CHAPTER I

INTRODUCTION

1.1 Background of the study

One of the ways of overcoming the current power challenges in Nigeria is through the incorporation of distributed generation in her power system/network. The abundant renewable energy resources available in the country can be put to use to fuel small generators which can be used to supply electric power to her cities, towns and remote/isolated villages. However, the current scenario in the Nigerian power system does not allow for the incorporation of these small-scale generators to help solve the aching power need.

Growth of power markets and accelerated technological progress has led to reductions in the generation facilities size and unitary costs. This trend has led to new investments in generation with private participation. Environmentally friendly renewable energy technologies and cleaner fossil fuel technologies are driving the demand for distributed energy generation (Lorrin, P. and Lee W., “Understanding Electric Utilities and De-Regulation” 2006).

The electrical energy industry is changing to compete in a deregulated market. In order to take advantage of new technologies, meet growing energy demand and meet stringent emission requirements, distributed generation technology is becoming a more viable option. The traditional electric utility perspective has been that large central power plants, because of their economies of scale, will continue to provide the vast majority of electric power for the foreseeable future. However, many utilities are investing in alternative generation technologies to meet future energy demands. As the market for distributed power technology matures, the cost of electricity from distributed power generation will decrease and offer many benefits that centralized utilities cannot match.

Competitive power market development is based on free and non-discriminatory access to networks for both big and small power generators and consumers. This can be achieved through well-defined rules for injecting or withdrawing power from the network at specific locations and strict control of its application. Contracts should establish fair tariffs for reimbursing transmission use and guaranteeing adequate network infrastructure expansion. (Camilo T., Hernando D. and Angela C., “Technical and Economic Impacts of Distributed Generation on the Transmission Networks” 2011).

The unbundling of the Nigerian power market and accelerated technological progress has created opportunities where private individuals can participate and invest in micro generation capabilities with attendant reduction in the generation facilities size and unitary costs. Environmentally friendly renewable energy technologies and cleaner fossil fuel technologies are driving the demand for distributed energy generation. Final users will be able to deliver energy on their own and to supply energy to the grid at low voltages. Energy reliability and security will be improved and losses recorded both in transmission and distribution networks will be reduced.

Distributed generation (DG) often corresponds to small power production located close to the customer and connected to the distribution system (medium and low voltage levels). It can be implemented either by final customers, independent power producers (IPPs) or by distribution utilities. Final customers get an alternative supply for peak consumption or a backup option. IPPs have a business opportunity in the competitive electricity market and the utility see it as an interesting option to reduce losses, to deal with voltage problems within the system, or to avoid or delay network expansion.

Benefits such as the reduction of energy losses and energy not supplied (ENS) as well as improvement of voltages profiles have been mentioned in literature and shall be taken into account when choosing the optimal place to install a new capacity, either by private investors, transmission or distribution owners. Others include economy power or “peak-shaving” which allows the customer to take advantage of time-of-day pricing, effectively leveraging fuel costs against electricity prices, cogeneration, premium power or uninterrupted power supply and high power quality, little or no transmission and distribution expansion costs and utilities can meet energy demand incrementally with a lower cost, lower risk investment—essentially enabling a “just-in-time” philosophy.

Niche markets, such as developing countries or remote locations where there is little or no existing transmission and distribution infrastructure and limited fuel options, could be served better. However, the impact on the transmission network, due to a massive installation of DG, should be considered for proper network expansion and operation planning process.

Furthermore, isolated areas in the Nigerian landscape that are not connected to the grid network due to natural factors such as Opobo, Bonny, Ndoni and Burutu islands in the South-South; Umuobom, Mmiata and other riverine communities in the South-East; rural communities and farmlands in the Jos-Plateau highlands; communities cut off by the Adamawa highlands and Gongola mountains in the North and other such communities or areas that cannot be easily connected to the national grid due to environmental factors, can be given electricity supply through distributed generation.

1.2 Statement of Problem

Nigeria's average electricity consumption per inhabitant is only 150kWh per capita, which is one of the lowest in the world (Energypedia, "Nigeria Energy Situation" 2019). Actual on-grid power generation is around 5GW which is based on only hydro and natural gas with an energy mix of 16%/84%. The transmission network is overloaded and experience losses of up to 25%. The frequent power cuts and very poor power availability is a hindrance to technological and economic development of the country. The decentralization of the electricity power market has not yielded much positive impact and the situation is getting worse. The abundant natural renewable energy resources available in the country could be put to use to correct these lapses and improve the energy profile of the country. Investors can be encouraged to invest in modular DG technologies that are much less capital intensive and yields a great dividend to the Nigerian power landscape, bringing about improved energy availability to the country.

1.3 Aim and Objectives

The aim of this work is to study the impact of the integration of distributed generation technology to the Nigerian power system with the objective of achieving the following:

i. To reduce transmission line losses by reducing the amount of power transmitted over the lines with the integration of DG units.
ii. To improve voltage profiles with the addition of dynamic reactive power resources at the various nodes of the power system with the integration of the DG units.
iii. To reduce transmission lines congestion with the integration of DG units in the power system network.

1.4 Scope of Work

The impact of the installation of DG units in the distribution network of the Nigerian power system will be studied. To achieve this, the transmission grid network will be divided into operational regions. DG capacity installation will be modelled in these regions based on two established location criteria: i.) Nodal factors and ii.) Declared investment options. Also, the feasibility of the installation of DG in areas that are not connected to the national grid in these operational regions will be studied and recommendations made.

1.5 Significance of the Research Work

The Nigerian power system is characterised by frequent power cuts, very poor node voltage profiles and high losses. The losses are factored into the energy bill paid by consumers. With the integration of DG technology in the power system, dynamic sources of reactive power will be available and injected into the power system network to improve node voltage profiles, minimise the losses of the network and improve transmission lines congestion. This will also translate to huge cost savings in the energy bills paid by the final consumers.

1.6 Outline of Work

This work consists of five chapters. In chapter 1, a brief introduction of this work is presented, followed by the statement of problem then the aim and objectives and scope of the work. In Chapter 2, various literatures, as it relates to this work, were reviewed. The research methodology, modelling and development of the work were handled in Chapter 3 while the tests and simulations were done in Chapter 4. The conclusion of this work and recommendation make up the last Chapter, 5.

CHAPTER II

LITERATURE REVIEW

2.1 Definition

Distributed generation (also called embedded generation, on-site generation or decentralized generation) is the generation of small pockets of power located close to the customer and connected to the grid through the distribution system (medium and low voltage levels). However, different authors have proposed different definitions based on the facility sizes, storage abilities and generation capabilities. These can be summarized as:

- Electricity generation through small applications in relation to big central generation stations and connected to the power system through the distribution network. (American Council for an Energy Efficient Economy, “Distributed Generation” 2002-2016) (Cypress, C., “What Is Distributed Generation and How Might It Shape the Utility Industry’s Future?” 2016) (Sailaja, Ch. V. S. S. and Prasad, P. V. N., “Cost Benefit Analysis of A DG Integrated System: Case Study” 2017)

- DG is generation or storage of electricity in a microscale and installed near to the load (U.S. Department of Energy, “The Potential Benefits of Distributed Generation and Rate Related Issues That May Impede Their Expansion: A Study Pursuant to Section 1817 of The Energy Policy Act of 2005” 2007), with the option to exchange (sell or buy) with the power network. In some cases, maximum energy efficiency is achieved. (Singh, S. N., Jacob O., Naveen J. “Distributed Generation in Power Systems: An Overview and Key Issues”) (Energy Centre, “Fuel Cells for Distributed Generation” 2000) (Kadir D., Bedri K., Recep Y., Ozan E. and Joao P. S. C., “Maximum Permissible Integration Capacity of Renewable DG Units Based on System Loads” 2018)

- Electric power generation that corresponds to small units connected at distribution voltage and placed at the consumption point. (Lorrin, P. and Lee W., “Understanding Electric Utilities and De-Regulation” 2006) (Thomas A., Goran A. and Lennart S., “Distributed Generation: A Definition” 2001) (Roger C. D., Mark F. M., Surya S. and Wayne H. B., “Electrical Power Systems Quality” 2004) (Eltaib S. E. and Ali M. A., “Distributed Generation: Definitions, Benefits, Technologies and Challenges” 2016) (Mahmoud S. K., Magdi M. E., Ahmed E. H. and Khaled M. A., “Dynamic Modelling and Control of Microturbine DG System for Autonomous Operation” 2019) (Borbely A. M., Kreider J. F., “Distributed Generation the Power Paradigm for the New Millenium” 2001) (Rajat B., Jonathan C. Sundeep R., “Challenges and Opportunities for The Biomass Fuelled Distribution Generation Power Market in Brazil” 2013)

These definitions are however, not exhaustive. The range of capacity used to consider an installation as DG varies widely, going from tens of kW to hundreds of MW. The range depends on the total installed capacity of the power system. A country or region with a robust power system can assimilate higher capacities of DG than a region with relatively low capacity power systems. Nevertheless, one distinguishing feature of DGs is that they are connected to the distribution network of the power system.

The essence of a power system is to generate electrical power and distribute it to consumers but in doing so, it must keep to the following:

i. It must do this economically as cost is an important criterion in electric power usage.
ii. It must do so reliably as electric power is very close to a necessity.
iii. It must deliver the power safely.
iv. It must function optimally within a de-regulated structure.

While (iii.) is a constant for all electric power utilities, DG technology is an attempt to meet criteria (i.), (ii.) and (iv.) as it aims to eliminate the need for transmission and distribution facilities and to bring the generated power closer to the end users.

2.2 Types of Distributed Generators

There are different types of DG technologies available. Some of them include:

2.2.1 Fuel Cells

A fuel cell is an electrochemical device that converts the chemical energy of a fuel directly into electrical energy. Intermediate conversions of the fuel to thermal and mechanical energy are not required. All fuel cells consist of two electrodes, anode and cathode, and an electrolyte usually retained in a matrix. They operate much like a battery except that the reactants and products are not stored but continuously fed to the cell.

Unlike ordinary combustion, the fuel which is hydrogen-rich and the oxidant which is typically air, are delivered to the fuel cell separately. The fuel and oxidant streams are separated by an electrode-electrolyte system. The fuel is fed to the anode, the negative electrode while the oxidant is fed to the cathode, the positive electrode. Electrochemical oxidation and reduction reactions take place at the electrodes to produce electric current. The primary product of fuel cell reactions is water.

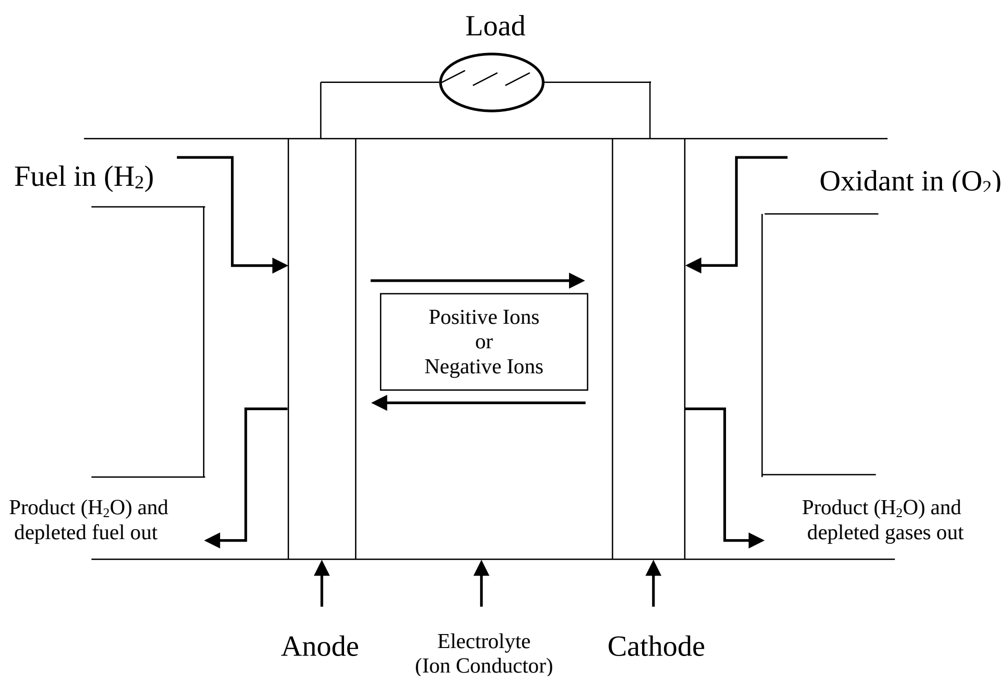

Figure 2.1: Schematic diagram of a fuel cell

Fuel cells are essentially fossil-fuelled batteries which, as long as they are provided with a flow of fuel and air, never run out of energy. They offer a completely different technology of generating electric power. In the presence of some catalysts, hydrogen in the fuel and oxygen in the air oxidise with plenty of heat to generate electricity.

Fuel cells have no moving parts and are quite reliable. They are noise free and produce very little pollution. However, they need complicated ancillary equipment such as reformers, pressurisation pumps and pressure control systems, high temperature seals and DC to AC conversion equipment. These make them quite expensive to use.

Fuel cells have a number of advantages over conventional power generating equipment:

- High efficiency
- Low chemical, acoustic and thermal emissions
- Siting flexibility
- Reliability
- Low maintenance
- Excellent part-load performance
- Modularity
- Fuel flexibility

Due to higher efficiencies and lower fuel oxidation temperatures, fuel cells emit less carbon(iv)oxide and nitrogen oxides per kilowatt of power generated. And since fuel cells have no moving parts (except for the pumps, blowers, and transformers that are a necessary part of any power producing system), noise and vibration are practically non-existent. Noise from fuel cell power plants is as low as 55 dB at 90 feet (Energy Centre, "Fuel Cells for Distributed Generation" 2000). This makes them easier to site in urban or suburban locations. The lack of moving parts also makes for high reliability and low maintenance.

Also, the efficiency of fuel cells increases at part-load conditions, unlike gas and steam turbines, fans and compressors. And fuel cells can use different types of fuel such as natural gas, propane, landfill gas, anaerobic digester gas, JP-8 jet fuel, diesel, naphtha, methanol and hydrogen. This versatility ensures that fuel cells will not become obsolete due to the unavailability of certain fuels.

A single fuel cell will produce less than one volt of electrical energy. To produce higher voltages, fuel cells are stacked on top of each other and connected in series. The stacks consist of repeating fuel cell units, each comprising an anode, cathode, electrolyte and a bipolar separator plate. The number of cells in a stack depends on the desired power output and individual cell performance. The stacks can range in size from a few (< 1 kW) to several hundred (250+ kW).

Reactant gases, typically desulphurized, reformed natural gas and air, flow over the electrode faces in channels through the bipolar separator plates. Because not all of the reactants are consumed in the oxidation process, about 20 percent of the hydrogen delivered to the fuel cell stack is unused and is often "burned" downstream of the fuel cell module.

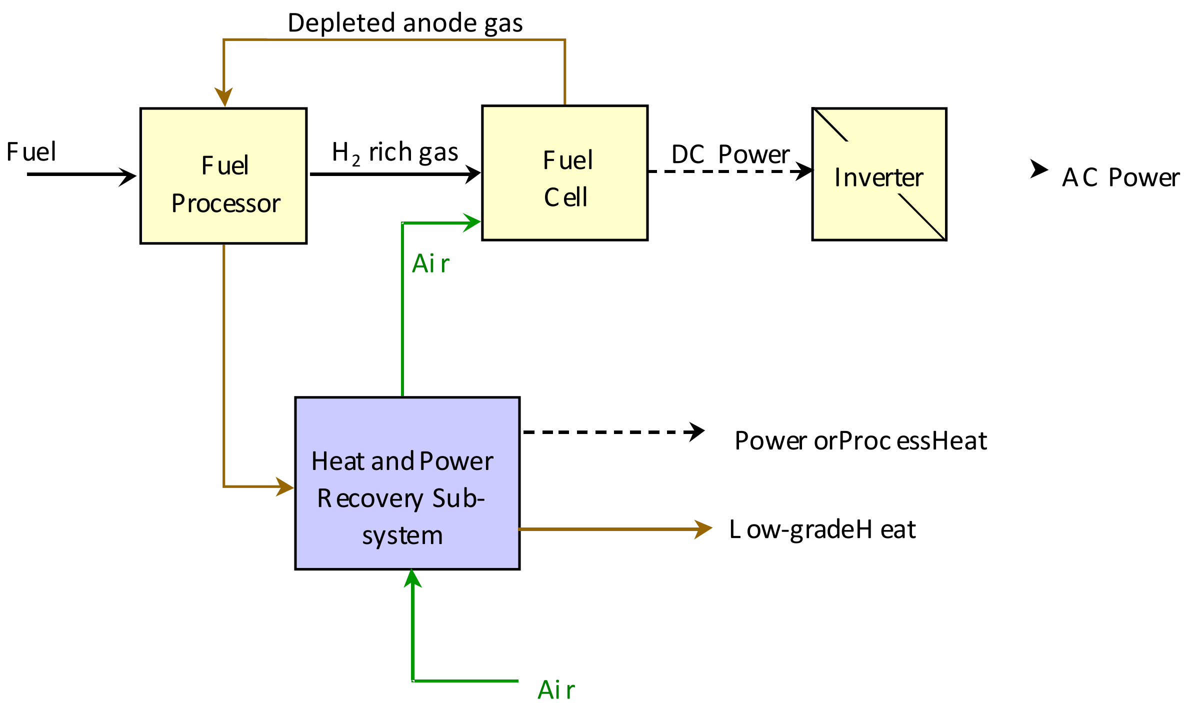

Figure 2.2: A generic fuel cell system (Energy Centre, 2000)

There are five different types of fuel cells. The major distinguishing differences between them are their chemical (fuel) composition and enabling catalysts. They are:

i. Proton Exchange Membrane Fuel Cells (PEMFC)
ii. Alkaline Fuel Cells (AFC)
iii. Phosphoric Acid Fuel Cells (PAFC)
iv. Molten Carbonate Fuel Cells (MCFC)

v. Solid Oxide Fuel Cells (SOFC)

The characteristics of the different types of fuel cells are highlighted in table 2.1 (Lorrin, P. and Lee W., "Understanding Electric Utilities and De-Regulation" 2006) below

Table 2.1: Fuel cells characteristics

Type	**PEMFC**	**AFC**	**PAFC**	**MCFC**	**SOFC**
Electrolyte	Polymer Membrane	KOH and H_2O Phosphoric acid	H_3PO_4 Lithium Carbonate	$LiCaCo_3$ Zirconia	Stabilized
Construction	Plastic, Metal	Plastic, Metal	Steel	Titanium	Ceramic
Need Reformer?	Yes	Yes	Yes	No	No
Oxidant	Air	Pure O_2	Air	Air	Air
Temperature	85ºC	120ºC	190ºC	650ºC	1000ºC
Efficiency	30%+	32%+	≈40%	≈42%	≈45%
Application	Cars, Spacecraft	Cars, Others	DG	Large DG	Very Large DG
Installation Cost (₦/kW)	1,400	2,700	2,100	2,600	3,000

Fuel cells for the distributed power market segment will supply power in the range of 3MW to 100MW. High temperature fuel cells (MCFCs and SOFCs) will serve this market, which includes traditional utilities, unregulated subsidiaries, municipal utilities and energy service providers. Fuel cells for this market may be integrated with coal gasification.

2.2.2 Micro-Gas Turbine Generators

They are miniature gas turbines used to turn generators that produce electric power. Like large gas turbines, they burn fossil fuel to produce a forceful stream of hot gas which drives a turbine which in turn spins an AC generator. MGTs employ innovations such as air bearings which is used for lubrication instead of oil to eliminate metal to metal contact and wear. They also have completely automated control systems that minimise exhaust emissions and can self-diagnose themselves and call for repairs.

MGTs are not very electrically efficient, however, as their efficiencies are in the range of 25% (Prasad K., Jukka R., "Generation of Heat and Power from Biogas for Stationary Applications: Boilers, Gas Engines and Turbines, Combined Heat and Power (CHP) Plants and Fuel Cells" 2013) but they are reliable, quiet and inexpensive and can also run on a wide variety of fuels such as natural gas, diesel, kerosene and pulverised coal. They operate based on the thermodynamic cycle known as the Brayton cycle (Mahmoud S. K., Magdi M. E., Ahmed E. H. and Khaled M. A., "Dynamic Modelling and Control of Microturbine DG System for Autonomous Operation" 2019) (Rena, Sunil K., "Landfill Gas as an Energy Source" 2019).

The quantity of fuel injected into a microturbine is determined by a valve that is controlled by the turbine speed controller signal. The valve position, V_p, can be represented as:

$$V_P = a + b + c \tag{2.1}$$

Where *a, b, c* are the valve position constants

The quantity of fuel injected into the microturbine can be represented by

$$F_i = (T_{Fi} + 1)^{-1} \tag{2.2}$$

Where T_{Fi} is the fuel control time constant in seconds.

The fuel combustion, F_c, process is given by

$$F_c = e^{-cr} \tag{2.3}$$

Where *cr* is the combustion reaction time delay.

The fuel expansion, F_e, can be defined by

$$F_e = (T_d + 1)^{-1} \tag{2.4}$$

Where T_d is the discharge volume time constant.

The mechanical torque, T_m, of the electric generator is given by (Mahmoud S. K., Magdi M. E., Ahmed E. H. and Khaled M. A., "Dynamic Modelling and Control of Microturbine DG System for Autonomous Operation" 2019):

$$T_m = 1.3(F_e - 0.23) + 0.5\,(1 - N) \qquad (2.5)$$

Where N is the per unit rotor speed.

The temperature of the turbine is given by (Mahmoud S. K., Magdi M. E., Ahmed E. H. and Khaled M. A., “Dynamic Modelling and Control of Microturbine DG System for Autonomous Operation” 2019):

$$T_t = T_m - 700\,(1 - e^{-t}) + 550\,(1 - N) \qquad (2.6)$$

Where

e^t is the turbine exhaust delay in seconds.

Using the Proportional Integral Derivative (PID) controller gives the following control features (Mahmoud S. K., Magdi M. E., Ahmed E. H. and Khaled M. A., “Dynamic Modelling and Control of Microturbine DG System for Autonomous Operation” 2019):

- Woodward PID Speed control acting under partial load conditions.
- Temperature control acting as an upper output power limit.
- Acceleration control to prevent over speed.

The output of these control function blocks are the inputs to a least value gate (LVG) whose output is the lowest of the three inputs and results to the injection of the least amount of fuel to the compressor-turbine. The temperature is transferred through the radiation shield to the thermocouple.

The radiation shield is given by (Mahmoud S. K., Magdi M. E., Ahmed E. H. and Khaled M. A., “Dynamic Modelling and Control of Microturbine DG System for Autonomous Operation” 2019)

$$R_s = 0.8 + \frac{2}{15^S + 1} \qquad (2.7)$$

While the thermocouple transfer function is given by

$$T_c = \frac{1}{2.5^S + 1} \qquad (2.8)$$

The turbine temperature is equated to the desired reference value and controlled by a temperature Proportional Integral (PI) given by the relation

$$T_{Ctl} = \frac{T_t}{3.3^S + 1} \quad (2.9)$$

Where

T_t is the temperature controller integration rate (F°)

MGTs operate at very high shaft speeds of up to 100,000 rpm (Robert B., "Small and Micro Combined Heat and Power Systems" 2011), thus their output frequencies are so high that they use electronic inverters for power conditioning to generate power at grid frequency. To also maximise fuel efficiencies of over 80%, the exhaust heat is used to preheat the compressed fuel (Robert B., "Small and Micro Combined Heat and Power Systems" 2011) (Rena, Sunil K., "Landfill Gas as an Energy Source" 2019) (Prasad K., Jukka R., "Generation of Heat and Power from Biogas for Stationary Applications: Boilers, Gas Engines and Turbines, Combined Heat and Power (CHP) Plants and Fuel Cells" 2013). Although they are quite expensive, yet their maintenance requirements and costs are very low.

They are manufactured in units as small as 25kW to 500kW each.

2.2.3 Internal Combustion Distributed Generators

These produce power by using an internal combustion reciprocating engine identical to those used in automobiles and trucks, and operates in the compression ignition cycle, to turn a generator. They are majorly piston engines and turn at speeds of 1,200 to 6,000 rpm. This necessitates the use of synchronous AC generators. Like MGTs, they can run on a variety of fuels, depending on availability and emissions such as gasoline, alcohol, diesel, natural gas or propane/methane.

The processes of liquid atomisation, evaporation and ignition are of fundamental importance to the behaviour of all combustion engine systems. These processes are extremely dependent on the particular fuel being used. They are designated Otto, diesel or dual combustion cycles depending on the operating cycle of the engine.

The overall efficiency, η, of a reciprocating engine is the product of the thermal efficiency, η_t, and mechanical efficiency, η_m (Desmond E. W., Ali T., "Reciprocating Internal Combustion Engines" 2015).

$$\eta = \eta_t \; x \; \eta_m \tag{2.10}$$

The engine efficiency is defined as the ratio of engine power output to the heat release rate of the fuel. It is given by (Jechan L., "A Study on Performance and Emissions of A 4-Stroke IC Engine Operating on Landfill Gas with the Addition of H_2, CO and Syngas" 2010)

$$\eta_f = \frac{P}{m_f Q_{HV}} = \frac{3600}{sfc Q_{HV}} \tag{2.11}$$

Where

P	=	The engine power output
M_f	=	Mass flow rate of the fuel
Q_{HV}	=	The heating value of the fuel
Sfc	=	The specific fuel consumption

The *sfc* can be found with the relation

$$sfc = \frac{m_f}{P} \tag{2.12}$$

Internal combustion engines have fuel efficiencies of about 45%, are inexpensive and have simple maintenance needs but they lack good exhaust heat for co-generation purposes, have emissions, are noisy and vibrates.

2.2.4 Renewable Energy Sources

Renewable energy is energy sourced from resources that are replaced naturally. Some of these include hydro, wind, photovoltaics, biomass, geothermal, tidal and ocean current sources.

2.2.4.1 Hydro Power Generation

Water possesses three forms of energy: kinetic energy, K_e, which is energy it possesses due to its motion; potential energy, P_e, which is energy due to a height of reference, especially in a waterfall and pressure energy, which is energy it possesses especially when it is stored. These forms of energy can be harnessed by hydroelectric machines to generate electric power.

Hydro energy is available in many forms: potential energy from high heads of water retained in dams, kinetic energy from current flow in rivers and tidal barrages, and kinetic energy also from the movement of waves on relatively static water masses. Many ingenious ways have been developed for harnessing this energy but most involve directing the water flow through a turbine to generate electricity. Those that don't, usually involve using the movement of the water to drive some other form of hydraulic or pneumatic mechanism to perform the same task (Electropaedia, “Hydroelectric Power” 2005).

Water turbines convert the energy of the water into rotational motion of the turbine shaft. Leonhard Euler showed that the torque on the shaft is equal to the change in angular momentum of the water flow as it is deflected by the turbine blades and the power generated is equal to the torque on the shaft multiplied by the rotational speed of the shaft (Giorgi Gvasalia “Euler’s Turbine Equation for Waterwheels and Jet Engines”).

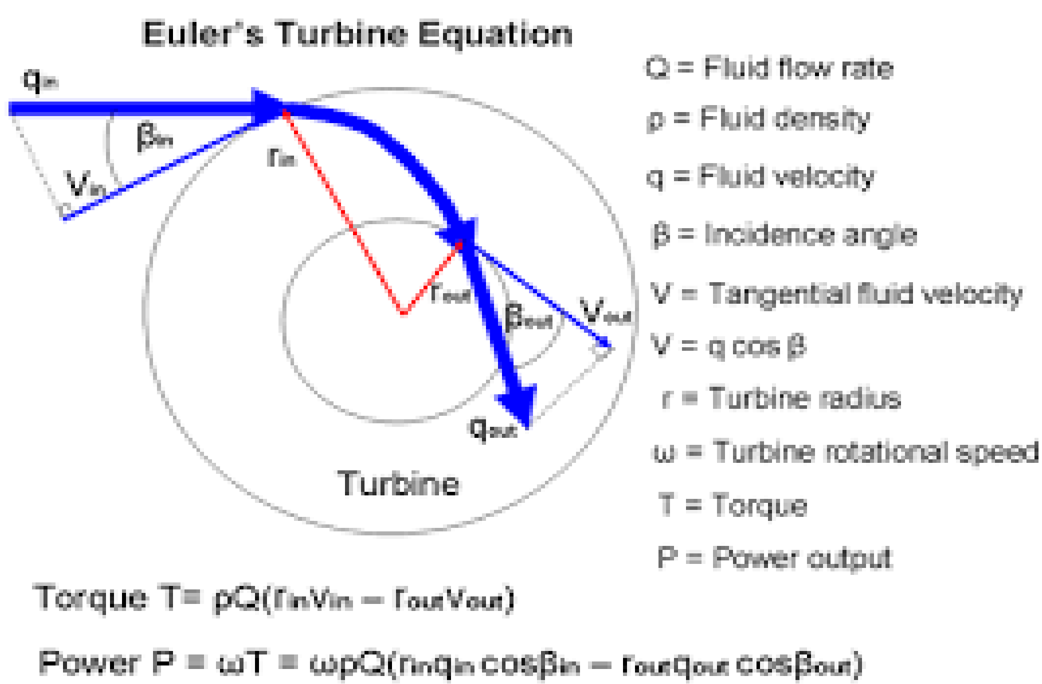

Figure 2.3: Euler’s turbine equation

For a given volume of water, the kinetic energy, K_e, is given by

$$K_e = \frac{1}{2} m V^2 \tag{2.13}$$

Where the volume of the water is given by

$$v = \frac{m}{\rho} \tag{2.14}$$

Where

m	=	Mass of the water
V	=	Velocity of the water
v	=	The volume of the water
ρ	=	The density of water

The potential energy of a volume of water from a height, h, is given by

$$P_e = mgh \tag{2.15}$$

Where

g	=	force of gravitational pull = 9.81m/s^2

Pressure is the force applied by a volume of water per unit area.

Hydropower plants capture this energy of falling water, at a given height, to drive a shaft which drives a turbine to generate electricity.

Hydroelectric power generation is the most efficient method of large-scale electric power generation. Energy flows are concentrated and can be controlled. The conversion process captures kinetic energy and converts it directly into electric energy. There are no inefficient intermediate thermodynamic or chemical processes and no heat losses. The conversion efficiency of a hydroelectric power plant depends mainly on the type of water turbine employed and can be as high as 95% for large installations. Smaller plants with output power less than 5MW may have efficiencies between 80% and 85% (Electropaedia, "Hydroelectric Power" 2005).

The amount of electricity a hydropower plant produces depends on two factors:

i. The height of the dam. The farther the water falls, the more kinetic energy it possesses. The kinetic energy of the water is directly proportional to the distance it falls as the velocity of the water will increase.

ii. Amount of water falling. More water falling through the turbine will produce more power as the mass (or volume) of the water will increase.

Given a dam of height, h_d, a river with a water flow rate, f_r, and a generator with efficiency, η_g, the amount of electrical energy that can be generated from the dam can be gotten from the relation

$$P = h_d f_r \eta_g \rho \qquad (2.16)$$

Where

ρ is the density of water.

Run-of-river installations use water from fast flowing rivers or streams to drive an electrical generator. The head of water may be not much more than zero. The available energy therefore depends on the quantity of water flowing through the turbine and the square of its velocity. They are typically used for smaller schemes generating less than 10MW output power.

Run-of-river projects are much less costly than dams because of the simpler civil works requirements. They are however susceptible to variations in the rainfall or water flow which reduce or even cut off potential power output during periods of drought. On the other hand, during flood conditions, the installation may not be able to accommodate the higher flow rates and water must be diverted around the turbine, thus losing the potential generating capacity of the increased water flow.

The maximum power output from a turbine used in a run of river application is equal to the kinetic energy, K_e, (equation 2.13) of the water impinging on the blades. Taking the efficiency, η, of the turbine and its installation into account, the maximum output power, P_{max}, is given by

$$P_{max} = {}^{1}/_{2}\, \eta \rho f_r V^2 \qquad (2.17)$$

f_r is given by

$$f_r = AV \qquad (2.18)$$

where A is the swept area of the turbine blades

Therefore

$$P_{max} = {}^{1}\!/_{2}\,\eta\rho A V^3 \qquad (2.19)$$

Harnessing the power of tides can be achieved by placing bi-directional turbines in the path of the tidal water flow in bays and river estuaries. To be viable, it needs a large tidal range and involves creating a barrier across the bay or estuary to funnel the water through the turbines as the tide comes in and goes out (Electropaedia, "Hydroelectric Power" 2005). However, the associated civil works are more complicated, and power is available for only six to twelve hours per day depending on the ebb and flow of the tides.

The energy available from the ocean's surface wave motion is almost unlimited, but it is fraught with a lot of technical challenges which, according to (Electropaedia, "Hydroelectric Power" 2005), includes variability of the sea conditions, matching the generating equipment to the wave characteristics, construction of the site and equipment, housing and mooring the equipment, transmitting the energy generated and resistance to storm damage.

The wave power per unit length of the wave front, P_L, is given as (Electropaedia, "Hydroelectric Power" 2005)

$$P_L = \frac{\rho g \lambda a^2}{4T} \qquad (2.20)$$

Where

- a is the wave amplitude,
- λ is the wave length of the oscillation
- T is the period of the wave.

Most governments do not include hydro as a source of renewable energy mostly as a source of tax incentives (Lorrin, P. and Lee W., "Understanding Electric Utilities and De-Regulation" 2006). It is also used mostly as a source of fuel for conventional electric energy generation but with smaller machines, it can also be used for DG.

2.2.4.2 Wind Power Generation

Wind, which is just moving air, has a good deal of energy. The wind turbine is used to capture the energy from the wind and convert it, first to mechanical energy, and then to electrical energy. However, because of the constant variation in wind speeds and impracticability in estimating the energy production of wind turbine generators, they are often called energy producers rather than power producers because they are not dispatchable (Leonard G., "Electric Power Generation, Transmission and Distribution" 2006). The speed of wind varies with the time of the day, time of the year, height above ground and location on the earth's surface. Therefore, to maximise the energy produced from wind turbines, some sort of energy storage is necessary.

Wind speed variation during the day is referred to as the diurnal cycle. It is higher near the earth's surface during the day and higher above the earth's surface at night. This is due to solar heating effect. To tap into the energy of winds, a tower about 50m to 65m is used and the spacing of the tower will be determined by the wind direction.

As wind has the same characteristics as a fluid, the same set of equations that held for the hydropower turbine holds for the wind turbine.

The energy of the wind is kinetic energy, K_e, and is same as given in equation 2.13

$$K_e = \frac{1}{2}mV^2$$

Where

m = Mass flow rate of the wind

V = Velocity of the wind

The mass flow rate of the wind, m, is given by

$$m = \rho AV \qquad (2.21)$$

Where

ρ = Wind density

A = Cross sectional area of the turbine blade

V = Wind velocity

Substituting for m in equation 2.13 gives

$$P = \frac{1}{2}\rho A V^3 C_p \qquad (2.22)$$

Where

C_p = The Betz limit coefficient of the turbine

Equation 2.22 represents the maximum power that can be gotten from the wind.

The Betz limit is the maximum theoretical power efficiency limit of a wind turbine. Also known as the power coefficient, it is the maximum amount of the kinetic energy of the wind that can be extracted by a wind turbine. The theoretical value is 59% (Royal Academy of Engineering, "Wind Turbine Power Calculations, RWE nPower Renewables" 2019). However, wind turbines cannot operate at this maximum limit because of the losses associated with their auxiliary equipment like bearings and gearbox. The C_p value is unique to each turbine type and is a function of the wind speed that the turbine is operating in. The actual value for even the most efficient wind turbines falls within 10 – 30% (Royal Academy of Engineering, "Wind Turbine Power Calculations, RWE nPower Renewables" 2019).

Two types of forces act on the propeller type blade of the wind turbine. These are the circumferential force acting in the direction of the rotation of the blade and the axial force acting in the direction of the windstream. The circumferential force, F_c, produces the rotating torque of the wind turbine.

If the output power of the wind turbine is given as P_a, the diameter of the rotor shaft is given as D and the speed of the rotor is given as N, then the circumferential torque can be gotten from the relation (Ezechukwu, O. A. "The Wind Powered Generator" 2013)

$$T_c = \frac{P_a}{\pi D N} \qquad (2.23)$$

Where

D = $\sqrt{4A/\pi}$

And A = Cross sectional area of the shaft.

The mean wind energy, E_m, can be obtained from the mean wind speed, V_{av}, measured at different intervals.

$$V_{av} = \sum_{1}^{n} \left(\frac{V^3}{n}\right)^{1/3} \qquad (2.24)$$

Where

n = Number of observations

$$E_m = P_m t = \delta \delta t \left(\sum_{1}^{n} \left(\frac{V^3}{n}\right)^{1/3} \right)^3 C_p \qquad (2.25)$$

Where

P_m = Mean power

t = Consumption intervals

There are two basic models of the wind turbine. These are the constant speed, constant frequency (CSCF) model and the variable speed, constant frequency (VSCF) model (Ezechukwu, O. A. "The Wind Powered Generator" 2013). Since the wind speed varies, the turbine rotor speed also varies resulting in a variable output. For CSCF models, the pitch of the turbine blades is adjusted so as to maintain constant speed irrespective of the wind speed. Also, induction machines are used as the wind turbine generators as they maintain fairly constant speeds at lower slip and become a generator when run above synchronous speed and runs at grid frequency when connected to the grid. On the other hand, VSCF models allow the turbine rotor to run with the wind speed while the output is rectified and fed to an inverter tuned to produce constant frequency.

According to (Darren Q., "Wind Turbine Placement to Optimize Wind Power Generation For A Given Area" 2011), two methods of wind turbine placement are the horizontal-axis wind turbines (HAWTs) and the vertical-axis wind turbines (VAWTs). HAWTs are installed far above the ground, to take advantage of the powerful gusts of wind found at greater heights and they are spaced about 25 metres apart to overcome aerodynamic interference between them. VAWTs, on the other hand, are installed very close to the ground surface and spaced 5 metres apart but VAWTs systems are yet to be well developed.

A major setback of wind power generation is that a lot of land is used up to set up the wind farm. For a 20MW generation, a land size of 640acres is needed. Thus, a lot of land is taken up for power generation that could be used for agricultural and other purposes. Going by the exorbitant cost of land in some locations, this means a lot of initial capital outlay to purchase land to site the wind farm.

On the average, it costs about ₦360,000/kW to install a wind turbine.

If ***P*** is a set of power to be generated in kilowatts = $\{P\}_1^{n=int.}$ (kW)

And $\boldsymbol{C_T}$ is the cost of installing a wind turbine = $\{C_T\}_1^n$ (₦)

And ***A*** is the acreage of land used = $\{A\}_1^n$

Then the cost of a wind turbine per acre of land, $\boldsymbol{CT_a}$**,** can be estimated from the following relation

$$C_{Ta} = \sum (PC_T A^{-1}) \quad (₦/kW) \qquad (2.26)$$

Also, the gross income, $\boldsymbol{I_g}$, to the utility per acre of land of actual land used can be estimated from

$$I_g = \sum (PFTVA^{-1}) \quad (₦/a/yr) \qquad (2.27)$$

Where

F	-	Plant factor
T	-	Time = $\{T\}_1^{8760}$ $(hours/year)$
V	-	Value of the land/acre

2.2.4.3 Solar Power Generation

Almost 100% of the energy flow on the earth is due to radiated energy from the sun. The energy of the sun is immense. Using the Einstein's equation, $E = mc^2$, the energy from the sun can be quantified as:

$$E_S = \left(4\ x\ 10^9 \frac{kg}{s}\right)\left(3\ x\ 10^8 \frac{m}{s}\right)^2 = 3.6\ x\ 10^{26} W \qquad (2.28)$$

However, because of the great distance of the earth from the sun (the earth is about 150 million kilometres from the sun), the earth receives less than 30% of this energy. As solar energy is evenly spread out through space, the energy getting to the earth is about $220W/m^2$

Solar cells absorb the energy of the sun and convert it to electricity. They consume no fuel, make no noise, pose no health hazards and produce no waste products (Ezechukwu, O. A. "Solar Energy - Clean and Silent" 2011). Sunlight, on a clear day, provides 1kW of energy per square meter which is over 4MW per acre but the most that can be converted to electricity using solar generation technology is 16% (Lorrin, P. and Lee W., "Understanding Electric Utilities and De-Regulation" 2006). Although efficiency can be improved using exotic materials and systems but the cost for the improvement in efficiency is prohibitive.

Light from the sun is on a wavelength of 0.4mm to 4mm but visible light is on a wavelength of 0.4mm to 0.8mm (Wakil, M. M. "Power Plant Technology" 1984). Solar energy conversion involves using the photon energy of the light to move electrons from the irradiated material.

The radiated energy is given by the wave equation

$$E_r = hf = \frac{hc}{\lambda} (2.29)$$

Where

h	=	Planck's constant = 6.63×10^{-34} J.s
c	=	Velocity of light = 3.00×10^{8} m/s
f	=	Frequency of the impinging light
λ	=	Wavelength of the impinging light

Due to attenuation losses, the radiated energy is depleted as it travels. Therefore, the energy at any point, p, is given by

$$E_r = E_p + E_l \qquad (2.30)$$

Where

E_p = Energy at the point p

E_l = Energy lost

Equation 2.29 can also be stated as

$$N_p = N_o e^{-\alpha p} \qquad (2.31)$$

Where

N_p = Energy photon at point p

N_o = Applied energy photon

α = The radiation coefficient at point p

Photovoltaic cells are made as flat as possible in order to have a large surface area to catch as much sunlight as is possible. They convert sunlight directly to electricity without any mechanical parts. A single PV cell will produce only a minute amount of electricity when exposed to adequate sunlight. They are thus stacked into modules, in order to produce considerable energy. Modules are stacked into panels. These panels are then deployed according to specific need. They are usually stacked in series to produce higher voltage and in parallel to produce higher current.

The characteristics of some materials used for photovoltaic cells are shown in table 2.2 below (Ezechukwu, O. A. "Solar Energy - Clean and Silent" 2011):

Table 2.2: Characteristics of some PV materials

Material	Radiated Energy		Intrinsic Concentration	Mobility $m^2v^{-1}s^{-1}$		Diffusion Constant m^2s^{-1}	
	EV	Joules	Ni (m^{-3})	μ_n	μ_p	D_n	D_p
Silicon	1.12	1.79×10^{-19}	10^{16}	0.15	0.045	0.0039	0.0012
Germanium	0.67	1.07×10^{-19}	10^{19}	0.39	0.19	0.010	0.0049
Galium Arsenide	1.42	2.27×10^{-19}	10^{12}	0.85	0.04	0.022	0.0010
Indium Phosphide	1.35	2.16×10^{-19}	10^{14}	0.46	0.015	0.012	0.0039

To improve their efficiency, PV cells can be equipped with a mechanism that aids in aiming themselves directly to the sun or with mirrors that can increase the concentration of sunlight on their surfaces but these only end up increasing the cost but they have distinct advantages, especially in areas that are remote and hard to reach as they require no fuel, have no environmental impact, are silent, produce no exhaust or thermal pollution, do not interfere with natural water or wind flow and are reliable.

Different types of PV cells and their efficiencies are listed in table 2.3 below: (Martin A. G., Yoshihiro H., Ewan D. D., Dean H. L., Jochen H., Masahiro Y., Anita H., “Solar Cell Efficiency Tables (Version 53)” 2018)

Table 2.3: PV cells efficiencies

Classification	Efficiency, %	Area, cm^2	V_{oc}, V	J_{sc}, mA/cm^2	Fill Factor, %
Silicon					
Si (crystalline cell)	26.7 ± 0.5	79.0	0.738	42.65	84.9
Si (multicrystalline cell)	22.3 ± 0.4	3.923	0.6742	41.08	80.5

Classification	**Efficiency, %**	**Area, cm^2**	**V_{oc}, V**	**J_{sc}, mA/cm^2**	**Fill Factor, %**
Si (thin transfer submodule)	21.2 ± 0.4	239.7	0.687	38.50	80.3
Si (thin film minimodule)	10.5 ± 0.3	94.0	0.492	29.7	72.1
III-V cells					
GaAs (thin film cell)	29.1 ± 0.6	0.998	1.1272	29.78	86.7
GaAs (multicrystalline)	18.4 ± 0.5	4.011	0.994	23.2	79.7
InP (crystalline cell)	24.2 ± 0.5b	1.008	0.939	31.15	82.6
Thin film chalcogenide					
CIGS (cell)	22.9 ± 0.5	1.041	0.744	38.77	79.5
CdTe (cell)	21.0 ± 0.4	1.0623	0.8759	30.25	79.4
CZTSSe (cell)	11.3 ± 0.3	1.1761	0.5333	33.57	63.0
CZTS (cell)	10.0 ± 0.2	1.113	0.7083	21.77	65.1
Amorphous/microcrystalline					
Si (amorphous cell)	10.2 ± 0.3	1.001	0.896	16.36	69.8
Si (microcrystalline cell)	11.9 ± 0.3	1.044	0.550	29.72	75.0
Perovskite					
Perovskite (cell)	20.9 ± 0.7	0.991	1.125	24.92	74.5

Classification	Efficiency, %	Area, cm^2	V_{oc}, V	J_{sc}, mA/cm^2	Fill Factor, %
Perovskite (minimodule)	17.25 ± 0.6	17.277	1.070	20.66	78.1
Perovskite (submodule)	11.7 ± 0.4	703	1.073	14.36	75.8
Dye sensitised					
Dye (cell)	11.9 ± 0.4	1.005	0.744	22.47	71.2
Dye (minimodule)	10.7 ± 0.4	26.55	0.754	20.19	69.9
Dye (submodule)	8.8 ± 0.3	398.8	0.697	18.42	68.7
Organic					
Organic (cell)	11.2 ± 0.3	0.992	0.780	19.30	74.2
Organic (minimodule)	9.7 ± 0.3	26.14	0.806	16.47	73.2

Solar panels are expensive to deploy. The average cost of installation is about ₦2,000/Watt (Ezechukwu, O. A. "Integrating Renewable Energy into Nigeria's Power System" 2015). Because of the exorbitant cost of deploying these, several adaptations were developed to improve the efficiency and reduce the cost of its use. Some of these adaptations are:

2.2.4.3.1 Solar Thermal Energy Storage (STES)

Thermal energy storage is a technology that allows the transfer of heat and storage in a suitable medium. It allows storage of thermal energy by heating or cooling a storage medium for later use for either heating or cooling applications and power generation. Seasonal storage is defined as the ability to store energy for days, weeks or months to compensate for a longer term supply disruption or seasonal variability on the supply and demand sides of the energy system. STES technology is where concentrated sunlight is used to heat up oil or liquid salt in a storage medium and the heat used to produce steam to drive a traditional steam turbine to generate electricity.

The most common type of thermal energy storage is sensible heat storage which utilizes both solid and liquid types of storage medium such as rock, sand, clay, earth, water and oil. In sensible heat storage change in temperature of the medium occurs, that is, the temperature is either increased or decreased. Heat is removed from the storage whenever required to satisfy a load, such as space heating or for domestic hot water. The removal of heat from the storage lowers its temperature. Although there are many possibilities of variations, sensible heat storage medium always consists of an insulated container, heat storage medium and means for adding and removing heat (Getu H., "Seasonal Thermal Energy Storage" 2018).

The amount of heat stored for sensible heat storage systems is given by the relation

$$Q = mC_p\Delta T = \rho V C_p \Delta T \qquad (2.32)$$

Where

Q	=	Amount of heat stored (J)
m	=	Mass of the storage material (kg)
C_p	=	Specific heat of the storage material (J/kg K)
ΔT	=	Temperature change (°C)
ρ	=	Density of the storage material (kg/m^3)
V	=	Volume of the storage material (m3).

Heat loss from a sensible thermal storage is directly proportional to the temperature difference between the storage and the environment. An important consideration in sensible thermal storage systems is the rate at which heat can be released and extracted, which is a function of thermal diffusivity. Thermal conductivity, which is material property of the thermal storage, affects charging and discharging rates of the storage. This relationship is expressed by the following equation (Getu H., "Seasonal Thermal Energy Storage" 2018).

$$\lambda = \rho C_p \alpha \qquad (2.33)$$

Where

λ = Thermal conductivity (W/m K)

ρ = Density (kg/m^3)

C_p = Specific heat (J/kg K)

α = Thermal diffusivity (m^2/s)

Latent heat storage is based on the absorption or release of heat when a storage material undergoes a phase change from solid to liquid or liquid to gas or vice versa. Latent heat thermal storage system involves the storage of energy in phase change materials. For example, when solid material melts and turns to liquid, it absorbs heat. Thermal energy is stored and released with changes in the material's phase.

A comparison of the latent heat storage and sensible heat storage system shows that with latent heat storage systems, about 5–10 times higher storage densities can be obtained and can also be used over a wide temperature range (Getu H., "Seasonal Thermal Energy Storage" 2018).

