **I. Alabi**: Supervision.: **Mustapha A. Shehu and Umar M. Jajere**: Software, Validation.: **Abba Muhammad Adua and Yau Alhaji Samaila:** Writing- Reviewing and Editing.

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