The storage capacity of the latent heat storage system is given by (Getu H., "Seasonal Thermal Energy Storage" 2018)

$$Q = mC_{sp}T_m - T_i + a_m \Delta h_m + C_{lp}T_f - T_m \qquad (2.34)$$

Where

Q = The amount of heat stored (J)

m = The mass of the heat storage medium (kg)

a_m = Fraction melted

C_{lp} = The average specific heat between T_m and T_f (J/kg K)

C_{sp} = The average specific heat between T_i and T_m (kJ/kg K)

Δh_m = The heat of fusion per unit mass (J/kg)

T_i = The initial temperature (^oC)

T_m = The melting temperature (^oC)

T_f = The final temperature (^oC)

Salts are commonly used as latent heat storage for solar thermal energy storage. Concentrated sunlight is directed on it until it melts. The liquid salt is then passed through a heat exchanger where it is used to heat up water to produce steam which is then used to drive a traditional steam turbine.

2.2.4.3.2 Solar Tower Generation System (STGS)

A solar tower generation system is a unique combination of solar energy extraction and wind power generation to produce dispatchable electric energy. It makes an interesting use of both the wind turbine and solar thermal energy storage systems to generate dispatchable electrical energy.

Here, a shallow, cone-shaped greenhouse is built on a light framework, with the edges of the greenhouse open. The space inside it gets heated up under the sun and the hot air rises, to the sloped ceiling and the funnel shaped chimney. This brings about a draught of air which is even accelerated more by natural forces inside the chimney. Built into the chimney is a wind-powered generator which is driven by the air draught to produce electricity.

When the sun is down at night, the rocks and stones inside the greenhouse that has been heated up all through the day ensure that the draught of air is sustained as the system becomes a solar thermal energy system. By adjusting the valves of the chimney, the wind speed can be controlled and the amount of electricity generated regulated.

Though the technology is simple, yet the primary setback of this method is that a large tract of land is needed for it and the efficiency of the energy conversion factor is quite very low (Lorrin, P. and Lee W., "Understanding Electric Utilities and De-Regulation" 2006).

2.2.4.4 Biomass (Thrash) Plants

This refers to electricity generated from renewable organic waste or thrash in large cosmopolitan cities that would otherwise be dumped in landfills, openly burnt or left as fodder for forest fires. They are burnt to produce heat which is used to produce steam that is used to drive a traditional steam turbine. At present, biomass accounts for 8.5% of the world's total energy consumption and is the 4th largest source of energy (Md Shahinur I., Ruma A., Mohammad A. R., "A Thorough Investigation on Hybrid Application of Biomass Gasifier and PV Resources to Meet Energy Needs for A Northern Rural Off-grid Region of Bangladesh" 2017).

There are three main biomass generations: (Zandi N. A., Labadie N., Prins C., "Modelling and Optimization of Biomass Supply Chains: A Review and A Critical Look" 2016)

- First generation which includes edible crops such as corn and cane sugar.
- Second generation which includes non-edible crops such as leaves, stems, husks, thrash, etc.
- Third generation which is mainly algae.

Some properties of biomass include the moisture content, calorific quality, extent of altered carbon and volatiles, residue content, alkali metal substance and cellulose/lignin proportion (Aakansha K., Pushpendra S., "Optimal Placement of Biomass for Minimization of Power Losses in Power System" 2016).

The landscape in most Nigerian cities is an eyesore due to festering filth. In most places, the refuse is left in the open or are burnt in the open leading to proliferation of diseases and climatic problems. Biomass presents an option to tackling these problems and the climate change problems caused by the burning of fossil fuels and, although the organic waste itself is cheap, yet the logistics costs present an important fraction in the price of a ton of the fuel delivered. Some of the logistics include biomass availability, cost and quality, pre-processing (drying), conversion performance, palletisation, transportation costs, etc. To minimise these costs, the production and processing of the biomass fuel need to be done within the precincts of the DG installation or in the close vicinity.

Specially grown grasses in rural areas, such as cane sugar, rice paddy, cactus plants, other agricultural wastes and thrash in large cosmopolitan areas are processed, packed and stored then used as fuel to produce heat to drive a traditional steam turbine. Most plants built in this way can produce electrical power within the range of 5MW to 25MW.

2.3 Benefits of the Use of Distributed Generation

DG facilities offer potential advantages for improving the transmission of power. Because they produce power locally for users, they aid the entire grid by reducing demand during peak periods and by minimising power congestion on the network.

Some of the benefits of the integration of distributed generation into a power system, as they relate to the technical, environmental and economic aspects of a power system are highlighted in literature and can be summarized as follows among others (American Council for an Energy Efficient Economy, "Distributed Generation" 2002-2016) (Michael C., "Distributed Generation: What Are the Benefits?" 2016) (Suresh M. C. V., Edward J. B. "Optimal DG Placement for Benefit Maximization in Distribution Networks by Using Dragonfly Algorithm" 2018) (Sailaja, Ch. V. S. S. and Prasad, P. V. N., "Cost Benefit Analysis of A DG Integrated System: Case Study" 2017):

2.3.1 Loss Reduction

Transmission and distribution losses amount for up to 30% of the cost of delivered electricity on the average (Eltaib S. E. and Ali M. A., "Distributed Generation: Definitions, Benefits, Technologies and Challenges" 2016) as approximately between 5% and 8% of the total energy generated by power plants are lost as heat before it gets to the consumer (U.S. Department of Energy, "The Potential Benefits of Distributed Generation and Rate Related Issues That May Impede Their Expansion: A Study Pursuant to Section 1817 of The Energy Policy Act of 2005" 2007) (Michael C., "Distributed Generation: What Are the Benefits?" 2016) (Suresh M. C. V., Edward J. B. "Optimal DG Placement for Benefit Maximization in Distribution Networks by Using Dragonfly Algorithm" 2018). The high cost of these arises mainly as a result of losses in the networks.

The current flow in a conductor, both for active and reactive power, causes heat on the conductor due to the ohmic resistance of the conductor. Reducing either the active or reactive power flow on a transmission line will therefore reduce the losses associated with the current. This will mean reducing the load connected to the transmission line or serving some of the load locally with a DG system.

Having the system voltage as a constant factor, the losses in the system can be calculated using the relation:

$$P_{loss} = \sum_{i}^{n} I_i^2 R_i \qquad (2.35)$$

Subject to the following constraints:

- Voltage constraints

  $0.95 \leq V_i \leq 1.05$
- Power balance constraints

  $P + \sum_{k=1}^{N} P_{DG} = P_d + P_{loss}$
- Upper and lower limits of DG

  $60 \leq P_{DG} \leq 3500$

The extent to which energy losses are reduced depends on the relative location of the central generating station and the load (Kadir D., Bedri K., Recep Y., Ozan E., Joao C., "Maximum Permissible Integration Capacity of Renewable DG Units Based on System Loads" 2018) and on the characteristics of the equipment components operated in-between them. Losses are also a function of the other demands on the system because a more heavily loaded system will run at a higher temperature and this increases the energy losses. One of the possible ways to identify an optimal location for DG placement is based on the losses at the nodes and their sensitivity after compensation. Real and reactive power losses are calculated at the buses then the location corresponding to the bus with the highest loss is selected as the best location for the DG placement. (Suresh M. C. V., Edward J. B. "Optimal DG Placement for Benefit Maximization in Distribution Networks by Using Dragonfly Algorithm" 2018). These losses are mitigated with the use of DG as it helps in losses reduction.

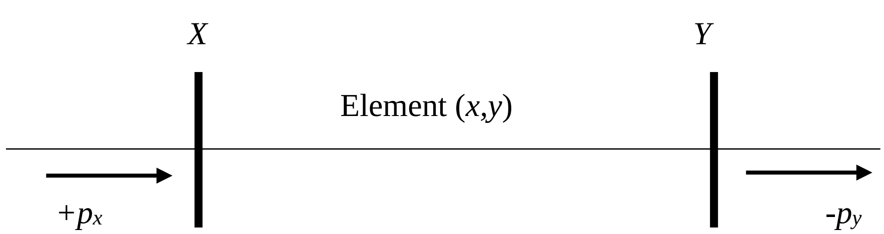

Figure 2.4: Power flow over a transmission network

A transmission network element is denoted in Figure 2.4 above with its initial and end nodes denoted by *X* and *Y* respectively. Power flow over the element (*x*, *y*) from node *X* is denoted as $+p_x$ as power flows into the network through the node while power delivered from the network through node *Y* is denoted as $-p_y$. (Camilo T., Hernando D. and Angela C., "Technical and Economic Impacts of Distributed Generation on the Transmission Networks" 2011).

The difference in the sum of power received and power delivered is the power losses in the corresponding element

$$E_{xy} = E_{yx} = p_x + p_y \tag{2.36}$$

Taking *Z* as the set of elements of a specific zone, the power losses of the zone are given by:

$$E_Z = \sum_{x \neq y \in z} \alpha_{xy} \tag{2.37}$$

The power entering the element (*x*, *y*) through node *x*, p_x^+ and the power leaving the element (*x*, *y*) through node *y*, p_y^- are given by:

$$p_x^+ = \max(0, p_x)\,; \qquad p_y^- = \min\left(0, p_y\right) \tag{2.38}$$

For the set *Z*, the power entering the set P_x^+ and the power leaving the set P_y^- are given by:

$$P_Z^+ = \sum_{x \neq y \in Z} p_x^+\,; \qquad P_Z^- = \sum_{y \neq x \in Z} p_y^- \tag{2.39}$$

The power transport, *T*, which is defined as the product of the sum of power received or delivered by the element (*x*, *y*) multiplied by its length l_{xy}, for the elements in set *Z*, is given by:

$$T_Z^+ = \sum_{x \neq y \in Z} p_x^+ * \, l_{xy} T_Z^- = -\sum_{y \neq x \in Z} p_x^- * \, l_{yx} \tag{2.40}$$

2.3.2 Avoided (or Delayed) Investment in Transmission and Distribution Infrastructure

Power demand from a utility peaks during some hours of the day and period of the year. The peak demand may stretch the available transmission and distribution facilities and significant investment will be required to upgrade the networks. This can be avoided with the use of DG (Michael C., “Distributed Generation: What Are the Benefits?” 2016) (Sailaja, Ch. V. S. S. and Prasad, P. V. N., “Cost Benefit Analysis of A DG Integrated System: Case Study” 2017) (Kadir D., Bedri K., Recep Y., Ozan E., Joao C., “Maximum Permissible Integration Capacity of Renewable DG Units Based on System Loads” 2018).

According to (U.S. Department of Energy, “The Potential Benefits of Distributed Generation and Rate Related Issues That May Impede Their Expansion: A Study Pursuant to Section 1817 of The Energy Policy Act of 2005” 2007), avoided transmission and distribution costs for DG do not necessarily occur at the same time that DG capacity is added because, often, the transmission and distribution resources are already in place. However, in the long run, transmission and distribution facilities must be maintained, replaced and usually reinforced to meet system growth. Therefore, in the long-term view, DG contributes to a reduction in the transmission and distribution network expansion expenses especially from the perspective of a long-run equilibrium in which the DG is planned and coordinated with a distribution system.

This can be stated mathematically as

$$C_d = \sum \left(\frac{C_a . R_f}{P_{DG}} \right) \tag{2.41}$$

Where

$\boldsymbol{C_d}$	=	Costs deferred
$\boldsymbol{C_a}$	=	Costs avoided
$\boldsymbol{R_f}$	=	Fixed Rate

Also, power transmission lines losses reduction of the set *Z* is evaluated with and without DG as given below:

$$\Delta E_Z = E_Z^0 - E_Z^{DG} \tag{2.42}$$

For a zone *g*, which comprises of the set *Z* and other sets, the reduction in the use of transmission lines is estimated through the micro-economic analysis of electricity transport activity (Cadena A., Marcucci A., Pérez J. F., Duran H., Mutis H., Tautiva C., Palacios F., “Efficiency Analysis in

Electricity Transmission Utilities" 2009) where the economic product of transport activity is given as a Cobb-Douglas function which is:

$$P_g * L = V * \phi * \sqrt{\left(\frac{M}{\rho}\right)} * \sqrt{E_g} \tag{2.43}$$

Where

P_g	=	Transmitted power for zone (g)
L	=	Transmission distance
V	=	Transmission voltage
Φ	=	Voltage phase angle
$(M/\rho)^{0.5}$	=	Electrical conducting material
$(E_g)^{0.5}$	=	Losses for the zone (g)

Therefore, from equation 2.40, electricity transport in set Z, T_Z, is the sum of the power delivered per element multiplied by the corresponding transmitted distance. From this, the percentage of avoided transport can be evaluated as:

$$\%T_z = \frac{(T_z^0 - T_z^{DG})}{T_Z^0} * 100 \tag{2.44}$$

2.3.3 Improved Energy Reliability and System Security

Electric system reliability is a measure of the utility's ability to meet the electricity needs of customers. The reliability of a utility's system depends on the reliability of the system's constituent parts such as power plants, transmission lines, substations and distribution feeder lines (U.S. Department of Energy, "The Potential Benefits of Distributed Generation and Rate Related Issues That May Impede Their Expansion: A Study Pursuant to Section 1817 of The Energy Policy Act of 2005" 2007). The efficiency of conventional generating machines rarely exceeds 40%. However, with the installation of DG that employ cogeneration facilities, making use of the waste exhaust heat for the heating system of the neighbourhood, efficiencies improve to 90% (Eltaib S. E. and Ali M. A., "Distributed Generation: Definitions, Benefits, Technologies and Challenges" 2016). Also, DG is employed as backup generation in vital and very sensitive places such as hospitals and main security outfits to ensure energy security (Michael C., "Distributed Generation: What Are the Benefits?" 2016).

One of the traditional approaches to achieving a reliable system involves building sufficient redundancy to ensure continued operations even with a loss of generator or transmission line. Another involves monitoring grid operations and making adjustments to the dynamic nature of the grid network to prevent momentary challenges from cascading into local or regional outages. DGs can be used to augment these approaches to electric system reliability.

2.3.4 Improved Ancillary Services

Ancillary services can be defined as those services necessary to support the transmission of electric power from the point of generation to the point of consumption (U.S. Department of Energy, "The Potential Benefits of Distributed Generation and Rate Related Issues That May Impede Their Expansion: A Study Pursuant to Section 1817 of The Energy Policy Act of 2005" 2007) and necessary to maintain reliable operation of the interconnected transmission network. These include voltage support, regulation, operating reserve and black start facilities.

The efficiency of a transmission and distribution network is greatly enhanced when reactive power production from a central power station facility is replaced by demand-side dynamic reactive power resources. Although static reactive power sources can provide reactive power support under normal regimes but they invariably fail under abnormal regimes or during emergencies. Thus, during emergency conditions, a dynamic reactive power source is most preferred and this can be provided easily by DGs.

The location of dynamic reactive power is also very important and DGs that are designed and operated to produce or absorb reactive power is more economically viable to the power system because, unlike real power which can be economically transmitted from a remote central generating station over long distances to load centres, there are often significant losses when transmitting reactive power over such distances. It is therefore a good utility practice to have these dynamic reactive power sources distributed throughout a network, both during normal and abnormal regimes, and located close to the load. This is a significant and economic value of DGs.

DGs are also best suited for blackstart services for system restoration. Units that provide black start services are paid monthly compensation given by the relation (U.S. Department of Energy, “The Potential Benefits of Distributed Generation and Rate Related Issues That May Impede Their Expansion: A Study Pursuant to Section 1817 of The Energy Policy Act of 2005” 2007)

$$I_c = \sum \left(\frac{R_f . P_m}{12} \right) \tag{2.45}$$

Where

I_c	=	Compensation Income
R_f	=	Fixed rate
P_m	=	Power availability of the unit for that month

2.3.5 Improved Power Quality

A high level of power quality is needed to avoid damages and downtimes to equipment that are sensitive to micro-second perturbations. Voltage surges and sags, frequency fluctuations, harmonics, flickers and phase imbalances are among the major power quality concerns that can cause substantial impact. (Roger C. D., Mark F. M., Surya S. and Wayne H. B., “Electrical Power Systems Quality” 2004) (U.S. Department of Energy, “The Potential Benefits of Distributed Generation and Rate Related Issues That May Impede Their Expansion: A Study Pursuant to Section 1817 of The Energy Policy Act of 2005” 2007). This becomes more of a concern with the growing digital load and the increased sensitivity of these loads.

Power quality incidents are often momentary and can best be addressed with local corrective actions. They are often caused by fault transients on the supply system, the customers themselves (through commutation transients) or by nature (as in lightning strikes for instance). Depending on the interconnection rules, DG has the ability to improve some aspects of power quality (Roger C. D., Mark F. M., Surya S. and Wayne H. B., “Electrical Power Systems Quality” 2004) (Kumar M., Samuel C., Jaiswal A., “ An Overview of Distributed Generation in Power Sector” 2015) (U.S. Department of Energy, “The Potential Benefits of Distributed Generation and Rate Related Issues That May Impede Their Expansion: A Study Pursuant to Section 1817 of The Energy Policy Act of 2005” 2007).

Most DGs employ energy storage technologies. These are very useful in addressing power quality problems such as voltage spikes and other potentially damaging power quality problems. Also, DGs equipped with a power inverter interface and power conditioning equipment can be used to alleviate power quality problems present in the grid network by independently controlling the active and reactive components of the power injected into the network.

2.4 Economic Considerations

Traditionally, electric power utilities use large, central station generators to generate power and employ transmission and distribution facilities to take the power to the point of utilisation because of the significant economy of scale that favoured such against DG technologies. However, this has dropped significantly enough to make a shift in the economics of scale in some situations because of the following (Lorrin, P. and Lee W., "Understanding Electric Utilities and De-Regulation" 2006) (Suresh M. C. V., Edward J. B. "Optimal DG Placement for Benefit Maximization in Distribution Networks by Using Dragonfly Algorithm" 2018)

- ✓ Innovation improved the efficiency of small gas turbines, combined cycle, hydro and fuel cells more than large ones.
- ✓ Improvement in materials, including new high temperature metals, special lubricants, ceramics and carbon fibre permit vastly stronger and less expensive small machinery to be built.
- ✓ Due to the use of computerisation and smart control systems, small and even some large units need no on-site operators.

Furthermore, in considering the economic value of installing a DG, the benefit to cost ratio of DG applications in which the cost and benefit of the DG to both the customer and utility are considered. The DG costs include the initial investment cost, operations and maintenance costs and the displacement cost while the benefits include the loss reduction revenue, power purchase savings and reduction of customer interruption costs due to the DG (Ahmadigorji M., Abbaspour A., Rajabi-Ghahnavieh A., Fotuhi-Firuzabad M. "Optimal DG Placement in Distribution Systems Using Cost/Worth Analysis" 2019). This is given mathematically as

$$Max_{BC} = \frac{B_{DG}}{C_{DG}} \tag{2.46}$$

Where

B_{DG} = Benefits of DG installation

C_{DG} = Costs of DG installation

$$B_{DG} = \sum_{i=1}^{N_{DG}} \sum_{k=1}^{N_{Loc}} (\Delta CIC_{ik} + LRR_{ik} + PPS_{ik}) \,.\, A_{ik} \tag{2.47}$$

Where

N_{DG} = Number of DGs

N_{Loc} = Number of DG locations

i = DG installed

k = Places DG installed

CIC = Customer interruption cost

LRR = Loss reduction revenue

PPS = Power purchase savings

$$LRR_{ik} = \sum_{k=1}^{N_{DG}} \sum_{k=1}^{N_{Loc}} \Delta Loss_{ik}.\, (1 + IR)\,.\,(EP) \tag{2.48}$$

$$PPS_i = \sum_{i=1}^{N_{DG}} (ADG_i \,.\, EP) \tag{2.49}$$

Where

IR = Interest rate

EP = Electricity price

ADG_i = Annual DG generation of DG *(i)*

These costs also apply to a conventional generating station where the result for both it and a DG can be placed side by side and adequate comparison made.

Also, economic evaluation is also done using the spot market price of electricity. Thus, the economic assessment of losses is obtained using the relation:

$$EAL = \frac{\sum_{i=1}^{g} \Delta E_i * mp}{IC^{DG}} \qquad (2.50)$$

Where

EAL	=	Economic Assessment of Losses
ΔE_i	=	Avoided losses for *g* zone
mp	=	Spot market price of electricity
IC^{DG}	=	Installed DG capacity

The savings in transmitted power can be measured through the difference between the power transmitted with the use of DG and without the use of DG. This can be used to determine the reduction in the use of transmission lines.

For the set of elements in the set *Z* (from equation 2.39), the savings in transmitted power can be determined from the relation:

$$\Delta P_Z = P_Z^0 - P_Z^{DG} \qquad (2.51)$$

The savings of the entire transmission network (*STP*) can be determined by summing the savings of all the zones and expressing it as a percentage of the transmitted power without DG. This, when multiplied by the transmission fee, will give the amount of money saved by the reduction of transmitted power due to the installation of DG in the system.

$$STP = \frac{\sum_{i=1}^{g} \Delta P_i}{\sum_{i=1}^{g} \Delta P_i^0} * T \qquad (2.52)$$

2.4.1 High Investment Costs

The traditional, conventional system of electric power generation employs the use of a large generator to generate the power at a remote site which is then transmitted thousands of kilometres to load centres. This requires a huge investment both in the generation and transmission facilities costs whereas DG systems are installed at the load centres and do not need transmission facilities.

The costs for building and running a DG cum conventional power generating station can be quantified using the relation (Prasad V. S. N. T., “Nigeria’s Electricity Sector - Electricity and Gas Pricing Barriers” 2009)

$$C_{DG} = \sum_{i=1}^{N_{DG}} IC_i + \sum_{i=1}^{N_{DG}} \sum_{k=1}^{N_{Loc}} (OP_i + MC_i) \,.\, A_{ik} \qquad (2.53)$$

Where

IC	=	Investment cost
OP	=	Operations cost
MC	=	Maintenance cost

Furthermore, the need to acquire a large tract of land to build a conventional power plant demands a huge capital investment (reference equation 2.27). The size of land required to site a central power station facility is dependent on two factors: the type of fuel to be used and the technology employed for the power plant (U.S. Department of Energy, “The Potential Benefits of Distributed Generation and Rate Related Issues That May Impede Their Expansion: A Study Pursuant to Section 1817 of The Energy Policy Act of 2005” 2007). This can be estimated from the relation –

$$L = \sum_{i=1}^{5} (X_i W_i) \qquad (2.54)$$

Where

$\boldsymbol{L}$	=	Average land use for a central power station
$\boldsymbol{X_i}$	=	Land area required for an i*th* central power station
$\boldsymbol{W_i}$	=	Percentage of electricity generation of the i*th* type
$\boldsymbol{i}$	=	Number of assumed generation facility types, where *i* ranges from 1 to 5.

Similarly, transmission and distribution lines take a lot of land for their right of way. Table 2.4 highlights the standard right of way for transmission and distribution lines (Eze P. I., Richard J. U., “Geospatial Analysis of Encroachments on the Nigeria Electricity Grid Right-of-Way in Parts of Port-Harcourt, Nigeria” 2018).

Table 2.4: Standard Right of Way for Transmission and Distribution Lines

S/N	VOLTAGE	TYPE	GROUND CLEARANCE	STANDARD RoW
1.	330kV	Transmission	30 metres	50 metres
2.	132kV	Transmission	30 metres	30 metres
3.	66kV	Sub-transmission	20 metres	20 metres
4.	33kV	Distribution	15 metres	15 metres
5.	11kV	Distribution	15 metres	12 metres

The wingspan of a 330kV line is 17.3 metres (Ezeakudo C. P., Ezechukwu O. A., Ani L. U., Ocheni A., “Voltage Stability Control Through Reactive Power Regulation in the Nigerian 330kV Grid” 2015) and Nigeria has 5,650kM of 330kV lines and 6,687kM of 132kV lines which connects 32 330kV and 105 132kV substations (Energypedia, “Nigeria Energy Situation” 2019). These lengths, multiplied by the wingspan and the required right of way for the lines, gives you the humongous amount of land used up for just the transmission lines. This cost of land, in addition to the land space required for the power station, is part of the initial investment cost, *IC*, of equation 2.53.

This, in addition to the huge equipment costs involved in building a central power station and transmission and distribution lines network could be avoided by investing in DG.

2.4.2 High Operation and Maintenance Costs

Plant operation level, cost, reliability, availability, safety and environmental compliance are priorities that determine power plant business performance. Failure of plants to attain high levels of availability can result in significant risks to the plant operators financially. In order to sustain high plant availability and also meet regulatory requirements and costs, appropriate maintenance strategies need to be integrated with other management functions (Dr Shyong W. F., Professor Mile T., "The Impact of Operations and Maintenance Practices on Power Plant Performance" 2014).

Since the power plants cannot deliver energy on the days of scheduled maintenance outage, D_{main}, then, according to (Ahmadigorji M., Abbaspour A., Rajabi-Ghahnavieh A., Fotuhi-Firuzabad M. "Optimal DG Placement in Distribution Systems Using Cost/Worth Analysis" 2019)

$$\Delta Loss_{ik} = \left(\frac{365 - D_{main}}{365}\right)(Loss_{old} - Loss_{ik}) + \left(\frac{D_{main}}{365}\right)(Loss_{old})(2.55)$$

$$\Delta CIC_{ik} = \left(\frac{365 - D_{main}}{365}\right)(CIC_{old} - CIC_{ik}) + \left(\frac{D_{main}}{365}\right)(CIC_{old})(2.56)$$

Where

$Loss_{old}$	=	Annual energy loss without DG
$Loss_{ik}$	=	Annual energy loss with DG
CIC_{old}	=	Annual customer interruption cost without DG
CIC_{ik}	=	Annual customer interruption cost with DG

Maintenance costs, *MC*, (from equation 2.53) includes lost plant revenue during maintenance, *MEC*, and repair costs, *RC*, and is given by

$$MC_i = HC_i + MEC_i(2.57)$$

Where

$$MEC_i = h_{main} \,.\, EP \,.\, (1 + IR) \,.\, G_{i,rated} \qquad (2.58)$$

Where

h_{main}	=	Maintenance duration (hours)
$G_{i,rated}$	=	Rated plant power

The fixed costs of power generation are essentially capital costs and land. Capital costs vary from region to region largely as a function of labour and regulatory costs. Operating costs, on the other hand, include fuel, labour and maintenance costs. These depend on how much power the plant produces and the plant factor.

The annual plant operations costs, ADG_i, OC is calculated as

$$OC_i = ADG_i\,.FC.FE \qquad (2.59)$$

Where

FC	=	Fuel Costs
FE	=	Thermal efficiency

The capital costs and operating costs of various power installations are compared in table 2.5 (John A. D., "Introduction to Electricity Markets" 2018).

Table 2.5: Comparison of the capital costs and operating costs of various power installations

Technology	**Capital Costs ($/kW)**	**Operating Costs ($/kWh)**
Coal Fire Combustion Turbine	500 – 1,000	0.04 – 0.20
Natural Gas Combustion Turbine	400 – 800	0.04 – 0.10
Coal Gasification Combined Cycle	1,000 – 1,500	0.08 – 0.04
Natural Gas Combined Cycle	600 – 1,200	0.04 – 0.10
Wind Turbine	1,200 – 5,000	Less than 0.01
Nuclear	1,200 – 5,000	0.05 – 0.02
Photovoltaic Solar	4,500 upwards	Less than 0.01
Hydroelectric	1,200 – 5,000	Less than 0.01

As can be observed from the above table, the operating costs (or plant factor) for DG technologies are far lower than for conventional plants as they involve innovative technologies and approaches and require less personnel and man hours. Thus, it is far more economical to integrate and run DG technology than conventional plants in a grid network.

2.4.3 DG Connection Charges

Grid connected DG is subject to a variety of rate-related and other impediments that can ultimately hinder the installation of DG units. Utility rates have the greatest impact on the practicability of DG because they affect the payback rate and time period for the DG investment. These impediments are as a result of regulations and rate making practices that have been in place for many years. Several econometric models have been developed in the pricing of electricity (Christoph W., "Uncertainty in The Electricity Power Industry: Methods and Models for Decision Support" 2005). Whichever model that is adopted must protect the interest of the investor in DG.

Rate classes are developed with the concept that various customer groups have similar characteristics. Thus, investors in DG technology may be lumped into the same class as investors in conventional power generation to their disadvantage. This is because the deregulated electricity industry is a very competitive one and is full of risks. (Christoph W., "Uncertainty in The Electricity Power Industry: Methods and Models for Decision Support" 2005) identified some of these risks as pricing, quantitative, liquidity, counter-party, political, financial, process and projects, personal, model and IT risks. These risks affect the psyche of an investor who may wish to invest in the DG market and would need regulations ensuring the protection of the investment. If rates, rules, requirements and procedures within a customer class are not comparable to all customers served under that class, this may bring about barriers or impediments to the development and expansion of DG.

There are also several non-rate related issues that affect the financial attractiveness of DG. Some of them are interconnection charges, application and study fees, insurance and liability requirements and the bureaucracy in the processing of the interconnection request application.

The following table shows the technologies and markets in which various DG technologies will compete. The size ranges given for each technology are approximate since distributed generation technology is modular and the economics of each site will determine the number of units or mix of technologies that will be used. The markets listed in the last column reflect current targets and expectations.

Table 2.6: Various DG technology and markets

DG	Types	Size	Efficiency	Markets
Fuel cells	PEM (80°C) PAFC (200°C) MCFC (650°C) SOFC (1000°C)	1–500kW 50 kW–1.2MW 1–20MW 1 kW–25MW	40% 40% 55% 45–65%	L&MT, residential, PP, RP MT, commercial cogeneration, PP HT, PP Residential, commercial cogeneration, PP, RP
Engines	Diesel Internal combustion—natural gas Stirling cycle	50kW–6MW 5kW–2MW 1–25kW	33–36% 33–35% 20%	SP for commercial and small industrial, T&D support, PP and commercial cogeneration Residential, RP
Combustion turbines	Microturbines “Small” turbines	25–500 kW 1–100 MW	26–30% 33–45%	SP, RP, commercial cogeneration Industrial cogeneration, T&D support
Renewables	Solar (PV) Wind Biomass	1–1000 kW	10–20%	RP, peak shaving, power quality, green power RP, peak shaving, green power

Note:

“Small” turbines include cascaded humidified air turbines, advanced turbine systems, and intercooled aeroderivative cycle.

Efficiencies = electric only (no heat recovery, HV basis unknown); PV efficiency is sunlight to AC power.

L&MT—Light and medium duty transportation applications (e.g., automobiles, trucks, buses)

MT—Medium duty transportation applications (e.g., trucks, buses)

HT—Heavy duty transportation applications (e.g., rail, marine—ships, naval vessels)

PP—Premium Power

RP—Remote Power

SP—Standby Power

2.5 Summary of Related Literature

According to (Energypedia, “Nigeria Energy Situation” 2019), Nigeria has tremendous natural energy resources such as natural gas, coal, water, mineral resources and adequate sunshine yet it is highly energy deficient. With just over 5,000MW generated energy against an estimated 26,0000MW power demand and per capita electricity consumption of less than 151kWh (Maria Y. R., Nnanna U., Ikenna-Donald O., “True Cost of Electricity - Comparing The Cost of Electricity Generation in Nigeria” 2017), Nigeria’s electricity sector has serious suppressed and unmet energy demand. With a population of about 200 million people and only about 40% having access to some form of electricity (Prasad V. S. N. T., “Nigeria’s Electricity Sector - Electricity and Gas Pricing Barriers” 2009), it is no wonder that the country is facing a huge developmental crisis. This was brought about by the neglect of the power sector over the decades as there was no new investment in the sector and the existing ones went into a state of comatose.

However, in 1999, the government embarked on an ambitious programme to improve the electricity infrastructure in the country and get the country back on her feet. This led to the opening up of the electricity market and the subsequent privatisation of the generation and distribution sectors in 2013. The aim of the government was to increase the generation capacity, reinforce and expand the transmission network, rehabilitate and extend the distribution network and also bring about sectoral reforms (Prasad V. S. N. T., “Nigeria’s Electricity Sector - Electricity and Gas Pricing Barriers” 2009). Yet investments in the sector over the years have been modest.

With the 2018 global economic recession, the humongous financial demand for investment and with the uncertainty surrounding the investment climate in Nigeria, many private investors are shy of investing in the electricity sector. DG comes to the rescue. Of the various types of DG technologies available and as listed by (Borbely A. M., Kreider J. F., “Distributed Generation the Power Paradigm for the New Millenium” 2001) and (Lorrin P. and Lee W., “Understanding Electric Utilities and De-Regulation” 2006) and considering the Nigerian environment, appropriate DG technologies such as photovoltaic, wind turbine, micro-hydro, gas and biomass plants can be built and integrated into the Nigerian power system. With the abundant natural reserves in the country, private and small to medium scale financial investors can invest in DG capabilities of their choice as these costs far lower and has a better promise of quick returns. (Maria Y. R., Nnanna U., Ikenna-Donald O., “True Cost of Electricity - Comparing The Cost of Electricity Generation in Nigeria” 2017) gave a comprehensive breakdown of the true cost of electricity generation in Nigeria and compared the cost of generating electricity in Nigeria using the various technologies available. (Dr Shyong W. F., Professor Mile T., “The Impact of Operations and Maintenance Practices on Power Plant Performance” 2014), however, argued that of the various technologies available for generating electricity, DG technologies are far more economical to invest in rather than the traditional, conventional concept of electric power generation. This view is also held by the (U.S. Department of Energy, “The Potential Benefits of Distributed Generation and Rate Related Issues That May Impede Their Expansion: A Study Pursuant to Section 1817 of The Energy Policy Act of 2005” 2007) following a comprehensive review of the power system of the United States of America.

(Camilo T., Hernando D. and Angela C., “Technical and Economic Impacts of Distributed Generation on the Transmission Networks” 2011) highlighted the benefits of the integration of the technology in the Columbian system, (U.S. Department of Energy, “The Potential Benefits of Distributed Generation and Rate Related Issues That May Impede Their Expansion: A Study Pursuant to Section 1817 of The Energy Policy Act of 2005” 2007) and (American Council for an Energy Efficient Economy, “Distributed Generation” 2002-2016) discussed the benefits of the integration of the technology in the power system of the United States of America, (Md Shahinur I., Ruma A., Mohammad A. R., "A Thorough Investigation on Hybrid Application of Biomass Gasifier and PV Resources to Meet Energy Needs for A Northern Rural Off-grid Region of Bangladesh" 2017) highlighted the potential for off-grid areas in Bangladesh while (Rajat B., Jonathan C. Sundeep R., "Challenges and Opportunities for The Biomass Fuelled Distribution Generation Power Market in Brazil" 2013) highlighted the challenges of integrating the technology in the Brazilian power system. Although (Ezechukwu, O. A. "Solar Energy - Clean and Silent" 2011), (Ezechukwu, O. A. "The Wind Powered Generator" 2013), (Ezechukwu, O. A. "Integrating Renewable Energy into Nigeria's Power System" 2015) discussed various types of these DG technologies and highlighted their potential benefits to the Nigerian power system, yet, a practical integration of these technologies was not done in order to substantiate their claim. This work was then undertaken to study the effects of integrating these technologies in the Nigerian power system.

The feasibility of the installation of different DG capabilities and the impact of the connection of these DG facilities to the grid is studied in this work. The installation is done on a region by region basis and the effect(s) of the installation on each region and across the grid is analysed and studied. The optimal location for the installation in each region was guided by the works of (Ahmadigorji M., Abbaspour A., Rajabi-Ghahnavieh A., Fotuhi-Firuzabad M. "Optimal DG Placement in Distribution Systems Using Cost/Worth Analysis" 2019), (Kadir D., Bedri K., Recep Y., Ozan E. and Joao P. S. C., "Maximum Permissible Integration Capacity of Renewable DG Units Based on System Loads" 2018) and (Suresh M. C. V., Edward J. B. "Optimal DG Placement for Benefit Maximization in Distribution Networks by Using Dragonfly Algorithm" 2018)) and the benefits (or otherwise) of the integration of the technology in the Nigerian power system will be discussed.

CHAPTER 3

METHODOLOGY

3.1 Power Flow Solution Model

The Nigerian power system was modelled and simulated using NEPLAN software and the Newton-Raphson load-flow technique was adopted in the load-flow algorithm and in finding the solutions to the power flow problems. The objective of the load-flow program is to obtain the following information:

a. The voltage magnitude and phase angle at each bus of the network.
b. The real and reactive power flowing in each element of the network.
c. The reactive power loading on each generator of the network.

The above objectives are achieved by supplying the load-flow program with the following information:

i. The branch list of the system connections that is, the impedance of each element, sending-end and receiving-end node codes. Lines and transformers are represented by their π-equivalent models.
ii. The voltage magnitude and phase-angle at one bus, which is the reference point for the rest of the system. This bus is referred to as the slack bus or swing bus.
iii. The real power generated and the voltage magnitude at each generator bus or PV bus.
iv. The real and reactive power demand at each load bus or PQ bus.

The foregoing information are the base values of the power system network which were obtained from the National Control Centre, Osogbo.

The load-flow problem was then developed as follows:

At any bus of the network, there are four quantities of interest: The voltage magnitude, $|V|$; the voltage angle, θ; the real power, P and the reactive power, Q. Any of these two quantities are specified in a bus while the other two are unknowns. Since the system losses are unknown until a solution to the load-flow problem has been found, the slack bus supplies these losses. The bus at Egbin was chosen as the slack bus. An angle of $\theta = 0$ is used at the slack bus and all other bus angles are expressed with respect to the slack bus. The load-flow analysis program is then executed on the network using the Newton-Raphson algorithm.

Results obtained in the load-flow output contain the following information:

i. All bus voltage magnitudes and phase angles with respect to the slack bus.
ii. The active and reactive power injected into all the busses.
iii. The sending and receiving end complex power flows for all the lines in the network.
iv. From (iii.), individual line losses can be deduced by subtracting receiving-end complex power from sending-end complex power.
v. The total system losses can be deduced by summing (iv.) for all lines, or by summing complex power at all loads and subtracting same from the sum of the generators loads.
vi. The voltage profiles of the busses of the network are also obtained.

If the voltage magnitude varies greatly over the system, it will result to large reactive flows in the network. This will lead to increased real power losses.

The usual practice in load-flow studies is to install determined reactive power compensation devices at busses with poor voltage profiles. If the voltage magnitude of the bus is not corrected, an appropriate FACTS device is installed to provide reactive power compensation for the load at that bus to correct the voltage profile and bring it within limits. If new lines or additional transformers are to be installed to reinforce the network, a load-flow will show how it will relieve overloads on the adjacent lines. It will also indicate how much reduction in losses will result from the installation of the new network element which is very important for economic assessment. However, in this work, the DG units were installed in such busses. The capacity of each installed DG unit is a percentage of the active power demand of the region. After the installation, the load flow program is re-executed and the results obtained are saved. From the results, the effects of the installation of the DG units in the region and across the entire grid is observed and analysed.

For reasons of results comparison and to be able to fully analyse the impact of the integration of the DG technology into the Nigerian power system, the modelling and simulation of the Nigerian power system network and the subsequent load flow program was done in three different tranches:

a. The 330kV grid network alone was modelled and simulated and a load flow program was run for it. The results obtained from it were saved.
b. The Nigerian power system network was modelled and simulated. That is, the 330kV grid network, the 132kV transmission network and the distribution network, were modelled and simulated. A load flow program was run for it and the results obtained were saved.
c. The Nigerian power system network, with the DG systems integrated at the distribution network, were modelled and simulated. A load flow program was run for it and the obtained results were saved.

Furthermore, for a more effective reach and easier results analysis, the Nigerian power system was divided into eight regions viz: Bauchi, Benin, Enugu, Kaduna, Lagos, Osogbo, Port-Harcourt and Shiroro. The DG technology was applied on a region by region basis and the network was modelled and simulated. The results obtained from the simulations were compared and analysed. From them, the effects of the integration of the DG technology in the Nigerian power system were observed.

In the economic assessment of the costs of integrating any particular type of DG technology in the Nigerian power system network, tables 3.1 and 3.2 which shows the sources of available electric power generated energy sources and their costs in Nigeria as at 2016 (Maria Y. R., Nnanna U., Ikenna-Donald O., “True Cost of Electricity - Comparing The Cost of Electricity Generation in Nigeria” 2017), and transmission system costs respectively (Nigerian Electricity Regulatory Commission, “MYTO 2015 TCN Tariff Order” 2015, edited) for same period, comes in handy. Also table 3.3 is the Distribution Companies energy tariff for 2016 (Nigerian Electricity Regulatory Commission, “MYTO 2015 Distribution Tariffs” 2015, edited) with which the savings for loss reduction is computed.

Table 3.1: Costs of generating energy in Nigeria

Parameters / Fuel Type	Capital Costs (₦/kW) '000	Technical Lifetime (yr)	Capacity Factor (%)	Fixed O & M (₦/kW/yr) '000	Variable O&M (₦/kWh)	Fuel Cost (₦ /Mbtu) '000
Open Cycle Gas Turbine	241.92	20	80	2.43	3.96	1.19
Combined Cycle Gas Turbine	393.84	20	80	3.58	0.72	1.19
Coal (Scrubbed, FGD, no CCS)	982.80	40	70	11.52	5.76	1.84
Nuclear	2116.80	60	80	35.87	0.72	0.31
Large Hydro	879.12	40	65	5.37	1.08	0
Small Hydro (<30MW)	1188	20	44	23.40	0	0
PV Utility Scale (>5MW)	819.72	20	19	7.80	0	0
PV Off-grid (Rooftop, residential)	1037.52	20	16	0	36	0
CSP	1505.52	35	32	25.20	0	0
Biomass	1364.40	20	60	39.72	1.98	0.54
Wind Onshore	606.96	20	32	16.82	0	0
Gas Off-grid	936	20	95	2.90	3.06	2.52
Diesel Off-grid	450	10	60	0	118.80	0.05
Petrol Off-grid	50.30	5	30	0	144	0.08

Table 3.2: Transmission system costs for energy in Nigeria at 2016

	₦/MWh
TSP	2975.12
SO	330.08
MO	22.21
NERC ISO	5.28
Ancillary Services	50.69
Total	3383.38

This charge translates to ₦3.38338/kWh of energy transmitted on the Nigerian grid network.

Table 3.3: Distribution Companies tariff for energy consumed in Nigeria at 2016

DisCo	**Tariff (₦/KWh)**	**Region Covered**
Abuja	46.23	Shiroro
Benin	38.56	Benin
Enugu	45.10	Enugu
Ibadan	41.31	Osogbo
Jos	43.91	Bauchi
Kaduna	42.74	Kaduna
Kano	38.38	Kaduna
Ikeja	36.49	Lagos
Port-Harcourt	48.35	Port-Harcourt
Eko	29	Lagos
Yola	41.22	Bauchi

3.2 Flow Chart for the Execution of the Load Flow Program

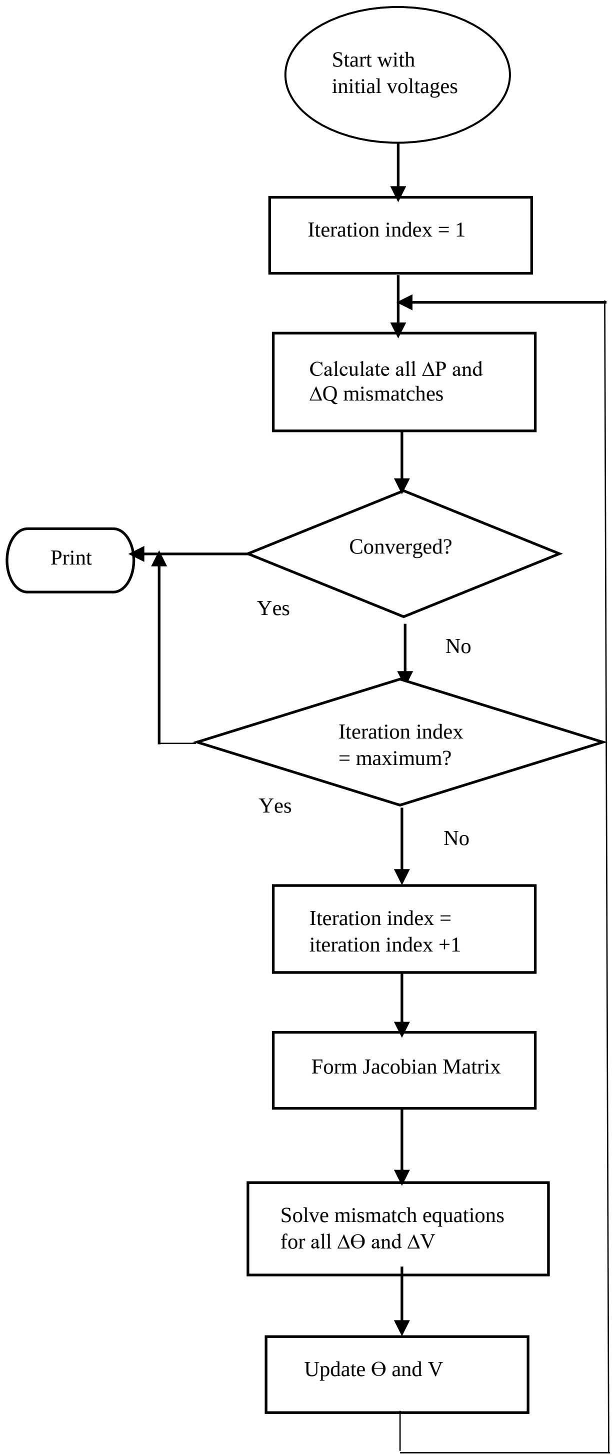

Figure 3.1: Load flow chart

Figure 3.1 shows a sketch of the load-flow chart that was used to run the load-flow program of the simulated networks using the NEPLAN software to obtain the results. The Newton-Raphson method was used for the solution of the load-flow algorithm. The figures of the different simulated networks are shown in Chapter 4 along with the results obtained for each.

3.3 Network Modelling

In analysing the impact of the integration of the DG technology on the Nigerian power system, following their installation in the 33kV distribution voltage network, the expanded 330kV grid network, which is a 60-bus network, was modelled and simulated using the NEPLAN software. Data from the National System Planning (NSP) office and the National Control Centre (NCC) were used in the modelling.

3.3.1 Transmission Network Modelling

The Nigerian power system has an installed capacity of 7,652MW as at May 2019, which is a mix of 18.30% hydro and 81.70% natural gas and steam. Its peak power generation is 5,375MW at 7th February 2019 (Osuoha K., "Daily Operational Reports" 2019).

The Transmission Company of Nigeria network is made up of 5,650kM of 330kV lines and 6,687kM of 132kV lines which connects 32 330kV and 105 132kV substations (Energypedia, "Nigeria Energy Situation" 2019), all linked to the various generating stations and distribution networks, who are guaranteed free access to the networks. These make up the national grid network. The Distribution system comprises of all networks, substations and equipment operating from 33kV and below.

In modelling the grid network in the NEPLAN software, the impedance of each transmission line was taken from real life values (see appendix III). Each phase of the transmission lines has double, bundled conductor made of steel reinforced aluminium. The cross section of every conductor is $350mm^2$ and the gap maintained between the diameters of two conductors in phase is 0.45M while the gap maintained between the phases is 8.65M (Ezeakudo C. P., Ezechukwu O. A., Ani L. U., Ocheni A., "Voltage Stability Control Through Reactive Power Regulation in the Nigerian 330kV Grid" 2015). The line impedance and shunt admittance which were used for the simulation are as shown in table 3.4. The impedance of every phase is symmetrical and transposition of conductors was assumed done along the lines.

Table 3.4: Line parameters used for simulation

Conductor Type	**R-line**	**X-line**	**Xc -line**	**G-line**
Bison	0.038175	0.3264310	0.0111	3.487

The above line parameters were used to model the lines in the NEPLAN software. Stations in load area were treated as load busses. Power transfer was simulated from the generation busses to load busses through the lines. To investigate voltage stability, the behaviour of bus voltage magnitude in the load area was observed.

The Nigerian national grid system is divided into eight operational regions following a geographical disposition of the networks and alongside the political divide of the Country. These regions are: Bauchi, Benin, Enugu, Kaduna, Lagos, Osogbo, Port-Harcourt and Shiroro.

The generating stations were modelled according to the voltage at which they generate but were all stepped up to 330kV, which is also the reality on ground. The generation dispatch scenarios used were as provided by the National Control Centre (NCC) while the loads used represent the maximum demand scenario of the various generating stations and load busses.

3.3.2 Location Criteria and Capacity of DG Installation

In defining the zones to install the DG systems, two different criteria were used:

i. Nodal factors and

ii. Premises provided by the NCC cum NSP according to the declarations of the investors.

3.3.3 Nodal Factors

Nodal factors can be defined as factors that indicate changes in network losses as a result of changes in active power demand in a defined node. They are determined by (Camilo T., Hernando D. and Angela C., “Technical and Economic Impacts of Distributed Generation on the Transmission Networks” 2011)

$$NF = 1 - \frac{\Delta P_{System}}{\Delta P_{Node}} \tag{3.1}$$

In line with these factors, regions and nodes to install DG are those with the highest nodal factors. These nodes have highest levels of losses and voltage problems as well. DG installation capacities were selected as a percentage of the total supplied demand in the corresponding region.

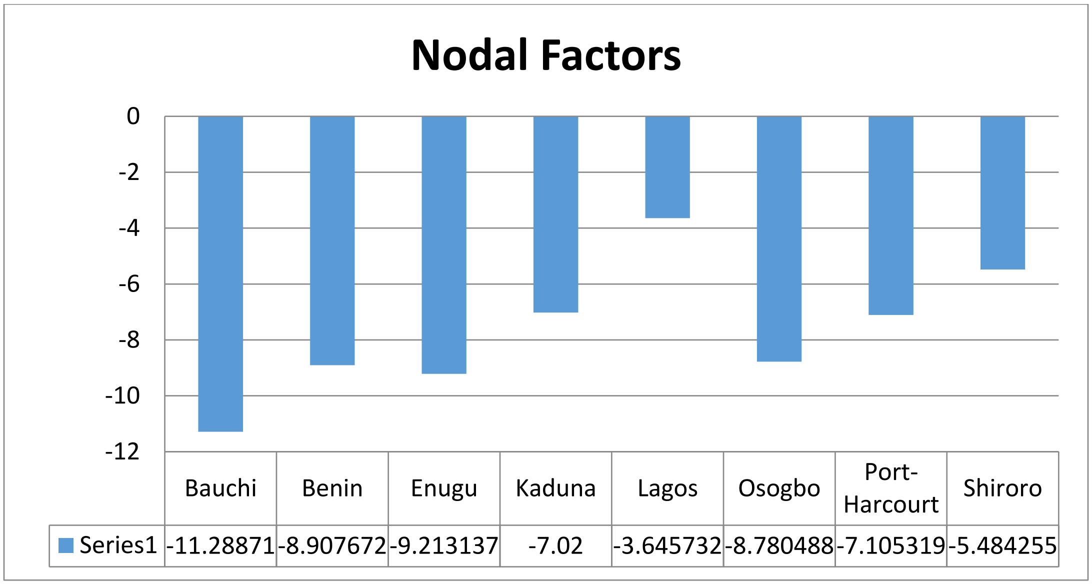

Figure 3.2: Average Nodal Factors for each region of the 330kV grid network

From the above chart, it is observed that Bauchi region has the highest nodal factors while Lagos region has the least. Bauchi region, a net importer of electricity, is characterised by very long transmission lines. The region has a very charged network and relatively low voltages requiring capacitive compensation. Enugu, Benin and Osogbo regions have very close nodal factors and have high voltage issues often. This results to quite high losses in the regions.

3.3.4 Premises Provided by NCC/NSP

The Transmission grid network expansion plan obtained from the NSP was used for the simulation and studied and zones in the country that have attractive potentials for the installation of DG of different technologies were identified. The installation of the different technologies in the regions were modelled and analysed.

3.3.5 Modelling the DG

Given its technical characteristics, DG is installed in medium voltage networks which correspond to 33kV voltage networks in Nigeria. The modelled capacities were installed as a reduction in active power in the nodes. Knowing that the entrance of new capacity will necessitate a new generation despatch, this is avoided by subtracting the DG capacity to be installed from the existing conventional generation capacity. This adjustment is known as uniform allocation.

The DGs were installed in the various regions according to the table below. Based on the renewable energy resources available in a region, a type of DG fuelled by those resources is chosen to be installed in that region.

Table 3.5: DG installations

S/N	**Region**	**Node Installed**	**Regional Power Demand (MW)**	**DG Capacity Installed (MW)**	**Percentage of Installed Capacity to Load Demand (%)**	**Criteria Used**	**Type of DG Installed**
1.	Bauchi	Jalingo	855.6	45	5.26	NF	Solar
2.	Benin	Lokoja	1061.22	26.5	2.5	NSP	Hydro
3.	Enugu	Asaba	1029.48	31	3	NSP	Gas
4.	Osogbo	Ayede	1075.02	68	6.3	NF	Biomass
5.	Kaduna	Mando	1311	40	3.05	NF	Solar
6.	Lagos	Akangba	2263.2	70	3.09	NF	Wind
7.	Port-Harcourt	Owerri	1297.2	35	2.7	NSP	Gas
8.	Shiroro	Katampe	1621.5	70	4.3	NF	Biomass

The choice of the node for the installation in the region was influenced by the node with the highest loss or poorest voltage regulation in each region. However, installation of the DG capacities in any node of each region or in a combination of several nodes in a region will still give the same results.

The simulations were done for each region and results obtained for each. The figure of the modelled network for each case is shown in Chapter 4 along with the results obtained for each of them.

CHAPTER 4

TESTS AND SIMULATIONS

The NEPLAN software was used to model the network elements and perform simulations. The load flow subroutine was used to obtain the results (BCP Busarello + Cott + Partner Inc., 2011). The DGs were installed on a region by region basis and simulated across the network to see the effect across the power system. The results obtained for each simulation are as presented.

4.1 Case 1: Nigerian 330kV Grid Network

The Nigerian 330kV grid system was simulated and the results obtained are given below. The network model used for the simulation is shown in figure 4.3. The data for the generators used are listed in appendices Ia, Ib and Ic while the transmission lines data used are listed in appendices IIIa, IIIb and IIIc. Similarly, the bus load data used for the network are listed in appendix II.

The expanded 60 bus 330kV transmission network only was simulated here without the distribution network in order to obtain the grid system parameters.

Table 4.1: Network generation, regional load demand and loss profile for case 1

	P Loss (MW)	**Q Loss (MVar)**	**P Imp (MW)**	**Q Imp (MVar)**	**P Gen (MW)**	**Q Gen (MVar)**	**P Load (MW)**	**Q Load (MVar)**
Network	114.465	-4458.89	1433.685	1212.795	10628.69	1454.491	10514.22	6120
Bauchi	9.388	-903.923	864.988	-370.923	0	0	855.6	533
Benin	23.398	-572.451	-2220.38	-69.36	3305	124.909	1061.22	628
Enugu	15.651	-235.972	509.131	438.205	536	-78.177	1029.48	596
Kaduna	7.351	-1177.48	1318.351	-445.48	0	0	1311	732
Lagos	7.458	-75.055	532.973	40.15	1737.685	1252.795	2263.2	1368
Osogbo	6.095	-146.109	777.115	499.891	304	50	1075.02	696
Port-Harcourt	13.079	-486.014	-1535.72	418.222	2846	-242.236	1297.2	662
Shiroro	32.044	-861.889	-246.456	-510.705	1900	347.2	1621.5	905

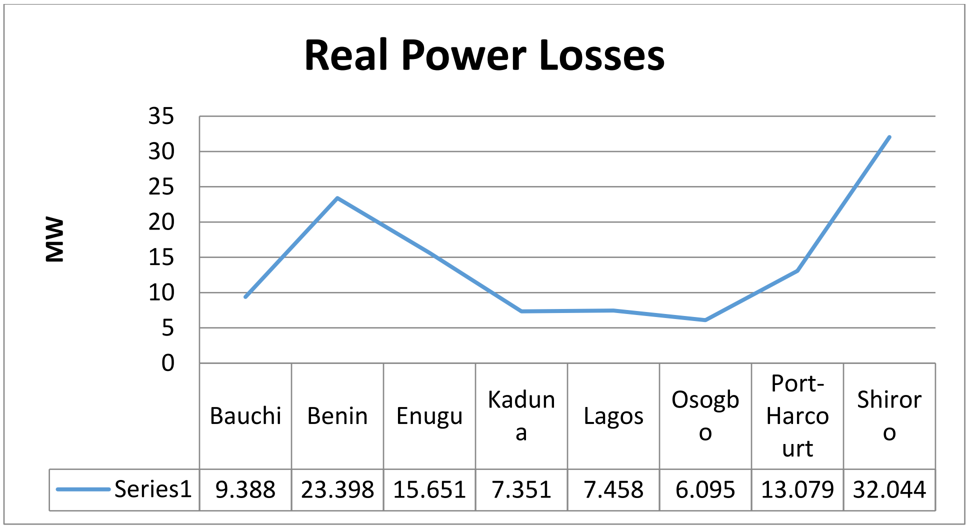

Figure 4.1: Real power losses for case 1

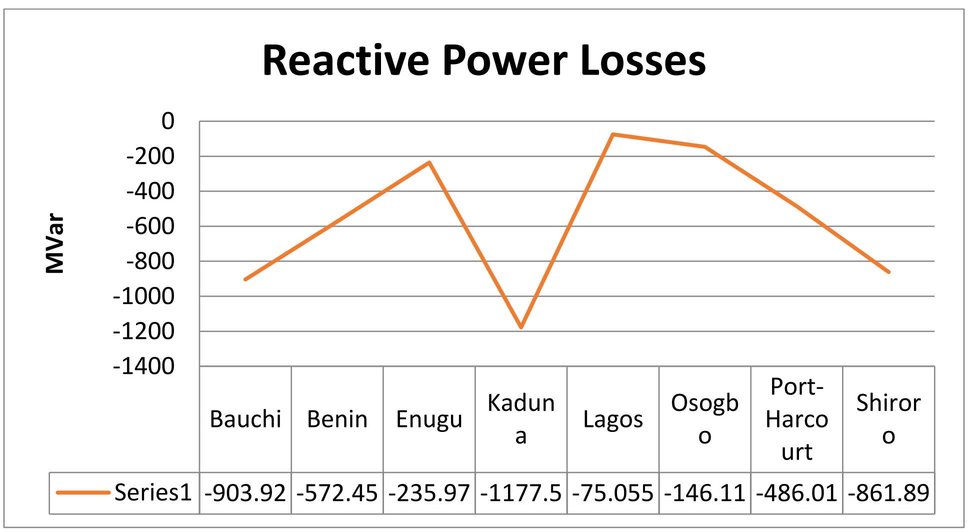

Figure 4.2: Reactive power losses for case 1

Table 4.2: Regional power flows for case 1

From Region	To Region	P Tie (MW)	Q Tie (MVar)
Bauchi	Enugu	-2026.82	997.453
Bauchi	Kaduna	1161.83	-626.531

Benin	Enugu	775.659	-117.808
Benin	Lagos	386.198	37.024
Benin	Osogbo	361.622	130.452
Benin	Port-Harcourt	224.57	-23.218
Benin	Shiroro	472.333	42.911
Enugu	Port-Harcourt	-1760.29	441.44
Kaduna	Shiroro	-156.52	-181.051
Lagos	Osogbo	-146.775	-3.126
Osogbo	Shiroro	-562.269	-372.566

Table 4.3: Node voltage profiles and loading for case 1

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
LC Jalingo	304.135	92.16	-14.1	69	40	0	0	0	Bauchi
GS Omoku	330	100	0.9	248.4	347.018	323	0	0	Port-Harcourt
LC Owerri	328.601	99.58	-0.8	220.8	105	0	0	0	Port-Harcourt
LC B_Kebbi	342.329	103.74	-7.5	151.8	90	0	0	0	Shiroro
GS kainji	352.552	106.83	6.4	0	0	760	146.8	0	Shiroro
LC Jebba	342.906	103.91	3.6	165.6	100	0	0	0	Shiroro
LC EastMain	330.931	100.28	-0.5	41.4	20	0	0	0	Shiroro
LC Onnie	329.473	99.84	1.1	165.6	80	0	0	0	Port-Harcourt
LC Ikot E.	331.094	100.33	0.5	0	0	0	0	0	Port-Harcourt
LC Okearo	326.34	98.89	-0.5	179.4	98	0	0	0	Lagos
LC Oshogbo	323.518	98.04	-0.8	345	237	0	0	0	Osogbo
GS Shiroro	336.166	101.87	-1.5	248.4	150	600	116	0	Shiroro
GS Egbema	330	100	1	0	43.269	338	0	0	Port-Harcourt

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
GS Okpai	330	100	1.3	0	78.177	536	0	0	Enugu
LC Mando	331.476	100.45	-2.3	276	150	0	0	0	Kaduna
GS Eyean	333.74	101.13	4.4	0	0	360	180	0	Benin
LC New H,	330.767	100.23	-1.9	311.88	195	0	0	0	Enugu
LC Lekki	325.605	98.67	-1.1	165.6	90	0	0	0	Lagos
LC Alagbon	325.447	98.62	-1.1	124.2	70	0	0	0	Lagos
LC Ikeja.W	323.518	98.04	-0.8	545.1	358	0	0	0	Lagos
LC Benin	329.564	99.87	3.9	409.86	240	0	0	0	Benin
LC Akangba	320.16	97.02	-1.5	538.2	326	0	0	0	Lagos
GS Olurunsogo	316.845	96.01	-0.4	0	0	304	40	0	Lagos
LC Kumbotso	331.476	100.45	-2.3	414	220	0	0	0	Kaduna
LC Asaba	328.509	99.55	-0.1	96.6	50	0	0	0	Enugu
LC Ugwuaji	331.216	100.37	-1.8	82.8	45	0	0	0	Enugu
LC Ayade	305.935	92.71	-3.5	426.42	281	0	0	0	Osogbo
LC Ganmo	328.05	99.41	0.1	96.6	50	0	0	0	Osogbo
LC Jos	331.476	100.45	-2.3	193.2	115	0	0	0	Bauchi
LC Sakete	316.277	95.84	-2.8	165.6	90	0	0	0	Lagos
LC Sokoto	341.892	103.6	-8.9	186.3	105	0	0	0	Shiroro
GS Egbin	330	100	0	0	0	1433.685	1212.795	0	Lagos
LC Gusau	339.553	102.89	-7.9	55.2	32	0	0	0	Kaduna
LC Gombe	331.476	100.45	-2.3	165.6	105	0	0	0	Bauchi
LC Katampe	330	100	-10.7	483	250	0	0	-206.616	Shiroro
LC Aja	326.05	98.8	-1	545.1	336	0	0	0	Lagos
LC Gwagwalada	331.114	100.34	-0.4	345	190	0	0	0	Shiroro
LC Yola	308.191	93.39	-12	151.8	95	0	0	0	Bauchi
LC Makurdi	331.476	100.45	-2.3	124.2	70	0	0	0	Enugu
GS Calabar	330	100	1.4	165.6	158.76	625	0	0	Port-Harcourt
LC Katsina	339.34	102.83	-6.1	124.2	70	0	0	0	Kaduna

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
LC Damaturu	329.626	99.89	-5.3	124.2	75	0	0	0	Bauchi
GS Jebba	343.473	104.08	4	0	0	540	84.4	0	Shiroro
LC Lokoja	330.247	100.07	3.2	220.8	120	0	0	0	Benin
LC Maiduguri	308.579	93.51	-11.7	138	95	0	0	0	Bauchi
LC Zaria	332.129	100.65	-4.8	124.2	70	0	0	0	Kaduna
LC Funtua	334.596	101.39	-6.8	165.6	100	0	0	0	Kaduna
LC Onitsha	330.172	100.05	-1.5	331.2	190	0	0	0	Enugu
GS Delta	333.601	101.09	7.8	0	0	950	100	0	Benin
LC Alaide	331.845	100.56	-2.4	82.8	46	0	0	0	Enugu
GS Omotosho	325.609	98.67	2.7	207	128	304	50	0	Osogbo
LC Mambila	332.254	100.68	-3.6	13.8	8	0	0	0	Bauchi
GS Geregu	330	100	4.8	0	136.464	885	0	0	Benin
LC Ajaokuta	330.025	100.01	4.7	124.2	75	0	0	0	Benin
LC Zamfara	336.43	101.95	-8.9	151.8	90	0	0	0	Kaduna
GS Obajana	329.985	100	4.6	165.6	98	150	90	0	Benin
LC Aladja	330.406	100.12	7	140.76	95	0	0	0	Benin
GS Sapele	330	100	6.7	0	108.628	960	0	0	Benin
GS Afam	330.279	100.08	0.9	0	0	975	200	0	Port-Harcourt
GS Alaoji	330	100	-1.4	496.8	370.189	585	0	0	Port-Harcourt

From tables 4.1, 4.2, 4.3 above, it is observed that the grid system has a real power loss of 114.465MW which is 1.09% of the total power generated in the grid. Benin region has the highest percentage loss of 2.204% of its total power demand of 1061.22MW while Lagos region has the lowest percentage loss 0.33% of its total power demand of 2263.2MW. Also, Bauchi and Kaduna regions generate no power and are totally dependent on power imported from other zones. Enugu, Lagos and Osogbo regions, though they generate power, are also net importers of electricity while Benin, Port-Harcourt and Shiroro regions are net exporters of electricity.

Furthermore, the voltage profile of so many nodes in the grid are not at the nominal voltage level with the worst cases with low voltage profiles being Jalingo and Yola nodes in Bauchi region while the worst cases with high voltage profiles are Kainji, Jebba and Sokoto, all in Shiroro region. This improvement in voltage is because of the addition of reactive power compensation devices in the network. It helped to improve node voltages to operational levels and also aided the clearing of congested nodes.

4.2 Case 2: Nigerian Power System Network without DG Installed

The Nigerian power system, which is the transmission and distribution networks, were simulated without the installation of the DG. This is to obtain the parameters of the network before the installation of the DG.

The network model used for the simulation is shown in figure 4.6. The data for the generators used are listed in appendices Ia, Ib and Ic while the transmission lines data used are listed in appendices IIIa, IIIb and IIIc. Similarly, the bus load data used for the network are listed in appendix II.

The results obtained are as below.

Table 4.4: Network generation, regional load demand and loss profile for case 2

	P Loss (MW)	**Q Loss (MVar)**	**P Imp (MW)**	**Q Imp (MVar)**	**P Gen (MW)**	**Q Gen (MVar)**	**P Load (MW)**	**Q Load (MVar)**
Network	131.597	-3970.07	1450.817	1446.231	10645.82	1883.858	10514.22	6120
Bauchi	11.307	-880.948	866.907	-347.948	0	0	855.6	533
Benin	25.59	-521.602	-2218.19	-98.305	3305	204.703	1061.22	628
Enugu	17.849	-213.738	511.329	458.992	536	-76.73	1029.48	596
Kaduna	7.954	-1144.76	1318.954	-412.763	0	0	1311	732
Lagos	10.525	27.826	518.908	-90.405	1754.817	1486.231	2263.2	1368
Osogbo	11.663	23.521	782.683	669.521	304	50	1075.02	696
Port-Harcourt	13.698	-461.976	-1535.1	327.571	2846	-127.547	1297.2	662
Shiroro	33.012	-798.393	-245.488	-506.662	1900	347.2	1621.5	905

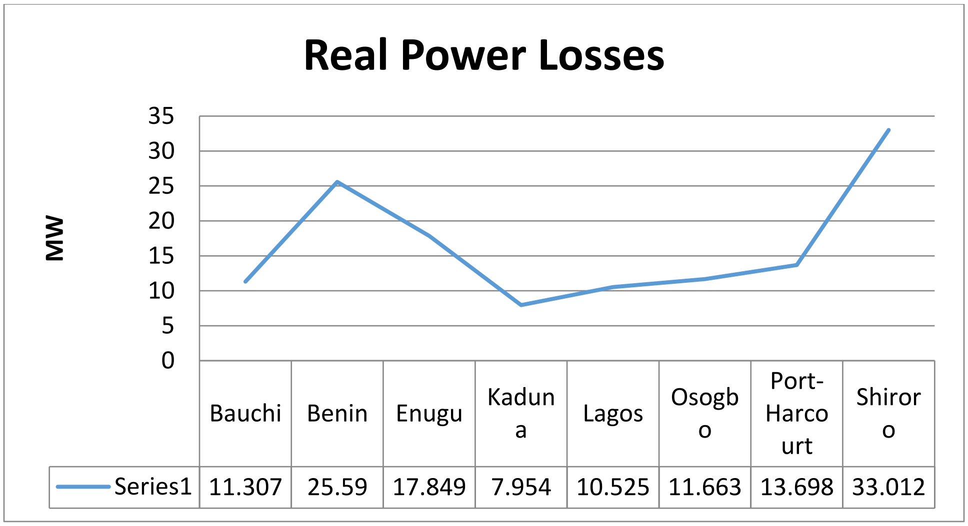

Figure 4.4: Real Power losses for case 2

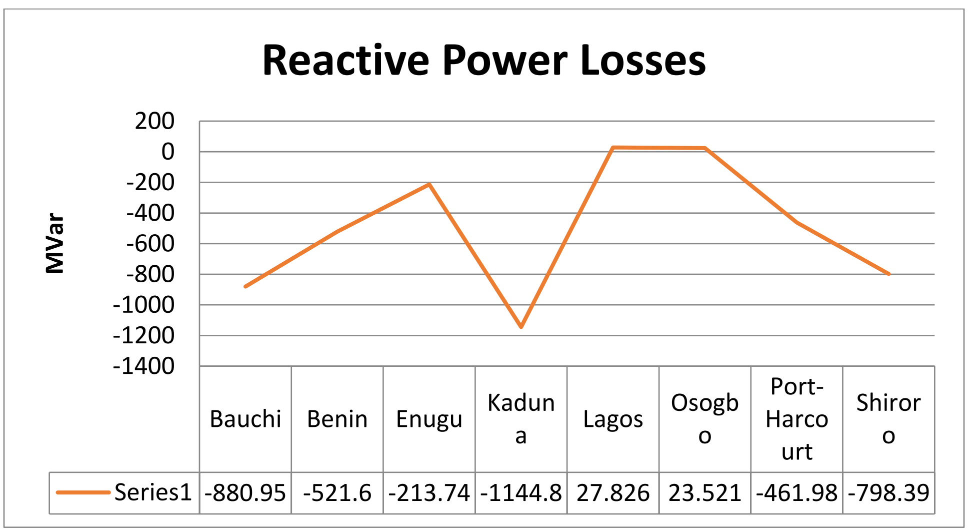

Figure 4.5: Reactive power losses for case 2

Table 4.5: Regional power flow for case 2

From Region	To Region	P Tie (MW)	Q Tie (MVar)
Bauchi	Enugu	-2028.9	930.003
Bauchi	Kaduna	1161.989	-582.055

From Region	**To Region**	**P Tie (MW)**	**Q Tie (MVar)**
Benin	Enugu	779.659	-118.979
Benin	Lagos	383.002	50.307
Benin	Osogbo	358.402	150.296
Benin	Port-Harcourt	225.464	-24.461
Benin	Shiroro	471.663	41.143
Enugu	Port-Harcourt	-1760.57	352.032
Kaduna	Shiroro	-156.965	-169.292
Lagos	Osogbo	-135.906	140.712
Osogbo	Shiroro	-560.186	-378.513
Overloads Nodes (lower)	**(%)**		
LC Ayade	88.73		

Table 4.6: Node voltage profiles and loading for case 2

Node Name	**U (kV)**	**u (%)**	**Angle U (°)**	**P Load (MW)**	**Q Load (MVar)**	**P Gen (MW)**	**Q Gen (MVar)**	**Q Shunt (MVar)**	**Region**
Jalingo 132kV	113.43	85.93	-17.1	0	0	0	0	0	Bauchi
LC Jalingo	295.877	89.66	-14.4	0	0	0	0	0	Bauchi
GS Omoku	330	100	0.9	248.4	345.154	323	0	0	Port-Harcourt
LC Owerri	328.227	99.46	-0.9	0	0	0	0	0	Port-Harcourt
LC B_Kebbi	341.385	103.45	-7.6	151.8	90	0	0	0	Shiroro
GS kainji	351.159	106.41	6.5	0	0	760	146.8	0	Shiroro
LC Jebba	341.454	103.47	3.7	165.6	100	0	0	0	Shiroro
Jalingo 33kV	26.646	80.75	-21.7	69	40	0	0	0	Bauchi
Lokoja 33kV	29.619	89.75	-5.4	220.8	120	0	0	0	Benin

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
LC EastMain	330.386	100.12	-0.6	41.4	20	0	0	0	Shiroro
LC Onnie	329.443	99.83	1.1	165.6	80	0	0	0	Port-Harcourt
LC Ikot E.	331.079	100.33	0.5	0	0	0	0	0	Port-Harcourt
LC Okearo	325.385	98.6	-0.5	179.4	98	0	0	0	Lagos
LC Oshogbo	321.611	97.46	-0.8	345	237	0	0	0	Osogbo
GS Shiroro	335.785	101.75	-1.6	248.4	150	600	116	0	Shiroro
GS Egbema	330	100	1	0	32.046	338	0	0	Port-Harcourt
GS Okpai	330	100	1.2	0	76.73	536	0	0	Enugu
Katampe 132kV	128.6	97.42	-13.1	0	0	0	0	0	Shiroro
LC Mando	331.302	100.39	-2.4	0	0	0	0	0	Kaduna
GS Eyean	333.11	100.94	4.4	0	0	360	180	0	Benin
LC New H,	330.659	100.2	-2	311.88	195	0	0	0	Enugu
Katampe 33kV	31.367	95.05	-15.7	483	250	0	0	0	Shiroro
Asaba	125.172	94.83	-3.3	0	0	0	0	0	Enugu
LC Lekki	325.605	98.67	-1.1	165.6	90	0	0	0	Lagos
LC Alagbon	325.447	98.62	-1.1	124.2	70	0	0	0	Lagos
LC Ikeja.W	321.611	97.46	-0.8	545.1	358	0	0	0	Lagos
LC Benin	329.149	99.74	3.9	409.86	240	0	0	0	Benin
LC Akangba	317.484	96.21	-1.5	0	0	0	0	0	Lagos
GS Olurunsogo	308.676	93.54	-0.3	0	0	304	40	0	Lagos
LC Kumbotso	331.302	100.39	-2.4	414	220	0	0	0	Kaduna
LC Asaba	327.657	99.29	-0.2	0	0	0	0	0	Enugu
LC Ugwuaji	331.113	100.34	-1.9	82.8	45	0	0	0	Enugu
LC Ayade	292.821	88.73	-3.5	0	0	0	0	0	Osogbo
Asaba 33kV	29.282	88.73	-8.6	96.6	50	0	0	0	Enugu
LC Ganmo	326.262	98.87	0.1	96.6	50	0	0	0	Osogbo

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
LC Jos	331.302	100.39	-2.4	193.2	115	0	0	0	Bauchi
LC Sakete	314.311	95.25	-2.8	165.6	90	0	0	0	Lagos
LC Sokoto	341.108	103.37	-9	186.3	105	0	0	0	Shiroro
GS Egbin	330	100	0	0	0	1450.817	1446.231	0	Lagos
LC Gusau	339.112	102.76	-8	55.2	32	0	0	0	Kaduna
LC Gombe	331.302	100.39	-2.4	165.6	105	0	0	0	Bauchi
LC Katampe	330	100	-10.7	0	0	0	0	-266.069	Shiroro
LC Aja	326.05	98.8	-1	545.1	336	0	0	0	Lagos
Owerri	128.839	97.61	-2.7	0	0	0	0	0	Port-Harcourt
LC Gwagwalada	330.571	100.17	-0.4	345	190	0	0	0	Shiroro
LC Yola	302.743	91.74	-12.2	151.8	95	0	0	0	Bauchi
LC Makurdi	331.302	100.39	-2.4	124.2	70	0	0	0	Enugu
GS Calabar	330	100	1.4	165.6	157.366	625	0	0	Port-Harcourt
Ayede 132kV	108.295	82.04	-8.2	0	0	0	0	0	Osogbo
LC Katsina	339.032	102.74	-6.2	124.2	70	0	0	0	Kaduna
LC Damaturu	329.432	99.83	-5.4	124.2	75	0	0	0	Bauchi
GS Jebba	342.024	103.64	4	0	0	540	84.4	0	Shiroro
Ayede 33kV	24.722	74.92	-14.9	426.42	281	0	0	0	Osogbo
LC Lokoja	329.643	99.89	3.2	0	0	0	0	0	Benin
LC Maiduguri	308.349	93.44	-11.8	138	95	0	0	0	Bauchi
Owerri 33kV	31.355	95.01	-5.6	220.8	105	0	0	0	Port-Harcourt
LC Zaria	331.869	100.57	-4.8	124.2	70	0	0	0	Kaduna
LC Funtua	334.242	101.29	-6.9	165.6	100	0	0	0	Kaduna
LC Onitsha	330.129	100.04	-1.6	331.2	190	0	0	0	Enugu
GS Delta	333.346	101.01	7.8	0	0	950	100	0	Benin
LC Alaide	331.683	100.51	-2.5	82.8	46	0	0	0	Enugu
Mando	129.129	97.82	-4.6	0	0	0	0	0	Kaduna

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
132kV									
Lokoja 132kV	125.379	94.98	-0.5	0	0	0	0	0	Benin
GS Omotosho	324.608	98.37	2.7	207	128	304	50	0	Osogbo
LC Mambila	332.071	100.63	-3.7	13.8	8	0	0	0	Bauchi
Mando 33kV	31.497	95.45	-7	276	150	0	0	0	Kaduna
Akangba	122.271	92.63	-4.4	0	0	0	0	0	Lagos
GS Geregu	330	100	4.7	0	84.416	885	0	0	Benin
LC Ajaokuta	329.986	100	4.6	124.2	75	0	0	0	Benin
LC Zamfara	335.981	101.81	-9	151.8	90	0	0	0	Kaduna
GS Obajana	329.946	99.98	4.5	165.6	98	150	90	0	Benin
LC Aladja	330.236	100.07	6.9	140.76	95	0	0	0	Benin
GS Sapele	330	100	6.7	0	80.881	960	0	0	Benin
Akangba 33kV	29.481	89.34	-7.6	538.2	326	0	0	0	Lagos
GS Afam	330.277	100.08	0.8	0	0	975	200	0	Port-Harcourt
GS Alaoji	330	100	-1.4	496.8	269.981	585	0	0	Port-Harcourt

From tables 4.4, 4.5 and 4.6 above, it is observed that the power system network has a real power loss of 131.597MW which is 1.25% of the total power generated in the grid. Benin region has the highest percentage loss of 2.41% of its total power demand of 1061.22MW while Lagos region has the lowest percentage loss 0.465% of its total power demand of 2263.2MW. Also, Bauchi and Kaduna regions generate no power and are totally dependent on power imported from other zones. Enugu, Lagos and Osogbo regions, though they generate power, are also net importers of electricity while Benin, Port-Harcourt and Shiroro regions are net exporters of electricity.

Furthermore, the voltage profile of so many nodes in the grid violates the acceptable voltage limits of $\pm 10\%$ with the worst low voltage profile cases being Aiyede in Osogbo region and

Jalingo in Bauchi region while Kainji in Shiroro region has the highest voltage profile. The voltage profiles were influenced by the reactive power compensation that was used.

Also, Aiyede node is overloaded or congested due to power flows within the regions.

4.3 Case 3: Nigerian Power System Network with DG Installed in Bauchi Region

The power system network profile with DG installed in Bauchi region: The grid system was simulated with a DG installed in Bauchi region and the results are as shown below.

Bauchi region covers most of the North-Eastern part of the country. It is presently a war zone, due to the fight against terrorism. Its vegetation is mostly Sudan Savannah and Sahel Savannah at the upper reaches of the region, towards the banks of the Lake Chad. It has vast stretches of sandy, arid soil and enjoys lots of hot, tropical sunshine most times of the year, making it a very hot zone. The occupation of the people in the region is primarily crop farming and animal husbandry.

The region is an importer of electricity as it does not have any generation station. The transmission lines in the region are very lengthy due to the dispersed settlement being practiced in the region. The region suffers from low voltages and requires high capacitive compensation.

The region also has an international node, albeit on the 132kV transmission circuit, two lines going to Chad Republic and Niamey in Niger.

Since the region has lots of sunshine all year round, a solar powered DG was installed in the region at Jalingo which is the node with the worst voltage profile. In order to maintain uniform allocation of the generator units in the grid, the equivalent of the generated power from the DG was removed from Shiroro GS.

The states that make up the region are Adamawa, Bauchi, Borno, Gombe, Jigawa, Plateau, Taraba and Yobe States.

The network model used for the simulation is shown in figure 4.9. The data for the generators used are listed in appendices Ia, Ib and Ic while the transmission lines data used are listed in appendices IIIa, IIIb and IIIc. Similarly, the bus load data used for the network are listed in appendix II.

Table 4.7: Network generation, regional load demand and loss profile for case 3

	P Loss (MW)	**Q Loss (MVar)**	**P Imp (MW)**	**Q Imp (MVar)**	**P Gen (MW)**	**Q Gen (MVar)**	**P Load (MW)**	**Q Load (MVar)**
Network	127.21	-4025.86	1446.43	1446.09	10641.43	1828.564	10514.22	6120

	P Loss (MW)	Q Loss (MVar)	P Imp (MW)	Q Imp (MVar)	P Gen (MW)	Q Gen (MVar)	P Load (MW)	Q Load (MVar)
Bauchi	6.997	-933.556	817.597	-428.556	45	28	855.6	533
Benin	25.751	-520.257	-2218.03	-96.121	3305	203.864	1061.22	628
Enugu	17.756	-214.736	511.236	459.293	536	-78.029	1029.48	596
Kaduna	7.979	-1146.18	1318.979	-414.179	0	0	1311	732
Lagos	10.512	27.704	523.282	-90.387	1750.43	1486.09	2263.2	1368
Osogbo	11.682	23.675	782.702	669.675	304	50	1075.02	696
Port-Harcourt	13.663	-462.377	-1535.14	408.184	2846	-208.561	1297.2	662
Shiroro	32.871	-800.137	-200.629	-507.91	1855	347.2	1621.5	905

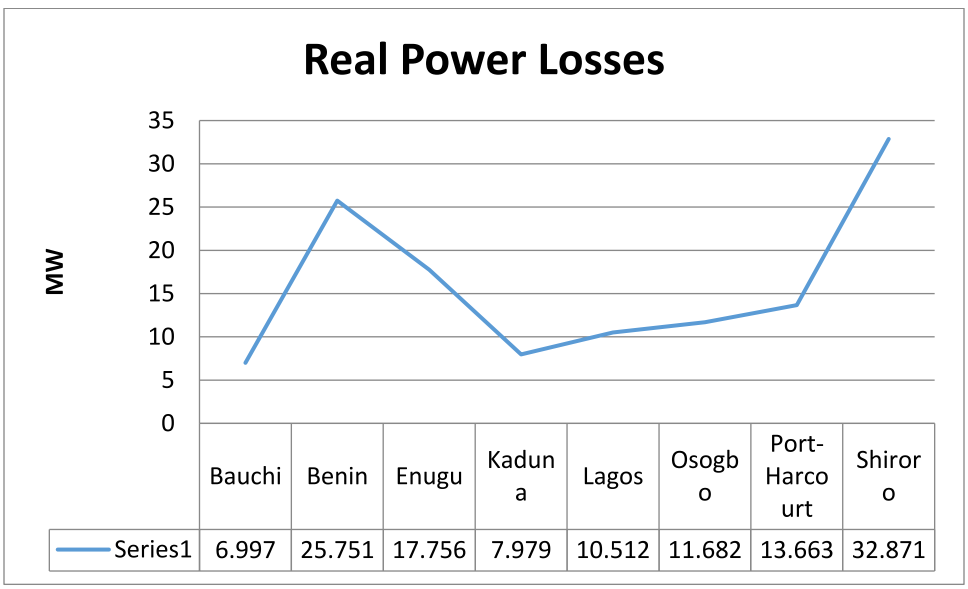

Figure 4.7: Real power losses for case 3

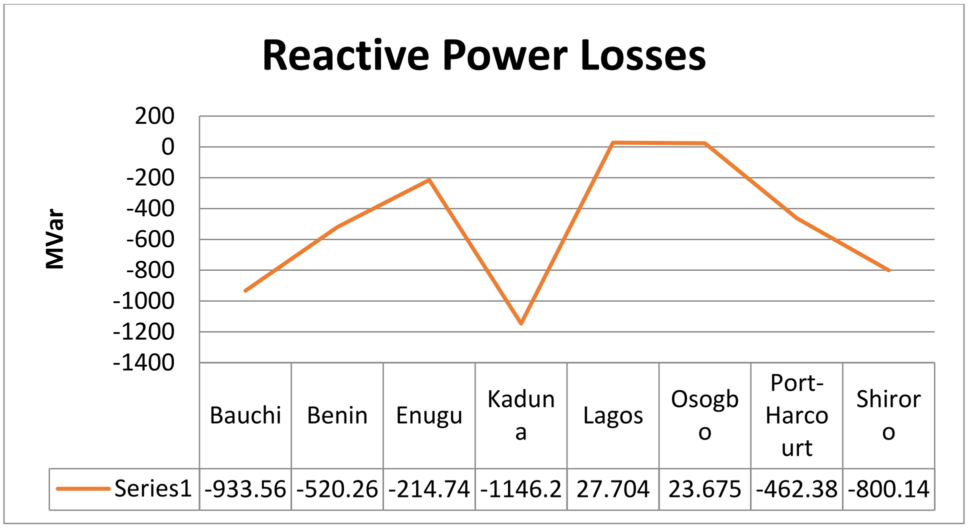

Figure 4.8: Reactive power losses for case 3

Table 4.8: Regional power flow for case 3

From Region	To Region	P Tie (MW)	Q Tie (MVar)
Bauchi	Enugu	-2020.16	1011.442
Bauchi	Kaduna	1202.558	-582.886
Benin	Enugu	772.161	-119.527
Benin	Lagos	386.247	49.779
Benin	Osogbo	361.184	149.957
Benin	Port-Harcourt	224.093	-24.437
Benin	Shiroro	474.345	40.349
Enugu	Port-Harcourt	-1759.23	432.621
Kaduna	Shiroro	-116.421	-168.707
Lagos	Osogbo	-137.035	140.166
Osogbo	Shiroro	-558.553	-379.552
Overloads Nodes (lower)	**(%)**		
LC Ayade	88.74		

Table 4.9: Node voltage profiles and loading for case 3

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
Jalingo 132kV	128.353	97.24	-11.3	0	0	0	0	0	Bauchi
LC Jalingo	323.797	98.12	-10.5	0	0	0	0	0	Bauchi
GS Omoku	330	100	1	248.4	345.936	323	0	0	Port-Harcourt
LC Owerri	328.227	99.46	-0.8	0	0	0	0	0	Port-Harcourt
LC B_Kebbi	341.629	103.52	-7.5	151.8	90	0	0	0	Shiroro
GS kainji	351.234	106.43	6.5	0	0	760	146.8	0	Shiroro
LC Jebba	341.497	103.48	3.7	165.6	100	0	0	0	Shiroro
Jalingo 33kV	31.662	95.95	-12.5	69	40	45	28	0	Bauchi
Lokoja 33kV	29.619	89.76	-5.4	220.8	120	0	0	0	Benin
LC EastMain	330.401	100.12	-0.6	41.4	20	0	0	0	Shiroro
LC Onnie	329.447	99.83	1.1	165.6	80	0	0	0	Port-Harcourt
LC Ikot E.	331.095	100.33	0.6	0	0	0	0	0	Port-Harcourt
LC Okearo	325.388	98.6	-0.5	179.4	98	0	0	0	Lagos
LC Oshogbo	321.616	97.46	-0.8	345	237	0	0	0	Osogbo
GS Shiroro	335.837	101.77	-1.7	248.4	150	555	116	0	Shiroro
GS Egbema	330	100	1.1	0	32.052	338	0	0	Port-Harcourt
GS Okpai	330	100	1.3	0	78.029	536	0	0	Enugu
Katampe 132kV	128.6	97.42	-13.2	0	0	0	0	0	Shiroro
LC Mando	331.5	100.45	-2.3	0	0	0	0	0	Kaduna
GS Eyean	333.117	100.94	4.5	0	0	360	180	0	Benin
LC New H,	330.777	100.24	-1.9	311.88	195	0	0	0	Enugu
Katampe 33kV	31.367	95.05	-15.7	483	250	0	0	0	Shiroro

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
Asaba	125.187	94.84	-3.2	0	0	0	0	0	Enugu
LC Lekki	325.605	98.67	-1.1	165.6	90	0	0	0	Lagos
LC Alagbon	325.447	98.62	-1.1	124.2	70	0	0	0	Lagos
LC Ikeja.W	321.616	97.46	-0.8	545.1	358	0	0	0	Lagos
LC Benin	329.159	99.75	3.9	409.86	240	0	0	0	Benin
LC Akangba	317.49	96.21	-1.5	0	0	0	0	0	Lagos
GS Olurunsogo	308.682	93.54	-0.3	0	0	304	40	0	Lagos
LC Kumbotso	331.5	100.45	-2.3	414	220	0	0	0	Kaduna
LC Asaba	327.693	99.3	-0.1	0	0	0	0	0	Enugu
LC Ugwuaji	331.226	100.37	-1.8	82.8	45	0	0	0	Enugu
LC Ayade	292.828	88.74	-3.5	0	0	0	0	0	Osogbo
Asaba 33kV	29.286	88.75	-8.5	96.6	50	0	0	0	Enugu
LC Ganmo	326.28	98.87	0.1	96.6	50	0	0	0	Osogbo
LC Jos	331.5	100.45	-2.3	193.2	115	0	0	0	Bauchi
LC Sakete	314.317	95.25	-2.8	165.6	90	0	0	0	Lagos
LC Sokoto	341.357	103.44	-8.9	186.3	105	0	0	0	Shiroro
GS Egbin	330	100	0	0	0	1446.43	1446.09	0	Lagos
LC Gusau	339.346	102.83	-7.9	55.2	32	0	0	0	Kaduna
LC Gombe	331.5	100.45	-2.3	165.6	105	0	0	0	Bauchi
LC Katampe	330	100	-10.8	0	0	0	0	-265.573	Shiroro
LC Aja	326.05	98.8	-1	545.1	336	0	0	0	Lagos
Owerri	128.839	97.61	-2.6	0	0	0	0	0	Port-Harcourt
LC Gwagwalada	330.585	100.18	-0.5	345	190	0	0	0	Shiroro
LC Yola	321.713	97.49	-9.8	151.8	95	0	0	0	Bauchi
LC Makurdi	331.5	100.45	-2.3	124.2	70	0	0	0	Enugu
GS Calabar	330	100	1.5	165.6	158.889	625	0	0	Port-Harcourt
Ayede 132kV	108.298	82.04	-8.2	0	0	0	0	0	Osogbo
LC Katsina	339.255	102.8	-6.1	124.2	70	0	0	0	Kaduna

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
LC Damaturu	329.653	99.89	-5.3	124.2	75	0	0	0	Bauchi
GS Jebba	342.067	103.66	4	0	0	540	84.4	0	Shiroro
Ayede 33kV	24.723	74.92	-14.9	426.42	281	0	0	0	Osogbo
LC Lokoja	329.644	99.89	3.2	0	0	0	0	0	Benin
LC Maiduguri	308.611	93.52	-11.7	138	95	0	0	0	Bauchi
Owerri 33kV	31.355	95.01	-5.5	220.8	105	0	0	0	Port-Harcourt
LC Zaria	332.08	100.63	-4.8	124.2	70	0	0	0	Kaduna
LC Funtua	334.466	101.35	-6.8	165.6	100	0	0	0	Kaduna
LC Onitsha	330.168	100.05	-1.5	331.2	190	0	0	0	Enugu
GS Delta	333.355	101.02	7.8	0	0	950	100	0	Benin
LC Alaide	331.867	100.57	-2.4	82.8	46	0	0	0	Enugu
Mando 132kV	129.211	97.89	-4.5	0	0	0	0	0	Kaduna
Lokoja 132kV	125.379	94.98	-0.5	0	0	0	0	0	Benin
GS Omotosho	324.613	98.37	2.7	207	128	304	50	0	Osogbo
LC Mambila	332.28	100.69	-3.6	13.8	8	0	0	0	Bauchi
Mando 33kV	31.519	95.51	-6.9	276	150	0	0	0	Kaduna
Akangba	122.273	92.63	-4.4	0	0	0	0	0	Lagos
GS Geregu	330	100	4.7	0	84.557	885	0	0	Benin
LC Ajaokuta	329.986	100	4.6	124.2	75	0	0	0	Benin
LC Zamfara	336.22	101.88	-8.9	151.8	90	0	0	0	Kaduna
GS Obajana	329.946	99.98	4.5	165.6	98	150	90	0	Benin
LC Aladja	330.242	100.07	7	140.76	95	0	0	0	Benin
GS Sapele	330	100	6.8	0	81.579	960	0	0	Benin
Akangba 33kV	29.482	89.34	-7.6	538.2	326	0	0	0	Lagos
GS Afam	330.278	100.08	0.9	0	0	975	200	0	Port-Harcourt

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
GS Alaoji	330	100	-1.3	496.8	348.685	585	0	0	Port-Harcourt

Tables 4.7, 4.8 and 4.9 show the results of the installation of a DG of 45MW capacity in Bauchi region which represents 5.26% of the 855.6MW load demand of the region. A comparison of tables 4.4 and 4.7 shows that the active power losses of the region dropped by 38.12% to 6.997MW while the losses in the grid reduced similarly by 3.32% to 127.21MW. It is to be noted that the losses in the region, vis-à-vis the grid system, reduced more with an increase in the output of the DG.

Voltages at all the nodes in the region improved to within limits, with the improvement being as much as 2.46% in some nodes in the transmission (330kV) network and 15.2% in some nodes in the distribution (33kV) network.

Also, although the line flows within the regions were reduced yet the congestion at Aiyede node was not cleared.

4.4 Case 4: Nigerian Power System Network with DG Installed in Benin Region

The power system network profile with DG installed in Benin region: The grid system was simulated with a DG installed in Benin region and the results are as shown below.

Benin region covers most of the Southern heartland of the country and part of the oil-rich Niger delta. Its vegetation is mainly wet lowlands rain forest and Southern Guinea Savannah; thus, it has lots of dense forests, riverine bodies and abundant rainfall all year long. The occupations of the people are mainly commerce and agriculture.

The region is a net exporter of electricity as it is host to many conventional power plants, due to the abundant gas reserves in the oil rich Niger delta within its coverage. It is the region that has the highest value of electric power generation. Its transmission networks are quite short, coming from the power stations. Its node voltages profiles are often above the higher limit, requiring inductive reactive compensation to keep it within limits.

Being a region with plenty of rivers, a hydro-run DG was installed at one of its nodes at Lokoja, being the node with the greatest losses in the region. In order to maintain uniform allocation of the generator units in the grid, the equivalent of the generated power from the DG was removed from Geregu GS.

Benin region is made up of Edo, Ekiti, Kogi, Ondo and parts of Delta and Kwara States.

The network model used for the simulation is shown in figure 4.12. The data for the generators used are listed in appendices Ia, Ib and Ic while the transmission lines data used are listed in appendices IIIa, IIIb and IIIc. Similarly, the bus load data used for the network are listed in appendix II.

Table 4.10: Network generation, regional load demand and loss profile for case 4

	P Loss (MW)	**Q Loss (MVar)**	**P Imp (MW)**	**Q Imp (MVar)**	**P Gen (MW)**	**Q Gen (MVar)**	**P Load (MW)**	**Q Load (MVar)**
Network	130.761	-3988.07	1449.981	1445.819	10644.98	1866.639	10514.22	6120
Bauchi	11.306	-881.009	866.906	-348.009	0	0	855.6	533
Benin	24.79	-538.679	-2218.99	-102.112	3305	191.434	1061.22	628

	P Loss (MW)	Q Loss (MVar)	P Imp (MW)	Q Imp (MVar)	P Gen (MW)	Q Gen (MVar)	P Load (MW)	Q Load (MVar)
Enugu	17.824	-213.963	511.304	458.822	536	-76.785	1029.48	596
Kaduna	7.956	-1144.83	1318.956	-412.833	0	0	1311	732
Lagos	10.52	27.778	519.74	-90.041	1753.981	1485.819	2263.2	1368
Osogbo	11.664	23.522	782.684	669.522	304	50	1075.02	696
Port-Harcourt	13.69	-462.041	-1535.11	330.987	2846	-131.028	1297.2	662
Shiroro	33.01	-798.849	-245.49	-506.336	1900	347.2	1621.5	905

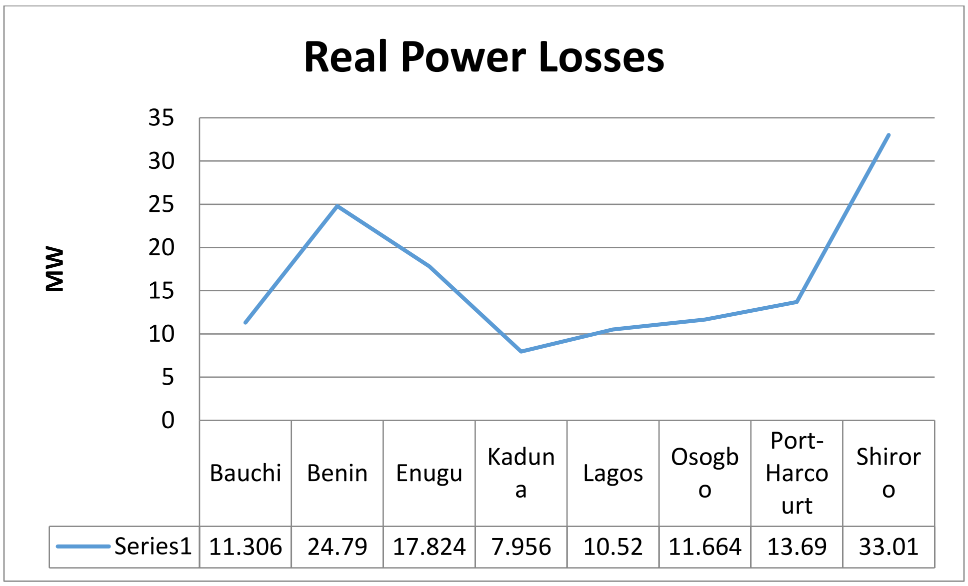

Figure 4.10: Real power losses for case 4

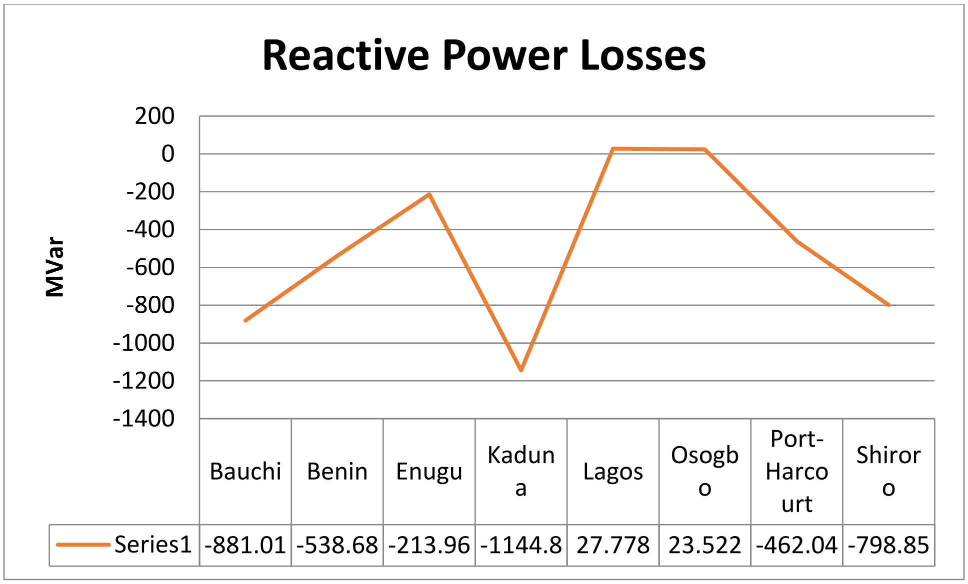

Figure 4.11: Reactive power losses for case 4

Table 4.11: Regional power flow for case 4

From Region	To Region	P Tie (MW)	Q Tie (MVar)
Bauchi	Enugu	-2027.62	933.155
Bauchi	Kaduna	1160.715	-585.146
Benin	Enugu	778.553	-118.897
Benin	Lagos	383.185	50.298
Benin	Osogbo	358.539	150.283
Benin	Port-Harcourt	225.262	-24.449
Benin	Shiroro	473.452	44.878
Enugu	Port-Harcourt	-1760.37	355.436
Kaduna	Shiroro	-158.242	-172.313
Lagos	Osogbo	-136.555	140.339
Osogbo	Shiroro	-560.7	-378.9
Overloads Nodes (lower) (%)			

From Region	To Region	P Tie (MW)	Q Tie (MVar)
LC Ayade	88.74		

Table 4.12: Node voltage profiles and loading for case 4

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
Jalingo 132kV	113.435	85.94	-17.1	0	0	0	0	0	Bauchi
LC Jalingo	295.889	89.66	-14.4	0	0	0	0	0	Bauchi
GS Omoku	330	100	0.9	248.4	345.219	323	0	0	Port-Harcourt
LC Owerri	328.227	99.46	-0.9	0	0	0	0	0	Port-Harcourt
LC B_Kebbi	341.41	103.46	-7.5	151.8	90	0	0	0	Shiroro
GS kainji	351.188	106.42	6.5	0	0	760	146.8	0	Shiroro
LC Jebba	341.483	103.48	3.7	165.6	100	0	0	0	Shiroro
Jalingo 33kV	26.648	80.75	-21.7	69	40	0	0	0	Bauchi
Lokoja 33kV	30.508	92.45	-4.1	220.8	120	26.5	28	0	Benin
LC EastMain	330.773	100.23	-0.5	41.4	20	0	0	0	Shiroro
LC Onnie	329.444	99.83	1.1	165.6	80	0	0	0	Port-Harcourt
LC Ikot E.	331.079	100.33	0.5	0	0	0	0	0	Port-Harcourt
LC Okearo	325.387	98.6	-0.5	179.4	98	0	0	0	Lagos
LC Oshogbo	321.614	97.46	-0.8	345	237	0	0	0	Osogbo
GS Shiroro	335.868	101.78	-1.6	248.4	150	600	116	0	Shiroro
GS Egbema	330	100	1	0	32.047	338	0	0	Port-Harcourt
GS Okpai	330	100	1.3	0	76.785	536	0	0	Enugu
Katampe 132kV	128.6	97.42	-13.1	0	0	0	0	0	Shiroro

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
LC Mando	331.31	100.4	-2.4	0	0	0	0	0	Kaduna
GS Eyean	333.114	100.94	4.4	0	0	360	180	0	Benin
LC New H,	330.664	100.2	-2	311.88	195	0	0	0	Enugu
Katampe 33kV	31.367	95.05	-15.6	483	250	0	0	0	Shiroro
Asaba	125.173	94.83	-3.3	0	0	0	0	0	Enugu
LC Lekki	325.605	98.67	-1.1	165.6	90	0	0	0	Lagos
LC Alagbon	325.447	98.62	-1.1	124.2	70	0	0	0	Lagos
LC Ikeja.W	321.614	97.46	-0.8	545.1	358	0	0	0	Lagos
LC Benin	329.153	99.74	3.9	409.86	240	0	0	0	Benin
LC Akangba	317.488	96.21	-1.5	0	0	0	0	0	Lagos
GS Olurunsogo	308.681	93.54	-0.3	0	0	304	40	0	Lagos
LC Kumbotso	331.31	100.4	-2.4	414	220	0	0	0	Kaduna
LC Asaba	327.66	99.29	-0.2	0	0	0	0	0	Enugu
LC Ugwuaji	331.118	100.34	-1.8	82.8	45	0	0	0	Enugu
LC Ayade	292.826	88.74	-3.5	0	0	0	0	0	Osogbo
Asaba 33kV	29.282	88.73	-8.6	96.6	50	0	0	0	Enugu
LC Ganmo	326.273	98.87	0.1	96.6	50	0	0	0	Osogbo
LC Jos	331.31	100.4	-2.4	193.2	115	0	0	0	Bauchi
LC Sakete	314.315	95.25	-2.8	165.6	90	0	0	0	Lagos
LC Sokoto	341.13	103.37	-9	186.3	105	0	0	0	Shiroro
GS Egbin	330	100	0	0	0	1449.981	1445.819	0	Lagos
LC Gusau	339.126	102.77	-8	55.2	32	0	0	0	Kaduna
LC Gombe	331.31	100.4	-2.4	165.6	105	0	0	0	Bauchi
LC Katampe	330	100	-10.7	0	0	0	0	-265.287	Shiroro
LC Aja	326.05	98.8	-1	545.1	336	0	0	0	Lagos
Owerri	128.839	97.61	-2.7	0	0	0	0	0	Port-Harcourt
LC Gwagwalada	330.957	100.29	-0.4	345	190	0	0	0	Shiroro
LC Yola	302.755	91.74	-12.2	151.8	95	0	0	0	Bauchi
LC Makurdi	331.31	100.4	-2.4	124.2	70	0	0	0	Enugu

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
GS Calabar	330	100	1.4	165.6	157.429	625	0	0	Port-Harcourt
Ayede 132kV	108.297	82.04	-8.2	0	0	0	0	0	Osogbo
LC Katsina	339.043	102.74	-6.2	124.2	70	0	0	0	Kaduna
LC Damaturu	329.441	99.83	-5.4	124.2	75	0	0	0	Bauchi
GS Jebba	342.053	103.65	4	0	0	540	84.4	0	Shiroro
Ayede 33kV	24.723	74.92	-14.9	426.42	281	0	0	0	Osogbo
LC Lokoja	330.188	100.06	3.2	0	0	0	0	0	Benin
LC Maiduguri	308.36	93.44	-11.8	138	95	0	0	0	Bauchi
Owerri 33kV	31.355	95.01	-5.6	220.8	105	0	0	0	Port-Harcourt
LC Zaria	331.879	100.57	-4.8	124.2	70	0	0	0	Kaduna
LC Funtua	334.254	101.29	-6.9	165.6	100	0	0	0	Kaduna
LC Onitsha	330.131	100.04	-1.5	331.2	190	0	0	0	Enugu
GS Delta	333.349	101.01	7.8	0	0	950	100	0	Benin
LC Alaide	331.69	100.51	-2.5	82.8	46	0	0	0	Enugu
Mando 132kV	129.132	97.83	-4.6	0	0	0	0	0	Kaduna
Lokoja 132kV	127.21	96.37	0	0	0	0	0	0	Benin
GS Omotosho	324.612	98.37	2.7	207	128	304	50	0	Osogbo
LC Mambila	332.08	100.63	-3.6	13.8	8	0	0	0	Bauchi
Mando 33kV	31.498	95.45	-7	276	150	0	0	0	Kaduna
Akangba	122.272	92.63	-4.4	0	0	0	0	0	Lagos
GS Geregu	330	100	4.7	0	125.396	858.5	0	0	Benin
LC Ajaokuta	330.019	100.01	4.6	124.2	75	0	0	0	Benin
LC Zamfara	335.995	101.82	-9	151.8	90	0	0	0	Kaduna
GS Obajana	329.979	99.99	4.5	165.6	98	150	90	0	Benin
LC Aladja	330.238	100.07	7	140.76	95	0	0	0	Benin

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
GS Sapele	330	100	6.7	0	81.17	960	0	0	Benin
Akangba 33kV	29.482	89.34	-7.6	538.2	326	0	0	0	Lagos
GS Afam	330.278	100.08	0.9	0	0	975	200	0	Port-Harcourt
GS Alaoji	330	100	-1.4	496.8	273.334	585	0	0	Port-Harcourt

From Tables 4.10, 4.11 and 4.12 the results of the installation of a DG of 26.5MW capacity in Benin region which represents 2.5% of the 1061.22MW load demand of the region is observed. From a comparison of tables 4.4 and 4.10, it is observed the active power losses of the region reduced by 3.13% to 24.79MW while that of the grid reduced by 0.64% to 130.761MW. The losses of the region increased with a corresponding increase in the output of the DG while the corresponding decrease in the losses of the grid remained largely insignificant.

Voltages at all the nodes in the region remained largely unchanged for the 330kV transmission network as only an improvement of 0.17% was recorded but an improvement of up to 2.7% was recorded on the 33kV distribution network.

Also, although the line flows within the network reduced slightly, the congested Aiyede node was not cleared. Thus, the installation of a DG in Benin region makes no meaningful impact.

4.5 Case 5: Nigerian Power System Network with DG Installed in Enugu Region

The power system network profile with DG installed in Enugu region: The grid system was simulated with a DG installed in Enugu region and the results are as shown below.

Enugu region covers most of the South-Eastern part of the country. Its vegetation is wet lowlands rain forest, so it enjoys a lot of rainfall but this also makes it vulnerable to landslides as the region has the most gully erosion sites in the country and has become a region of ecological disaster. The occupation of the people in the region is primarily commerce.

The region is a net importer of electricity as electrical power generation within the region falls short of the power demands of the region. The transmission networks are quite short and charged, making the region to have node voltages that are always at the upper limit, requiring reactive power compensation.

The region boasts of the largest coal deposits in the country (Ezekwe C. I., Odukwe A. O., "Coal in Nigeria" 1980) and a lot of gas reserves. A gas fired DG was installed in the region at Asaba which is the node with the highest losses. In order to maintain uniform allocation of the generator units in the grid, the equivalent of the generated power from the DG was removed from Okpai GS.

The states that make up the region are Anambra, Ebonyi, Enugu, and parts of Abia, Delta, Imo and Kogi States.

The network model used for the simulation is shown in figure 4.15. The data for the generators used are listed in appendices Ia, Ib and Ic while the transmission lines data used are listed in appendices IIIa, IIIb and IIIc. Similarly, the bus load data used for the network are listed in appendix II.

Table 4.13: Network generation, regional load demand and loss profile for case 5

	P Loss (MW)	**Q Loss (MVar)**	**P Imp (MW)**	**Q Imp (MVar)**	**P Gen (MW)**	**Q Gen (MVar)**	**P Load (MW)**	**Q Load (MVar)**
Network	129.984	-3986.71	1449.204	1443.085	10644.2	1867.321	10514.22	6120
Bauchi	11.305	-881.069	866.905	-348.069	0	0	855.6	533
Benin	25.63	-521.432	-2218.15	-88.225	3305	194.794	1061.22	628
Enugu	16.16	-230.409	509.64	412.711	536	-47.12	1029.48	596

	P Loss (MW)	Q Loss (MVar)	P Imp (MW)	Q Imp (MVar)	P Gen (MW)	Q Gen (MVar)	P Load (MW)	Q Load (MVar)
Kaduna	7.948	-1144.94	1318.948	-412.941	0	0	1311	732
Lagos	10.506	27.636	520.502	-87.448	1753.204	1483.085	2263.2	1368
Osogbo	11.667	23.493	782.687	669.493	304	50	1075.02	696
Port-Harcourt	13.74	-461.642	-1535.06	360.996	2846	-160.637	1297.2	662
Shiroro	33.027	-798.345	-245.473	-506.515	1900	347.2	1621.5	905

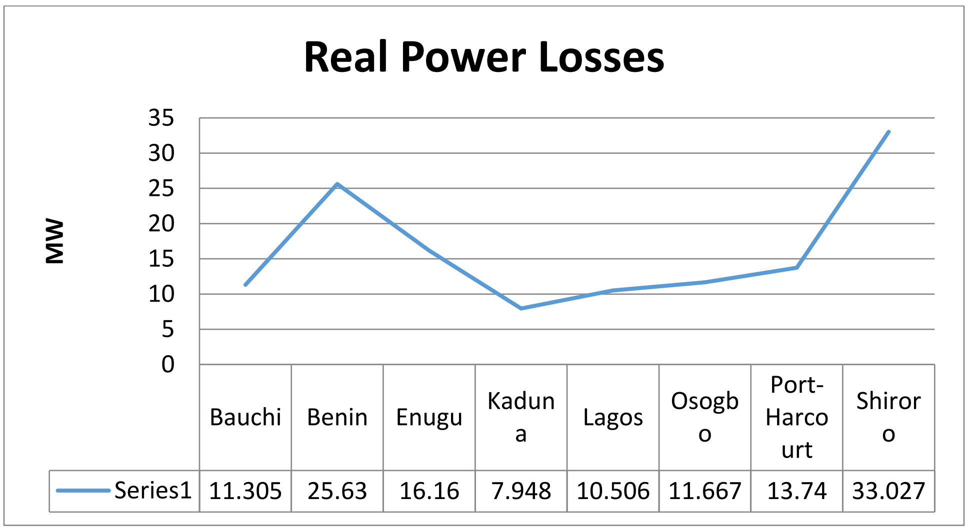

Figure 4.13: Real power losses for case 5

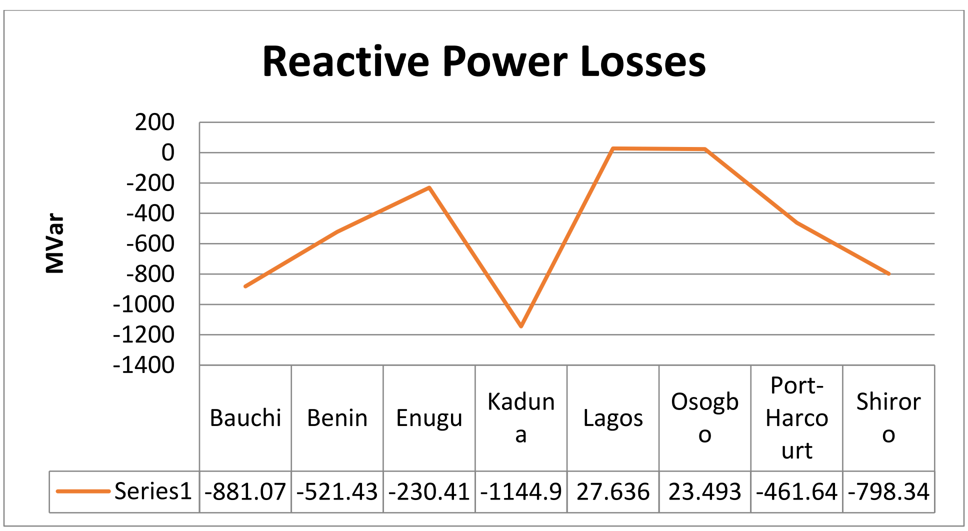

Figure 4.14: Reactive power losses for case 5

Table 4.14: Regional power flow for case 5

From Region	To Region	P Tie (MW)	Q Tie (MVar)
Bauchi	Enugu	-2027.18	929.835
Bauchi	Kaduna	1160.275	-581.766
Benin	Enugu	775.283	-132.061
Benin	Lagos	384.327	51.811
Benin	Osogbo	359.536	151.598
Benin	Port-Harcourt	226.477	-24.068
Benin	Shiroro	472.527	40.945
Enugu	Port-Harcourt	-1761.54	385.063
Kaduna	Shiroro	-158.673	-168.825
Lagos	Osogbo	-136.176	139.26
Osogbo	Shiroro	-559.327	-378.635
Overloads Nodes (lower) (%)			
LC Ayade	88.74		

Table 4.15: Node voltage profiles and loading for case 5

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
Jalingo 132kV	113.441	85.94	-17.1	0	0	0	0	0	Bauchi
LC Jalingo	295.902	89.67	-14.4	0	0	0	0	0	Bauchi
GS Omoku	330	100	0.8	248.4	345.467	323	0	0	Port-Harcourt
LC Owerri	328.227	99.46	-0.9	0	0	0	0	0	Port-Harcourt
LC B_Kebbi	341.399	103.45	-7.6	151.8	90	0	0	0	Shiroro
GS kainji	351.176	106.42	6.5	0	0	760	146.8	0	Shiroro

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
LC Jebba	341.472	103.48	3.7	165.6	100	0	0	0	Shiroro
Jalingo 33kV	26.649	80.75	-21.7	69	40	0	0	0	Bauchi
Lokoja 33kV	29.619	89.76	-5.4	220.8	120	0	0	0	Benin
LC EastMain	330.388	100.12	-0.6	41.4	20	0	0	0	Shiroro
LC Onnie	329.449	99.83	1	165.6	80	0	0	0	Port-Harcourt
LC Ikot E.	331.081	100.33	0.4	0	0	0	0	0	Port-Harcourt
LC Okearo	325.396	98.6	-0.5	179.4	98	0	0	0	Lagos
LC Oshogbo	321.633	97.46	-0.8	345	237	0	0	0	Osogbo
GS Shiroro	335.795	101.76	-1.6	248.4	150	600	116	0	Shiroro
GS Egbema	330	100	0.9	0	32.041	338	0	0	Port-Harcourt
GS Okpai	330	100	1.1	0	75.12	505	0	0	Enugu
Katampe 132kV	128.6	97.42	-13.2	0	0	0	0	0	Shiroro
LC Mando	331.318	100.4	-2.4	0	0	0	0	0	Kaduna
GS Eyean	333.221	100.98	4.4	0	0	360	180	0	Benin
LC New H,	330.675	100.2	-2	311.88	195	0	0	0	Enugu
Katampe 33kV	31.367	95.05	-15.7	483	250	0	0	0	Shiroro
Asaba	129.046	97.76	-2.1	0	0	0	0	0	Enugu
LC Lekki	325.605	98.67	-1.1	165.6	90	0	0	0	Lagos
LC Alagbon	325.447	98.62	-1.1	124.2	70	0	0	0	Lagos
LC Ikeja.W	321.633	97.46	-0.8	545.1	358	0	0	0	Lagos
LC Benin	329.278	99.78	3.9	409.86	240	0	0	0	Benin
LC Akangba	317.507	96.21	-1.5	0	0	0	0	0	Lagos
GS Olurunsogo	308.702	93.55	-0.3	0	0	304	40	0	Lagos
LC Kumbotso	331.318	100.4	-2.4	414	220	0	0	0	Kaduna

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
LC Asaba	329.14	99.74	0	0	0	0	0	0	Enugu
LC Ugwuaji	331.128	100.34	-1.9	82.8	45	0	0	0	Enugu
LC Ayade	292.85	88.74	-3.5	0	0	0	0	0	Osogbo
Asaba 33kV	31.368	95.06	-5.4	96.6	50	31	28	0	Enugu
LC Ganmo	326.284	98.87	0.1	96.6	50	0	0	0	Osogbo
LC Jos	331.318	100.4	-2.4	193.2	115	0	0	0	Bauchi
LC Sakete	314.334	95.25	-2.8	165.6	90	0	0	0	Lagos
LC Sokoto	341.124	103.37	-9	186.3	105	0	0	0	Shiroro
GS Egbin	330	100	0	0	0	1449.204	1443.085	0	Lagos
LC Gusau	339.13	102.77	-8	55.2	32	0	0	0	Kaduna
LC Gombe	331.318	100.4	-2.4	165.6	105	0	0	0	Bauchi
LC Katampe	330	100	-10.8	0	0	0	0	-265.97	Shiroro
LC Aja	326.05	98.8	-1	545.1	336	0	0	0	Lagos
Owerri	128.839	97.61	-2.7	0	0	0	0	0	Port-Harcourt
LC Gwagwalada	330.573	100.17	-0.4	345	190	0	0	0	Shiroro
LC Yola	302.766	91.75	-12.2	151.8	95	0	0	0	Bauchi
LC Makurdi	331.318	100.4	-2.4	124.2	70	0	0	0	Enugu
GS Calabar	330	100	1.3	165.6	157.563	625	0	0	Port-Harcourt
Ayede 132kV	108.308	82.05	-8.2	0	0	0	0	0	Osogbo
LC Katsina	339.05	102.74	-6.2	124.2	70	0	0	0	Kaduna
LC Damaturu	329.45	99.83	-5.4	124.2	75	0	0	0	Bauchi
GS Jebba	342.042	103.65	4	0	0	540	84.4	0	Shiroro
Ayede 33kV	24.726	74.93	-14.9	426.42	281	0	0	0	Osogbo
LC Lokoja	329.643	99.89	3.2	0	0	0	0	0	Benin
LC Maiduguri	308.37	93.45	-11.8	138	95	0	0	0	Bauchi
Owerri 33kV	31.355	95.01	-5.6	220.8	105	0	0	0	Port-Harcourt

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
LC Zaria	331.886	100.57	-4.9	124.2	70	0	0	0	Kaduna
LC Funtua	334.26	101.29	-6.9	165.6	100	0	0	0	Kaduna
LC Onitsha	330.145	100.04	-1.6	331.2	190	0	0	0	Enugu
GS Delta	333.423	101.04	7.8	0	0	950	100	0	Benin
LC Alaide	331.698	100.51	-2.5	82.8	46	0	0	0	Enugu
Mando 132kV	129.135	97.83	-4.6	0	0	0	0	0	Kaduna
Lokoja 132kV	125.379	94.98	-0.5	0	0	0	0	0	Benin
GS Omotosho	324.695	98.39	2.7	207	128	304	50	0	Osogbo
LC Mambila	332.088	100.63	-3.7	13.8	8	0	0	0	Bauchi
Mando 33kV	31.499	95.45	-7	276	150	0	0	0	Kaduna
Akangba	122.28	92.64	-4.4	0	0	0	0	0	Lagos
GS Geregu	330	100	4.7	0	85.695	885	0	0	Benin
LC Ajaokuta	329.987	100	4.6	124.2	75	0	0	0	Benin
LC Zamfara	336	101.82	-9	151.8	90	0	0	0	Kaduna
GS Obajana	329.947	99.98	4.5	165.6	98	150	90	0	Benin
LC Aladja	330.287	100.09	7	140.76	95	0	0	0	Benin
GS Sapele	330	100	6.7	0	89.512	960	0	0	Benin
Akangba 33kV	29.484	89.34	-7.6	538.2	326	0	0	0	Lagos
GS Afam	330.278	100.08	0.8	0	0	975	200	0	Port-Harcourt
GS Alaoji	330	100	-1.5	496.8	302.566	585	0	0	Port-Harcourt

Tables 4.13, 4.14 and 4.15 gives the results of the installation of a DG of 31MW capacity in Enugu region which represents 3% of the 1029.48MW load demand of the region. Comparing the results with tables 4.1 and 4.3, it is observed that the active power losses of the region reduced by 9.46% to 16.16MW while that of the grid reduced by 1.23% to 129.984MW. With an

increase in the output of the DG, the losses of the region decreased only marginally along with the losses of the grid.

Voltages at all the nodes in the region remained largely unchanged for the 330kV transmission network as only an improvement of 0.45% was recorded. On the 33kV distribution network, however, voltage profile improvement of up to 6.33% was recorded.

The line flows within the regions had only slight changes. The overloaded Aiyede node was not cleared. Thus, the installation of a DG in Enugu region makes no great impact.

4.6 Case 6: Nigerian Power System Network with DG Installed in Osogbo Region

The power system network profile with DG installed in Osogbo region: The grid system was simulated with a DG installed in Osogbo region and the results are as shown below.

Osogbo, the hinterland region, covers a large part of the Mid-Western zone of the country. Its vegetation is mainly dry lowlands rain forest and Southern Guinea Savanna so it enjoys a good amount of rainfall. The occupations of the people in the region are primarily commerce and artistry.

The region is a net importer of electricity as electrical power generation within it falls short of its power demands. The transmission networks are median in length and its node voltages are within limits.

The region is a cosmopolitan area cum forest region which generates a lot of organic and inorganic waste. Consequently, a biomass run DG was installed in the region at Ayede which is the node with the highest losses and least voltage profile. In order to maintain uniform allocation of the generator units in the grid, the equivalent of the generated power from the DG was removed from Omotosho GS.

The States that make up the region are Kwara, Osun, Oyo, and parts of Ekiti and Ondo States. It is also home to the National Control Centre.

The network model used for the simulation is shown in figure 4.18. The data for the generators used are listed in appendices Ia, Ib and Ic while the transmission lines data used are listed in appendices IIIa, IIIb and IIIc. Similarly, the bus load data used for the network are listed in appendix II.

Table 4.16: Network generation, regional load demand and loss profile for case 6

	P Loss (MW)	Q Loss (MVar)	P Imp (MW)	Q Imp (MVar)	P Gen (MW)	Q Gen (MVar)	P Load (MW)	Q Load (MVar)
Network	126.187	-4064.05	1445.407	1344.44	10640.41	1790.605	10514.22	6120
Bauchi	11.305	-881.041	866.905	-348.041	0	0	855.6	533
Benin	25.255	-524.846	-2218.53	-90.667	3305	193.821	1061.22	628
Enugu	17.722	-214.895	511.202	457.962	536	-76.857	1029.48	596
Kaduna	7.928	-1145.41	1318.928	-413.41	0	0	1311	732

	P Loss (MW)	Q Loss (MVar)	P Imp (MW)	Q Imp (MVar)	P Gen (MW)	Q Gen (MVar)	P Load (MW)	Q Load (MVar)
Lagos	9.606	18.777	523.399	2.337	1749.407	1384.44	2263.2	1368
Osogbo	7.714	-53.924	778.734	564.076	304	78	1075.02	696
Port-Harcourt	13.664	-462.289	-1535.14	335.709	2846	-135.998	1297.2	662
Shiroro	32.993	-800.425	-245.507	-507.967	1900	347.2	1621.5	905

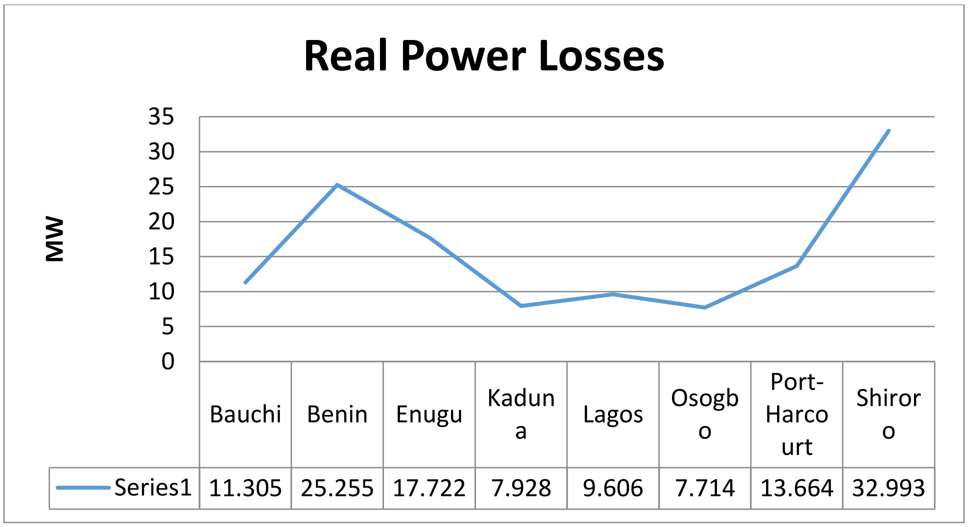

Figure 4.16: Real power losses for case 6

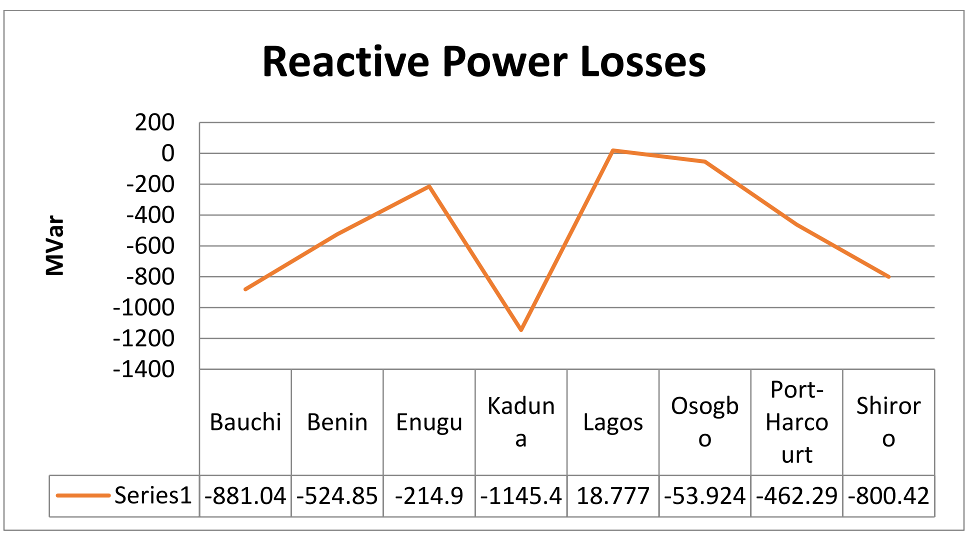

Figure 4.17: Reactive power losses for case 6

Table 4.17: Regional power flow for case 6

From Region	To Region	P Tie (MW)	Q Tie (MVar)
Bauchi	Enugu	-2023.6	933.688
Bauchi	Kaduna	1156.692	-585.647
Benin	Enugu	775.091	-115.944
Benin	Lagos	364.809	47.597
Benin	Osogbo	383.718	142.353
Benin	Port-Harcourt	224.573	-24.073
Benin	Shiroro	470.335	40.733
Enugu	Port-Harcourt	-1759.71	359.782
Kaduna	Shiroro	-162.235	-172.237
Lagos	Osogbo	-158.591	45.26
Osogbo	Shiroro	-553.607	-376.463

Table 4.18: Node voltage profiles and loading for case 6

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
Jalingo 132kV	113.438	85.94	-17.3	0	0	0	0	0	Bauchi
LC Jalingo	295.896	89.67	-14.6	0	0	0	0	0	Bauchi
GS Omoku	330	100	0.7	248.4	345.704	323	0	0	Port-Harcourt
LC Owerri	328.227	99.46	-1.1	0	0	0	0	0	Port-Harcourt
LC B_Kebbi	341.649	103.53	-7.7	151.8	90	0	0	0	Shiroro
GS kainji	351.698	106.58	6.4	0	0	760	146.8	0	Shiroro
LC Jebba	342.04	103.65	3.6	165.6	100	0	0	0	Shiroro
Jalingo 33kV	26.648	80.75	-21.8	69	40	0	0	0	Bauchi
Lokoja 33kV	29.62	89.76	-5.6	220.8	120	0	0	0	Benin
LC EastMain	330.426	100.13	-0.7	41.4	20	0	0	0	Shiroro
LC Onnie	329.454	99.83	0.9	165.6	80	0	0	0	Port-Harcourt

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
LC Ikot E.	331.08	100.33	0.3	0	0	0	0	0	Port-Harcourt
LC Okearo	325.8	98.73	-0.5	179.4	98	0	0	0	Lagos
LC Oshogbo	322.438	97.71	-0.8	345	237	0	0	0	Osogbo
GS Shiroro	335.862	101.78	-1.7	248.4	150	600	116	0	Shiroro
GS Egbema	330	100	0.8	0	32.049	338	0	0	Port-Harcourt
GS Okpai	330	100	1.1	0	76.857	536	0	0	Enugu
Katampe 132kV	128.6	97.42	-13.3	0	0	0	0	0	Shiroro
LC Mando	331.315	100.4	-2.5	0	0	0	0	0	Kaduna
GS Eyean	333.355	101.02	4.2	0	0	360	180	0	Benin
LC New H,	330.667	100.2	-2.1	311.88	195	0	0	0	Enugu
Katampe 33kV	31.367	95.05	-15.8	483	250	0	0	0	Shiroro
Asaba	125.195	94.84	-3.5	0	0	0	0	0	Enugu
LC Lekki	325.605	98.67	-1.1	165.6	90	0	0	0	Lagos
LC Alagbon	325.447	98.62	-1.1	124.2	70	0	0	0	Lagos
LC Ikeja.W	322.438	97.71	-0.8	545.1	358	0	0	0	Lagos
LC Benin	329.279	99.78	3.7	409.86	240	0	0	0	Benin
LC Akangba	318.328	96.46	-1.5	0	0	0	0	0	Lagos
GS Olurunsogo	313.519	95.01	0.1	0	0	304	40	0	Lagos
LC Kumbotso	331.315	100.4	-2.5	414	220	0	0	0	Kaduna
LC Asaba	327.71	99.31	-0.4	0	0	0	0	0	Enugu
LC Ugwuaji	331.121	100.34	-2	82.8	45	0	0	0	Enugu
LC Ayade	300.75	91.14	-2.7	0	0	0	0	0	Osogbo
Asaba 33kV	29.288	88.75	-8.8	96.6	50	0	0	0	Enugu
LC Ganmo	327.031	99.1	0.1	96.6	50	0	0	0	Osogbo
LC Jos	331.315	100.4	-2.5	193.2	115	0	0	0	Bauchi
LC Sakete	315.165	95.5	-2.8	165.6	90	0	0	0	Lagos
LC Sokoto	341.318	103.43	-9.1	186.3	105	0	0	0	Shiroro
GS Egbin	330	100	0	0	0	1445.407	1344.44	0	Lagos
LC Gusau	339.213	102.79	-8.1	55.2	32	0	0	0	Kaduna

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
LC Gombe	331.315	100.4	-2.5	165.6	105	0	0	0	Bauchi
LC Katampe	330	100	-10.9	0	0	0	0	-265.342	Shiroro
LC Aja	326.05	98.8	-1	545.1	336	0	0	0	Lagos
Owerri	128.839	97.61	-2.9	0	0	0	0	0	Port-Harcourt
LC Gwagwalada	330.611	100.19	-0.6	345	190	0	0	0	Shiroro
LC Yola	302.761	91.75	-12.3	151.8	95	0	0	0	Bauchi
LC Makurdi	331.315	100.4	-2.5	124.2	70	0	0	0	Enugu
GS Calabar	330	100	1.2	165.6	157.477	625	0	0	Port-Harcourt
Ayede 132kV	113.232	85.78	-6.4	0	0	0	0	0	Osogbo
LC Katsina	339.089	102.75	-6.3	124.2	70	0	0	0	Kaduna
LC Damaturu	329.446	99.83	-5.6	124.2	75	0	0	0	Bauchi
GS Jebba	342.609	103.82	3.9	0	0	540	84.4	0	Shiroro
Ayede 33kV	26.373	79.92	-11.4	426.42	281	68	28	0	Osogbo
LC Lokoja	329.654	99.9	3	0	0	0	0	0	Benin
LC Maiduguri	308.365	93.44	-12	138	95	0	0	0	Bauchi
Owerri 33kV	31.355	95.01	-5.7	220.8	105	0	0	0	Port-Harcourt
LC Zaria	331.911	100.58	-5	124.2	70	0	0	0	Kaduna
LC Funtua	334.315	101.31	-7.1	165.6	100	0	0	0	Kaduna
LC Onitsha	330.133	100.04	-1.7	331.2	190	0	0	0	Enugu
GS Delta	333.427	101.04	7.6	0	0	950	100	0	Benin
LC Alaide	331.694	100.51	-2.7	82.8	46	0	0	0	Enugu
Mando 132kV	129.134	97.83	-4.8	0	0	0	0	0	Kaduna
Lokoja 132kV	125.384	94.99	-0.7	0	0	0	0	0	Benin
GS Omotosho	324.799	98.42	2.2	207	128	236	50	0	Osogbo
LC Mambila	332.084	100.63	-3.8	13.8	8	0	0	0	Bauchi
Mando 33kV	31.499	95.45	-7.2	276	150	0	0	0	Kaduna

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
Akangba	122.626	92.9	-4.4	0	0	0	0	0	Lagos
GS Geregu	330	100	4.6	0	86.572	885	0	0	Benin
LC Ajaokuta	329.987	100	4.4	124.2	75	0	0	0	Benin
LC Zamfara	336.083	101.84	-9.2	151.8	90	0	0	0	Kaduna
GS Obajana	329.948	99.98	4.3	165.6	98	150	90	0	Benin
LC Aladja	330.29	100.09	6.7	140.76	95	0	0	0	Benin
GS Sapele	330	100	6.5	0	89.608	960	0	0	Benin
Akangba 33kV	29.574	89.62	-7.5	538.2	326	0	0	0	Lagos
GS Afam	330.278	100.08	0.7	0	0	975	200	0	Port-Harcourt
GS Alaoji	330	100	-1.6	496.8	277.768	585	0	0	Port-Harcourt

Tables 4.16, 4.17 and 4.18 details the results of the installation of a DG of 68MW capacity in Osogbo region which is 6.3% of the 1075.02MW load demand of the region. Comparing the results with tables 4.1 and 4.3, the active power losses of the region reduced by 33.86% to 7.714MW while that of the grid also reduced by 4.11% to 126.187MW. When the output of the DG was increased, the losses, both of the region and the grid, decreased further but marginally.

Voltages at all the nodes in the region improved to near nominal values with that of the 330kV transmission network improving by as much as 2.41% while the 33kV distribution network improved by 5%.

Also, the line flows within the regions changed considerably and the overloaded Aiyede node cleared out.

4.7 Case 7: Nigerian Power System Network with DG Installed in Kaduna Region

The power system network profile with DG installed in Kaduna region: The grid system was simulated with a DG installed in Kaduna region and the results are as shown below.

Kaduna region covers the North-Western part of the country. It is the seat of the Islamic caliphate. Its vegetation is Northern Guinea Savanna and Sudan Savanna. It has vast stretches of sandy, arid soil and enjoys lots of hot, tropical sunshine most times of the year, making it a very hot zone. The occupation of the people in the region is primarily crop farming and animal husbandry.

The region is an importer of electricity as it does not have any generation station. The transmission lines in the region are very lengthy due to the dispersed settlement being practiced in the region. Node voltages in the region are all at the nominal values as the network has low charges.

Since the region has lots of sunshine all year round, a solar powered DG was installed in the region at Mando which is the node with the worst voltage profile and greatest losses in the region. In order to maintain uniform allocation of the generator units in the grid, the equivalent of the generated power from the DG was removed from Kainji GS.

The States that make up the region are Kaduna, Kano, Katsina, Kebbi, Sokoto and Zamfara States.

The network model used for the simulation is shown in figure 4.21. The data for the generators used are listed in appendices Ia, Ib and Ic while the transmission lines data used are listed in appendices IIIa, IIIb and IIIc. Similarly, the bus load data used for the network are listed in appendix II.

Table 4.19: Network generation, regional load demand and loss profile for case 7

	P Loss (MW)	**Q Loss (MVar)**	**P Imp (MW)**	**Q Imp (MVar)**	**P Gen (MW)**	**Q Gen (MVar)**	**P Load (MW)**	**Q Load (MVar)**
Network	130.063	-3994.1	1449.283	1443.556	10644.28	1860.96	10514.22	6120
Bauchi	11.293	-881.771	866.893	-348.771	0	0	855.6	533
Benin	25.892	-519.106	-2217.89	-93.982	3305	202.876	1061.22	628
Enugu	17.518	-216.673	510.998	456.784	536	-77.457	1029.48	596

	P Loss (MW)	Q Loss (MVar)	P Imp (MW)	Q Imp (MVar)	P Gen (MW)	Q Gen (MVar)	P Load (MW)	Q Load (MVar)
Kaduna	7.948	-1153.54	1278.948	-449.54	40	28	1311	732
Lagos	10.512	27.689	520.43	-87.867	1753.283	1483.556	2263.2	1368
Osogbo	11.713	23.879	782.733	669.879	304	50	1075.02	696
Port-Harcourt	13.604	-462.83	-1535.2	372.385	2846	-173.215	1297.2	662
Shiroro	31.581	-811.749	-206.919	-518.887	1860	347.2	1621.5	905

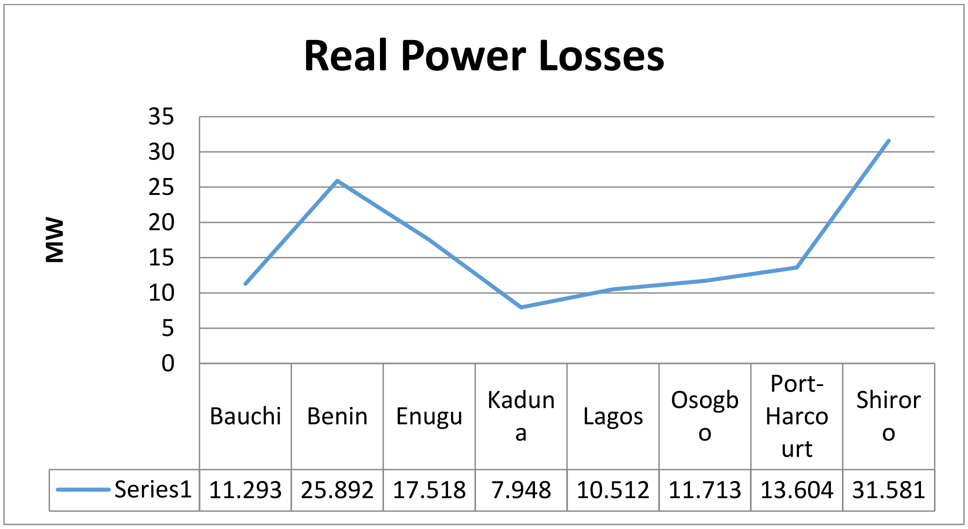

Figure 4.19: Real power losses for case 7

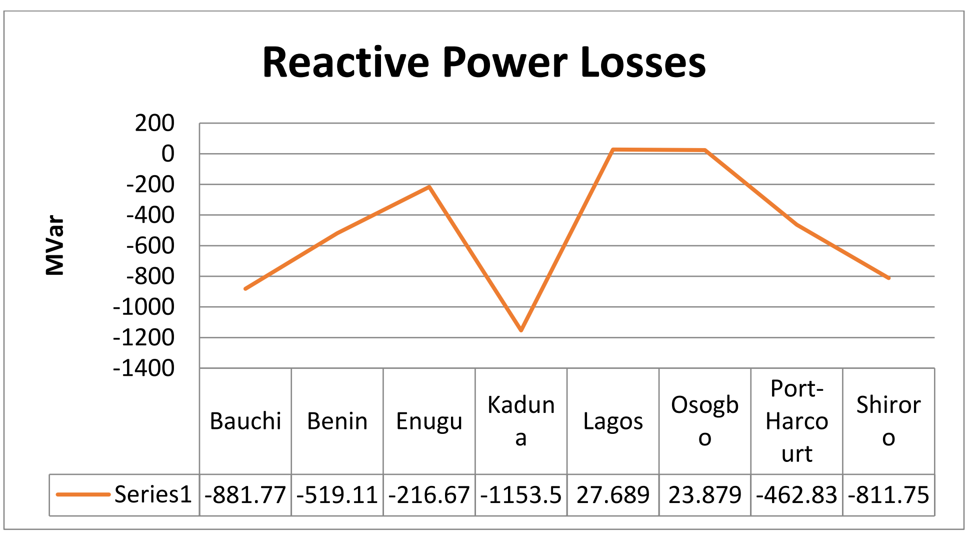

Figure 4.20: Reactive power losses for case 7

Table 4.20: Regional power flow for case 7

From Region	To Region	P Tie (MW)	Q Tie (MVar)
Bauchi	Enugu	-2011.67	972.617
Bauchi	Kaduna	1144.775	-623.845
Benin	Enugu	764.715	-119.002
Benin	Lagos	392.719	48.281
Benin	Osogbo	367.165	148.789
Benin	Port-Harcourt	222.755	-24.446
Benin	Shiroro	470.534	40.36
Enugu	Port-Harcourt	-1757.95	396.831
Kaduna	Shiroro	-134.174	-174.305
Lagos	Osogbo	-127.711	136.148
Osogbo	Shiroro	-543.279	-384.942
Overloads Nodes (lower) (%)			
LC Ayade	88.74		

Table 4.21: Node voltage profiles and loading for case 7

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
Jalingo 132kV	113.503	85.99	-16.9	0	0	0	0	0	Bauchi
LC Jalingo	296.048	89.71	-14.2	0	0	0	0	0	Bauchi
GS Omoku	330	100	1.1	248.4	345.866	323	0	0	Port-Harcourt
LC Owerri	328.228	99.46	-0.7	0	0	0	0	0	Port-Harcourt
LC B_Kebbi	341.828	103.58	-7.6	151.8	90	0	0	0	Shiroro
GS kainji	351.335	106.47	6.1	0	0	720	146.8	0	Shiroro
LC Jebba	341.651	103.53	3.5	165.6	100	0	0	0	Shiroro

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
Jalingo 33kV	26.666	80.81	-21.4	69	40	0	0	0	Bauchi
Lokoja 33kV	29.621	89.76	-5.3	220.8	120	0	0	0	Benin
LC EastMain	330.445	100.13	-0.4	41.4	20	0	0	0	Shiroro
LC Onnie	329.45	99.83	1.3	165.6	80	0	0	0	Port-Harcourt
LC Ikot E.	331.088	100.33	0.7	0	0	0	0	0	Port-Harcourt
LC Okearo	325.398	98.61	-0.5	179.4	98	0	0	0	Lagos
LC Oshogbo	321.636	97.47	-0.8	345	237	0	0	0	Osogbo
GS Shiroro	335.905	101.79	-1.4	248.4	150	600	116	0	Shiroro
GS Egbema	330	100	1.2	0	32.057	338	0	0	Port-Harcourt
GS Okpai	330	100	1.5	0	77.457	536	0	0	Enugu
Katampe 132kV	128.6	97.42	-13	0	0	0	0	0	Shiroro
LC Mando	331.411	100.43	-2.1	0	0	0	0	0	Kaduna
GS Eyean	333.114	100.94	4.5	0	0	360	180	0	Benin
LC New H,	330.724	100.22	-1.7	311.88	195	0	0	0	Enugu
Katampe 33kV	31.367	95.05	-15.5	483	250	0	0	0	Shiroro
Asaba	125.185	94.84	-3.1	0	0	0	0	0	Enugu
LC Lekki	325.605	98.67	-1.1	165.6	90	0	0	0	Lagos
LC Alagbon	325.447	98.62	-1.1	124.2	70	0	0	0	Lagos
LC Ikeja.W	321.636	97.47	-0.8	545.1	358	0	0	0	Lagos
LC Benin	329.158	99.74	4	409.86	240	0	0	0	Benin
LC Akangba	317.51	96.22	-1.5	0	0	0	0	0	Lagos
GS Olurunsogo	308.705	93.55	-0.3	0	0	304	40	0	Lagos
LC Kumbotso	331.411	100.43	-2.1	414	220	0	0	0	Kaduna
LC Asaba	327.688	99.3	0	0	0	0	0	0	Enugu

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
LC Ugwuaji	331.175	100.36	-1.6	82.8	45	0	0	0	Enugu
LC Ayade	292.854	88.74	-3.5	0	0	0	0	0	Osogbo
Asaba 33kV	29.286	88.74	-8.4	96.6	50	0	0	0	Enugu
LC Ganmo	326.354	98.9	0	96.6	50	0	0	0	Osogbo
LC Jos	331.411	100.43	-2.1	193.2	115	0	0	0	Bauchi
LC Sakete	314.337	95.25	-2.8	165.6	90	0	0	0	Lagos
LC Sokoto	341.473	103.48	-8.9	186.3	105	0	0	0	Shiroro
GS Egbin	330	100	0	0	0	1449.283	1443.556	0	Lagos
LC Gusau	339.308	102.82	-7.8	55.2	32	0	0	0	Kaduna
LC Gombe	331.411	100.43	-2.1	165.6	105	0	0	0	Bauchi
LC Katampe	330	100	-10.6	0	0	0	0	-264.938	Shiroro
LC Aja	326.05	98.8	-1	545.1	336	0	0	0	Lagos
Owerri	128.839	97.61	-2.5	0	0	0	0	0	Port-Harcourt
LC Gwagwalada	330.629	100.19	-0.3	345	190	0	0	0	Shiroro
LC Yola	302.901	91.79	-11.9	151.8	95	0	0	0	Bauchi
LC Makurdi	331.411	100.43	-2.1	124.2	70	0	0	0	Enugu
GS Calabar	330	100	1.6	165.6	158.216	625	0	0	Port-Harcourt
Ayede 132kV	108.31	82.05	-8.2	0	0	0	0	0	Osogbo
LC Katsina	339.176	102.78	-6	124.2	70	0	0	0	Kaduna
LC Damaturu	329.553	99.86	-5.2	124.2	75	0	0	0	Bauchi
GS Jebba	342.22	103.7	3.9	0	0	540	84.4	0	Shiroro
Ayede 33kV	24.726	74.93	-14.9	426.42	281	0	0	0	Osogbo
LC Lokoja	329.657	99.9	3.3	0	0	0	0	0	Benin
LC Maiduguri	308.492	93.48	-11.6	138	95	0	0	0	Bauchi
Owerri 33kV	31.355	95.01	-5.4	220.8	105	0	0	0	Port-Harcourt

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
LC Zaria	331.996	100.6	-4.6	124.2	70	0	0	0	Kaduna
LC Funtua	334.401	101.33	-6.7	165.6	100	0	0	0	Kaduna
LC Onitsha	330.151	100.05	-1.3	331.2	190	0	0	0	Enugu
GS Delta	333.356	101.02	7.9	0	0	950	100	0	Benin
LC Alaide	331.784	100.54	-2.3	82.8	46	0	0	0	Enugu
Mando 132kV	129.857	98.38	-4.1	0	0	0	0	0	Kaduna
Lokoja 132kV	125.385	94.99	-0.3	0	0	0	0	0	Benin
GS Omotosho	324.611	98.37	2.7	207	128	304	50	0	Osogbo
LC Mambila	332.185	100.66	-3.4	13.8	8	0	0	0	Bauchi
Mando 33kV	31.834	96.47	-6.1	276	150	40	28	0	Kaduna
Akangba	122.282	92.64	-4.4	0	0	0	0	0	Lagos
GS Geregu	330	100	4.9	0	85.649	885	0	0	Benin
LC Ajaokuta	329.987	100	4.8	124.2	75	0	0	0	Benin
LC Zamfara	336.181	101.87	-8.8	151.8	90	0	0	0	Kaduna
GS Obajana	329.947	99.98	4.6	165.6	98	150	90	0	Benin
LC Aladja	330.242	100.07	7.1	140.76	95	0	0	0	Benin
GS Sapele	330	100	6.8	0	81.475	960	0	0	Benin
Akangba 33kV	29.484	89.35	-7.6	538.2	326	0	0	0	Lagos
GS Afam	330.278	100.08	1.1	0	0	975	200	0	Port-Harcourt
GS Alaoji	330	100	-1.2	496.8	314.075	585	0	0	Port-Harcourt

Tables 4.19, 4.20 and 4.21 details the results of the installation of a DG of 40MW capacity in Kaduna region which is 3.05% of the 1311MW load demand of the region. With the installation, the active power losses of the region dropped by 0.08% to 7.948MW while that of the grid also dropped by 1.17% to 130.063MW. With an increase in the output of the DG, the losses, both of

the region and grid reduced further but very minimally due to the reactive power compensation devices installed in the region.

Improvement of voltages at all the nodes in the region was very negligible due to the reactive power compensation devices installed in the region. An increase of 0.04% and 1.02% were recorded in the 330kV transmission and 33kV distribution networks respectively.

Also, the redistribution of line flow currents within the regions was also negligible and the overloaded Aiyede node did not clear out.

4.8 Case 8: Nigerian Power System Network with DG Installed in Lagos Region

The power system network profile with DG installed in Lagos region: The grid system was simulated with a DG installed in Lagos region and the results are as shown below.

Lagos region is the economic hub of the country. The region covers most of the South-Western part of the country, towards the shores of the Atlantic. It is a heavily industrialised region. Its vegetation is mixed and comprises both Mangrove swamps towards the shores of the Atlantic, Fresh water swamps, Wet lowland rain forests, dry lowland rain forests and a bite of Southern Guinea Savanna. The region has rich supplies of hydrocarbon fuels. It is the commercial nerve centre of the country.

Though the region is host to the biggest single power generating station in Nigeria (Wikipedia, 2018) and a pocket of other conventional power generating stations, the region imports electrical power but can also export power depending on the grid dynamics. The transmission lines in the region are quite short as they take power to the various industrial clusters. Node voltages in the region hover around the nominal value.

Lagos region also has an international node, a line going to Sakete in Benin Republic.

Since the region has abundant supplies of hydrocarbon fuels, and is a cosmopolitan area which generates huge organic and inorganic wastes which can be used as fuel for a biomass powered DG. However, a wind driven turbine DG was installed in the region at Akangba which is the node with the lowest voltage profile, as the area is on the shores of the Atlantic and has lots of wind.In order to maintain uniform allocation of the generator units in the grid, the equivalent of the generated power from the DG was removed from Olorunsogo GS.

The states that make up the region are Lagos and Ogun States.

The network model used for the simulation is shown in figure 4.24. The data for the generators used are listed in appendices Ia, Ib and Ic while the transmission lines data used are listed in appendices IIIa, IIIb and IIIc. Similarly, the bus load data used for the network are listed in appendix II.

Table 4.22: Network generation, regional load demand and loss profile for case 8

	P Loss (MW)	Q Loss (MVar)	P Imp (MW)	Q Imp (MVar)	P Gen (MW)	Q Gen (MVar)	P Load (MW)	Q Load (MVar)
Network	130.664	-3998.2	1449.884	1400.134	10644.88	1856.102	10514.22	6120
Bauchi	11.306	-880.994	866.906	-347.994	0	0	855.6	533
Benin	25.562	-522.025	-2218.22	-93.112	3305	199.087	1061.22	628
Enugu	17.843	-213.821	511.323	458.969	536	-76.791	1029.48	596
Kaduna	7.958	-1144.95	1318.958	-412.951	0	0	1311	732
Lagos	9.678	2.405	518.994	-97.73	1753.884	1468.134	2263.2	1368
Osogbo	11.649	22.842	782.669	668.842	304	50	1075.02	696
Port-Harcourt	13.696	-462.001	-1535.1	331.527	2846	-131.528	1297.2	662
Shiroro	32.97	-799.653	-245.53	-507.552	1900	347.2	1621.5	905

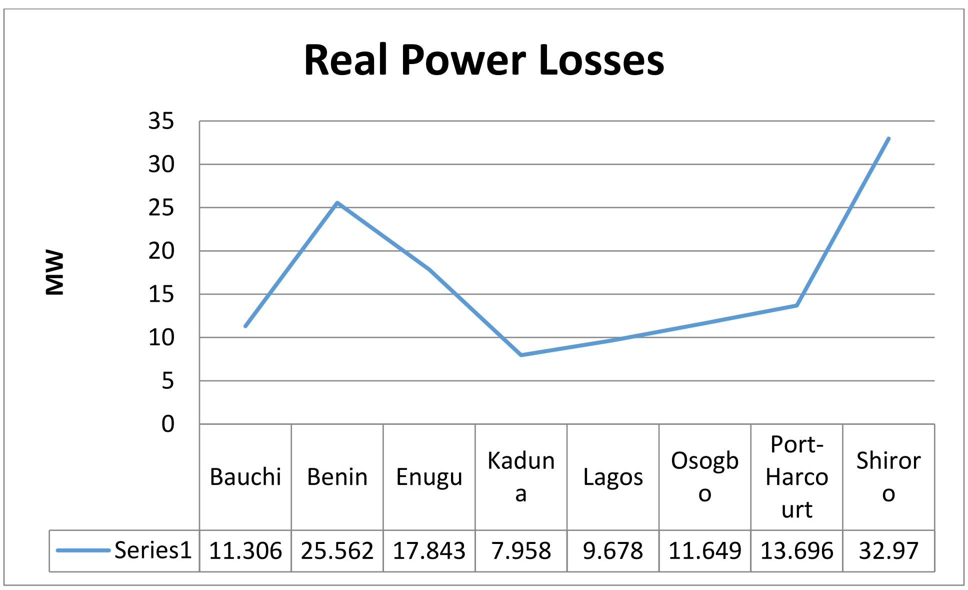

Figure 4.22: Real power losses for case 8

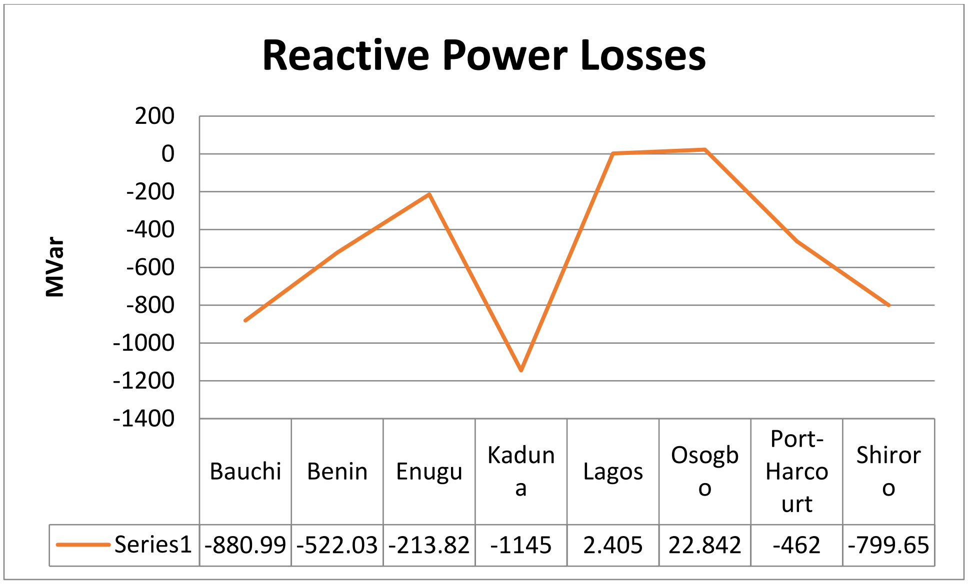

Figure 4.23: Reactive power losses for case 8

Table 4.23: Regional power flow for case 8

From Region	To Region	P Tie (MW)	Q Tie (MVar)
Bauchi	Enugu	-2028.85	932.174
Bauchi	Kaduna	1161.947	-584.18
Benin	Enugu	779.646	-117.423
Benin	Lagos	382.973	47.64
Benin	Osogbo	358.529	146.308
Benin	Port-Harcourt	225.426	-24.255
Benin	Shiroro	471.643	40.842
Enugu	Port-Harcourt	-1760.53	355.782
Kaduna	Shiroro	-157.011	-171.229
Lagos	Osogbo	-136.021	145.369
Osogbo	Shiroro	-560.161	-377.165
Overloads Nodes (lower) (%)			

LC Ayade	88.78		

Table 4.24: Node voltage profiles and loading for case 8

Node Name	U (kV)	U (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
Jalingo 132kV	113.434	85.93	-17.1	0	0	0	0	0	Bauchi
LC Jalingo	295.886	89.66	-14.4	0	0	0	0	0	Bauchi
GS Omoku	330	100	0.9	248.4	345.381	323	0	0	Port-Harcourt
LC Owerri	328.227	99.46	-0.9	0	0	0	0	0	Port-Harcourt
LC B_Kebbi	341.535	103.5	-7.6	151.8	90	0	0	0	Shiroro
GS kainji	351.416	106.49	6.5	0	0	760	146.8	0	Shiroro
LC Jebba	341.726	103.55	3.7	165.6	100	0	0	0	Shiroro
Jalingo 33kV	26.647	80.75	-21.7	69	40	0	0	0	Bauchi
Lokoja 33kV	29.62	89.76	-5.4	220.8	120	0	0	0	Benin
LC EastMain	330.404	100.12	-0.6	41.4	20	0	0	0	Shiroro
LC Onnie	329.448	99.83	1.1	165.6	80	0	0	0	Port-Harcourt
LC Ikot E.	331.079	100.33	0.5	0	0	0	0	0	Port-Harcourt
LC Okearo	325.573	98.66	-0.5	179.4	98	0	0	0	Lagos
LC Oshogbo	321.985	97.57	-0.8	345	237	0	0	0	Osogbo
GS Shiroro	335.824	101.76	-1.6	248.4	150	600	116	0	Shiroro
GS Egbema	330	100	1	0	32.046	338	0	0	Port-Harcourt
GS Okpai	330	100	1.2	0	76.791	536	0	0	Enugu
Katampe	128.6	97.42	-13.1	0	0	0	0	0	Shiroro

Node Name	U (kV)	U (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
132kV									
LC Mando	331.308	100.4	-2.4	0	0	0	0	0	Kaduna
GS Eyean	333.223	100.98	4.4	0	0	360	180	0	Benin
LC New H,	330.663	100.2	-2	311.88	195	0	0	0	Enugu
Katampe 33kV	31.367	95.05	-15.7	483	250	0	0	0	Shiroro
Asaba	125.183	94.84	-3.3	0	0	0	0	0	Enugu
LC Lekki	325.605	98.67	-1.1	165.6	90	0	0	0	Lagos
LC Alagbon	325.447	98.62	-1.1	124.2	70	0	0	0	Lagos
LC Ikeja.W	321.985	97.57	-0.8	545.1	358	0	0	0	Lagos
LC Benin	329.218	99.76	3.9	409.86	240	0	0	0	Benin
LC Akangba	318.371	96.48	-1.4	0	0	0	0	0	Lagos
GS Olurunsogo	308.678	93.54	-1	0	0	234	40	0	Lagos
LC Kumbotso	331.308	100.4	-2.4	414	220	0	0	0	Kaduna
LC Asaba	327.683	99.3	-0.2	0	0	0	0	0	Enugu
LC Ugwuaji	331.117	100.34	-1.9	82.8	45	0	0	0	Enugu
LC Ayade	292.976	88.78	-4	0	0	0	0	0	Osogbo
Asaba 33kV	29.285	88.74	-8.6	96.6	50	0	0	0	Enugu
LC Ganmo	326.61	98.97	0.1	96.6	50	0	0	0	Osogbo
LC Jos	331.308	100.4	-2.4	193.2	115	0	0	0	Bauchi
LC Sakete	314.698	95.36	-2.8	165.6	90	0	0	0	Lagos
LC Sokoto	341.226	103.4	-9	186.3	105	0	0	0	Shiroro
GS Egbin	330	100	0	0	0	1449.884	1400.134	0	Lagos
LC Gusau	339.165	102.78	-8	55.2	32	0	0	0	Kaduna
LC Gombe	331.308	100.4	-2.4	165.6	105	0	0	0	Bauchi
LC Katampe	330	100	-10.7	0	0	0	0	-265.699	Shiroro
LC Aja	326.05	98.8	-1	545.1	336	0	0	0	Lagos
Owerri	128.839	97.61	-2.7	0	0	0	0	0	Port-Harcourt
LC	330.589	100.18	-0.4	345	190	0	0	0	Shiroro

Node Name	U (kV)	U (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
Gwagwalada									
LC Yola	302.752	91.74	-12.2	151.8	95	0	0	0	Bauchi
LC Makurdi	331.308	100.4	-2.4	124.2	70	0	0	0	Enugu
GS Calabar	330	100	1.4	165.6	157.417	625	0	0	Port-Harcourt
Ayede 132kV	108.366	82.1	-8.7	0	0	0	0	0	Osogbo
LC Katsina	339.061	102.75	-6.2	124.2	70	0	0	0	Kaduna
LC Damaturu	329.439	99.83	-5.4	124.2	75	0	0	0	Bauchi
GS Jebba	342.295	103.73	4	0	0	540	84.4	0	Shiroro
Ayede 33kV	24.742	74.98	-15.3	426.42	281	0	0	0	Osogbo
LC Lokoja	329.647	99.89	3.2	0	0	0	0	0	Benin
LC Maiduguri	308.357	93.44	-11.8	138	95	0	0	0	Bauchi
Owerri 33kV	31.355	95.01	-5.6	220.8	105	0	0	0	Port-Harcourt
LC Zaria	331.889	100.57	-4.8	124.2	70	0	0	0	Kaduna
LC Funtua	334.279	101.3	-6.9	165.6	100	0	0	0	Kaduna
LC Onitsha	330.131	100.04	-1.6	331.2	190	0	0	0	Enugu
GS Delta	333.388	101.03	7.8	0	0	950	100	0	Benin
LC Alaide	331.688	100.51	-2.5	82.8	46	0	0	0	Enugu
Mando 132kV	129.131	97.83	-4.6	0	0	0	0	0	Kaduna
Lokoja 132kV	125.381	94.99	-0.5	0	0	0	0	0	Benin
GS Omotosho	324.798	98.42	2.7	207	128	304	50	0	Osogbo
LC Mambila	332.077	100.63	-3.7	13.8	8	0	0	0	Bauchi
Mando 33kV	31.498	95.45	-7	276	150	0	0	0	Kaduna
Akangba	123.172	93.31	-3.9	0	0	0	0	0	Lagos
GS Geregu	330	100	4.7	0	85.44	885	0	0	Benin

Node Name	U (kV)	U (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
LC Ajaokuta	329.987	100	4.6	124.2	75	0	0	0	Benin
LC Zamfara	336.035	101.83	-9	151.8	90	0	0	0	Kaduna
GS Obajana	329.947	99.98	4.5	165.6	98	150	90	0	Benin
LC Aladja	330.264	100.08	6.9	140.76	95	0	0	0	Benin
GS Sapele	330	100	6.7	0	85.473	960	0	0	Benin
Akangba 33kV	29.82	90.36	-6.6	538.2	326	70	28	0	Lagos
GS Afam	330.278	100.08	0.8	0	0	975	200	0	Port-Harcourt
GS Alaoji	330	100	-1.4	496.8	273.683	585	0	0	Port-Harcourt

Lagos region has one of the lowest active power losses in the grid network. This can be attributed to the very short spans of its transmission lines. Tables 4.22, 4.23 and 4.24 details the results of the installation of a DG of 70MW capacity in Lagos region. This is 3.09% of the 2263.2MW load demand of the region. With the installation, the active power losses of the region dropped by 8.05% to 9.678MW while that of the grid also dropped by 0.71% to 130.664MW. With an increase in the output of the DG, the losses reduced marginally.

Node voltages across the region improved marginally with the installation of the DG. An improvement of 0.27% was recorded in the 330kV transmission network while the 33kV distribution network recorded an improvement of 1.02%.

Also, there was not much change to the redistribution of line flows within the regions and the overloaded node of Aiyede remained uncleared.

4.9 Case 9: Nigerian Power System Network with DG Installed in Port-Harcourt Region

The power system network profile with DG installed in Port-Harcourt region: The grid system was simulated with a DG installed in Port-Harcourt region and the results are as shown below.

Port-Harcourt region is home to the oil rich Niger delta. Covering the South-South part of the country all the way to the Atlantic, its vegetation is a mix of Mangrove swamp, Fresh water swamp and Wet lowland rain forest. It is mainly marshland polluted by the spills of the oil drills as it is home to most of the country's oil wells. The occupation of the people in the region is mainly commerce.

Port-Harcourt region is a net exporter of electricity as it has myriads of conventional gas generating stations. The transmission lines in the region are moderate in length and the region has robust voltages across its nodes.

Since the region has abundant supplies of hydrocarbon fuels, a gas-fuelled DG was installed in the region at Owerri which is the node with the lowest voltage profile. In order to maintain uniform allocation of the generator units in the grid, the equivalent of the generated power from the DG was removed from Afam GS.

The states that make up the region are Abia, Akwa Ibom, Bayelsa, Cross River, Imo and Rivers States.

The network model used for the simulation is shown in figure 4.27. The data for the generators used are listed in appendices Ia, Ib and Ic while the transmission lines data used are listed in appendices IIIa, IIIb and IIIc. Similarly, the bus load data used for the network are listed in appendix II.

Table 4.25: Network generation, regional load demand and loss profile for case 9

	P Loss (MW)	Q Loss (MVar)	P Imp (MW)	Q Imp (MVar)	P Gen (MW)	Q Gen (MVar)	P Load (MW)	Q Load (MVar)
Network	131.127	-3980.64	1450.347	1446.284	10645.35	1873.303	10514.22	6120
Bauchi	11.307	-880.95	866.907	-347.95	0	0	855.6	533
Benin	25.578	-521.702	-2218.2	-98.343	3305	204.642	1061.22	628
Enugu	17.833	-213.877	511.313	458.856	536	-76.733	1029.48	596
Kaduna	7.956	-1144.76	1318.956	-412.755	0	0	1311	732

	P Loss (MW)	Q Loss (MVar)	P Imp (MW)	Q Imp (MVar)	P Gen (MW)	Q Gen (MVar)	P Load (MW)	Q Load (MVar)
Lagos	10.524	27.815	519.377	-90.469	1754.347	1486.284	2263.2	1368
Osogbo	11.664	23.53	782.684	669.53	304	50	1075.02	696
Port-Harcourt	13.257	-472.263	-1535.54	327.828	2846	-138.09	1297.2	662
Shiroro	33.008	-798.435	-245.492	-506.697	1900	347.2	1621.5	905

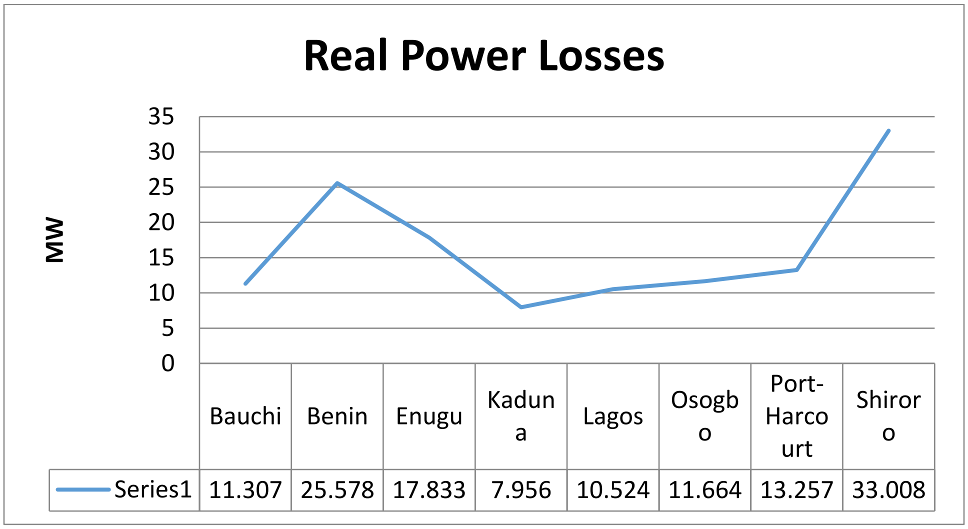

Figure 4.25: Real power losses for case 9

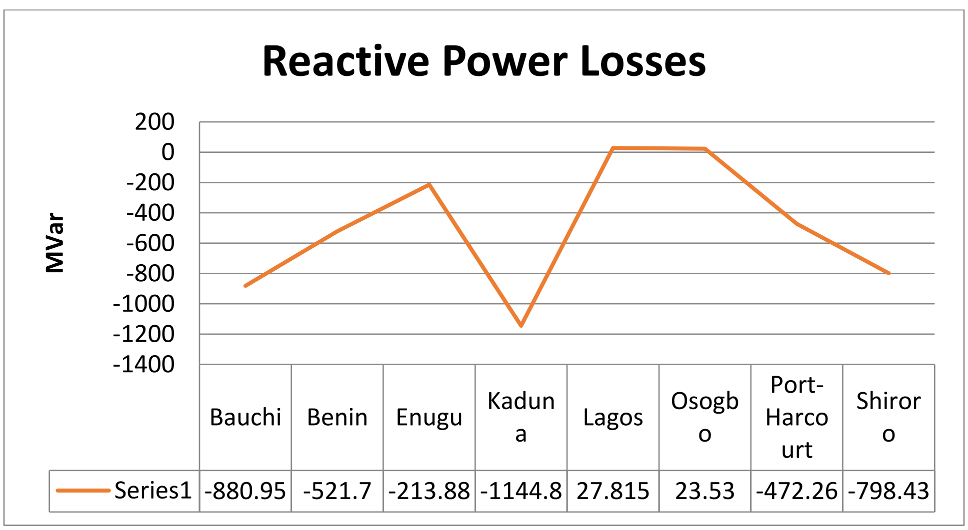

Figure 4.26: Reactive power losses for case 9

Table 4.26: Regional power flow for case 9

From Region	To Region	P Tie (MW)	Q Tie (MVar)
Bauchi	Enugu	-2029.26	930.075
Bauchi	Kaduna	1162.349	-582.125
Benin	Enugu	778.757	-118.95
Benin	Lagos	383.131	50.291
Benin	Osogbo	358.502	150.289
Benin	Port-Harcourt	226.269	-24.441
Benin	Shiroro	471.543	41.155
Enugu	Port-Harcourt	-1761.81	352.269
Kaduna	Shiroro	-156.607	-169.37
Lagos	Osogbo	-136.247	140.76
Osogbo	Shiroro	-560.428	-378.481
Overloads Nodes (lower)	**(%)**		
LC Ayade	88.73		

Table 4.27: Node voltage profiles and loading for case 9

	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
Jalingo 132kV	113.43	85.93	-17.1	0	0	0	0	0	Bauchi
LC Jalingo	295.877	89.66	-14.4	0	0	0	0	0	Bauchi
GS Omoku	330	100	0.8	248.4	341.98	323	0	0	Port-Harcourt
LC Owerri	328.869	99.66	-0.8	0	0	0	0	0	Port-Harcourt
LC B_Kebbi	341.388	103.45	-7.5	151.8	90	0	0	0	Shiroro
GS kainji	351.161	106.41	6.5	0	0	760	146.8	0	Shiroro

	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
LC Jebba	341.455	103.47	3.7	165.6	100	0	0	0	Shiroro
Jalingo 33kV	26.646	80.75	-21.7	69	40	0	0	0	Bauchi
Lokoja 33kV	29.619	89.75	-5.4	220.8	120	0	0	0	Benin
LC EastMain	330.387	100.12	-0.6	41.4	20	0	0	0	Shiroro
LC Onnie	329.438	99.83	1	165.6	80	0	0	0	Port-Harcourt
LC Ikot E.	331.08	100.33	0.5	0	0	0	0	0	Port-Harcourt
LC Okearo	325.385	98.6	-0.5	179.4	98	0	0	0	Lagos
LC Oshogbo	321.611	97.46	-0.8	345	237	0	0	0	Osogbo
GS Shiroro	335.786	101.75	-1.6	248.4	150	600	116	0	Shiroro
GS Egbema	330	100	1	0	51.659	338	0	0	Port-Harcourt
GS Okpai	330	100	1.2	0	76.733	536	0	0	Enugu
Katampe 132kV	128.6	97.42	-13.1	0	0	0	0	0	Shiroro
LC Mando	331.303	100.39	-2.4	0	0	0	0	0	Kaduna
GS Eyean	333.11	100.94	4.4	0	0	360	180	0	Benin
LC New H,	330.659	100.2	-2	311.88	195	0	0	0	Enugu
Katampe 33kV	31.367	95.05	-15.7	483	250	0	0	0	Shiroro
Asaba	125.172	94.83	-3.3	0	0	0	0	0	Enugu
LC Lekki	325.605	98.67	-1.1	165.6	90	0	0	0	Lagos
LC Alagbon	325.447	98.62	-1.1	124.2	70	0	0	0	Lagos
LC Ikeja.W	321.611	97.46	-0.8	545.1	358	0	0	0	Lagos
LC Benin	329.149	99.74	3.9	409.86	240	0	0	0	Benin
LC Akangba	317.484	96.21	-1.5	0	0	0	0	0	Lagos
GS	308.676	93.54	-0.3	0	0	304	40	0	Lagos

	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
Olurunsogo									
LC Kumbotso	331.303	100.39	-2.4	414	220	0	0	0	Kaduna
LC Asaba	327.658	99.29	-0.2	0	0	0	0	0	Enugu
LC Ugwuaji	331.113	100.34	-1.9	82.8	45	0	0	0	Enugu
LC Ayade	292.821	88.73	-3.5	0	0	0	0	0	Osogbo
Asaba 33kV	29.282	88.73	-8.6	96.6	50	0	0	0	Enugu
LC Ganmo	326.262	98.87	0.1	96.6	50	0	0	0	Osogbo
LC Jos	331.303	100.39	-2.4	193.2	115	0	0	0	Bauchi
LC Sakete	314.311	95.25	-2.8	165.6	90	0	0	0	Lagos
LC Sokoto	341.11	103.37	-9	186.3	105	0	0	0	Shiroro
GS Egbin	330	100	0	0	0	1450.347	1446.284	0	Lagos
LC Gusau	339.113	102.76	-8	55.2	32	0	0	0	Kaduna
LC Gombe	331.303	100.39	-2.4	165.6	105	0	0	0	Bauchi
LC Katampe	330	100	-10.7	0	0	0	0	-266.062	Shiroro
LC Aja	326.05	98.8	-1	545.1	336	0	0	0	Lagos
Owerri	129.774	98.31	-2.3	0	0	0	0	0	Port-Harcourt
LC Gwagwalada	330.572	100.17	-0.4	345	190	0	0	0	Shiroro
LC Yola	302.743	91.74	-12.2	151.8	95	0	0	0	Bauchi
LC Makurdi	331.303	100.39	-2.4	124.2	70	0	0	0	Enugu
GS Calabar	330	100	1.4	165.6	157.444	625	0	0	Port-Harcourt
Ayede 132kV	108.295	82.04	-8.2	0	0	0	0	0	Osogbo
LC Katsina	339.033	102.74	-6.2	124.2	70	0	0	0	Kaduna
LC Damaturu	329.433	99.83	-5.4	124.2	75	0	0	0	Bauchi

	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
GS Jebba	342.025	103.64	4	0	0	540	84.4	0	Shiroro
Ayede 33kV	24.722	74.92	-14.9	426.42	281	0	0	0	Osogbo
LC Lokoja	329.643	99.89	3.2	0	0	0	0	0	Benin
LC Maiduguri	308.349	93.44	-11.8	138	95	0	0	0	Bauchi
Owerri 33kV	31.823	96.43	-4.7	220.8	105	35	28	0	Port-Harcourt
LC Zaria	331.869	100.57	-4.8	124.2	70	0	0	0	Kaduna
LC Funtua	334.242	101.29	-6.9	165.6	100	0	0	0	Kaduna
LC Onitsha	330.129	100.04	-1.6	331.2	190	0	0	0	Enugu
GS Delta	333.345	101.01	7.8	0	0	950	100	0	Benin
LC Alaide	331.683	100.51	-2.5	82.8	46	0	0	0	Enugu
Mando 132kV	129.129	97.82	-4.6	0	0	0	0	0	Kaduna
Lokoja 132kV	125.379	94.98	-0.5	0	0	0	0	0	Benin
GS Omotosho	324.609	98.37	2.7	207	128	304	50	0	Osogbo
LC Mambila	332.071	100.63	-3.7	13.8	8	0	0	0	Bauchi
Mando 33kV	31.498	95.45	-7	276	150	0	0	0	Kaduna
Akangba	122.271	92.63	-4.4	0	0	0	0	0	Lagos
GS Geregu	330	100	4.7	0	84.445	885	0	0	Benin
LC Ajaokuta	329.986	100	4.6	124.2	75	0	0	0	Benin
LC Zamfara	335.982	101.81	-9	151.8	90	0	0	0	Kaduna
GS Obajana	329.946	99.98	4.5	165.6	98	150	90	0	Benin
LC Aladja	330.235	100.07	6.9	140.76	95	0	0	0	Benin
GS Sapele	330	100	6.7	0	80.913	960	0	0	Benin
Akangba	29.481	89.34	-7.6	538.2	326	0	0	0	Lagos

	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
33kV									
GS Afam	330.274	100.08	0.8	0	0	940	200	0	Port-Harcourt
GS Alaoji	330	100	-1.4	496.8	292.007	585	0	0	Port-Harcourt

Tables 4.25, 4.26 and 4.27 details the results of the installation of a DG of 35MW capacity in Port-Harcourt region. This is 2.7% of the 1297.2MW load demand of the region. With the installation, the active power losses of the region reduced by 3.22% to 13.257MW while the active losses for the grid also reduced by 0.36% to 131.127MW. The losses reduction, both for the region and the grid, were negligible with an increase in the output of the DG.

Node voltages across the region remained largely unchanged as only very minimal improvements were recorded. On the 330kV transmission network, an improvement of 0.2% was recorded while an improvement of 1.42% was recorded on the 33kV distribution network. This can be attributed to the dynamics and loading factor of the transmission lines.

Also, there was not much change to the redistribution of line flows within the regions and the overloaded Aiyede node remained uncleared. Thus, the installation of a DG at Port-Harcourt region has very little benefits.

4.10 Case 10: Nigerian Power System Network with DG Installed in Shiroro Region

The power system network profile with DG installed in Shiroro region: The grid system was simulated with a DG installed in Shiroro region and the results are as shown below.

Shiroro region covers most of the Middle belt of the country and the country's seat of power. Its vegetation is Southern Guinea Savannah and is home to some of the country's natural tourist sites. The occupation of the people in the region is primarily crop farming and animal husbandry.

The region is a net exporter of electricity as it is home to the three hydro generating stations in the country. The transmission lines in the region are about average in length. The region has robust voltages across its nodes.

Since the region is a cosmopolitan region and also has abundant fauna, it generates a lot of organic and inorganic wastes which can be used to run a biomass DG. Thus, a biomass powered DG was installed in the region at Katampe which is the node with the worst voltage profile. In order to maintain uniform allocation of the generator units in the grid, the equivalent of the generated power from the DG was removed from Shiroro GS.

The states that make up the region are Kebbi, Nassarawa, Niger, Abuja FCT and parts of Kogi and Kwara States.

The network model used for the simulation is shown in figure 4.30. The data for the generators used are listed in appendices Ia, Ib and Ic while the transmission lines data used are listed in appendices IIIa, IIIb and IIIc. Similarly, the bus load data used for the network are listed in appendix II.

Table 4.28: Network generation, regional load demand and loss profile for case 10

	P Loss (MW)	**Q Loss (MVar)**	**P Imp (MW)**	**Q Imp (MVar)**	**P Gen (MW)**	**Q Gen (MVar)**	**P Load (MW)**	**Q Load (MVar)**
Network	128.893	-4006.54	1448.113	1446.44	10643.11	1909.711	10514.22	6120
Bauchi	11.306	-880.981	866.906	-347.981	0	0	855.6	533
Benin	25.614	-521.421	-2218.17	-97.692	3305	204.271	1061.22	628
Enugu	17.82	-213.992	511.3	458.768	536	-76.76	1029.48	596
Kaduna	7.958	-1144.78	1318.958	-412.784	0	0	1311	732
Lagos	10.518	27.759	521.605	-90.681	1752.113	1486.44	2263.2	1368

	P Loss (MW)	Q Loss (MVar)	P Imp (MW)	Q Imp (MVar)	P Gen (MW)	Q Gen (MVar)	P Load (MW)	Q Load (MVar)
Osogbo	11.67	23.581	782.69	669.581	304	50	1075.02	696
Port-Harcourt	13.69	-462.046	-1535.11	329.394	2846	-129.44	1297.2	662
Shiroro	30.318	-834.656	-248.182	-508.606	1900	375.2	1621.5	905

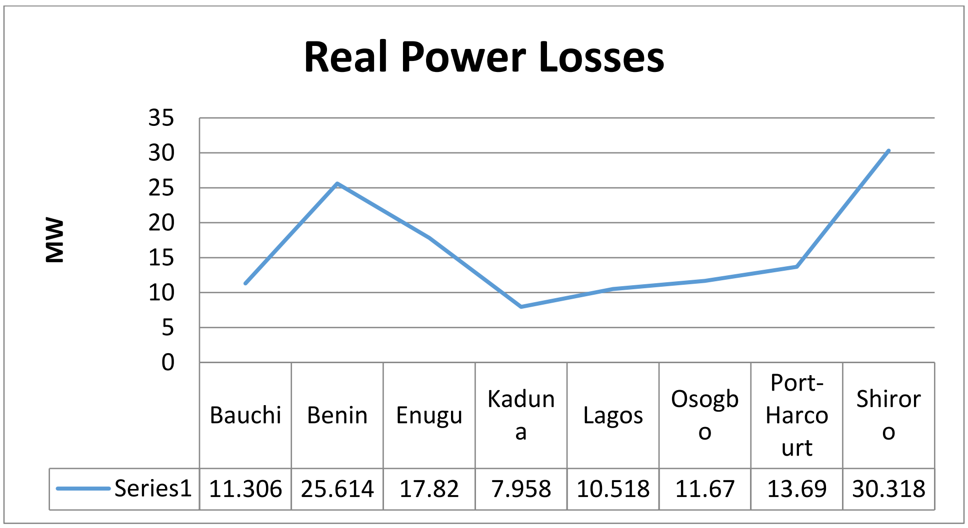

Figure 4.28: Real power losses for case 10

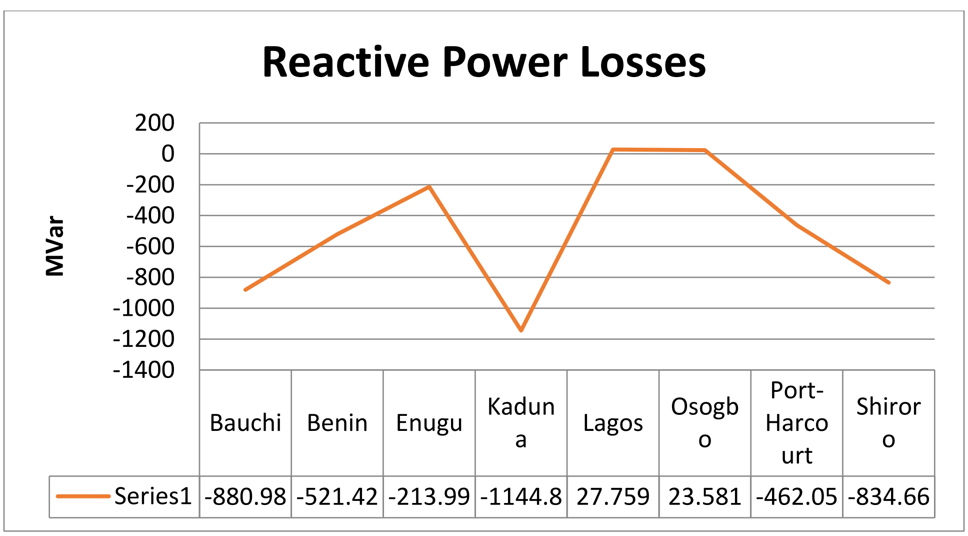

Figure 4.29: Reactive power losses for case 10

Table 4.29: Regional power flow for case 10

From Region	To Region	P Tie (MW)	Q Tie (MVar)
Bauchi	Enugu	-2027.51	931.597
Bauchi	Kaduna	1160.601	-583.616
Benin	Enugu	778.451	-118.973
Benin	Lagos	383.986	50.11
Benin	Osogbo	359.196	150.17
Benin	Port-Harcourt	225.245	-24.461
Benin	Shiroro	471.288	40.847
Enugu	Port-Harcourt	-1760.36	353.855
Kaduna	Shiroro	-158.357	-170.832
Lagos	Osogbo	-137.619	140.79
Osogbo	Shiroro	-561.112	-378.621
Overloads Nodes (lower) (%)			
LC Ayade	88.73		

Table 4.30: Node voltage profiles and loading for case 10

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
Jalingo 132kV	113.433	85.93	-17.1	0	0	0	0	0	Bauchi
LC Jalingo	295.883	89.66	-14.4	0	0	0	0	0	Bauchi
GS Omoku	330	100	0.9	248.4	345.198	323	0	0	Port-Harcourt
LC Owerri	328.227	99.46	-0.9	0	0	0	0	0	Port-Harcourt
LC B_Kebbi	341.402	103.46	-7.5	151.8	90	0	0	0	Shiroro
GS kainji	351.176	106.42	6.5	0	0	760	146.8	0	Shiroro
LC Jebba	341.469	103.48	3.7	165.6	100	0	0	0	Shiroro

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
Jalingo 33kV	26.647	80.75	-21.6	69	40	0	0	0	Bauchi
Lokoja 33kV	29.62	89.76	-5.4	220.8	120	0	0	0	Benin
LC EastMain	330.408	100.12	-0.5	41.4	20	0	0	0	Shiroro
LC Onnie	329.443	99.83	1.1	165.6	80	0	0	0	Port-Harcourt
LC Ikot E.	331.079	100.33	0.5	0	0	0	0	0	Port-Harcourt
LC Okearo	325.386	98.6	-0.5	179.4	98	0	0	0	Lagos
LC Oshogbo	321.611	97.46	-0.8	345	237	0	0	0	Osogbo
GS Shiroro	335.829	101.77	-1.6	248.4	150	530	116	0	Shiroro
GS Egbema	330	100	1	0	32.047	338	0	0	Port-Harcourt
GS Okpai	330	100	1.3	0	76.76	536	0	0	Enugu
Katampe 132kV	129.062	97.77	-11.4	0	0	0	0	0	Shiroro
LC Mando	331.307	100.4	-2.3	0	0	0	0	0	Kaduna
GS Eyean	333.11	100.94	4.4	0	0	360	180	0	Benin
LC New H,	330.662	100.2	-2	311.88	195	0	0	0	Enugu
Katampe 33kV	31.58	95.7	-13.5	483	250	70	28	0	Shiroro
Asaba	125.172	94.83	-3.3	0	0	0	0	0	Enugu
LC Lekki	325.605	98.67	-1.1	165.6	90	0	0	0	Lagos
LC Alagbon	325.447	98.62	-1.1	124.2	70	0	0	0	Lagos
LC Ikeja.W	321.611	97.46	-0.8	545.1	358	0	0	0	Lagos
LC Benin	329.149	99.74	3.9	409.86	240	0	0	0	Benin
LC Akangba	317.485	96.21	-1.5	0	0	0	0	0	Lagos
GS Olurunsogo	308.677	93.54	-0.3	0	0	304	40	0	Lagos
LC Kumbotso	331.307	100.4	-2.3	414	220	0	0	0	Kaduna
LC Asaba	327.658	99.29	-0.1	0	0	0	0	0	Enugu

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
LC Ugwuaji	331.115	100.34	-1.8	82.8	45	0	0	0	Enugu
LC Ayade	292.822	88.73	-3.5	0	0	0	0	0	Osogbo
Asaba 33kV	29.282	88.73	-8.6	96.6	50	0	0	0	Enugu
LC Ganmo	326.266	98.87	0.1	96.6	50	0	0	0	Osogbo
LC Jos	331.307	100.4	-2.3	193.2	115	0	0	0	Bauchi
LC Sakete	314.312	95.25	-2.8	165.6	90	0	0	0	Lagos
LC Sokoto	341.123	103.37	-9	186.3	105	0	0	0	Shiroro
GS Egbin	330	100	0	0	0	1448.113	1446.44	0	Lagos
LC Gusau	339.12	102.76	-8	55.2	32	0	0	0	Kaduna
LC Gombe	331.307	100.4	-2.3	165.6	105	0	0	0	Bauchi
LC Katampe	330	100	-9.3	0	0	0	0	-203.75	Shiroro
LC Aja	326.05	98.8	-1	545.1	336	0	0	0	Lagos
Owerri	128.839	97.61	-2.7	0	0	0	0	0	Port-Harcourt
LC Gwagwalada	330.592	100.18	-0.4	345	190	0	0	0	Shiroro
LC Yola	302.749	91.74	-12.1	151.8	95	0	0	0	Bauchi
LC Makurdi	331.307	100.4	-2.3	124.2	70	0	0	0	Enugu
GS Calabar	330	100	1.4	165.6	157.401	625	0	0	Port-Harcourt
Ayede 132kV	108.295	82.04	-8.2	0	0	0	0	0	Osogbo
LC Katsina	339.038	102.74	-6.2	124.2	70	0	0	0	Kaduna
LC Damaturu	329.437	99.83	-5.4	124.2	75	0	0	0	Bauchi
GS Jebba	342.039	103.65	4	0	0	540	84.4	0	Shiroro
Ayede 33kV	24.722	74.92	-14.9	426.42	281	0	0	0	Osogbo
LC Lokoja	329.648	99.89	3.2	0	0	0	0	0	Benin
LC Maiduguri	308.355	93.44	-11.8	138	95	0	0	0	Bauchi
Owerri 33kV	31.355	95.01	-5.5	220.8	105	0	0	0	Port-Harcourt
LC Zaria	331.874	100.57	-4.8	124.2	70	0	0	0	Kaduna
LC Funtua	334.249	101.29	-6.9	165.6	100	0	0	0	Kaduna

Node Name	U (kV)	u (%)	Angle U (°)	P Load (MW)	Q Load (MVar)	P Gen (MW)	Q Gen (MVar)	Q Shunt (MVar)	Region
LC Onitsha	330.13	100.04	-1.5	331.2	190	0	0	0	Enugu
GS Delta	333.347	101.01	7.8	0	0	950	100	0	Benin
LC Alaide	331.687	100.51	-2.5	82.8	46	0	0	0	Enugu
Mando 132kV	129.13	97.83	-4.6	0	0	0	0	0	Kaduna
Lokoja 132kV	125.381	94.99	-0.5	0	0	0	0	0	Benin
GS Omotosho	324.608	98.37	2.7	207	128	304	50	0	Osogbo
LC Mambila	332.076	100.63	-3.6	13.8	8	0	0	0	Bauchi
Mando 33kV	31.498	95.45	-7	276	150	0	0	0	Kaduna
Akangba	122.271	92.63	-4.4	0	0	0	0	0	Lagos
GS Geregu	330	100	4.8	0	84.835	885	0	0	Benin
LC Ajaokuta	329.986	100	4.7	124.2	75	0	0	0	Benin
LC Zamfara	335.989	101.81	-9	151.8	90	0	0	0	Kaduna
GS Obajana	329.946	99.98	4.5	165.6	98	150	90	0	Benin
LC Aladja	330.236	100.07	7	140.76	95	0	0	0	Benin
GS Sapele	330	100	6.7	0	80.894	960	0	0	Benin
Akangba 33kV	29.481	89.34	-7.6	538.2	326	0	0	0	Lagos
GS Afam	330.278	100.08	0.9	0	0	975	200	0	Port-Harcourt
GS Alaoji	330	100	-1.4	496.8	271.795	585	0	0	Port-Harcourt

Tables 4.28, 4.29 and 4.30 details the results of the installation of a DG of 70MW capacity in Shiroro region. This is 4.3% of the 1621.5MW load demand of the region. With the installation, the active power losses of the region dropped by 8.16% to 30.318MW while that of the grid also dropped by 2.05% to 128.893MW. With an increase in the output of the DG, the losses, both of the region and the grid, dropped slightly further, being helped by the reactive power compensation device installed in the region.

With the installation of the DG, node voltages across the region largely remained unchanged. Due to reactive power compensation devices installed in the region, there was no change in the voltages of the 330kV transmission network as they remained at the nominal values while an improvement of 0.2% was recorded in the 33kV distribution network.

Also, the redistribution of line flows within the regions was very minimal and the overloaded Aiyede node was not cleared.

CHAPTER 5

SUMMARY AND CONCLUSION

5.1 Summary

From the results obtained, it is observed that the integration of DG technology in the Nigerian power system has immense benefits. Some of these benefits, as obtained from the results are summarised below:

5.1.1 Active Power Losses Reduction

Both the Nigerian grid system and the distribution network witnessed active power losses reduction with the integration of DG technology in the network. This is as summarised in table 5.1.

Table 5.1: Losses reduction and cost savings with DG installation

Regions	Losses					Reduction (%)	
	330kV Grid	Without DG		With DG		330/132/ 33kV Network	Region
		330/132/ 33kV Network (MW)	Region (MW)	330/132/ 33kV Network (MW)	Region (MW)		
Bauchi	9.388	131.597	11.307	127.210	6.997	3.333	38.118
Benin	23.398	131.597	25.590	130.761	24.790	0.635	3.126
Enugu	15.651	131.597	17.849	129.984	16.160	1.226	9.463
Osogbo	6.095	131.597	11.663	126.187	7.714	4.111	33.859
Kaduna	7.351	131.597	7.954	130.063	7.948	1.166	4.772
Lagos	7.458	131.597	10.525	130.664	9.678	0.709	8.048
Port-Harcourt	13.079	131.597	13.698	131.127	13.257	0.357	3.219
Shiroro	32.044	131.597	33.012	128.893	30.318	2.055	8.161

From table 5.1 above, it is observed that the integration of the DG technology in the Nigerian power system resulted to active power losses reduction. From the table it is seen that the Nigerian power system has an active power loss of 131.597MW without the integration of the

DG technology. This is 1.25% of the active power demand of the power system. With the integration of the DG technology in the power system, the active power losses in the system were reduced. The grid had the highest loss reduction of 4.111% when the technology was implemented in Osogbo region. Next to that was a loss reduction of 3.333% when the technology was implemented in Bauchi region. Similarly, the grid witnessed a reduction in losses of 2.055%, 1.226%, 1.166%, 0.709%, 0.635% and 0.357% respectively when the technology was implemented in Shiroro, Enugu, Kaduna, Lagos, Benin and Port-Harcourt regions respectively.

Similarly, the distribution network recorded active power losses reduction with the integration of the technology. The distribution network of Bauchi region had the highest active power losses reduction of 38.118%. Next to it was Osogbo region with a loss reduction of 33.859%. Others are Enugu, Shiroro, Lagos, Kaduna, Port-Harcourt and Benin regions with losses reduction of 9.463%, 8.161%, 8.048%, 4.772%, 3.219% and 3.126% respectively in their distribution networks.

From the foregoing, it is observed that DG technology can be installed beneficially in all regions of the country but the most viable places to install the technology are in the Northern part of the country as represented by Bauchi, Shiroro and Kaduna regions although Osogbo in the South-West and Enugu in the South-East are also very viable markets.

5.1.2 Voltage Profile Improvement

The voltage profile of most nodes of the grid system witnessed an improvement with the integration of DG technology in the network. This is as summarised in table 5.2.

Table 5.2: Voltage profile improvement with DG installation

Regions	**Voltage Profile**						**Improvement (%)**		
	Without DG (kV)			**With DG (kV)**			**330kV**	**132kV**	**33kV**
	330	**132**	**33**	**330**	**132**	**33**			
Bauchi	295.877	113.43	26.646	323.797	128.353	31.662	8.623	11.627	15.842
Benin	329.643	125.379	26.619	330.188	127.210	30.508	0.165	1.440	12.747
Enugu	327.657	125.172	29.282	329.140	129.046	31.363	0.451	3.002	6.635
Osogbo	292.821	108.295	24.722	300.750	113.232	26.373	2.636	4.360	6.260
Kaduna	331.302	129.129	31.497	331.411	129.857	31.834	0.032	0.561	1.059
Lagos	317.484	122.271	29.481	318.371	123.172	29.820	0.279	0.731	1.137

Regions	Voltage Profile						Improvement (%)		
	Without DG (kV)			With DG (kV)			330kV	132kV	33kV
	330	132	33	330	132	33			
Port-Harcourt	328.227	128.839	31.355	328.869	129.774	31.823	0.195	0.720	1.471
Shiroro	330.000	128.600	31.367	330.000	129.062	31.580	0.000	0.358	0.674

From table 5.2, it is observed that the deployment of the DG technology in the Nigerian power system corrected the voltage profile lapses in the network and brought the voltages of all the nodes in the network to within acceptable limits. The grid nodes within Bauchi region had the best voltage profile improvement of 8.623% and 11.627% in the sub-grid when the technology was implemented in the region. Next was Osogbo region where the node voltage profiles improved by 2.636% and 4.360% for the 330kV grid network and 132kV sub-grid network respectively. Others are Enugu with 0.451% and 3.002% improvement for the 330kV grid and 132kV sub-grid networks respectively, Lagos with 0.279% and 0.731% improvement respectively for the 330kV grid and 132kV sub-grid networks respectively, Port-Harcourt, Benin, Kaduna and Shiroro regions with 0.195% and 0.720%; 0.165% and 1.440%; 0.032% and 0.561%; 0.000% and 0.358% improvements for their 330kV grid networks and 132kV sub-grid networks respectively.

It is to be noted that Shiroro region recorded a voltage profile improvement of 0.000% in its grid network when the technology was implemented within the region because a FACTS device was installed in the region to correct the very poor voltages profiles of the nodes within the region to ensure stability. This helped reduce the active power losses in the region and also helped improve the voltage profile across the region.

On the distribution network, Bauchi region has the best voltage profile improvement of 15.842%. It is followed by Benin region which has an improvement of 12.747%. Others are Enugu, Osogbo, Port-Harcourt, Lagos, Kaduna and Shiroro regions with voltages profiles improvement of 6.635%, 6.260%, 1.471%, 1.137%, 1.059%, 0.674% respectively in their distribution network.

5.1.3 Transmission Lines Decongestion

With the integration of DG technology in the Nigerian power system, there was a decongestion of transmission lines within the grid system due to a redistribution of power flows. This is as summarised in tables 5.3a and 5.3b below.

Table 5.3a: Transmission lines decongestion due to DG installation

		330/132/33kV Network	**Bauchi**	**Benin**	**Enugu**	**Osogbo**	**Kaduna**	**Lagos**	**Port-Harcourt**	**Shiroro**	**Most % Drop**	**Region DG Installed**
From Region	**To Region**	**P Tie (MW)**	**P Tie (MW)**	**P Tie (MW)**	**P Tie (MW)**	**P Tie (MW)**	**P Tie (MW)**	**P Tie (MW)**	**P Tie (MW)**	**P Tie (MW)**		
Bauchi	Enugu	-2028.9	-2020.16	-2027.62	-2027.18	-2023.6	-2011.67	-2028.85	-2029.26	-2027.51	0.849	Kaduna
Bauchi	Kaduna	1161.989	1202.558	1160.715	1160.275	1156.692	1144.775	1161.947	1162.349	1160.601	1.481	Kaduna
Benin	Enugu	779.659	772.161	778.553	775.283	775.091	764.715	779.646	778.757	778.451	1.917	Kaduna
Benin	Lagos	383.002	386.247	383.185	384.327	364.809	392.719	382.973	383.131	383.986	4.750	Osogbo
Benin	Osogbo	358.402	361.184	358.539	359.536	383.718	367.165	358.529	358.502	359.196	-0.028	Port-Harcourt
Benin	Port-Harcourt	225.464	224.093	225.262	226.477	224.573	222.755	225.426	226.269	225.245	1.202	Kaduna
Benin	Shiroro	471.663	474.345	473.452	472.527	470.335	470.534	471.643	471.543	471.288	0.282	Osogbo
Enugu	Port-Harcourt	-1760.57	-1759.23	-1760.37	-1761.54	-1759.71	-1757.95	-1760.53	-1761.81	-1760.36	0.149	Kaduna
Kaduna	Shiroro	-156.965	-116.421	-158.242	-158.673	-162.235	-134.174	-157.011	-156.607	-158.357	25.830	Bauchi
Lagos	Osogbo	-135.906	-137.035	-136.555	-136.176	-158.591	-127.711	-136.021	-136.247	-137.619	6.038	Kaduna
Osogbo	Shiroro	-560.186	-558.553	-560.7	-559.327	-553.607	-543.279	-560.161	-560.428	-561.112	3.018	Kaduna

Table 5.3b: Transmission lines decongestion due to DG installation

		330/132/33kV Network	**Bauchi**	**Benin**	**Enugu**	**Osogbo**	**Kaduna**	**Lagos**	**Port-Harcourt**	**Shiroro**	**Most % Drop**	**Region DG Installed**
From Region	**To Region**	**Q Tie (MVar)**	**Q Tie (MVar)**	**Q Tie (MVar)**	**Q Tie (MVar)**	**Q Tie (MVar)**	**Q Tie (MVar)**	**Q Tie (MVar)**	**Q Tie (MVar)**	**Q Tie (MVar)**		
Bauchi	Enugu	930.003	1011.442	933.155	929.835	933.688	972.617	932.174	930.075	931.597	-4.381	Kaduna
Bauchi	Kaduna	-582.055	-582.886	-585.146	-581.766	-585.647	-623.845	-584.18	-582.125	-583.616	-6.699	Kaduna
Benin	Enugu	-118.979	-119.527	-118.897	-132.061	-115.944	-119.002	-117.423	-118.95	-118.973	-0.019	Kaduna
Benin	Lagos	50.307	49.779	50.298	51.811	47.597	48.281	47.64	50.291	50.11	5.694	Osogbo
Benin	Osogbo	150.296	149.957	150.283	151.598	142.353	148.789	146.308	150.289	150.17	0.005	Port-Harcourt
Benin	Port-Harcourt	-24.461	-24.437	-24.449	-24.068	-24.073	-24.446	-24.255	-24.441	-24.461	0.061	Kaduna
Benin	Shiroro	41.143	40.349	44.878	40.945	40.733	40.36	40.842	41.155	40.847	1.007	Osogbo

		330/132/33kV Network	Bauchi	Benin	Enugu	Osogbo	Kaduna	Lagos	Port-Harcourt	Shiroro	Most % Drop	Region DG Installed
From Region	**To Region**	**Q Tie (MVar)**	**Q Tie (MVar)**	**Q Tie (MVar)**	**Q Tie (MVar)**	**Q Tie (MVar)**	**Q Tie (MVar)**	**Q Tie (MVar)**	**Q Tie (MVar)**	**Q Tie (MVar)**		
Enugu	Port-Harcourt	352.032	432.621	355.436	385.063	359.782	396.831	355.782	352.269	353.855	-11.289	Kaduna
Kaduna	Shiroro	-169.292	-168.707	-172.313	-168.825	-172.237	-174.305	-171.229	-169.37	-170.832	0.347	Bauchi
Lagos	Osogbo	140.712	140.166	140.339	139.26	45.26	136.148	145.369	140.76	140.79	3.352	Kaduna
Osogbo	Shiroro	-378.513	-379.552	-378.9	-378.635	-376.463	-384.942	-377.165	-378.481	-378.621	-1.670	Kaduna

From tables 5.3a and 5.3b, it is observed that the most reduction in grid active line flows was achieved when the DG units were installed in Kaduna region. This can be attributed to the fact that Kaduna region is the gateway to the North-Eastern and North-Western parts of the country as power flows to those parts of the country pass through the region. This is compounded by the non-availability of power generating stations in those parts of the country, hence the regions import power from the Southern part of the country.

The most improvement in transmission tie lines decongestion was with the installation of the DG units in Bauchi region as there was a 25.830% reduction of power flow across the tie lines. However, the grid tie lines were slightly more congested, by 0.028%, when the DG units were installed in Port-Harcourt region.

5.2 Contribution to Knowledge

The following are my contributions to knowledge after undertaking this research:

i. Application of the distributed generation technology in the Nigerian power system will bring about improved node voltages profiles, thus improving the quality and stability of the Nigerian power system.

ii. With the application of the distributed generation technology in the Nigerian power system, there will be decongestion of the Nigerian grid transmission lines with an attendant reduction in transmission line losses.

iii. In this work, the Nigerian 330kV grid system was successfully expanded to a 60-bus network from the present 32-bus network, thus creating a roadmap for the expansion of the grid network.

5.3 Conclusion

Nigeria has tremendous natural energy resources in the form of water, wind, plentiful sunshine, natural gas and mineral resources yet it is highly energy deficient. That Nigerians are not able to harness the benefits of these energy resources to solve her aching need is a classic developmental paradox. This problem can be solved economically with the integration of distributed generation technology in the power production mix of Nigeria, using the abundant energy resources in the country.

The impact of the integration of DG technology in the Nigerian grid was studied in this work. The grid network witnessed a drop both in losses and line flows, with the integration, along with improvements of the voltage profiles across the nodes. Also, with the reduction in line flows, the need for the reinforcement of the power network was deferred in some zones, thus paving the way for the use of scarce resource in carrying out other important developmental projects.

From this research, it is observed that DG technology can be installed in all regions of the country but the most viable places to install the technology are in the Northern part of the country as represented by Bauchi, Shiroro and Kaduna regions.

One unique feature of DG technology is that fuels from the community where it is installed will be used to run it. Our cosmopolitan cities, such as Lagos, Abuja, Kano, Port-Harcourt and others can use the waste products generated in the cities to run biomass plants. This will have the dual advantage of keeping the cities and towns clean as well as providing electrical energy for use. The abundant sunshine in the Northern part of the country such as Sokoto and Maiduguri could be used to run solar PVCs. The coastal regions of the South-East and South-South such as Warri, Lagos and Port-Harcourt, boast of good wind velocity and it can be harnessed with wind turbines to provide electrical power. The rivers and the waterfalls of the Central region could be harnessed into micro-turbines to provide power for the isolated communities in the Adamawa highlands and Jos plateaus and the fossil fuels found in the South-East and South-South such as coal in Enugu, could be used to generate power.

5.4 Further Research

Since DG technologies are connected in the distribution networks of the power system, it tends to cause some difficulties such as protection distortion problems due to dual power flow in the network, short circuit currents increase, voltage distortion problems arise and congestions can appear in network branches. A further research into the mitigation of these problems is highly recommended.

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APPENDIX

I. DATA OF GENERATORS OF THE NIGERIAN POWER SYSTEM

I. A

Bus Number	Bus Name	Zone Name	PGen (MW)	PMax (MW)	PMin (MW)	QGen (Mvar)	QMax (Mvar)	QMin (Mvar)
117	EGBIN ST 1 16.000	LAGOS	0	220	0	95.9	95.9	-30
118	EGBIN ST 2 16.000	LAGOS	187.8504	220	0	28.2895	95.9	-30
119	EGBIN ST 3 16.000	LAGOS	0	220	0	85.3252	95.9	-30
120	EGBIN ST 4 16.000	LAGOS	169	220	0	27.4544	95.9	-30
121	EGBIN ST 5 16.000	LAGOS	173	220	0	27.6211	95.9	-30
122	EGBIN ST 6 16.000	LAGOS	0	220	0	68.596	95.9	-30
135	IJORA GT 4-611.000	LAGOS	0	20	0	0	12	-10
143	AES BERG202 11.000	LAGOS	0	33	0	0.7062	14.5	-10
144	AES BERG203 11.000	LAGOS	0	33	0	14.5	14.5	-10
145	AES BERG204 11.000	LAGOS	0	32.4	0	0.7626	14.5	-10
146	AES BERG205 11.000	LAGOS	0	32.4	0	2.3892	14.5	-10
147	AES BERG207 11.000	LAGOS	0	32.6	0	2.395	14.5	-10
148	AES BERG208 11.000	LAGOS	0	32.6	0	14.455	14.5	-10
149	AES BERG209 11.000	LAGOS	0	32.6	0	14.455	14.5	-10
150	AES BERG210 11.000	LAGOS	0	40	0	5.8402	14.5	-10
151	AES BERG211 11.000	LAGOS	0	40	0	5.8402	14.5	-10
152	OLORUNSO GT110.500	LAGOS	32.3	38	0	-15	23	-15
153	OLORUNSO GT210.500	LAGOS	34.3	38	0	-15	23	-15
154	OLORUNSO GT310.500	LAGOS	35.4	38	0	-11.7936	23	-15
155	OLORUNSO GT410.500	LAGOS	34.8	38	0	-15	23	-15
156	OLORUNSO GT510.500	LAGOS	33.5	38	0	-15	23	-15
157	OLORUNSO GT610.500	LAGOS	34	38	0	-15	23	-15
158	OLORUNSO GT710.500	LAGOS	0	38	0	10.928	23	-15
159	OLORUNSO GT810.500	LAGOS	0	38	0	10.412	23	-15
160	OLORNIPPGT1110.500	LAGOS	0	120	0	13.9719	70.5	-25
161	OLORNIPPGT1210.500	LAGOS	0	120	0	-13.57	70.5	-25
162	OLORNIPPGT2110.500	LAGOS	0	120	0	15.6853	70.5	-25
163	OLORNIPPGT2210.500	LAGOS	0	120	0	10.928	70.5	-25
164	OLOR NIPPST110.500	LAGOS	0	120	0	10.412	70.5	-25
165	OLOR NIPPST210.500	LAGOS	0	120	0	10.412	70.5	-25
248	OMOTOSO GT1 10.500	OSOGBO	36.5	38	0	-15	23	-15
248	OMOTOSO GT1 10.500	OSOGBO	35.9	38	0	-15	23	-15
249	OMOTOSO GT3 10.500	OSOGBO	36.6	38	0	-3.5372	23	-15
249	OMOTOSO GT3 10.500	OSOGBO	35.8	38	0	-3.4599	23	-15
250	OMOTOSO GT5 10.500	OSOGBO	0	38	0	0.7198	23	-15
250	OMOTOSO GT5 10.500	OSOGBO	0	38	0	1.6553	23	-15
251	OMOTOSO GT7 10.500	OSOGBO	0	38	0	3.363	23	-15
251	OMOTOSO GT7 10.500	OSOGBO	0	38	0	23	23	-15
252	OMOTNIPP GT110.500	OSOGBO	0	250	0	-21.7968	100	-45
253	OMOTNIPP GT210.500	OSOGBO	106.5	250	0	-40.7535	100	-45
254	OMOTNIPP GT310.500	OSOGBO	0	250	0	0	100	-45
255	OMOTNIPP GT410.500	OSOGBO	0	250	0	0	100	-45
347	KAINJ 1G5 16.000	SHIRORO	119	120	0	-14.5121	37.5	-30
348	KAINJ 1G6 16.000	SHIRORO	119	120	0	-14.5121	37.5	-30
349	KAINJ 1G7-8 16.000	SHIRORO	0	80	0	5.7441	25	-30

Bus Number	Bus Name	Zone Name	PGen (MW)	PMax (MW)	PMin (MW)	QGen (Mvar)	QMax (Mvar)	QMin (Mvar)
349	KAINJ 1G7-8 16.000	SHIRORO	0	80	0	5.7441	25	-30
350	KAINJ 1G9-1016.000	SHIRORO	0	80	0	0	25	-30
350	KAINJ 1G9-1016.000	SHIRORO	83	80	0	-14.5121	25	-30
351	KAINJ 1G11 16.000	SHIRORO	91	100	0	-14.5121	35.9	-30
352	KAINJ 1G12 16.000	SHIRORO	0	100	0	-17.6277	35.9	-30
353	JEBBA 2G1 16.000	SHIRORO	94	90	0	-4.5958	47.4	-30
354	JEBBA 2G2 16.000	SHIRORO	96	90	0	-4.5081	47.4	-30
355	JEBBA 2G3 16.000	SHIRORO	95	90	0	-4.5524	47.4	-30
356	JEBBA 2G4 16.000	SHIRORO	94	90	0	-4.5958	47.4	-30
357	JEBBA 2G5 16.000	SHIRORO	95	90	0	-4.5524	47.4	-30
358	JEBBA 2G6 16.000	SHIRORO	0	90	0	-20.119	47.4	-30
359	SHIROR 411G116.000	SHIRORO	140	150	0	0.7708	79	-30
360	SHIROR 411G216.000	SHIRORO	0	150	0	-6.7633	79	-30
361	SHIROR 411G316.000	SHIRORO	143	150	0	0.8626	79	-30
362	SHIROR 411G416.000	SHIRORO	0	150	0	26.093	79	-30
420	DELTA1 GT1 11.500	BENIN	0	30	0	-10	13	-10
421	DELTA1 GT2 11.500	BENIN	20	30	0	-10	13	-10
422	DELTA2 GT3-511.500	BENIN	20	30	0	11.986	12	-9
422	DELTA2 GT3-511.500	BENIN	20	30	0	9.8786	12	-9
422	DELTA2 GT3-511.500	BENIN	20	30	0	11.986	12	-9
423	DELTA2 GT6-811.500	BENIN	20	20	0	9.3721	12	-9
423	DELTA2 GT6-811.500	BENIN	20	20	0	11.986	12	-9
423	DELTA2 GT6-811.500	BENIN	20	20	0	11.986	12	-9
424	DELT3 GT9-1111.500	BENIN	0	20	0	8.462	12	-9
424	DELT3 GT9-1111.500	BENIN	0	20	0	8.462	12	-9
424	DELT3 GT9-1111.500	BENIN	0	20	0	8.462	12	-9
425	DELT3GT12-1411.500	BENIN	0	20	0	8.462	12	-9
425	DELT3GT12-1411.500	BENIN	0	20	0	-9	12	-9
425	DELT3GT12-1411.500	BENIN	0	20	0	-9	12	-9
426	DELTA GT 15 11.500	BENIN	0	120	0	-30	60	-30
427	DELTA GT16 11.500	BENIN	83	100	0	25.29	60	-30
428	DELTA GT17 11.500	BENIN	0	100	0	-2.47	60	-30
429	DELTA GT18 11.500	BENIN	90	100	0	-30	60	-30
430	DELTA GT19 11.500	BENIN	87	100	0	1.8237	60	-30
431	DELTA GT20 11.500	BENIN	0	100	0	45.24	60	-30
432	SAPELE GT1-215.800	BENIN	61	60	0	-7.7708	52.3	-30
432	SAPELE GT1-215.800	BENIN	111.8	60	0	-14.2423	52.3	-30
433	SAPELE GT3-415.800	BENIN	0	60	0	28.9978	52.3	-30
433	SAPELE GT3-415.800	BENIN	0	60	0	52.3	52.3	-30
434	SAPELE ST1 15.800	BENIN	0	120	0	-9.6057	52.3	-30
435	SAPELE ST2 15.800	BENIN	108.6	120	0	-9.8179	52.3	-30
436	SAPELE ST3 15.800	BENIN	0	120	0	48.4627	52.3	-30
437	SAPELE ST4 15.800	BENIN	0	120	0	52.3	52.3	-30
438	SAPELE ST5 15.800	BENIN	0	120	0	52.3	52.3	-30
439	GEREGU GT11 10.500	BENIN	115	150	0	7.0662	85	-45
440	GEREGU GT12 10.500	BENIN	115	150	0	-45	85	-45
441	GEREGU GT13 10.500	BENIN	0	150	0	18	108.5	-72.3
442	GER NIPPGT2110.500	BENIN	130	145	0	7.0662	85	-45
443	GER NIPPGT2210.500	BENIN	0	145	0	50.75	85	-45
444	GER NIPPGT2310.500	BENIN	0	145	0	50.75	85	-45
446	IHOVBOR_GTB215.000	BENIN	103.1	120	0	-12.4876	60	-40
447	IHOVBOR_GTB315.000	BENIN	0	120	0	-0.2597	60	-40

Bus Number	Bus Name	Zone Name	PGen (MW)	PMax (MW)	PMin (MW)	QGen (Mvar)	QMax (Mvar)	QMin (Mvar)
448	IHOVBOR_GTB415.000	BENIN	0	120	0	-40	60	-40
449	GEN DANGOTE 15.000	BENIN	0	500	0	36.88	310	-206
450	OBAJANA 15.000	BENIN	0	150	0	75	75	-60
563	KT WF 33 33.000	KADUNA	0	10	0	0	0	0
566	GURARA GBUS 11.500	KADUNA	0	30	0	0	0	0
568	GEN_KADUNA 15.000	KADUNA	0	215	0	16.4263	133.2	-88.8
594	JOS 3 330.00	BAUCHI	0	9999	-9999	6.489	9999	-9999
596	MAIDUGURI 3 330.00	BAUCHI	0	9999	-9999	-91.383	9999	-9999
635	KAFANC M TR133.000	BAUCHI	0	10	8	3.844	7	-7
647	NHAVEN 1 132.00	ENUGU	0	9999	-9999	232.05	9999	-9999
741	OKPAI GT11 11.500	ENUGU	62	178.5	3	-18.033	110	-60
742	OKPAI GT12 11.500	ENUGU	118	178.5	3	-15.7515	110	-60
743	OKPAI ST18 11.500	ENUGU	118	178.5	3	-15.7515	110	-60
834	AFAM1GT1-2 11.500	PT HARCO	0	12.5	0	6	6	-3
834	AFAM1GT1-2 11.500	PT HARCO	0	12.5	0	6	6	-3
835	AFAM1GT3-4 11.500	PT HARCO	0	20	0	10	10	-8
835	AFAM1GT3-4 11.500	PT HARCO	0	20	0	10	10	-8
836	AFAM2 GT5-6 11.500	PT HARCO	0	24	0	15	15	-10
836	AFAM2 GT5-6 11.500	PT HARCO	0	24	0	15	15	-10
837	AFAM2GT 7-8 11.500	PT HARCO	0	24	0	15	15	-10
837	AFAM2GT 7-8 11.500	PT HARCO	0	24	0	15	15	-10
838	AFAM3 GT9-1011.500	PT HARCO	0	27.2	0	3.492	18	-13
838	AFAM3 GT9-1011.500	PT HARCO	0	27.2	0	3.492	18	-13
839	AFAM3GT11-1211.500	PT HARCO	0	27.2	0	3.492	18	-13
839	AFAM3GT11-1211.500	PT HARCO	0	27.2	0	3.492	18	-13
840	AFAM4GT13-1411.500	PT HARCO	0	67.5	0	12.02	79.6	-50
840	AFAM4GT13-1411.500	PT HARCO	0	67.5	0	12.02	79.6	-50
841	AFAM4GT15-1611.500	PT HARCO	0	67.5	0	12.02	79.6	-50
841	AFAM4GT15-1611.500	PT HARCO	0	67.5	0	12.02	79.6	-50
842	AFAM4GT17-1811.500	PT HARCO	0	65	0	12.02	79.6	-50
842	AFAM4GT17-1811.500	PT HARCO	0	65	0	12.02	79.6	-50
843	AFAMV GT 19 11.500	PT HARCO	0	138	0	-5.8856	85	-45
844	AFAMV GT 20 11.500	PT HARCO	0	138	0	32.1017	85	-45
845	AFAM VI GT1111.500	PT HARCO	129	150	0	-5.8738	90	-50
846	AFAM VI GT1211.500	PT HARCO	0	150	0	-8.3018	90	-50
847	AFAM VI GT1311.500	PT HARCO	119	150	0	-6.5133	90	-50
848	AFAM VI ST1011.500	PT HARCO	0	150	0	91	91	-50
854	OMOKU2 GT1 15.000	PT HARCO	61.7	112.5	0	15.5827	70	-46
855	OMOKU2 GT2 15.000	PT HARCO	0	112.5	0	18.133	84.4	-56.3
856	OMOKU1 GT1 15.000	PT HARCO	0	50	0	4.87	27	-20
857	OMOKU1 GT2 15.000	PT HARCO	0	50	0	4.87	27	-20
858	IBOM GT1 11.500	PT HARCO	0	39	0	6.9314	24	-20
859	IBOM GT2 11.500	PT HARCO	0	39	0	6.9314	24	-20
860	IBOM GT3 11.500	PT HARCO	38.6	115	0	11.1156	24	-20
861	RIVERS _GT1 10.500	PT HARCO	0	150	0	3.3485	50	-70
862	RIVERS_GT2 10.500	PT HARCO	61.5	150	0	50	50	-70
863	ALAOJI_GTB2 15.000	PT HARCO	0	125	0	-6.548	84.4	-56.3
864	ALAOJI_GTB3 15.000	PT HARCO	0	125	0	-33.9855	84.4	-56.3
865	ALAOJI_GTB4 15.000	PT HARCO	0	125	0	-12.9345	84.4	-56.3
866	ALAOJI_STB1 17.000	PT HARCO	0	255	0	-7.1985	158	-105
867	ALAOJI_STB2 17.000	PT HARCO	0	255	0	-7.1984	158	-105
868	ALAOJI_GTB1 15.000	PT HARCO	117.4	112.5	0	-33.1982	84.4	-56.3

Bus Number	Bus Name	Zone Name	PGen (MW)	PMax (MW)	PMin (MW)	QGen (Mvar)	QMax (Mvar)	QMin (Mvar)
869	GEOMETRIC_AB15.000	PT HARCO	0	728	0	-12.36	360	-180
870	NOTORE 15.000	PT HARCO	0	525	0	237	237	-150
871	GEN_AMADI 15.000	PT HARCO	0	124	0	44.582	93.75	-62.5
872	CALABAR_GTB315.000	PT HARCO	96.7	125	0	0.9092	84.4	-56.3
873	CALABAR_GTB215.000	PT HARCO	94.4	125	0	0.7185	84.4	-56.3
874	CALABAR_GTB115.000	PT HARCO	96.3	125	0	0.8756	84.4	-56.3
875	CALABAR_GTB415.000	PT HARCO	0	125	0	8.5961	84.4	-56.3
876	CALABAR_GTB515.000	PT HARCO	0	125	0	8.5961	84.4	-56.3
877	EGBEMA_GTB1 15.000	PT HARCO	0	112.5	0	15.797	84.4	-56.3
878	EGBEMA_GTB2 15.000	PT HARCO	0	112.5	0	15.797	84.4	-56.3
879	EGBEMA_GTB3 15.000	PT HARCO	0	112.5	0	15.797	84.4	-56.3
880	GABARIN_GTB115.000	PT HARCO	109.7	112.5	0	14.4107	84.4	-56.3
881	GABARIN_GTB215.000	PT HARCO	0	112.5	0	14.169	84.4	-56.3
882	SAPELE ST6 15.800	BENIN	0	120	0	47.3816	52.3	-30
884	NEW_PV_GEN 15.800	KADUNA	0	100	0	-9.0156	48.43	-48.43
886	IBOMGT 11.500	PT HARCO	0	39	9.75	4.0159	29.25	-17.55
887	IBOMGT 11.500	PT HARCO	0	41	10.25	4.1297	30.75	-18.45
888	KANKIA PV 33.000	KADUNA	0	75	0	-5.3002	36.3242	-36.3242
10006	PARAS ENERGY11.500	LAGOS	69.4	90	0	-12	25	-12

I. B

Bus Number	Base (MVA)	R Source (pu)	X Source (pu)	RTran (pu)	XTran (pu)	Gentap (pu)	Positive R (pu)	Sub-transient X (pu)	Transient X (pu)
117	245.8	0	0.23	0	0	1	0	0.23	0.23
118	245.8	0	0.23	0	0	1	0	0.23	0.23
119	245.8	0	0.23	0	0	1	0	0.23	0.23
120	245.8	0	0.23	0	0	1	0	0.23	0.23
121	245.8	0	0.23	0	0	1	0	0.23	0.23
122	245.8	0	0.23	0	0	1	0	0.23	0.23
135	32	0	0.142	0	0	1	0	0.142	0.142
143	39	0	0.133	0	0	1	0	0.133	0.133
144	39	0	0.133	0	0	1	0	0.133	0.133
145	39	0	0.133	0	0	1	0	0.133	0.133
146	39.54	0	0.133	0	0	1	0	0.133	0.133
147	39.54	0	0.133	0	0	1	0	0.133	0.133
148	39.54	0	0.133	0	0	1	0	0.133	0.133
149	40.5	0	0.133	0	0	1	0	0.133	0.133
150	50	0	0.133	0	0	1	0	0.133	0.133
151	50	0	0.133	0	0	1	0	0.133	0.133
152	52.3	0	0.148	0	0	1	0	0.148	0.148
153	52.3	0	0.148	0	0	1	0	0.148	0.148
154	52.3	0	0.148	0	0	1	0	0.148	0.148

Bus Number	Base (MVA)	R Source (pu)	X Source (pu)	RTran (pu)	XTran (pu)	Gentap (pu)	Positive R (pu)	Sub-transient X (pu)	Transient X (pu)
155	52.3	0	0.148	0	0	1	0	0.148	0.148
156	52.3	0	0.148	0	0	1	0	0.148	0.148
157	52.3	0	0.148	0	0	1	0	0.148	0.148
158	52.3	0	0.148	0	0	1	0	0.148	0.148
159	52.3	0	0.148	0	0	1	0	0.148	0.148
160	150	0	0.161	0	0	1	0	0.148	0.148
161	150	0	0.161	0	0	1	0	0.148	0.148
162	150	0	0.161	0	0	1	0	0.148	0.148
163	150	0	0.161	0	0	1	0	0.148	0.148
164	150	0	0.148	0	0	1	0	0.148	0.148
165	150	0	0.148	0	0	1	0	0.148	0.148
248	52.3	0	0.148	0	0	1	0	0.148	0.148
248	52.3	0	0.148	0	0	1	0	0.148	0.148
249	52.3	0	0.148	0	0	1	0	0.148	0.148
249	52.3	0	0.148	0	0	1	0	0.148	0.148
250	52.3	0	0.148	0	0	1	0	0.148	0.148
250	52.3	0	0.148	0	0	1	0	0.148	0.148
251	52.3	0	0.148	0	0	1	0	0.148	0.148
251	52.3	0	0.148	0	0	1	0	0.148	0.148
252	312.5	0	0.148	0	0	1	0	0.148	0.148
253	312.5	0	0.148	0	0	1	0	0.148	0.148
254	312.5	0	0.148	0	0	1	0	0.148	0.148
255	312.5	0	0.148	0	0	1	0	0.148	0.148
347	125	0	0.22	0	0	1	0	0.172	0.172
348	125	0	0.22	0	0	1	0	0.2	0.2
349	85	0	0.22	0	0	1	0	0.22	0.22
349	85	0	0.22	0	0	1	0	0.22	0.22
350	85	0	0.22	0	0	1	0	0.2	0.2
350	85	0	0.22	0	0	1	0	0.2	0.2
351	115	0	0.22	0	0	1	0	0.2	0.2
352	115	0	0.22	0	0	1	0	0.2	0.2
353	119	0	0.24	0	0	1	0	0.26	0.26
354	119	0	0.24	0	0	1	0	0.26	0.26
355	119	0	0.24	0	0	1	0	0.26	0.26
356	119	0	0.24	0	0	1	0	0.26	0.26
357	119	0	0.24	0	0	1	0	0.26	0.26
358	119	0	0.24	0	0	1	0	0.26	0.26
359	177	0	0.23	0	0	1	0	0.2	0.2
360	177	0	0.23	0	0	1	0	0.2	0.2
361	177	0	0.23	0	0	1	0	0.2	0.2
362	177	0	0.23	0	0	1	0	0.2	0.2
420	40	0	0.276	0	0	1	0	0.276	0.276
421	40	0	0.276	0	0	1	0	0.276	0.276
422	25	0	0.13	0	0	1	0	0.276	0.276
422	25	0	0.13	0	0	1	0	0.276	0.276
422	25	0	0.13	0	0	1	0	0.276	0.276
423	25	0	0.13	0	0	1	0	0.276	0.276
423	25	0	0.13	0	0	1	0	0.276	0.276
423	25	0	0.13	0	0	1	0	0.276	0.276
424	25	0	0.115	0	0	1	0	0.276	0.276
424	25	0	0.115	0	0	1	0	0.276	0.276

Bus Number	Base (MVA)	R Source (pu)	X Source (pu)	RTran (pu)	XTran (pu)	Gentap (pu)	Positive R (pu)	Sub-transient X (pu)	Transient X (pu)
424	25	0	0.115	0	0	1	0	0.276	0.276
425	25	0	0.115	0	0	1	0	0.276	0.276
425	25	0	0.115	0	0	1	0	0.276	0.276
425	25	0	0.115	0	0	1	0	0.276	0.276
426	117.65	0	0.19	0	0	1	0	0.276	0.276
427	117.65	0	0.19	0	0	1	0	0.276	0.276
428	117.65	0	0.19	0	0	1	0	0.276	0.276
429	117.65	0	0.19	0	0	1	0	0.276	0.276
430	117.65	0	0.19	0	0	1	0	0.276	0.276
431	117.65	0	0.19	0	0	1	0	0.276	0.276
432	75	0	0.13	0	0	1	0	0.133	0.133
432	75	0	0.13	0	0	1	0	0.133	0.133
433	75	0	0.13	0	0	1	0	0.133	0.133
433	75	0	0.13	0	0	1	0	0.133	0.133
434	133.97	0	0.16	0	0	1	0	0.16	0.16
435	133.97	0	0.16	0	0	1	0	0.16	0.16
436	133.97	0	0.16	0	0	1	0	0.16	0.16
437	133.97	0	0.16	0	0	1	0	0.16	0.16
438	133.97	0	0.16	0	0	1	0	0.16	0.16
439	174	0	0.17	0	0	1	0	0.148	0.148
440	174	0	0.17	0	0	1	0	0.148	0.148
441	174	0	0.17	0	0	1	0	0.148	0.148
442	226.6	0	0.148	0	0	1	0	0.148	0.148
443	226.6	0	0.148	0	0	1	0	0.148	0.148
444	226.6	0	0.148	0	0	1	0	0.148	0.148
446	141.3	0	0.145	0	0	1	0	1	1
447	145	0	0.145	0	0	1	0	1	1
448	141.3	0	0.145	0	0	1	0	1	1
449	588.2	0	1	0	0	1	0	1	1
450	141.25	0	1	0	0	1	0	1	1
563	10	0	1	0	0	1	0	1	1
566	45	0	0.24	0	0	1	0	1	1
568	252.9	0	0.23	0	0	1	0	1	1
594	100	0	1	0	0	1	0	1	1
596	100	0	1	0	0	1	0	1	1
635	15	0	1	0	0	1	0	1	1
647	100	0	1	0	0	1	0	1	1
741	210	0	0.14	0	0	1	0	0.133	0.133
742	210	0	0.14	0	0	1	0	0.133	0.133
743	210	0	0.14	0	0	1	0	0.133	0.133
834	16	0	0.133	0	0	1	0	0.133	0.133
834	16	0	0.133	0	0	1	0	0.133	0.133
835	25	0	0.133	0	0	1	0	0.133	0.133
835	25	0	0.133	0	0	1	0	0.133	0.133
836	30	0	0.133	0	0	1	0	0.133	0.133
836	30	0	0.133	0	0	1	0	0.133	0.133
837	30	0	0.133	0	0	1	0	0.133	0.133
837	30	0	0.133	0	0	1	0	0.133	0.133
838	34	0	0.133	0	0	1	0	0.133	0.133
838	34	0	0.133	0	0	1	0	0.133	0.133
839	34	0	0.133	0	0	1	0	0.133	0.133

Bus Number	Base (MVA)	R Source (pu)	X Source (pu)	RTran (pu)	XTran (pu)	Gentap (pu)	Positive R (pu)	Sub-transient X (pu)	Transient X (pu)
839	34	0	0.133	0	0	1	0	0.133	0.133
840	83.3	0	0.133	0	0	1	0	0.133	0.133
840	83.3	0	0.133	0	0	1	0	0.133	0.133
841	83.3	0	0.133	0	0	1	0	0.133	0.133
841	83.3	0	0.133	0	0	1	0	0.133	0.133
842	83.3	0	0.133	0	0	1	0	0.133	0.133
842	83.3	0	0.133	0	0	1	0	0.133	0.133
843	162.7	0	0.2	0	0	1	0	0.133	0.133
844	162.7	0	0.2	0	0	1	0	0.133	0.133
845	176	0	0.133	0	0	1	0	0.133	0.133
846	176	0	0.133	0	0	1	0	0.133	0.133
847	176	0	0.133	0	0	1	0	0.133	0.133
848	176	0	0.12	0	0	1	0	1	1
854	141.25	0	0.16	0	0	1	0	1	1
855	141.25	0	0.16	0	0	1	0	1	1
856	57	0	0.16	0	0	1	0	0.2	0.2
857	57	0	0.16	0	0	1	0	0.2	0.2
858	46	0	0.17	0	0	1	0	0.2	0.2
859	46	0	0.17	0	0	1	0	0.2	0.2
860	46	0	0.16	0	0	1	0	0.2	0.2
861	176	0	0.148	0	0	1	0	0.148	0.148
862	176	0	0.148	0	0	1	0	0.148	0.148
863	141.25	0	0.16	0	0	1	0	1	1
864	141.25	0	0.16	0	0	1	0	1	1
865	141.25	0	0.16	0	0	1	0	1	1
866	382	0	0.16	0	0	1	0	1	1
867	382	0	0.16	0	0	1	0	1	1
868	141.25	0	0.16	0	0	1	0	1	1
869	856.47	0	1	0	0	1	0	1	1
870	617.6	0	1	0	0	1	0	1	1
871	156.25	0	1	0	0	1	0	1	1
872	141.25	0	0.148	0	0	1	0	1	1
873	141.25	0	0.16	0	0	1	0	1	1
874	141.25	0	0.16	0	0	1	0	1	1
875	141.25	0	0.16	0	0	1	0	1	1
876	141.25	0	0.16	0	0	1	0	1	1
877	141.25	0	0.148	0	0	1	0	1	1
878	141.25	0	0.148	0	0	1	0	1	1
879	141.25	0	0.148	0	0	1	0	1	1
880	141.25	0	0.148	0	0	1	0	1	1
881	141.25	0	0.148	0	0	1	0	1	1
882	133.97	0	0.16	0	0	1	0	0.16	0.16
884	111.11	0	9999	0	0	1	0	1	1
886	48.75	0	0.22	0	0	1	0	1	1
887	51.25	0	0.22	0	0	1	0	1	1
888	83.33	0	9999	0	0	1	0	1	1
10006	105	0	0.156	0	0	1	0	1	1

I. C

Bus Number	Synchronous X (pu)	Negative R (pu)	Negative X (pu)	Zero R (pu)	Zero X (pu)	Grounding Z units	Grounding R	Grounding X
117	0.23	0	0.23	0	0.23	P.U.	0	0
118	0.23	0	0.23	0	0.23	P.U.	0	0
119	0.23	0	0.23	0	0.23	P.U.	0	0
120	0.23	0	0.23	0	0.23	P.U.	0	0
121	0.23	0	0.23	0	0.23	P.U.	0	0
122	0.23	0	0.23	0	0.23	P.U.	0	0
135	0.142	0	0.142	0	0.142	P.U.	0	0
143	0.133	0	0.133	0	0.133	P.U.	0	0
144	0.133	0	0.133	0	0.133	P.U.	0	0
145	0.133	0	0.133	0	0.133	P.U.	0	0
146	0.133	0	0.133	0	0.133	P.U.	0	0
147	0.133	0	0.133	0	0.133	P.U.	0	0
148	0.133	0	0.133	0	0.133	P.U.	0	0
149	0.133	0	0.133	0	0.133	P.U.	0	0
150	0.133	0	0.133	0	0.133	P.U.	0	0
151	0.133	0	0.133	0	0.133	P.U.	0	0
152	0.148	0	0.148	0	0.148	P.U.	0	0
153	0.148	0	0.148	0	0.148	P.U.	0	0
154	0.148	0	0.148	0	0.148	P.U.	0	0
155	0.148	0	0.148	0	0.148	P.U.	0	0
156	0.148	0	0.148	0	0.148	P.U.	0	0
157	0.148	0	0.148	0	0.148	P.U.	0	0
158	0.148	0	0.148	0	0.148	P.U.	0	0
159	0.148	0	0.148	0	0.148	P.U.	0	0
160	0.148	0	0.148	0	0.148	P.U.	0	0
161	0.148	0	0.148	0	0.148	P.U.	0	0
162	0.148	0	0.148	0	0.148	P.U.	0	0
163	0.148	0	0.148	0	0.148	P.U.	0	0
164	0.148	0	0.148	0	0.148	P.U.	0	0
165	0.148	0	0.148	0	0.148	P.U.	0	0
248	0.148	0	0.148	0	0.148	P.U.	0	0
248	0.148	0	0.148	0	0.148	P.U.	0	0
249	0.148	0	0.148	0	0.148	P.U.	0	0
249	0.148	0	0.148	0	0.148	P.U.	0	0
250	0.148	0	0.148	0	0.148	P.U.	0	0
250	0.148	0	0.148	0	0.148	P.U.	0	0
251	0.148	0	0.148	0	0.148	P.U.	0	0
251	0.148	0	0.148	0	0.148	P.U.	0	0
252	0.148	0	0.148	0	0.148	P.U.	0	0
253	0.148	0	0.148	0	0.148	P.U.	0	0
254	0.148	0	0.148	0	0.148	P.U.	0	0
255	0.148	0	0.148	0	0.148	P.U.	0	0
347	0.172	0	0.172	0	0.172	P.U.	0	0
348	0.2	0	0.2	0	0.2	P.U.	0	0
349	0.22	0	0.22	0	0.22	P.U.	0	0
349	0.22	0	0.22	0	0.22	P.U.	0	0
350	0.2	0	0.2	0	0.2	P.U.	0	0
350	0.2	0	0.2	0	0.2	P.U.	0	0
351	0.2	0	0.2	0	0.2	P.U.	0	0

Bus Number	Synchronous X (pu)	Negative R (pu)	Negative X (pu)	Zero R (pu)	Zero X (pu)	Grounding Z units	Grounding R	Grounding X
352	0.2	0	0.2	0	0.2	P.U.	0	0
353	0.26	0	0.26	0	0.26	P.U.	0	0
354	0.26	0	0.26	0	0.26	P.U.	0	0
355	0.26	0	0.26	0	0.26	P.U.	0	0
356	0.26	0	0.26	0	0.26	P.U.	0	0
357	0.26	0	0.26	0	0.26	P.U.	0	0
358	0.26	0	0.26	0	0.26	P.U.	0	0
359	0.2	0	0.2	0	0.2	P.U.	0	0
360	0.2	0	0.2	0	0.2	P.U.	0	0
361	0.2	0	0.2	0	0.2	P.U.	0	0
362	0.2	0	0.2	0	0.2	P.U.	0	0
420	0.276	0	0.276	0	0.276	P.U.	0	0
421	0.276	0	0.276	0	0.276	P.U.	0	0
422	0.276	0	0.276	0	0.276	P.U.	0	0
422	0.276	0	0.276	0	0.276	P.U.	0	0
422	0.276	0	0.276	0	0.276	P.U.	0	0
423	0.276	0	0.276	0	0.276	P.U.	0	0
423	0.276	0	0.276	0	0.276	P.U.	0	0
423	0.276	0	0.276	0	0.276	P.U.	0	0
424	0.276	0	0.276	0	0.276	P.U.	0	0
424	0.276	0	0.276	0	0.276	P.U.	0	0
424	0.276	0	0.276	0	0.276	P.U.	0	0
425	0.276	0	0.276	0	0.276	P.U.	0	0
425	0.276	0	0.276	0	0.276	P.U.	0	0
425	0.276	0	0.276	0	0.276	P.U.	0	0
426	0.276	0	0.276	0	0.276	P.U.	0	0
427	0.276	0	0.276	0	0.276	P.U.	0	0
428	0.276	0	0.276	0	0.276	P.U.	0	0
429	0.276	0	0.276	0	0.276	P.U.	0	0
430	0.276	0	0.276	0	0.276	P.U.	0	0
431	0.276	0	0.276	0	0.276	P.U.	0	0
432	0.133	0	0.133	0	0.133	P.U.	0	0
432	0.133	0	0.133	0	0.133	P.U.	0	0
433	0.133	0	0.133	0	0.133	P.U.	0	0
433	0.133	0	0.133	0	0.133	P.U.	0	0
434	0.16	0	0.16	0	0.16	P.U.	0	0
435	0.16	0	0.16	0	0.16	P.U.	0	0
436	0.16	0	0.16	0	0.16	P.U.	0	0
437	0.16	0	0.16	0	0.16	P.U.	0	0
438	0.16	0	0.16	0	0.16	P.U.	0	0
439	0.148	0	0.148	0	0.148	P.U.	0	0
440	0.148	0	0.148	0	0.148	P.U.	0	0
441	0.148	0	0.148	0	0.148	P.U.	0	0
442	0.148	0	0.148	0	0.148	P.U.	0	0
443	0.148	0	0.148	0	0.148	P.U.	0	0
444	0.148	0	0.148	0	0.148	P.U.	0	0
446	1	0	1	0	1	P.U.	0	0
447	1	0	1	0	1	P.U.	0	0
448	1	0	1	0	1	P.U.	0	0
449	1	0	1	0	1	P.U.	0	0
450	1	0	1	0	1	P.U.	0	0
563	1	0	1	0	1	P.U.	0	0

Bus Number	Synchronous X (pu)	Negative R (pu)	Negative X (pu)	Zero R (pu)	Zero X (pu)	Grounding Z units	Grounding R	Grounding X
566	1	0	1	0	1	P.U.	0	0
568	1	0	1	0	1	P.U.	0	0
594	1	0	1	0	1	P.U.	0	0
596	1	0	1	0	1	P.U.	0	0
635	1	0	1	0	1	P.U.	0	0
647	1	0	1	0	1	P.U.	0	0
741	0.133	0	0.133	0	0.133	P.U.	0	0
742	0.133	0	0.133	0	0.133	P.U.	0	0
743	0.133	0	0.133	0	0.133	P.U.	0	0
834	0.133	0	0.133	0	0.133	P.U.	0	0
834	0.133	0	0.133	0	0.133	P.U.	0	0
835	0.133	0	0.133	0	0.133	P.U.	0	0
835	0.133	0	0.133	0	0.133	P.U.	0	0
836	0.133	0	0.133	0	0.133	P.U.	0	0
836	0.133	0	0.133	0	0.133	P.U.	0	0
837	0.133	0	0.133	0	0.133	P.U.	0	0
837	0.133	0	0.133	0	0.133	P.U.	0	0
838	0.133	0	0.133	0	0.133	P.U.	0	0
838	0.133	0	0.133	0	0.133	P.U.	0	0
839	0.133	0	0.133	0	0.133	P.U.	0	0
839	0.133	0	0.133	0	0.133	P.U.	0	0
840	0.133	0	0.133	0	0.133	P.U.	0	0
840	0.133	0	0.133	0	0.133	P.U.	0	0
841	0.133	0	0.133	0	0.133	P.U.	0	0
841	0.133	0	0.133	0	0.133	P.U.	0	0
842	0.133	0	0.133	0	0.133	P.U.	0	0
842	0.133	0	0.133	0	0.133	P.U.	0	0
843	0.133	0	0.133	0	0.133	P.U.	0	0
844	0.133	0	0.133	0	0.133	P.U.	0	0
845	0.133	0	0.133	0	0.133	P.U.	0	0
846	0.133	0	0.133	0	0.133	P.U.	0	0
847	0.133	0	0.133	0	0.133	P.U.	0	0
848	1	0	1	0	1	P.U.	0	0
854	1	0	1	0	1	P.U.	0	0
855	1	0	1	0	1	P.U.	0	0
856	0.2	0	0.2	0	0.2	P.U.	0	0
857	0.2	0	0.2	0	0.2	P.U.	0	0
858	0.2	0	0.2	0	0.2	P.U.	0	0
859	0.2	0	0.2	0	0.2	P.U.	0	0
860	0.2	0	0.2	0	0.2	P.U.	0	0
861	0.148	0	0.148	0	0.148	P.U.	0	0
862	0.148	0	0.148	0	0.148	P.U.	0	0
863	1	0	1	0	1	P.U.	0	0
864	1	0	1	0	1	P.U.	0	0
865	1	0	1	0	1	P.U.	0	0
866	1	0	1	0	1	P.U.	0	0
867	1	0	1	0	1	P.U.	0	0
868	1	0	1	0	1	P.U.	0	0
869	1	0	1	0	1	P.U.	0	0
870	1	0	1	0	1	P.U.	0	0
871	1	0	1	0	1	P.U.	0	0
872	1	0	1	0	1	P.U.	0	0

Bus Number	Synchronous X (pu)	Negative R (pu)	Negative X (pu)	Zero R (pu)	Zero X (pu)	Grounding Z units	Grounding R	Grounding X
873	1	0	1	0	1	P.U.	0	0
874	1	0	1	0	1	P.U.	0	0
875	1	0	1	0	1	P.U.	0	0
876	1	0	1	0	1	P.U.	0	0
877	1	0	1	0	1	P.U.	0	0
878	1	0	1	0	1	P.U.	0	0
879	1	0	1	0	1	P.U.	0	0
880	1	0	1	0	1	P.U.	0	0
881	1	0	1	0	1	P.U.	0	0
882	0.16	0	0.16	0	0.16	P.U.	0	0
884	1	0	1	0	1	P.U.	0	0
886	1	0	1	0	1	P.U.	0	0
887	1	0	1	0	1	P.U.	0	0
888	1	0	1	0	1	P.U.	0	0
10006	1	0	1	0	1	P.U.	0	0

II. BUS LOAD DATA OF THE NIGERIAN POWER SYSTEM

Bus Number	Bus Name	Zone Name	P load (MW)	Q load (Mvar)
42	5T 4B AKANGB33.000	LAGOS	5.5531	6.1
43	5T 4A AKANGB33.000	LAGOS	6.4037	6.1
44	AGBARA 33 33.000	LAGOS	5.9696	15.75
45	AJA 33 33.000	LAGOS	5.9697	25.515
47	AJA TR2 33 33.000	LAGOS	6.4034	6.2
48	AKANG T1A 3333.000	LAGOS	9.1241	14.39
49	AKOKA T1 33 33.000	LAGOS	9.3537	7.15
50	ALAGBON 33 33.000	LAGOS	15.9672	25
51	ALAUSA 33 33.000	LAGOS	9.3751	9.075
52	ALIMOSHO 33 33.000	LAGOS	12.738	12.342
53	AMUWO ODOFIN33.000	LAGOS	10.9281	17.16
54	APAPA RD 33 33.000	LAGOS	10.6802	11.058
55	EJIGBO 33 33.000	LAGOS	12.824	24.829
56	IJORA 33 33.000	LAGOS	9.9665	9.661
57	MARYLAND 33 33.000	LAGOS	8.9465	8.664
57	MARYLAND 33 33.000	LAGOS	13.2292	6.2
58	OGBA T4 33 33.000	LAGOS	16.2107	15.685
59	OWOROSOKI 3333.000	LAGOS	13.0396	12.625
60	PAPALANTO T133.000	LAGOS	14.8044	6.05
61	IKORODU 33 33.000	LAGOS	15.8056	15
65	IKW T2B 33 33.000	LAGOS	8.7203	0.2
66	ILUPEJU 33 33.000	LAGOS	10.9289	8.928
67	ISOLO 33 33.000	LAGOS	15.1771	14.685
68	ISOLOTR3 33 33.000	LAGOS	12.9352	12.5
69	OJO 33 33.000	LAGOS	9.5382	17.508
70	EGBIN TR1 3333.000	LAGOS	8.7203	0.2
72	EGBIN 33 33.000	LAGOS	4.1623	4
75	LEKKI 33 33.000	LAGOS	10.6827	21
76	LEKKI T1 33.000	LAGOS	16.2764	7.5
76	LEKKI T1 33.000	LAGOS	10.6827	15
77	LEKKI 33 BB 33.000	LAGOS	3.2018	3.1
79	ALAGB TR2 3333.000	LAGOS	10.6827	18.4
80	IJORA T1A&B 33.000	LAGOS	13.3131	12.89
80	IJORA T1A&B 33.000	LAGOS	11.7299	3
81	IJORA T2B 33.000	LAGOS	13.3352	4.62
81	IJORA T2B 33.000	LAGOS	13.3308	4.6
82	OJO T3_T4 33.000	LAGOS	13.1913	12.8
83	T3 45MVA 33.000	LAGOS	15.1212	6.336
84	MARYLAND T2 33.000	LAGOS	16.1567	7.364
84	MARYLAND T2 33.000	LAGOS	16.2124	7.5
85	IKORODU T3 33.000	LAGOS	7.1265	21.945
86	AJA T3 TERT 33.000	LAGOS	8.7203	0.2
86	AJA T3 TERT 33.000	LAGOS	6.4034	6.1
87	AKANG T2B 3333.000	LAGOS	11.7299	3.1
88	AKANGBA 33 33.000	LAGOS	15.9242	7.173
89	ABEOKUTA OLD33.000	LAGOS	12.6008	3.3
90	OWORO 33 BBI33.000	LAGOS	4.5411	9.337
91	APAPA RDT4 33.000	LAGOS	9.2965	0.744
92	AKOKA T3 33.000	LAGOS	9.6678	15.126

Bus Number	Bus Name	Zone Name	P load (MW)	Q load (Mvar)
93	AJA TR1 33.000	LAGOS	11.0236	13.125
94	APAPA T1 33.000	LAGOS	7.396	7.15
95	PAPALANTO T233.000	LAGOS	5.0453	4.873
96	IJORA 33.000	LAGOS	5.0294	4.851
96	IJORA 33.000	LAGOS	6.4034	6.1
97	OGBA 33 2 33.000	LAGOS	15.4396	4.18
98	AKOKA T4 33.000	LAGOS	10.7772	10.45
99	AMUWO T2 30M33.000	LAGOS	6.2243	6
100	AMUWO T3 40M33.000	LAGOS	9.2981	9
101	OGBAT1 60MVA33.000	LAGOS	8.5354	15.685
102	OGBAT2 60MVA33.000	LAGOS	5.9769	15.685
103	ALIMOSHO T1 33.000	LAGOS	7.7483	7.5
104	ALIMOSHO T2 33.000	LAGOS	14.7394	6
104	ALIMOSHO T2 33.000	LAGOS	14.9316	6.1
105	AGBARA TI 33.000	LAGOS	15.1174	6.405
106	AGBARA T2 33.000	LAGOS	6.5891	6.405
107	ALAUSA T3 33.000	LAGOS	7.8208	15.851
108	ALAUSA T4 33.000	LAGOS	9.3756	9.075
109	OTTA T1 33.000	LAGOS	8.6448	8.4
110	OTTA T2 33.000	LAGOS	3.6183	12.6
111	OLD ABEOK T233.000	LAGOS	8.0192	5.913
112	T3 30MVA 33.000	LAGOS	4.5337	3.65
113	OKE_ARO_TR1 33.000	LAGOS	2.4461	9.823
114	AYOBO 33 33.000	LAGOS	1.7529	21.5
115	OKE_ARO_TR2 33.000	LAGOS	10.2457	9.9
116	ALAGT-93440333.000	LAGOS	2.1545	18.6
123	SHAG CEM 11 15.000	LAGOS	5.1869	5
125	5T1B AKANGBA13.800	LAGOS	6.4034	6.1
126	5T2A AKANGBA13.800	LAGOS	0.1921	0.2
126	5T2A AKANGBA13.800	LAGOS	6.4034	6.1
127	5T2B AKANGBA13.800	LAGOS	6.4034	6.1
128	AJA 11 11.000	LAGOS	7.7483	7.5
129	AKOKA 11 11.000	LAGOS	6.4034	6.2
132	ILUPEJU 11 11.000	LAGOS	1.5691	10.602
133	ISOLO 11 11.000	LAGOS	3.8953	3.802
134	OGBA T3 11 11.000	LAGOS	6.0226	5.831
136	ITIRE 11 11.000	LAGOS	8.7689	10.967
137	T2 SEC 11.000	LAGOS	9.2444	10.602
138	T3 40MVA 11.000	LAGOS	10.1326	14.774
141	ALAUSA 11 11.000	LAGOS	20.258	3.1
142	SHAG CEM 11 11.000	LAGOS	6.2113	5.985
166	IJORA11 11.000	LAGOS	11.7299	3.1
167	OGABA 11 2 11.000	LAGOS	11.1382	2.508
168	BGWARI 33.000	SHIRORO	6.7932	6.2
184	OMOTOSHO 1 132.00	OSOGBO	3.7698	33
201	GANMO T2 33 33.000	OSOGBO	4.4978	13.95
201	GANMO T2 33 33.000	OSOGBO	5.1085	3.1
202	ADO EKITI 3333.000	OSOGBO	15.3252	9.3
203	AKURE 33 33.000	OSOGBO	8.0815	5.132
204	AYEDE 33 33.000	OSOGBO	7.1069	32.34
205	AYEDE TR1 3333.000	OSOGBO	0.3065	0.2
205	AYEDE TR1 3333.000	OSOGBO	9.1619	9.3

Bus Number	Bus Name	Zone Name	P load (MW)	Q load (Mvar)
206	AYEDE TR2 3333.000	OSOGBO	9.1619	9.3
207	IBADAN NORTH33.000	OSOGBO	3.0555	12.127
208	IFE 33 33.000	OSOGBO	2.526	12.753
208	IFE 33 33.000	OSOGBO	9.1619	9.3
209	JERICHO 33 33.000	OSOGBO	4.2624	11.025
210	ILESHA 33 33.000	OSOGBO	12.0559	7.3
210	ILESHA 33 33.000	OSOGBO	5.1085	3.1
211	ILORIN 33 33.000	OSOGBO	8.0064	17.012
212	ISEYIN 33 33.000	OSOGBO	12.0701	7.297
212	ISEYIN 33 33.000	OSOGBO	10.2168	6.1
213	JERICHO2 33 33.000	OSOGBO	8.8849	11.025
214	IWO 33 33.000	OSOGBO	5.3761	3.231
215	OFFA 33 33.000	OSOGBO	13.5884	8.265
216	OMUARAN 33 33.000	OSOGBO	7.867	4.76
216	OMUARAN 33 33.000	OSOGBO	8.1733	5.2
217	ONDO1 33 33.000	OSOGBO	11.5697	7.032
218	AKURE T3A 3333.000	OSOGBO	12.9694	13.509
219	OGBOMOSO 33 33.000	OSOGBO	10.7824	16.8
222	OSOGBO 4T1 33.000	OSOGBO	9.1619	9.3
224	OMOTOSHO TR133.000	OSOGBO	9.1619	9.3
225	OMOTOSHO TR233.000	OSOGBO	9.1619	9.3
226	OSOGBO 33 33.000	OSOGBO	12.2183	7.667
226	OSOGBO 33 33.000	OSOGBO	11.8208	7.2
227	AKURE T2A 33.000	OSOGBO	21.146	3.456
228	T1 30MVA 33.000	OSOGBO	20.7689	12.584
229	T2 30MVA 33.000	OSOGBO	12.9285	7.866
230	ILESHA T1 33.000	OSOGBO	8.6844	5.3
230	ILESHA T1 33.000	OSOGBO	8.6844	3.7
231	T1 60MVA 33.000	OSOGBO	14.7565	28.633
232	ILORIN T2A B33.000	OSOGBO	10.9727	16.009
233	ONDO T2 33 B33.000	OSOGBO	5.1085	3.1
233	ONDO T2 33 B33.000	OSOGBO	15.3252	9.3
234	SHAGAMU 33 33.000	OSOGBO	10.2858	10
235	AYEDE TR3 3333.000	OSOGBO	15.3252	9.3
237	IJEBU ODE 3333.000	OSOGBO	16.9491	10.62
238	GANMO TR2 33.000	OSOGBO	15.3252	9.3
239	SHAGAM T2 BB33.000	OSOGBO	11.5451	7
240	IJEBU T1 BB 33.000	OSOGBO	9.9101	6
241	IBADAN T2 BB33.000	OSOGBO	11.2943	12.584
243	AYEDE T2_T3 33.000	OSOGBO	4.9424	21.688
244	OMUARAN T2 33.000	OSOGBO	10.6255	6.46
244	OMUARAN T2 33.000	OSOGBO	5.1085	3.1
246	JERICHO 11 11.000	OSOGBO	10.5939	6.44
266	JEGA 1 132.00	SHIRORO	10.9513	5
295	AKWANGA 33 33.000	SHIRORO	15.5787	4.217
296	APO 33 33.000	SHIRORO	5.5308	19.8
297	BIDA 33 33.000	SHIRORO	12.2142	10
298	CENTRAL AREA33.000	SHIRORO	7.4668	44.85
298	CENTRAL AREA33.000	SHIRORO	11.2482	9.3
299	JEBBA 33 33.000	SHIRORO	14.3804	12.4
300	KARU 33 33.000	SHIRORO	11.4616	16.941
301	KATAMPE 33 33.000	SHIRORO	11.0619	34.65

Bus Number	Bus Name	Zone Name	P load (MW)	Q load (Mvar)
302	KEFFI 33 33.000	SHIRORO	4.9778	7.15
303	KONTAGORA 3333.000	SHIRORO	6.0229	3.348
303	KONTAGORA 3333.000	SHIRORO	2.7654	3.1
304	KUBWA 33 33.000	SHIRORO	6.084	24.2
304	KUBWA 33 33.000	SHIRORO	13.8272	6.1
305	APO_60MVA T333.000	SHIRORO	13.8272	10.8
305	APO_60MVA T333.000	SHIRORO	4.609	3.1
306	MINNA 33 33.000	SHIRORO	4.609	9.68
306	MINNA 33 33.000	SHIRORO	13.8272	9.3
307	SHIRORO 33 33.000	SHIRORO	9.2181	11.483
308	SOKOTO 33 33.000	SHIRORO	13.8272	7.2
308	SOKOTO 33 33.000	SHIRORO	12.0759	7.2
309	TEGINA 33 33.000	SHIRORO	4.609	4.774
309	TEGINA 33 33.000	SHIRORO	6.4527	3.2
310	SHIRORO TR1 33.000	SHIRORO	10.825	12.6
311	SHIRORO TR2 33.000	SHIRORO	6.6099	12.6
312	KATEMPE TR1 33.000	SHIRORO	6.6433	12.4
313	KATEMPE TR2 33.000	SHIRORO	6.6433	12.4
314	KATEMPE TR3 33.000	SHIRORO	6.9421	12.4
320	GWAG T2 TER 33.000	SHIRORO	7.5589	9.3
329	T2 GWAGWALA 33.000	SHIRORO	7.5589	9.3
333	BKEBBI 33 33.000	SHIRORO	2.7562	8.82
334	YELWA T1 33.000	SHIRORO	7.098	3.105
335	SULEJA T2 33.000	SHIRORO	6.084	2.4
335	SULEJA T2 33.000	SHIRORO	6.084	2.1
336	SULEJA T3 33.000	SHIRORO	4.4247	2.4
336	SULEJA T3 33.000	SHIRORO	6.9163	2.1
337	MINNA T2 33.000	SHIRORO	5.6784	9.79
338	AKWANGA MOB 33.000	SHIRORO	9.4024	4.356
339	SOKOTO T3 33.000	SHIRORO	2.7654	3.06
339	SOKOTO T3 33.000	SHIRORO	12.0235	3.1
340	BKEBBI T8 33.000	SHIRORO	9.2181	19.219
341	BKEBBI MBH 33.000	SHIRORO	2.9498	2.31
341	BKEBBI MBH 33.000	SHIRORO	9.2181	9.3
342	GWAGW_TR1_3333.000	SHIRORO	5.9917	4.5
342	GWAGW_TR1_3333.000	SHIRORO	4.1482	9.3
343	GWAGW_TR2 3333.000	SHIRORO	9.3289	4.5
343	GWAGW_TR2 3333.000	SHIRORO	4.609	9.3
344	APO_100MVAT333.000	SHIRORO	9.7732	23.436
344	APO_100MVAT333.000	SHIRORO	9.3575	3.1
346	YELWA T2 33.000	SHIRORO	9.3575	0.713
363	SULEJA 11 11.000	SHIRORO	9.6362	1.25
364	JEBBA TR1 13.800	SHIRORO	9.241	6.2
366	BKB5 13.800	SHIRORO	9.6886	3.1
368	APO TR1 11 11.000	SHIRORO	9.3575	3.1
369	APO TR2 11 11.000	SHIRORO	5.4843	3.1
390	BENIN 33 33.000	BENINNIGERIA	6.786	23.1
391	DELTA 33 33.000	BENINNIGERIA	14.4733	8.294
392	IRRUA 33 33.000	BENINNIGERIA	10.1789	11.04
393	OKENE 33 33.000	BENINNIGERIA	20.3802	9.92
394	UKPILLA 33 33.000	BENINNIGERIA	20.3802	4.416

Bus Number	Bus Name	Zone Name	P load (MW)	Q load (Mvar)
399	AJAOKUTA T1A33.000	BENINNIGERIA	20.3802	24.6
400	AJAOKUTA T2A33.000	BENINNIGERIA	18.1156	24.6
401	AJAOKUTA T3A33.000	BENINNIGERIA	20.3802	24.6
402	DELTA T2 33 33.000	BENINNIGERIA	20.3802	4.147
403	LOKOJA_33 33.000	BENINNIGERIA	20.3802	9.3
405	AMUKPE 33 33.000	BENINNIGERIA	20.3802	5.824
406	EFFURUN 33 33.000	BENINNIGERIA	18.1156	6.5
407	EFFURUN TR2 33.000	BENINNIGERIA	18.1156	5.85
407	EFFURUN TR2 33.000	BENINNIGERIA	18.1156	2
408	EFFURUN TR3 33.000	BENINNIGERIA	18.1156	6.5
409	AMUKPE BB 3333.000	BENINNIGERIA	27.1736	6.72
409	AMUKPE BB 3333.000	BENINNIGERIA	27.1736	1.5
410	IRRUA BBII3333.000	BENINNIGERIA	18.1156	10.24
411	OKENE T2 SEC33.000	BENINNIGERIA	27.1736	9.6
412	BENIN T22 3333.000	BENINNIGERIA	27.1736	21.78
413	BENIN T23 3333.000	BENINNIGERIA	18.1156	22.44
414	BENIN T24 3333.000	BENINNIGERIA	27.1736	21.78
415	AJAOKUTA T1 33.000	BENINNIGERIA	20.3802	16.008
416	AJAOKUTA T2 33.000	BENINNIGERIA	20.3802	16.008
417	GEREGU 33 33.000	BENINNIGERIA	18.1156	16.008
418	LOKOJA T2A 33.000	BENINNIGERIA	18.1156	9.3
419	LOKOJA T1T2 33.000	BENINNIGERIA	18.1156	15
419	LOKOJA T1T2 33.000	BENINNIGERIA	18.1156	15.8
493	DAKATA 33 33.000	KADUNA	13.2675	7.37
494	DAN AGUNDI 333.000	KADUNA	18.8736	10.5
495	DUTSE 33 33.000	KADUNA	6.7006	3.72
496	FUNTUA 33 33.000	KADUNA	14.7974	8.168
497	GUSAU 33 33.000	KADUNA	9.0461	5.04
498	KADUNA 33 33.000	KADUNA	13.6273	19.8
498	KADUNA 33 33.000	KADUNA	17.4218	10
499	KADUNA TOWN 33.000	KADUNA	13.8858	14.465
500	KANKIA 33 33.000	KADUNA	13.4014	7.44
501	KANO 33 33.000	KADUNA	6.0306	3.36
502	KATSINA 33 33.000	KADUNA	7.2967	17.64
503	ZARIA T1 33.000	KADUNA	3.3502	1.86
504	AZARE 33 33.000	KADUNA	7.3707	4.092
505	KANO T1A 33.000	KADUNA	16.7517	9.3
506	KANO T2A 33.000	KADUNA	16.7517	9.3
507	KADUNA T1A 33.000	KADUNA	5.5839	3
508	KADUNA T2A 33.000	KADUNA	5.5839	3
509	KADUNA T4A 33.000	KADUNA	16.7517	9.3
510	KADUNA T3A 33.000	KADUNA	11.1678	6
511	KANO T3A 33.000	KADUNA	16.7517	9.3
512	WUDIL 33 33.000	KADUNA	14.6299	8.1
513	KWANAR DANGO33.000	KADUNA	5.5839	3.1
514	TAMBURAWA 3333.000	KADUNA	7.8174	4.34
517	HADEJIA 33 33.000	KADUNA	13.1144	0.5
519	T2-KATSINA 33.000	KADUNA	8.008	22.6
530	KAD 33 BBII 33.000	KADUNA	8.0484	11.22
530	KAD 33 BBII 33.000	KADUNA	8.0484	12

Bus Number	Bus Name	Zone Name	P load (MW)	Q load (Mvar)
531	KAD T2 33.000	KADUNA	8.4103	20.3
532	KAD T4 33.000	KADUNA	9.1576	5.1
532	KAD T4 33.000	KADUNA	9.1576	5.2
533	TMAFARA 33 33.000	SHIRORO	3.3391	1.84
536	GUSAU T1 33.000	KADUNA	8.5993	4.8
538	AZARE T2 33.000	KADUNA	7.3707	4.092
539	DUTSE T1 33.000	KADUNA	7.3707	4.092
540	HADEJIA T2 33.000	KADUNA	5.3605	3
541	DAKATA T2 33.000	KADUNA	8.379	7.37
542	DAKATA T3 33.000	KADUNA	6.8794	3.85
543	DAGUNDI T2 33.000	KADUNA	11.3911	6.3
544	KANKIA T1 33.000	KADUNA	3.3502	1.86
545	KATSINA T2 33.000	KADUNA	14.5663	1.3
545	KATSINA T2 33.000	KADUNA	11.1678	6.2
546	KATSINA T3 33.000	KADUNA	3.5737	2
546	KATSINA T3 33.000	KADUNA	11.1678	6.2
547	KUMB T2 33.000	KADUNA	7.2589	4
548	KUMB T3 MOB33.000	KADUNA	5.0255	2.8
549	KUMB T4 33.000	KADUNA	11.3019	6.27
550	ZARIA T2 33.000	KADUNA	5.5839	3.1
551	KD TWN T1 33.000	KADUNA	11.8403	8.618
552	KANO_NEW T3333.000	KADUNA	11.3366	12.2
553	KANO NEW T2 33.000	KADUNA	11.3366	12.4
555	KATSIN NEW T33.000	KADUNA	11.6743	22.6
558	KD TWN T2 33.000	KADUNA	11.1954	17.756
559	KANOII 33 33.000	KADUNA	11.7378	31.8
560	KANO T4A 33.000	KADUNA	11.3366	12.4
561	KD TWN T3 33.000	KADUNA	6.6442	17.942
564	FUNTUA 11 11.000	KADUNA	3.5737	2
565	KADUNA TOWN 11.000	KADUNA	7.622	4.2
567	FUNTUA T2 11.000	KADUNA	5.3605	3
599	YOLA 33 33.000	BAUCHI	8.325	9.45
600	YOLA T1 33 33.000	BAUCHI	6.1006	12.4
601	ASHAKA 33 33.000	BAUCHI	7.2053	6.2
602	BAUCHI 33 33.000	BAUCHI	7.1287	8.2
604	JOS T4 60MVA33.000	BAUCHI	7.2051	16.3
605	GOMBE 33 33.000	BAUCHI	7.7405	12.5
606	JOS 33 33.000	BAUCHI	4.9449	16.55
608	POTISKUM 33 33.000	BAUCHI	5.2256	2.518
609	SAVANNAH 33 33.000	BAUCHI	7.6311	6.36
610	BAUCHI T4 33.000	BAUCHI	5.166	5.2
611	JOS T3A 33.000	BAUCHI	7.2053	6.2
613	GOMBE T4A 33.000	BAUCHI	8.8706	12.4
614	JALINGO 33B 33.000	BAUCHI	7.8982	9.882
617	JALINGO 33A 33.000	BAUCHI	7.307	5.531
618	NUMAN 33 33.000	BAUCHI	5.0984	2.5
619	DAMBOA 33 33.000	BAUCHI	15.7463	2.424
620	MAIDUG 33 33.000	BAUCHI	7.01	3.4
625	GOMBE TR3 3333.000	BAUCHI	23.5452	10.1
628	MUBI_33 33.000	BAUCHI	8.055	10
629	SONG 33 33.000	BAUCHI	5.285	10
631	KAFANCH T1 33.000	BAUCHI	7.4007	9

Bus Number	Bus Name	Zone Name	P load (MW)	Q load (Mvar)
632	MAKERI 33 33.000	BAUCHI	20.6772	12.75
633	GOMBI_33 33.000	BAUCHI	6.67	10
634	KAFANCH T2 33.000	BAUCHI	4.6307	9
635	KAFANC M TR133.000	BAUCHI	7.1374	3.5
636	MAKERI TR2 33.000	BAUCHI	6.3727	3.1
637	POTISK T2 33.000	BAUCHI	5.2256	2.518
638	BIU T2 33.000	BAUCHI	8.7195	6.946
639	MAID T2 33.000	BAUCHI	12.2331	3.946
640	MAID T1 33.000	BAUCHI	5.285	10
641	YOLA T1_A 33.000	BAUCHI	9.5166	8
642	DAMATUR 33 33.000	BAUCHI	8.1061	12
644	GOMBE T3 11.000	BAUCHI	4.9113	5.1
691	ABAKALIKI 3333.000	ENUGU	13.3965	3.5
691	ABAKALIKI 3333.000	ENUGU	14.5702	3.5
692	APIR 33 33.000	ENUGU	14.5702	3.948
694	AWKA 33 33.000	ENUGU	11.1791	6.2
695	AYANGBA 33 33.000	ENUGU	0	5
697	NHAVEN 33 33.000	ENUGU	6.4006	4.398
697	NHAVEN 33 33.000	ENUGU	5.6096	8.43
698	NKALAGU 33 33.000	ENUGU	6.2601	5.04
698	NKALAGU 33 33.000	ENUGU	6.3721	5
700	NSUKKA 33 33.000	ENUGU	6.3216	1.65
702	OJI RIVER 3333.000	ENUGU	10.0611	2.5
704	ONTISHA 33 33.000	ENUGU	7.7708	8.3
705	OTURKPO 33 33.000	ENUGU	14.5702	4.5
706	YANDEV 33 33.000	ENUGU	0	6.39
709	NHAVEN T3 33.000	ENUGU	11.1791	12.4
710	ONITSHA T2A 33.000	ENUGU	5.7426	6.2
711	NHAVEN T4 33.000	ENUGU	0	12.4
713	ONITSHA T3A 33.000	ENUGU	5.7426	12.4
714	MAKURDI 33 33.000	ENUGU	0	12.4
715	T1-UGWUAJI_333.000	ENUGU	7.7708	37
716	T2-UGWUAJI_333.000	ENUGU	7.7708	37
720	GCM 33 33.000	ENUGU	0	13.3
722	AGU-AWKA 33 33.000	ENUGU	11.1791	7.6
723	TR14 SEC 33.000	ENUGU	11.1791	12
724	60 MVA TR11 33.000	ENUGU	11.1791	22
725	NHAV TR2 33.000	ENUGU	11.1791	10.23
726	NHAV TR3 33.000	ENUGU	0	11
727	NHAV TR4 33.000	ENUGU	0	16.5
728	ABAKALIK T2 33.000	ENUGU	11.1791	5
728	ABAKALIK T2 33.000	ENUGU	0	5.2
729	OTURK T2 33.000	ENUGU	0	2
730	NKALGU T1A 33.000	ENUGU	0	2.857
730	NKALGU T1A 33.000	ENUGU	11.1791	9.207
731	YANDEB T2 33.000	ENUGU	22.3582	14.52
732	TR3 30MVA 33.000	ENUGU	11.1791	6.2
733	NSUKKA 15MVA33.000	ENUGU	14.5328	2.48
735	NSUKKA N 33 33.000	ENUGU	22.3582	3.1
736	MAKURDI T2 33.000	ENUGU	16.7686	47.6
745	ONTISHA 11 11.000	ENUGU	7.7708	6.5
746	ONITSHA T1A 13.800	ENUGU	24.2837	6.2

Bus Number	Bus Name	Zone Name	P load (MW)	Q load (Mvar)
747	ONITSHA T6A 13.800	ENUGU	37.3969	6.2
786	AFAM 33 33.000	PT HARCO	30.9197	6
787	CALABAR T13333.000	PT HARCO	16.8645	12.4
787	CALABAR T13333.000	PT HARCO	13.4289	12.4
788	EKET T1B 33.000	PT HARCO	5.4389	5
789	EKET 33 33.000	PT HARCO	8.8631	8.2
790	ITU 33 33.000	PT HARCO	6.5801	6.1
791	ALAOJI T1A 33.000	PT HARCO	13.4289	12.4
792	PHCT TOWN1 333.000	PT HARCO	5.9087	5.483
793	UYO 33 33.000	PT HARCO	13.59	12.524
794	ALAOJI T2A 33.000	PT HARCO	13.4289	12.4
795	PHCT MAIN 3333.000	PT HARCO	15.3925	14.192
797	ALAOJI T3A 33.000	PT HARCO	13.4289	12.4
799	OGOJA 33 33.000	PT HARCO	5.4389	5
800	AHOADA 33 33.000	PT HARCO	3.2228	3
801	YENAGOA 33 33.000	PT HARCO	2.4171	2.263
802	OWERRI 33 33.000	PT HARCO	11.8849	11
802	OWERRI 33 33.000	PT HARCO	17.0206	24.6
803	ABA T1 33 33.000	PT HARCO	11.8849	11
804	ABA T2B 33 33.000	PT HARCO	10.8104	10
805	OWERRI 33 TR33.000	PT HARCO	12.207	11.25
806	OWERR T1MOB 33.000	PT HARCO	13.0127	12.003
807	ABA T2A 33 33.000	PT HARCO	21.6877	20
808	CALAB T1A 33.000	PT HARCO	17.4891	43.4
809	T4A(MOB) 33.000	PT HARCO	5.4389	5
810	UMUAHIA 33 33.000	PT HARCO	20.5119	28
811	T3A SEC 33.000	PT HARCO	15.4365	14.25
812	PHCT T2A 33.000	PT HARCO	8.3475	7.716
813	PHCT T1A 33.000	PT HARCO	18.8711	17.448
814	YANAG T2 SEC33.000	PT HARCO	2.4171	2.263
815	CALABAR T33333.000	PT HARCO	12.153	11.191
815	CALABAR T33333.000	PT HARCO	12.153	12
816	UYO T2B 33.000	PT HARCO	7.5875	7
817	ABA 33 33.000	PT HARCO	19.472	18
819	TR2 SEC 33.000	PT HARCO	4.3644	4
820	OBUDU_33 33.000	PT HARCO	13.4289	12.4
821	IKOM_33 33.000	PT HARCO	13.4289	12.4
829	CALAB T1B 33.000	PT HARCO	3.7471	43.8
833	AFAM 11 11.000	PT HARCO	19.472	18
850	PHCT MAIN 1111.000	PT HARCO	16.7251	15.433
851	PHCT TOWN 1111.000	PT HARCO	14.302	13.2
852	OWERR TR1 11.000	PT HARCO	5.7123	5.462
853	ABA T1A 6.6 6.6000	PT HARCO	2.0816	1.9
1000	SAKETE 3 330.00	BENIN	240	6.1
10002	GAZAOUA 132.00	NIGER_GAZAOU	89	5.7
10003	DOSSO 132.00	NIGER_DOSSO	45.26	-2.5
10008	EFFERUN10 132.00	BENINNIGERIA	100	0

III. TRANSMISSION LINES DATA OF THE NIGERIAN POWER SYSTEM

III. A

From Bus (Number)	From Bus (Name)	To Bus (Number)	To Bus (Name)	Line R (ohms)	Line X (ohms)	Charging B (uF)
2	AKANGBA 1 132.00	12	ITIRE 1 132.00	0.369389	1.175946	0.028681
2	AKANGBA 1 132.00	12	ITIRE 1 132.00	0.369389	1.175946	0.028681
2	AKANGBA 1 132.00	12	ITIRE 1 132.00	0.369389	1.175946	0.028681
2	AKANGBA 1 132.00	14	APAPA RD 1 132.00	0.553561	1.764006	0.041835
2	AKANGBA 1 132.00	16	IJORA 1 132.00	1.0209	3.253601	0.077276
2	AKANGBA 1 132.00	16	IJORA 1 132.00	1.0209	3.253601	0.077276
2	AKANGBA 1 132.00	19	ISOLO 1 132.00	0.5535	1.764006	0.041835
2	AKANGBA 1 132.00	19	ISOLO 1 132.00	0.5535	1.764006	0.041835
3	EGBIN 1 132.00	17	IKORODU 132.00	2.460007	7.839998	0.185973
3	EGBIN 1 132.00	17	IKORODU 132.00	2.460007	7.839998	0.185973
4	IKEJA W 1BB1132.00	7	AGBARA 1 132.00	3.940926	12.55967	0.297959
4	IKEJA W 1BB1132.00	7	AGBARA 1 132.00	3.940926	12.55967	0.297959
4	IKEJA W 1BB1132.00	11	ALIMOSHO 1 132.00	0.4305	1.372001	0.032518
4	IKEJA W 1BB1132.00	11	ALIMOSHO 1 132.00	0.4305	1.372001	0.032518
4	IKEJA W 1BB1132.00	18	ILLUPEJU 1 132.00	2.460007	7.839998	0.185973
4	IKEJA W 1BB1132.00	18	ILLUPEJU 1 132.00	2.460007	7.839998	0.185973
4	IKEJA W 1BB1132.00	25	OWOROSOKI 1 132.00	6.026997	19.20804	0.455798
4	IKEJA W 1BB1132.00	25	OWOROSOKI 1 132.00	6.026997	19.20804	0.455798
4	IKEJA W 1BB1132.00	29	OKE_ARO_1 132.00	1.968041	6.272118	0.148705
4	IKEJA W 1BB1132.00	29	OKE_ARO_1 132.00	1.968041	6.272118	0.148705
5	AKANGBA BBII132.00	13	AMUWO ODOFIN132.00	1.23	3.919999	0.092987
5	AKANGBA BBII132.00	13	AMUWO ODOFIN132.00	1.22996	3.920052	0.092987
5	AKANGBA BBII132.00	14	APAPA RD 1 132.00	0.5535	1.764006	0.041835
6	PAPALANTO 1 132.00	24	OTTA 1 132.00	3.690002	11.76	0.27896
6	PAPALANTO 1 132.00	24	OTTA 1 132.00	3.690055	11.75998	0.27896
6	PAPALANTO 1 132.00	28	OLD ABEOKUTA132.00	6.765007	21.55993	0.511517
6	PAPALANTO 1 132.00	28	OLD ABEOKUTA132.00	6.765007	21.55993	0.511517
6	PAPALANTO 1 132.00	28	OLD ABEOKUTA132.00	6.765007	21.55993	0.511517
7	AGBARA 1 132.00	20	OJO 1 132.00	2.013518	6.417033	0.152176
7	AGBARA 1 132.00	20	OJO 1 132.00	2.013518	6.417033	0.152176
8	AKOKA 1 132.00	9	ALAGBON 1 132.00	1.475999	4.703992	0.11162
8	AKOKA 1 132.00	16	IJORA 1 132.00	0.984	3.136006	0.074353
8	AKOKA 1 132.00	25	OWOROSOKI 1 132.00	0.547351	1.744404	0.041469
8	AKOKA 1 132.00	25	OWOROSOKI 1 132.00	0.547351	1.744404	0.041469
9	ALAGBON 1 132.00	16	IJORA 1 132.00	0.492	1.568	0.037268
9	ALAGBON 1 132.00	21	LEKKI 1 132.00	1.599062	5.095945	0.120937
9	ALAGBON 1 132.00	21	LEKKI 1 132.00	1.599062	5.095945	0.120937
10	ALAUSA 1 132.00	23	OGBA 1 132.00	0.246001	0.784	0.018634
10	ALAUSA 1 132.00	23	OGBA 1 132.00	0.246001	0.784	0.018634
11	ALIMOSHO 1 132.00	23	OGBA 1 132.00	1.1685	3.723997	0.088419
11	ALIMOSHO 1 132.00	23	OGBA 1 132.00	1.1685	3.723997	0.088419
12	ITIRE 1 132.00	15	EJIGBO 1 132.00	0.984	3.136006	0.074353
12	ITIRE 1 132.00	15	EJIGBO 1 132.00	0.984	3.136006	0.074353
13	AMUWO ODOFIN132.00	14	APAPA RD 1 132.00	0.246001	0.784	0.018634
13	AMUWO ODOFIN132.00	14	APAPA RD 1 132.00	0.246027	0.78408	0.018634
13	AMUWO	20	OJO 1 132.00	1.094699	3.488807	0.082756

From Bus (Number)	From Bus (Name)	To Bus (Number)	To Bus (Name)	Line R (ohms)	Line X (ohms)	Charging B (uF)
	ODOFIN132.00					
13	AMUWO ODOFIN132.00	20	OJO 1 132.00	1.094699	3.488807	0.082756
15	EJIGBO 1 132.00	32	IKJW T1BT2B 132.00	1.63836	5.221433	0.12386
15	EJIGBO 1 132.00	32	IKJW T1BT2B 132.00	1.63836	5.221433	0.12386
17	IKORODU 132.00	22	MARYLAND1 132.00	2.458945	7.838831	0.186338
17	IKORODU 132.00	22	MARYLAND1 132.00	2.458945	7.838831	0.186338
17	IKORODU 132.00	27	SHAGAMU CEME132.00	2.207847	7.036404	0.166974
18	ILLUPEJU 1 132.00	22	MARYLAND1 132.00	0.7011	2.234401	0.052979
18	ILLUPEJU 1 132.00	22	MARYLAND1 132.00	0.7011	2.234401	0.052979
21	LEKKI 1 132.00	31	AJA 132 BBII132.00	0.865363	2.743966	0.065036
21	LEKKI 1 132.00	31	AJA 132 BBII132.00	0.865363	2.743966	0.065036
23	OGBA 1 132.00	24	OTTA 1 132.00	5.448486	17.36476	0.411954
24	OTTA 1 132.00	32	IKJW T1BT2B 132.00	1.475999	4.703992	0.11162
24	OTTA 1 132.00	32	IKJW T1BT2B 132.00	1.475999	4.703992	0.11162
25	OWOROSOKI 1 132.00	29	OKE_ARO_1 132.00	5.043029	16.07207	0.38108
25	OWOROSOKI 1 132.00	29	OKE_ARO_1 132.00	5.043029	16.07207	0.38108
26	AYOBO 1 132.00	32	IKJW T1BT2B 132.00	0.123	0.392	0.009317
26	AYOBO 1 132.00	32	IKJW T1BT2B 132.00	0.123	0.392	0.009317
27	SHAGAMU CEME132.00	192	SHAGAMU 1 132.00	2.207847	7.036404	0.166974
33	AJA 3 330.00	35	EGBIN 3 330.00	0.546	4.634	0.155414
33	AJA 3 330.00	35	EGBIN 3 330.00	0.546	4.634	0.155414
33	AJA 3 330.00	39	LEKKI 330 330.00	5.409063	17.14957	0.010406
33	AJA 3 330.00	39	LEKKI 330 330.00	5.409063	17.14957	0.010406
33	AJA 3 330.00	41	ALAGBON_3 330.00	1.024749	7.877826	0.315475
33	AJA 3 330.00	41	ALAGBON_3 330.00	1.024749	7.877826	0.315475
34	AKANGBA 3 330.00	36	IKEJA W 3 330.00	0.6698	5.151002	0.205688
34	AKANGBA 3 330.00	36	IKEJA W 3 330.00	0.6698	5.151002	0.205688
35	EGBIN 3 330.00	36	IKEJA W 3 330.00	0.702405	5.957919	0.199813
35	EGBIN 3 330.00	40	OKE_ARO_3 330.00	0.702405	5.957919	0.199813
35	EGBIN 3 330.00	40	OKE_ARO_3 330.00	0.702405	5.957919	0.199813
35	EGBIN 3 330.00	383	BENIN 3 330.00	7.799994	66.19998	2.220014
36	IKEJA W 3 330.00	38	OLORUNSOGO3 330.00	3.001937	25.48587	0.854643
36	IKEJA W 3 330.00	40	OKE_ARO_3 330.00	0.702405	5.957919	0.199813
36	IKEJA W 3 330.00	40	OKE_ARO_3 330.00	0.702405	5.957919	0.199813
36	IKEJA W 3 330.00	198	OSOGBO 3 330.00	9.750002	82.74995	2.774996
36	IKEJA W 3 330.00	199	OMOTOSHO3 330.00	3.118896	26.47904	0.887965
36	IKEJA W 3 330.00	1000	SAKETE 3 330.00	2.730004	23.17	0.777009
38	OLORUNSOGO3 330.00	197	AYEDE 3 330.00	2.34	19.85998	0.665995
39	LEKKI 330 330.00	41	ALAGBON_3 330.00	9.986131	31.84998	0.01935
39	LEKKI 330 330.00	41	ALAGBON_3 330.00	9.986131	31.84998	0.01935
169	UGWUAJI_3 330.00	683	NHAVEN 3 330.00	0.275517	2.121372	0.084941
169	UGWUAJI_3 330.00	683	NHAVEN 3 330.00	0.275517	2.121372	0.084941
169	UGWUAJI_3 330.00	687	ALIADE_3 330.00	6.185519	47.57079	1.905037
169	UGWUAJI_3 330.00	687	ALIADE_3 330.00	6.185519	47.57079	1.905037
169	UGWUAJI_3 330.00	779	IKOT-EKPENE_330.00	6.382628	49.08559	1.965717
169	UGWUAJI_3 330.00	779	IKOT-EKPENE_330.00	6.382628	49.08559	1.965717
169	UGWUAJI_3 330.00	779	IKOT-EKPENE_330.00	6.382628	49.08559	1.965717
169	UGWUAJI_3 330.00	779	IKOT-EKPENE_330.00	6.382628	49.08559	1.965717
170	AYEDE 1 132.00	176	IBADAN NORTH132.00	0.738081	2.35224	0.055902
170	AYEDE 1 132.00	182	JERICHO 1 132.00	0.246001	0.784	0.018634

From Bus (Number)	From Bus (Name)	To Bus (Number)	To Bus (Name)	Line R (ohms)	Line X (ohms)	Charging B (uF)
170	AYEDE 1 132.00	192	SHAGAMU 1 132.00	11.31515	36.06385	0.855513
171	OSOGBO 1 132.00	175	AKURE 1 132.00	11.8119	37.64508	0.892232
171	OSOGBO 1 132.00	175	AKURE 1 132.00	11.8119	37.64508	0.892232
171	OSOGBO 1 132.00	183	OFFA 1 132.00	6.457335	20.58001	0.488316
171	OSOGBO 1 132.00	188	OGBOMOSO 1 132.00	11.06999	35.27994	0.837062
171	OSOGBO 1 132.00	188	OGBOMOSO 1 132.00	11.06999	35.27994	0.837062
171	OSOGBO 1 132.00	194	ILESHA TEE1 132.00	1.781953	5.680154	0.134821
171	OSOGBO 1 132.00	194	ILESHA TEE1 132.00	1.781953	5.680224	0.134821
171	OSOGBO 1 132.00	195	OWO 1 132.00	18.20285	58.01617	1.376895
171	OSOGBO 1 132.00	196	EDE_1 132.00	1.845027	5.879903	0.139571
171	OSOGBO 1 132.00	196	EDE_1 132.00	1.845027	5.879903	0.139571
172	OSOGBO 4T2 132.00	175	AKURE 1 132.00	11.43886	36.45624	0.864099
172	OSOGBO 4T2 132.00	178	IWO 1 132.00	9.839681	31.35971	0.743892
173	GANMO TR2 BB132.00	180	ILORIN 1 132.00	0.614999	1.960008	0.046585
173	GANMO TR2 BB132.00	180	ILORIN 1 132.00	0.614999	1.960008	0.046585
173	GANMO TR2 BB132.00	188	OGBOMOSO 1 132.00	4.305	13.72001	0.325544
173	GANMO TR2 BB132.00	188	OGBOMOSO 1 132.00	4.305	13.72001	0.325544
173	GANMO TR2 BB132.00	191	SHONGO_1 132.00	7.379065	23.52014	0.558102
173	GANMO TR2 BB132.00	191	SHONGO_1 132.00	7.379065	23.52014	0.558102
174	ADO EKITI 1 132.00	175	AKURE 1 132.00	5.781004	18.42396	0.437165
174	ADO EKITI 1 132.00	175	AKURE 1 132.00	5.780935	18.42396	0.437165
176	IBADAN NORTH132.00	178	IWO 1 132.00	2.213998	7.056005	0.167339
177	IFE 1 132.00	179	ILESHA 1 132.00	2.398588	7.644083	0.181406
177	IFE 1 132.00	187	ONDO2 1 132.00	5.351346	17.05505	0.404647
177	IFE 1 132.00	194	ILESHA TEE1 132.00	2.398501	7.643996	0.181406
178	IWO 1 132.00	181	ISEYIN 1 132.00	8.732996	27.83205	0.660223
179	ILESHA 1 132.00	194	ILESHA TEE1 132.00	2.460792	7.844024	0.186156
180	ILORIN 1 132.00	183	OFFA 1 132.00	5.845752	18.63148	0.442097
183	OFFA 1 132.00	185	OMUARAN 1 132.00	5.846188	18.63183	0.442097
185	OMUARAN 1 132.00	190	EGBE_1 132.00	8.61007	27.44019	0.650906
186	ONDO1 1 132.00	187	ONDO2 1 132.00	1.783782	5.685016	0.135004
192	SHAGAMU 1 132.00	193	IJEBU ODE 1 132.00	5.042505	16.0719	0.381263
197	AYEDE 3 330.00	198	OSOGBO 3 330.00	4.485003	38.06502	1.276513
198	OSOGBO 3 330.00	200	GANMO 3 330.00	1.833223	15.55745	0.521689
198	OSOGBO 3 330.00	288	JEBBA T.S.3 330.00	6.123	51.96697	1.742696
198	OSOGBO 3 330.00	288	JEBBA T.S.3 330.00	6.123	51.96697	1.742696
198	OSOGBO 3 330.00	389	EYEAN_3 330.00	9.789021	83.0809	2.786103
199	OMOTOSHO3 330.00	383	BENIN 3 330.00	1.989004	16.88103	0.566089
200	GANMO 3 330.00	288	JEBBA T.S.3 330.00	4.28957	14.53053	1.223023
257	SHIRORO 1 132.00	270	TEGINA 1 132.00	7.995003	25.47999	0.604504
257	SHIRORO 1 132.00	271	MINNA 1 132.00	8.363991	26.65593	0.632455
257	SHIRORO 1 132.00	271	MINNA 1 132.00	8.363991	26.65593	0.632455
257	SHIRORO 1 132.00	273	SULEJA 1 132.00	20.54098	65.46407	1.553186
258	KATAMPE 1 132.00	260	KUBWA 132.00	0.861	2.744001	0.065036
258	KATAMPE 1 132.00	260	KUBWA 132.00	0.86092	2.743932	0.065036
258	KATAMPE 1 132.00	262	APO 1 132.00	1.844993	5.880008	0.139571
258	KATAMPE 1 132.00	262	APO 1 132.00	1.844993	5.880008	0.139571
258	KATAMPE 1 132.00	262	APO 1 132.00	1.845028	5.880077	0.139571
258	KATAMPE 1 132.00	265	GARKI NODE 1132.00	0.738001	2.351996	0.055719
258	KATAMPE 1 132.00	265	GARKI NODE 1132.00	0.738001	2.351996	0.055719
258	KATAMPE 1 132.00	273	SULEJA 1 132.00	5.781004	18.42396	0.437165
258	KATAMPE 1 132.00	275	NAT STADIUM1132.00	0.983933	3.135972	0.074353

From Bus (Number)	From Bus (Name)	To Bus (Number)	To Bus (Name)	Line R (ohms)	Line X (ohms)	Charging B (uF)
258	KATAMPE 1 132.00	275	NAT STADIUM1132.00	0.983933	3.135972	0.074353
259	BKEBBI 1 132.00	266	JEGA 1 132.00	4.305	13.72001	0.325544
259	BKEBBI 1 132.00	266	JEGA 1 132.00	4.305	13.72001	0.325544
259	BKEBBI 1 132.00	272	SOKOTO 1 132.00	15.99001	50.95998	1.20919
259	BKEBBI 1 132.00	272	SOKOTO 1 132.00	15.99001	50.95998	1.20919
259	BKEBBI 1 132.00	10003	DOSSO 132.00	23.36402	54.64794	1.179961
260	KUBWA 132.00	273	SULEJA 1 132.00	4.919998	15.68	0.372129
261	AKWANGA 1 132.00	268	KEFFI 1 132.00	7.625998	24.30404	0.576736
261	AKWANGA 1 132.00	282	LAFIA 1 132.00	7.379936	23.51996	0.558102
262	APO 1 132.00	267	KARU 1 132.00	1.23	3.919999	0.092987
262	APO 1 132.00	267	KARU 1 132.00	1.22996	3.920052	0.092987
262	APO 1 132.00	279	GWAGWALADA_1132.00	5.165833	16.46422	0.39058
262	APO 1 132.00	279	GWAGWALADA_1132.00	5.165833	16.46422	0.39058
263	BIDA 1 132.00	271	MINNA 1 132.00	11.06999	35.27994	0.837062
264	CENTRAL AREA132.00	265	GARKI NODE 1132.00	0.216	0.42	1.472074
264	CENTRAL AREA132.00	265	GARKI NODE 1132.00	0.216	0.42	1.472074
267	KARU 1 132.00	268	KEFFI 1 132.00	5.042993	16.072	0.381263
268	KEFFI 1 132.00	281	KWOI_1 132.00	3.689881	11.75998	0.27896
268	KEFFI 1 132.00	285	KACHIA_1 132.00	7.379936	23.4649	0.55664
269	KONTAGORA 1 132.00	270	TEGINA 1 132.00	11.06999	35.27994	0.837062
269	KONTAGORA 1 132.00	277	YELWA 1 132.00	10.824	34.49603	0.818428
270	TEGINA 1 132.00	283	BIRNIN GWARI132.00	5.780935	18.42396	0.437165
271	MINNA 1 132.00	273	SULEJA 1 132.00	12.17701	38.80795	0.920731
271	MINNA 1 132.00	273	SULEJA 1 132.00	12.17701	38.80795	0.920731
272	SOKOTO 1 132.00	284	B/KEBBI II 132.00	15.99001	50.95998	1.20919
272	SOKOTO 1 132.00	454	TMAFARA 1 132.00	15.37501	48.99995	1.162606
275	NAT STADIUM1132.00	280	EASTMAIN_1 132.00	2.951974	9.408089	0.223241
275	NAT STADIUM1132.00	280	EASTMAIN_1 132.00	2.951974	9.408089	0.223241
277	YELWA 1 132.00	278	YAURI_1 132.00	13.53148	51.83466	1.023217
281	KWOI_1 132.00	285	KACHIA_1 132.00	3.689881	11.75998	0.27896
286	KATAMPE 3 330.00	292	GWAGW BB1 330.00	2.836845	21.8192	0.873759
286	KATAMPE 3 330.00	294	SHIRORO 3 330.00	8.589203	66.05405	2.637792
286	KATAMPE 3 330.00	294	SHIRORO 3 330.00	8.589203	66.05405	2.637792
287	BKEBBI 3 330.00	290	KAINJI G.S.3330.00	12.08997	102.61	3.440991
287	BKEBBI 3 330.00	291	SOKOTO 3 330.00	5.069295	43.01877	1.44394
287	BKEBBI 3 330.00	291	SOKOTO 3 330.00	5.069295	43.01877	1.44394
288	JEBBA T.S.3 330.00	289	JEBBA G.S.3 330.00	0.314721	2.42847	0.09675
288	JEBBA T.S.3 330.00	289	JEBBA G.S.3 330.00	0.3152	2.424005	0.096808
288	JEBBA T.S.3 330.00	290	KAINJI G.S.3330.00	3.159004	26.81096	0.899101
288	JEBBA T.S.3 330.00	290	KAINJI G.S.3330.00	3.159004	26.81096	0.899101
288	JEBBA T.S.3 330.00	294	SHIRORO 3 330.00	9.515996	80.76405	2.708411
288	JEBBA T.S.3 330.00	294	SHIRORO 3 330.00	9.515681	80.7635	2.708411
291	SOKOTO 3 330.00	492	GUSAU 3 330.00	8.696754	73.81242	2.477205
291	SOKOTO 3 330.00	492	GUSAU 3 330.00	8.696754	73.81242	2.477205
292	GWAGW BB1 330.00	293	EASTMAIN_3 330.00	1.65528	12.72605	0.509617
292	GWAGW BB1 330.00	293	EASTMAIN_3 330.00	1.65528	12.72605	0.509617
292	GWAGW BB1 330.00	294	SHIRORO 3 330.00	5.752098	44.23518	1.771428
292	GWAGW BB1 330.00	294	SHIRORO 3 330.00	5.752098	44.23518	1.771428
292	GWAGW BB1 330.00	387	LOKOJA _3 330.00	6.879213	52.90362	2.118588
292	GWAGW BB1 330.00	387	LOKOJA _3 330.00	6.879213	52.90362	2.118588
292	GWAGW BB1 330.00	387	LOKOJA _3 330.00	6.879213	52.90362	2.118588
292	GWAGW BB1 330.00	387	LOKOJA _3 330.00	6.879213	52.90362	2.118588

From Bus (Number)	From Bus (Name)	To Bus (Number)	To Bus (Name)	Line R (ohms)	Line X (ohms)	Charging B (uF)
292	GWAGW BB1 330.00	388	OBAJANA_3 330.00	6.879213	52.90362	2.118588
294	SHIRORO 3 330.00	485	KADUNA 3 330.00	3.744004	31.77604	1.065593
294	SHIRORO 3 330.00	485	KADUNA 3 330.00	3.744004	31.77604	1.065593
294	SHIRORO 3 330.00	485	KADUNA 3 330.00	3.7026	31.7988	1.063956
294	SHIRORO 3 330.00	485	KADUNA 3 330.00	3.7026	31.7988	1.063956
370	AJAOKUTA 1 132.00	374	OKENE 1 132.00	7.380005	23.51996	0.558102
371	DELTA 1 132.00	372	BENIN 1 132.00	13.16099	41.94392	0.995084
371	DELTA 1 132.00	372	BENIN 1 132.00	12.546	39.98407	0.948682
371	DELTA 1 132.00	372	BENIN 1 132.00	13.16099	41.94392	0.995084
371	DELTA 1 132.00	372	BENIN 1 132.00	13.16099	41.94392	0.995084
371	DELTA 1 132.00	376	EFFURUN 1 132.00	7.452001	14.868	0.316775
371	DELTA 1 132.00	376	EFFURUN 1 132.00	7.452001	14.868	0.316775
371	DELTA 1 132.00	376	EFFURUN 1 132.00	7.452072	14.86807	0.316775
371	DELTA 1 132.00	377	AMUKPE 1 132.00	11.06999	35.27994	0.837062
372	BENIN 1 132.00	373	IRRUA 1 132.00	10.92239	34.80967	0.825918
372	BENIN 1 132.00	373	IRRUA 1 132.00	10.92241	34.80967	0.825918
372	BENIN 1 132.00	377	AMUKPE 1 132.00	1.475999	4.703992	0.11162
373	IRRUA 1 132.00	375	UKPILLA 1 132.00	5.289002	16.85599	0.399897
374	OKENE 1 132.00	375	UKPILLA 1 132.00	4.059008	12.936	0.30691
379	OBAJANA_1 132.00	380	OKEAGBE_1 132.00	11.06999	35.27994	0.837062
379	OBAJANA_1 132.00	380	OKEAGBE_1 132.00	11.06999	35.27994	0.837062
381	AJAOKUTA 3 330.00	383	BENIN 3 330.00	7.683004	59.085	2.359498
381	AJAOKUTA 3 330.00	383	BENIN 3 330.00	7.683004	59.085	2.359498
381	AJAOKUTA 3 330.00	386	GEREGU 330.00	0.058806	0.55539	0.018152
381	AJAOKUTA 3 330.00	386	GEREGU 330.00	0.058806	0.55539	0.018152
381	AJAOKUTA 3 330.00	387	LOKOJA _3 330.00	1.867635	14.35955	0.575033
381	AJAOKUTA 3 330.00	387	LOKOJA _3 330.00	1.867635	14.35955	0.575033
381	AJAOKUTA 3 330.00	387	LOKOJA _3 330.00	1.867635	14.35955	0.575033
381	AJAOKUTA 3 330.00	387	LOKOJA _3 330.00	1.867635	14.35955	0.575033
381	AJAOKUTA 3 330.00	388	OBAJANA_3 330.00	1.852389	14.8202	0.529201
382	ALADJA 3 330.00	384	DELTA IV 3 330.00	1.248005	10.592	0.355198
382	ALADJA 3 330.00	385	SAPELE 3 330.00	2.457002	20.85304	0.699288
383	BENIN 3 330.00	384	DELTA IV 3 330.00	1.599001	13.57101	0.455104
383	BENIN 3 330.00	385	SAPELE 3 330.00	1.970001	15.14995	0.604993
383	BENIN 3 330.00	385	SAPELE 3 330.00	1.970001	15.14995	0.604993
383	BENIN 3 330.00	385	SAPELE 3 330.00	1.970001	15.14995	0.604993
383	BENIN 3 330.00	389	EYEAN_3 330.00	0.979011	8.307981	0.278616
383	BENIN 3 330.00	684	ONITSHA 3 330.00	5.343004	45.34705	1.520697
383	BENIN 3 330.00	684	ONITSHA 3 330.00	5.342635	45.34705	1.520697
383	BENIN 3 330.00	688	ASABA_3 330.00	3.472712	29.47553	0.988456
384	DELTA IV 3 330.00	782	ONNIE_3 330.00	6.824763	57.925	1.944087
451	KANO 1 132.00	457	DAN AGUNDI 1132.00	1.106947	3.527837	0.08367
451	KANO 1 132.00	457	DAN AGUNDI 1132.00	1.106947	3.527837	0.08367
451	KANO 1 132.00	457	DAN AGUNDI 1132.00	1.106947	3.527837	0.08367
451	KANO 1 132.00	457	DAN AGUNDI 1132.00	1.7424	3.31056	0.073074
451	KANO 1 132.00	476	DANBATTA_1 132.00	7.379065	23.52014	0.558102
451	KANO 1 132.00	476	DANBATTA_1 132.00	7.379065	23.52014	0.558102
452	KADUNA 1 132.00	465	ZARIA 1 132.00	12.834	25.60596	0.545679
452	KADUNA 1 132.00	468	GURARA 1 132.00	17.21996	54.88002	1.302177
452	KADUNA 1 132.00	468	GURARA 1 132.00	17.21996	54.88002	1.302177
452	KADUNA 1 132.00	885	KADUNAPP 132132.00	0.985336	7.574833	0.303341
452	KADUNA 1 132.00	885	KADUNAPP 132132.00	0.985336	7.574833	0.303341

From Bus (Number)	From Bus (Name)	To Bus (Number)	To Bus (Name)	Line R (ohms)	Line X (ohms)	Charging B (uF)
453	KADUNA TOWN 132.00	483	MANDO T4A BB132.00	2.460007	7.839998	0.185973
453	KADUNA TOWN 132.00	483	MANDO T4A BB132.00	2.460007	7.839998	0.185973
454	TMAFARA 1 132.00	461	GUSAU 1 132.00	10.45499	33.31992	0.79066
455	KANKIA 1 132.00	462	KATSINA 1 132.00	8.487004	27.04797	0.641772
455	KANKIA 1 132.00	481	KUMB T2A BB 132.00	13.899	44.29599	1.050985
456	DAKATA 1 132.00	469	WALALAMBE 1 132.00	0.983933	3.135972	0.074353
456	DAKATA 1 132.00	469	WALALAMBE 1 132.00	0.983933	3.135972	0.074353
456	DAKATA 1 132.00	469	WALALAMBE 1 132.00	0.983933	3.135972	0.074353
456	DAKATA 1 132.00	472	HADEJIA 1 132.00	45.65088	69.69601	1.278793
456	DAKATA 1 132.00	478	GAGARAWA_1 132.00	39.12298	78.05726	1.663162
456	DAKATA 1 132.00	478	GAGARAWA_1 132.00	39.12298	78.05726	1.663162
456	DAKATA 1 132.00	480	KUMB T1A BB 132.00	2.683296	5.57568	0.109611
456	DAKATA 1 132.00	480	KUMB T1A BB 132.00	2.683296	5.57568	0.109611
458	AZARE 1 132.00	459	DUTSE 1 132.00	5.289002	16.85599	0.399897
458	AZARE 1 132.00	482	KUMB T4A BB 132.00	26.07153	83.09489	1.96788
459	DUTSE 1 132.00	470	BIRNIN KUDU 132.00	5.534995	17.64006	0.418531
459	DUTSE 1 132.00	471	WUDIL 1 132.00	6.248403	19.91354	0.472423
459	DUTSE 1 132.00	482	KUMB T4A BB 132.00	13.34556	42.53199	1.009151
461	GUSAU 1 132.00	466	FUNTUA 1 132.00	22.77003	45.42994	0.968046
462	KATSINA 1 132.00	467	DAURA 1 132.00	9.84003	31.36007	0.744075
462	KATSINA 1 132.00	467	DAURA 1 132.00	9.84003	31.36007	0.744075
462	KATSINA 1 132.00	475	KURFI_1 132.00	2.45992	7.839929	0.185973
462	KATSINA 1 132.00	475	KURFI_1 132.00	2.45992	7.839929	0.185973
462	KATSINA 1 132.00	883	NEW_PV 132.00	8.489476	27.05586	0.641923
462	KATSINA 1 132.00	10002	GAZAOUA 132.00	4.820001	32.06992	0.641041
463	TAMBURAWA 1 132.00	464	KWANAR DANGO132.00	8.280007	16.51999	0.352034
463	TAMBURAWA 1 132.00	480	KUMB T1A BB 132.00	4.139995	8.260004	0.175925
464	KWANAR DANGO132.00	465	ZARIA 1 132.00	17.55364	35.02242	0.746267
465	ZARIA 1 132.00	466	FUNTUA 1 132.00	14.49001	28.91008	0.616013
469	WALALAMBE 1 132.00	480	KUMB T1A BB 132.00	1.22996	3.920052	0.092987
469	WALALAMBE 1 132.00	480	KUMB T1A BB 132.00	1.22996	3.920052	0.092987
469	WALALAMBE 1 132.00	480	KUMB T1A BB 132.00	1.22996	3.920052	0.092987
469	WALALAMBE 1 132.00	480	KUMB T1A BB 132.00	1.22996	3.920052	0.092987
471	WUDIL 1 132.00	482	KUMB T4A BB 132.00	6.149992	19.60008	0.465115
472	HADEJIA 1 132.00	478	GAGARAWA_1 132.00	6.780027	18.56005	0.339976
472	HADEJIA 1 132.00	478	GAGARAWA_1 132.00	6.780027	18.56005	0.339976
473	DUTSIN_MA_1 132.00	475	KURFI_1 132.00	4.91984	15.67986	0.372129
473	DUTSIN_MA_1 132.00	475	KURFI_1 132.00	4.91984	15.67986	0.372129
473	DUTSIN_MA_1 132.00	477	KANKARA_1 132.00	4.91984	15.67986	0.372129
473	DUTSIN_MA_1 132.00	477	KANKARA_1 132.00	4.91984	15.67986	0.372129
474	MALUMFASHI_1132.00	477	KANKARA_1 132.00	8.978588	28.61544	0.679039
474	MALUMFASHI_1132.00	477	KANKARA_1 132.00	8.978588	28.61544	0.679039
481	KUMB T2A BB 132.00	883	NEW_PV 132.00	9.345559	29.78419	0.706655
485	KADUNA 3 330.00	486	KANO 3 330.00	8.969995	76.13004	2.552997
485	KADUNA 3 330.00	486	KANO 3 330.00	8.970093	76.12981	2.555073
485	KADUNA 3 330.00	486	KANO 3 330.00	8.970093	76.12981	2.555073
485	KADUNA 3 330.00	488	ZARIA 3 330.00	2.41758	20.5222	0.68821
485	KADUNA 3 330.00	488	ZARIA 3 330.00	2.41758	20.5222	0.68821
485	KADUNA 3 330.00	594	JOS 3 330.00	7.643996	64.87598	2.175615

From Bus (Number)	From Bus (Name)	To Bus (Number)	To Bus (Name)	Line R (ohms)	Line X (ohms)	Charging B (uF)
485	KADUNA 3 330.00	594	JOS 3 330.00	7.583795	64.90004	2.175264
485	KADUNA 3 330.00	594	JOS 3 330.00	7.583795	64.90004	2.175264
486	KANO 3 330.00	487	KATSINA 3 330.00	7.019694	59.58028	1.999623
486	KANO 3 330.00	487	KATSINA 3 330.00	7.019694	59.58028	1.999623
486	KANO 3 330.00	490	KANO_NEW330 330.00	0.702405	5.957919	0.199959
486	KANO 3 330.00	490	KANO_NEW330 330.00	0.702405	5.957919	0.199959
487	KATSINA 3 330.00	490	KANO_NEW330 330.00	6.30383	48.4796	1.941449
487	KATSINA 3 330.00	490	KANO_NEW330 330.00	6.30383	48.4796	1.941449
487	KATSINA 3 330.00	492	GUSAU 3 330.00	9.196606	78.04972	2.619495
487	KATSINA 3 330.00	492	GUSAU 3 330.00	9.196606	78.04972	2.619495
488	ZARIA 3 330.00	489	FUNTUA 3 330.00	2.730123	23.16957	0.777009
488	ZARIA 3 330.00	489	FUNTUA 3 330.00	2.730123	23.16957	0.777009
489	FUNTUA 3 330.00	492	GUSAU 3 330.00	2.730123	23.16957	0.777009
489	FUNTUA 3 330.00	492	GUSAU 3 330.00	2.730123	23.16957	0.777009
491	TMAFARA3 330.00	492	GUSAU 3 330.00	3.314916	28.12778	0.944115
491	TMAFARA3 330.00	492	GUSAU 3 330.00	3.314916	28.12778	0.944115
502	KATSINA 33 33.000	563	KT WF 33 33.000	0.145294	0.463054	2.835267
544	KANKIA T1 33.000	888	KANKIA PV 33.000	0	0.001089	0
569	GOMBE 1 132.00	573	ASHAKA RNDAB132.00	9.347994	29.79208	0.706807
569	GOMBE 1 132.00	574	BAUCHI 1 132.00	17.95805	57.23192	1.357713
569	GOMBE 1 132.00	579	T-JUNCTION 1132.00	12.37278	18.56005	3.400128
569	GOMBE 1 132.00	591	DADINKOWA 1 132.00	7.872006	25.08795	0.595187
570	JOS 1 132.00	574	BAUCHI 1 132.00	14.514	46.25602	1.097387
570	JOS 1 132.00	574	BAUCHI 1 132.00	14.51402	46.25602	1.097387
570	JOS 1 132.00	589	MAKERI 1 132.00	6.149992	19.60008	0.465115
570	JOS 1 132.00	589	MAKERI 1 132.00	6.149992	19.60008	0.465115
570	JOS 1 132.00	590	KAFANCHAN 1 132.00	9.471007	30.18394	0.716124
570	JOS 1 132.00	590	KAFANCHAN 1 132.00	9.471007	30.18394	0.716124
571	YOLA 1 132.00	579	T-JUNCTION 1132.00	57.84559	86.76804	1.58954
571	YOLA 1 132.00	582	SONG 1 132.00	8.610001	27.44001	0.651088
571	YOLA 1 132.00	582	SONG 1 132.00	8.610001	27.44001	0.651088
571	YOLA 1 132.00	586	JALINGO 1 132.00	0.998395	8.473466	11.09262
572	ASHAKA 1 132.00	573	ASHAKA RNDAB132.00	1.23	3.919999	0.092987
573	ASHAKA RNDAB132.00	577	POTISKUM 1 132.00	13.038	41.55206	0.985767
575	BIU 1 132.00	585	DAMBOA 1 132.00	17.46582	55.66271	1.320445
575	BIU 1 132.00	591	DADINKOWA 1 132.00	8.732908	27.83136	0.660223
576	PANKSHIN 1 132.00	589	MAKERI 1 132.00	11.06999	35.27994	0.837062
576	PANKSHIN 1 132.00	589	MAKERI 1 132.00	11.06999	35.27994	0.837062
578	SAVANNAH 1 132.00	579	T-JUNCTION 1132.00	16.0841	24.12806	4.420057
580	MUBI 1 132.00	581	GOMBI 1 132.00	9.224998	29.40004	0.69749
580	MUBI 1 132.00	581	GOMBI 1 132.00	6.149992	19.60008	0.465115
580	MUBI 1 132.00	592	GULAK 1 132.00	14.75999	47.03992	1.116204
580	MUBI 1 132.00	592	GULAK 1 132.00	14.75999	47.03992	1.116204
581	GOMBI 1 132.00	582	SONG 1 132.00	6.149992	19.60008	0.465115
581	GOMBI 1 132.00	582	SONG 1 132.00	6.149992	19.60008	0.465115
585	DAMBOA 1 132.00	587	MAIDUGURI 1 132.00	8.732908	27.83136	0.660223
593	GOMBE 3 330.00	594	JOS 3 330.00	10.29599	87.38398	2.930409
593	GOMBE 3 330.00	594	JOS 3 330.00	10.3063	87.87576	2.941049
593	GOMBE 3 330.00	595	YOLA 3 330.00	9.359999	79.44005	2.664011
593	GOMBE 3 330.00	598	DAMATURU 3 330.00	7.019694	59.58028	1.999623
594	JOS 3 330.00	686	MAKURDI_3 330.00	11.26788	86.65826	3.470309

From Bus (Number)	From Bus (Name)	To Bus (Number)	To Bus (Name)	Line R (ohms)	Line X (ohms)	Charging B (uF)
594	JOS 3 330.00	686	MAKURDI_3 330.00	11.26788	86.65826	3.470309
594	JOS 3 330.00	686	MAKURDI_3 330.00	11.26788	86.65826	3.470309
595	YOLA 3 330.00	597	JALINGO_3 330.00	6.224375	52.82782	1.771574
596	MAIDUGURI 3 330.00	598	DAMATURU 3 330.00	10.13968	86.0604	2.888348
645	ONITSHA BBI 132.00	658	OBA 1 132.00	2.767506	8.819994	0.209357
645	ONITSHA BBI 132.00	658	OBA 1 132.00	2.767506	8.819994	0.209357
645	ONITSHA BBI 132.00	670	GCM 1 132.00	2.275574	7.257619	0.172272
646	ONITSHA 1 132.00	653	AWKA 1 132.00	3.690055	11.75998	0.27896
646	ONITSHA 1 132.00	653	AWKA 1 132.00	3.690055	11.75998	0.27896
647	NHAVEN 1 132.00	650	9TH MILE 1 132.00	1.23	3.919999	0.092987
647	NHAVEN 1 132.00	655	NKALAGU 1 132.00	4.797001	15.28799	0.362812
647	NHAVEN 1 132.00	655	NKALAGU 1 132.00	4.797001	15.28799	0.362812
647	NHAVEN 1 132.00	659	OJI RIVER 1 132.00	5.4243	17.2872	0.410127
647	NHAVEN 1 132.00	662	OTURKPO 1 132.00	19.19951	61.19082	1.451065
648	AGU-AWKA 132.00	653	AWKA 1 132.00	1.640818	5.229274	0.124043
648	AGU-AWKA 132.00	659	OJI RIVER 1 132.00	2.461227	7.843919	0.186156
649	ONITSHA BBII132.00	653	AWKA 1 132.00	3.690002	11.76	0.27896
650	9TH MILE 1 132.00	657	NSUKKA 1 132.00	4.550992	14.504	0.344178
651	APIR 1 132.00	678	ALIADE 1 132.00	3.075006	9.800008	0.232558
652	AROCHUKWU 1 132.00	666	OHAFIA 1 132.00	4.059008	12.936	0.30691
654	AYANGBA 1 132.00	657	NSUKKA 1 132.00	9.839995	31.36007	0.744075
654	AYANGBA 1 132.00	657	NSUKKA 1 132.00	9.84003	31.36007	0.744075
655	NKALAGU 1 132.00	660	ABAKALIKI 1 132.00	6.672747	21.26599	0.504575
655	NKALAGU 1 132.00	660	ABAKALIKI 1 132.00	6.672747	21.26599	0.504575
655	NKALAGU 1 132.00	660	ABAKALIKI 1 132.00	6.672747	21.26599	0.504575
656	NNEWI 1 132.00	658	OBA 1 132.00	2.767506	8.819994	0.209357
656	NNEWI 1 132.00	658	OBA 1 132.00	2.767506	8.819994	0.209357
656	NNEWI 1 132.00	665	IDEATO 1 132.00	2.767506	8.819994	0.209357
656	NNEWI 1 132.00	665	IDEATO 1 132.00	2.767506	8.819994	0.209357
656	NNEWI 1 132.00	677	IHIALA 1 132.00	2.460007	7.839998	0.185973
656	NNEWI 1 132.00	677	IHIALA 1 132.00	2.45992	7.839929	0.185973
660	ABAKALIKI 1 132.00	676	AMASIRI_1 132.00	8.610069	27.44001	0.651088
660	ABAKALIKI 1 132.00	676	AMASIRI_1 132.00	8.610069	27.44001	0.651088
660	ABAKALIKI 1 132.00	765	IKOM 1 132.00	4.797001	15.28799	0.362812
660	ABAKALIKI 1 132.00	765	IKOM 1 132.00	4.797001	15.28799	0.362812
661	OKIGWE 1 132.00	664	MBALANO 1 132.00	2.705999	8.623992	0.204607
661	OKIGWE 1 132.00	665	IDEATO 1 132.00	2.767506	8.819994	0.209357
661	OKIGWE 1 132.00	665	IDEATO 1 132.00	2.767506	8.819994	0.209357
662	OTURKPO 1 132.00	678	ALIADE 1 132.00	4.821221	15.36623	0.364639
663	YANDEV 1 132.00	678	ALIADE 1 132.00	4.821221	15.36623	0.364639
664	MBALANO 1 132.00	768	UMUAHIA 1 132.00	3.075006	9.800008	0.232558
666	OHAFIA 1 132.00	768	UMUAHIA 1 132.00	4.919998	15.68	0.372129
667	ASABA 1 132.00	668	AGBOR 1 132.00	7.380005	23.51996	0.558102
667	ASABA 1 132.00	668	AGBOR 1 132.00	7.380005	23.51996	0.558102
669	MAKURDI 1 132.00	678	ALIADE 1 132.00	5.780935	18.42396	0.437165
671	ORLU_1 132.00	677	IHIALA 1 132.00	3.21769	10.25472	0.243336
671	ORLU_1 132.00	677	IHIALA 1 132.00	3.21769	10.25472	0.243336
672	MPU_1 132.00	674	NENWE_1 132.00	3.074988	9.799955	0.232558
672	MPU_1 132.00	674	NENWE_1 132.00	3.074988	9.799955	0.232558
672	MPU_1 132.00	677	IHIALA 1 132.00	2.145069	6.836481	0.162224
672	MPU_1 132.00	677	IHIALA 1 132.00	2.145069	6.836481	0.162224
673	UGWUAJI_1 132.00	674	NENWE_1 132.00	5.535604	17.63988	0.418531

From Bus (Number)	From Bus (Name)	To Bus (Number)	To Bus (Name)	Line R (ohms)	Line X (ohms)	Charging B (uF)
673	UGWUAJI_1 132.00	674	NENWE_1 132.00	5.535604	17.63988	0.418531
674	NENWE_1 132.00	675	AMMASOMA_1 132.00	3.074988	9.799955	0.232558
675	AMMASOMA_1 132.00	681	OPROMA_1 132.00	3.074988	9.799955	0.232558
679	IGBUMATORU_1132.00	680	EKAWE_1 132.00	2.619873	8.349581	0.19803
680	EKAWE_1 132.00	682	UKUBIE_1 132.00	2.619873	8.349581	0.19803
681	OPROMA_1 132.00	682	UKUBIE_1 132.00	2.619873	8.349581	0.19803
683	NHAVEN 3 330.00	684	ONITSHA 3 330.00	3.744004	31.77604	1.065593
684	ONITSHA 3 330.00	685	OKPAI 3 330.00	2.364002	18.17998	0.726004
684	ONITSHA 3 330.00	685	OKPAI 3 330.00	2.364002	18.17998	0.726004
684	ONITSHA 3 330.00	688	ASABA_3 330.00	1.869922	15.87152	0.532241
684	ONITSHA 3 330.00	777	ALAOJI 3 330.00	5.382002	45.67799	1.531804
684	ONITSHA 3 330.00	777	ALAOJI 3 330.00	5.3361	45.6291	1.531629
686	MAKURDI_3 330.00	687	ALIADE_3 330.00	1.867635	14.35955	0.575033
686	MAKURDI_3 330.00	687	ALIADE_3 330.00	1.867635	14.35955	0.575033
686	MAKURDI_3 330.00	687	ALIADE_3 330.00	1.867635	14.35955	0.575033
686	MAKURDI_3 330.00	687	ALIADE_3 330.00	1.867635	14.35955	0.575033
689	NSUKKA 66 66.000	690	OJI RIVER 6666.000	2.459999	7.840016	0.186338
749	AFAM 1 132.00	750	ALAOJI 1 132.00	5.658008	18.03192	0.427848
749	AFAM 1 132.00	754	PHCT MAIN1 132.00	6.658076	13.53679	0.292296
749	AFAM 1 132.00	759	RIVERS_IPP 132.00	4.327738	8.798859	0.189992
750	ALAOJI 1 132.00	767	ABA 1 132.00	1.23	3.919999	0.092987
750	ALAOJI 1 132.00	767	ABA 1 132.00	1.23	3.919999	0.092987
750	ALAOJI 1 132.00	768	UMUAHIA 1 132.00	8.117998	25.87203	0.613821
750	ALAOJI 1 132.00	768	UMUAHIA 1 132.00	8.117998	25.87203	0.613821
750	ALAOJI 1 132.00	769	OWERRI 1 132.00	7.362686	23.4649	0.55664
750	ALAOJI 1 132.00	769	OWERRI 1 132.00	7.362686	23.4649	0.55664
751	CALABAR 1 132.00	753	ITU 1 132.00	5.825279	18.5651	0.440453
751	CALABAR 1 132.00	774	CALABAR_AD 132.00	0.615067	1.960026	0.046585
751	CALABAR 1 132.00	774	CALABAR_AD 132.00	0.615067	1.960026	0.046585
751	CALABAR 1 132.00	774	CALABAR_AD 132.00	0.983933	3.135972	0.074353
751	CALABAR 1 132.00	774	CALABAR_AD 132.00	0.983933	3.135972	0.074353
752	EKET 1 132.00	757	UYO 1 132.00	5.658008	18.03192	0.427848
752	EKET 1 132.00	757	UYO 1 132.00	5.658008	18.03192	0.427848
753	ITU 1 132.00	757	UYO 1 132.00	2.213998	7.056005	0.167339
753	ITU 1 132.00	757	UYO 1 132.00	2.213998	7.056005	0.167339
753	ITU 1 132.00	767	ABA 1 132.00	10.5042	33.47673	0.794313
753	ITU 1 132.00	774	CALABAR_AD 132.00	5.825192	18.5651	0.440453
754	PHCT MAIN1 132.00	755	PHCT TOWN1 1132.00	0.369	1.176	0.027951
754	PHCT MAIN1 132.00	756	PHCT TOWN2 1132.00	0.369	1.176	0.027951
754	PHCT MAIN1 132.00	758	ONNE 1 132.00	1.23	3.919999	0.092987
754	PHCT MAIN1 132.00	758	ONNE 1 132.00	1.23	3.919999	0.092987
754	PHCT MAIN1 132.00	759	RIVERS_IPP 132.00	2.330321	4.737847	0.102304
754	PHCT MAIN1 132.00	759	RIVERS_IPP 132.00	2.330286	4.737934	0.102304
758	ONNE 1 132.00	775	TRAMADI 132.00	1.22996	3.920052	0.092987
760	ABOH MBAISE 132.00	769	OWERRI 1 132.00	3.198001	10.192	0.241875
760	ABOH MBAISE 132.00	769	OWERRI 1 132.00	3.198001	10.192	0.241875
761	YENAGOA 1 132.00	762	AHOADA 1 132.00	5.658008	18.03192	0.427848
761	YENAGOA 1 132.00	762	AHOADA 1 132.00	5.658008	18.03192	0.427848
761	YENAGOA 1 132.00	766	GBARAIN UBIE132.00	0.614999	1.960008	0.046585
761	YENAGOA 1 132.00	766	GBARAIN UBIE132.00	0.615	1.960008	0.046585
762	AHOADA 1 132.00	763	OMOKU 1 132.00	1.844993	5.880008	0.139571
762	AHOADA 1 132.00	763	OMOKU 1 132.00	1.844993	5.880008	0.139571

From Bus (Number)	From Bus (Name)	To Bus (Number)	To Bus (Name)	Line R (ohms)	Line X (ohms)	Charging B (uF)
762	AHOADA 1 132.00	769	OWERRI 1 132.00	8.979006	28.61596	0.679039
762	AHOADA 1 132.00	769	OWERRI 1 132.00	8.979006	28.61596	0.679039
764	OBUDU 1 132.00	765	IKOM 1 132.00	5.658008	18.03192	0.427848
764	OBUDU 1 132.00	765	IKOM 1 132.00	5.658008	18.03192	0.427848
764	OBUDU 1 132.00	771	OGOJA 1 132.00	5.534995	17.64006	0.418531
764	OBUDU 1 132.00	771	OGOJA 1 132.00	5.534995	17.64006	0.418531
770	OGOJA-GAKEM 132.00	771	OGOJA 1 132.00	3.690002	11.76	0.27896
770	OGOJA-GAKEM 132.00	771	OGOJA 1 132.00	3.690002	11.76	0.27896
773	CALABAR_EP 132.00	774	CALABAR_AD 132.00	0.615067	1.960026	0.046585
773	CALABAR_EP 132.00	774	CALABAR_AD 132.00	0.615067	1.960026	0.046585
776	AFAM IV 3 330.00	777	ALAOJI 3 330.00	0.985	7.574996	0.302497
776	AFAM IV 3 330.00	777	ALAOJI 3 330.00	0.985	7.574996	0.302497
776	AFAM IV 3 330.00	779	IKOT-EKPENE_330.00	3.191859	24.54279	0.982844
776	AFAM IV 3 330.00	782	ONNIE_3 330.00	1.575783	12.11948	0.485357
776	AFAM IV 3 330.00	782	ONNIE_3 330.00	1.575783	12.11948	0.485357
777	ALAOJI 3 330.00	779	IKOT-EKPENE_330.00	2.147508	16.5136	0.661289
777	ALAOJI 3 330.00	780	OWERRI_3 330.00	2.31957	19.83831	0.665937
777	ALAOJI 3 330.00	780	OWERRI_3 330.00	2.31957	19.83831	0.665937
778	CALABAR_3 330.00	783	CALABAR_PS_3330.00	1.891593	14.5436	0.582428
778	CALABAR_3 330.00	783	CALABAR_PS_3330.00	1.891593	14.5436	0.582428
779	IKOT-EKPENE_330.00	783	CALABAR_PS_3330.00	0.866844	6.665769	0.266954
779	IKOT-EKPENE_330.00	783	CALABAR_PS_3330.00	0.866844	6.665769	0.266954
779	IKOT-EKPENE_330.00	785	ABASI_3 330.00	3.073158	23.63348	0.946453
779	IKOT-EKPENE_330.00	785	ABASI_3 330.00	3.073158	23.63348	0.946453
780	OWERRI_3 330.00	781	EGBEMA_3 330.00	2.639736	20.30114	0.812991
780	OWERRI_3 330.00	781	EGBEMA_3 330.00	2.639736	20.30114	0.812991
781	EGBEMA_3 330.00	784	OMOKU_3 330.00	2.639736	20.30114	0.812991
781	EGBEMA_3 330.00	784	OMOKU_3 330.00	2.639736	20.30114	0.812991

III. B

From Bus (Number)	To Bus (Number)	Rate A	Rate B	Rate C	Line G From (pu)	Line B From (pu)	Line G To (pu)	Line B To (pu)	Length (Km)
2	12	125.7	138.3	0	0	0	0	0	3
2	12	125.7	138.3	0	0	0	0	0	3
2	12	125.7	138.3	0	0	0	0	0	3
2	14	125.7	138.3	0	0	0	0	0	4.5
2	16	125.7	138.3	0	0	0	0	0	8.3
2	16	125.7	138.3	0	0	0	0	0	8.3
2	19	125.7	138.3	0	0	0	0	0	4.5
2	19	125.7	138.3	0	0	0	0	0	4.5
3	17	125.7	138.3	0	0	0	0	0	20
3	17	125.7	138.3	0	0	0	0	0	20
4	7	125.7	138.3	0	0	0	0	0	32.04
4	7	125.7	138.3	0	0	0	0	0	32.04
4	11	125.7	138.3	0	0	0	0	0	3.5
4	11	125.7	138.3	0	0	0	0	0	3.5

From Bus (Number)	To Bus (Number)	Rate A	Rate B	Rate C	Line G From (pu)	Line B From (pu)	Line G To (pu)	Line B To (pu)	Length (Km)
4	18	125.7	138.3	0	0	0	0	0	20
4	18	125.7	138.3	0	0	0	0	0	20
4	25	125.7	138.3	0	0	0	0	0	49
4	25	125.7	138.3	0	0	0	0	0	49
4	29	125.7	138.3	0	0	0	0	0	16
4	29	125.7	138.3	0	0	0	0	0	16
5	13	125.7	138.3	0	0	0	0	0	10
5	13	125.7	138.3	0	0	0	0	0	10
5	14	125.7	138.3	0	0	0	0	0	4.5
6	24	125.7	138.3	0	0	0	0	0	30
6	24	125.7	138.3	0	0	0	0	0	30
6	28	125.7	138.3	0	0	0	0	0	55
6	28	125.7	138.3	0	0	0	0	0	55
6	28	125.7	138.3	0	0	0	0	0	55
7	20	125.7	138.3	0	0	0	0	0	16.37
7	20	125.7	138.3	0	0	0	0	0	16.37
8	9	125.7	138.3	0	0	0	0	0	12
8	16	125.7	138.3	0	0	0	0	0	8
8	25	125.7	138.3	0	0	0	0	0	4.45
8	25	125.7	138.3	0	0	0	0	0	4.45
9	16	125.7	138.3	0	0	0	0	0	4
9	21	125.7	138.3	0	0	0	0	0	13
9	21	125.7	138.3	0	0	0	0	0	13
10	23	125.7	138.3	0	0	0	0	0	2
10	23	125.7	138.3	0	0	0	0	0	2
11	23	125.7	138.3	0	0	0	0	0	9.5
11	23	125.7	138.3	0	0	0	0	0	9.5
12	15	125.7	138.3	0	0	0	0	0	8
12	15	125.7	138.3	0	0	0	0	0	8
13	14	125.7	138.3	0	0	0	0	0	2
13	14	125.7	138.3	0	0	0	0	0	2
13	20	125.7	138.3	0	0	0	0	0	8.9
13	20	125.7	138.3	0	0	0	0	0	8.9
15	32	125.7	138.3	0	0	0	0	0	13.32
15	32	125.7	138.3	0	0	0	0	0	13.32
17	22	125.7	138.3	0	0	0	0	0	20
17	22	125.7	138.3	0	0	0	0	0	20
17	27	125.7	138.3	0	0	0	0	0	17.95
18	22	125.7	138.3	0	0	0	0	0	5.7
18	22	125.7	138.3	0	0	0	0	0	5.7
21	31	125.7	138.3	0	0	0	0	0	7
21	31	125.7	138.3	0	0	0	0	0	7
23	24	125.7	138.3	0	0	0	0	0	44.3
24	32	125.7	138.3	0	0	0	0	0	12
24	32	125.7	138.3	0	0	0	0	0	12
25	29	125.7	138.3	0	0	0	0	0	41
25	29	125.7	138.3	0	0	0	0	0	41
26	32	125.7	138.3	0	0	0	0	0	1
26	32	125.7	138.3	0	0	0	0	0	1
27	192	125.7	138.3	0	0	0	0	0	17.95
33	35	777.3	855.1	0	0	0	0	0	14
33	35	777.3	855.1	0	0	0	0	0	14

From Bus (Number)	To Bus (Number)	Rate A	Rate B	Rate C	Line G From (pu)	Line B From (pu)	Line G To (pu)	Line B To (pu)	Length (Km)
33	39	125.7	138.3	0	0	0	0	0	7
33	39	125.7	138.3	0	0	0	0	0	7
33	41	777.3	855.1	0	0	0	0	0	26
33	41	777.3	855.1	0	0	0	0	0	26
34	36	777.3	855.1	0	0	0	0	0	17
34	36	777.3	855.1	0	0	0	0	0	17
35	36	777.3	855.1	0	0	0	0	0	18
35	40	777.3	855.1	0	0	0	0	0	15.2
35	40	777.3	855.1	0	0	0	0	0	15.2
35	383	777.3	855.1	0	0	0	0	0	200
36	38	777.3	855.1	0	0	0	0	0	77
36	40	777.3	855.1	0	0	0	0	0	15.2
36	40	777.3	855.1	0	0	0	0	0	15.2
36	198	777.3	855.1	0	0	0	0	0	250
36	199	777.3	855.1	0	0	0	0	0	80
36	1000	777.3	855.1	0	0	0	0	0	70
38	197	777.3	855.1	0	0	0	0	0	60
39	41	125.7	138.5	0	0	0	0	0	13
39	41	125.7	138.3	0	0	0	0	0	13
169	683	777.3	855.1	0	0	0	0	0	7
169	683	777.3	855.1	0	0	0	0	0	7
169	687	777.3	855.1	0	0	0	0	0	157
169	687	777.3	855.1	0	0	0	0	0	157
169	779	777.3	855.1	0	0	0	0	0	162
169	779	777.3	855.1	0	0	0	0	0	162
169	779	777.3	855.1	0	0	0	0	0	162
169	779	777.3	855.1	0	0	0	0	0	162
170	176	125.7	138.3	0	0	0	0	0	12
170	182	125.7	138.3	0	0	0	0	0	2
170	192	125.7	138.3	0	0	0	0	0	92
171	175	125.7	138.3	0	0	0	0	0	95
171	175	125.7	138.3	0	0	0	0	0	95
171	183	125.7	138.3	0	0	0	0	0	43.5
171	188	125.7	138.3	0	0	0	0	0	90
171	188	125.7	138.3	0	0	0	0	0	90
171	194	125.7	138.3	0	0	0	0	0	14.7
171	194	125.7	138.3	0	0	0	0	0	14.7
171	195	125.7	138.3	0	0	0	0	0	148
171	196	550	605	0	0	0	0	0	15
171	196	550	605	0	0	0	0	0	15
172	175	125.7	138.3	0	0	0	0	0	92
172	178	125.7	138.3	0	0	0	0	0	80
173	180	125.7	138.3	0	0	0	0	0	5
173	180	125.7	138.3	0	0	0	0	0	5
173	188	125.7	138.3	0	0	0	0	0	35
173	188	125.7	138.3	0	0	0	0	0	35
173	191	550	605	0	0	0	0	0	60
173	191	550	605	0	0	0	0	0	60
174	175	125.7	138.3	0	0	0	0	0	47
174	175	125.7	138.3	0	0	0	0	0	47
176	178	125.7	138.3	0	0	0	0	0	18
177	179	125.7	138.3	0	0	0	0	0	19.5

From Bus (Number)	To Bus (Number)	Rate A	Rate B	Rate C	Line G From (pu)	Line B From (pu)	Line G To (pu)	Line B To (pu)	Length (Km)
177	187	125.7	138.3	0	0	0	0	0	43.5
177	194	125.7	138.3	0	0	0	0	0	19.5
178	181	125.7	138.3	0	0	0	0	0	71
179	194	125.7	138.3	0	0	0	0	0	20.3
180	183	125.7	138.3	0	0	0	0	0	47.53
183	185	125.7	138.3	0	0	0	0	0	47.53
185	190	550	605	0	0	0	0	0	70
186	187	125.7	138.3	0	0	0	0	0	14.5
192	193	125.7	138.3	0	0	0	0	0	41
197	198	777.3	855.1	0	0	0	0	0	115
198	200	777.3	855.1	0	0	0	0	0	47
198	288	777.3	855.1	0	0	0	0	0	157
198	288	777.3	855.1	0	0	0	0	0	157
198	389	777.3	855.1	0	0	0	0	0	141
199	383	777.3	855.1	0	0	0	0	0	51
200	288	777.3	855.1	0	0	0	0	0	110
257	270	125.7	138.3	0	0	0	0	0	65
257	271	125.7	138.3	0	0	0	0	0	68
257	271	125.7	138.3	0	0	0	0	0	68
257	273	125.7	138.3	0	0	0	0	0	167
258	260	125.7	138.3	0	0	0	0	0	7
258	260	125.7	138.3	0	0	0	0	0	7
258	262	125.7	138.3	0	0	0	0	0	15
258	262	125.7	138.3	0	0	0	0	0	15
258	262	125.7	138.3	0	0	0	0	0	15
258	265	125.7	138.3	0	0	0	0	0	6
258	265	125.7	138.3	0	0	0	0	0	6
258	273	125.7	138.3	0	0	0	0	0	47
258	275	550	605	0	0	0	0	0	8
258	275	550	605	0	0	0	0	0	8
259	266	125.7	138.3	0	0	0	0	0	35
259	266	125.7	138.3	0	0	0	0	0	35
259	272	125.7	138.3	0	0	0	0	0	130
259	272	125.7	138.3	0	0	0	0	0	130
259	10003	107.6	0	0	0	0	0	0	132
260	273	125.7	138.3	0	0	0	0	0	40
261	268	125.7	138.3	0	0	0	0	0	62
261	282	550	605	0	0	0	0	0	60
262	267	125.7	138.3	0	0	0	0	0	10
262	267	125.7	138.3	0	0	0	0	0	10
262	279	125.7	138.3	0	0	0	0	0	42
262	279	125.7	138.3	0	0	0	0	0	42
263	271	125.7	138.3	0	0	0	0	0	90
264	265	154.1	169.5	0	0	0	0	0	4
264	265	154.1	169.5	0	0	0	0	0	4
267	268	125.7	138.3	0	0	0	0	0	41
268	281	550	605	0	0	0	0	0	30
268	285	550	605	0	0	0	0	0	60
269	270	125.7	138.3	0	0	0	0	0	90
269	277	125.7	138.3	0	0	0	0	0	88
270	283	125.7	138.3	0	0	0	0	0	50
271	273	125.7	138.3	0	0	0	0	0	99

From Bus (Number)	To Bus (Number)	Rate A	Rate B	Rate C	Line G From (pu)	Line B From (pu)	Line G To (pu)	Line B To (pu)	Length (Km)
271	273	125.7	138.3	0	0	0	0	0	99
272	284	125.7	138.3	0	0	0	0	0	130
272	454	125.7	138.3	0	0	0	0	0	125
275	280	550	605	0	0	0	0	0	24
275	280	550	605	0	0	0	0	0	24
277	278	550	605	0	0	0	0	0	100
281	285	550	605	0	0	0	0	0	30
286	292	777.3	855.1	0	0	0	0	0	72.01
286	294	777.3	855.1	0	0	0	0	0	218
286	294	777.3	855.1	0	0	0	0	0	218
287	290	777.3	855.1	0	0	0	0	0	310
287	291	777.3	855.1	0	0	0	0	0	130
287	291	777.3	855.1	0	0	0	0	0	130
288	289	777.3	855.1	0	0	0	0	0	8
288	289	777.3	855.1	0	0	0	0	0	8
288	290	777.3	855.1	0	0	0	0	0	81
288	290	777.3	855.1	0	0	0	0	0	81
288	294	777.3	855.1	0	0	0	0	0	244
288	294	777.3	855.1	0	0	0	0	0	244
291	492	777.3	855.1	0	0	0	0	0	223
291	492	777.3	855.1	0	0	0	0	0	223
292	293	777.3	855.1	0	0	0	0	0	42
292	293	777.3	855.1	0	0	0	0	0	42
292	294	777.3	855.1	0	0	0	0	0	145.99
292	294	777.3	855.1	0	0	0	0	0	145.99
292	387	777.3	0	0	0	0	0	0	174.6
292	387	777.3	855.1	0	0	0	0	0	174.6
292	387	777.3	855.1	0	0	0	0	0	174.6
292	387	777.3	855.1	0	0	0	0	0	174.6
292	388	777.3	0	0	0	0	0	0	174.6
294	485	777.3	855.1	0	0	0	0	0	96
294	485	777.3	855.1	0	0	0	0	0	96
294	485	777.3	855.1	0	0	0	0	0	96
294	485	777.3	855.1	0	0	0	0	0	96
370	374	125.7	138.3	0	0	0	0	0	60
371	372	125.7	138.3	0	0	0	0	0	107
371	372	125.7	138.3	0	0	0	0	0	102
371	372	125.7	138.3	0	0	0	0	0	107
371	372	125.7	138.3	0	0	0	0	0	107
371	376	90.3	99.3	0	0	0	0	0	36
371	376	90.3	99.3	0	0	0	0	0	36
371	376	90.3	99.3	0	0	0	0	0	36
371	377	125.7	138.3	0	0	0	0	0	90
372	373	125.7	138.3	0	0	0	0	0	88.8
372	373	125.7	138.3	0	0	0	0	0	88.8
372	377	125.7	138.3	0	0	0	0	0	12
373	375	125.7	138.3	0	0	0	0	0	43
374	375	125.7	138.3	0	0	0	0	0	33
379	380	550	605	0	0	0	0	0	90
379	380	550	605	0	0	0	0	0	90
381	383	777.3	855.1	0	0	0	0	0	195
381	383	777.3	855.1	0	0	0	0	0	195

From Bus (Number)	To Bus (Number)	Rate A	Rate B	Rate C	Line G From (pu)	Line B From (pu)	Line G To (pu)	Line B To (pu)	Length (Km)
381	386	777.3	855.1	0	0	0	0	0	1.5
381	386	777.3	855.1	0	0	0	0	0	1.5
381	387	777.3	0	0	0	0	0	0	47.39
381	387	777.3	855.1	0	0	0	0	0	47.39
381	387	777.3	855.1	0	0	0	0	0	47.39
381	387	777.3	855.1	0	0	0	0	0	47.39
381	388	777.3	0	0	0	0	0	0	47.39
382	384	777.3	855.1	0	0	0	0	0	32
382	385	777.3	855.1	0	0	0	0	0	63
383	384	777.3	855.1	0	0	0	0	0	41
383	385	777.3	855.1	0	0	0	0	0	50
383	385	777.3	855.1	0	0	0	0	0	50
383	385	777.3	855.1	0	0	0	0	0	50
383	389	777.3	855.1	0	0	0	0	0	25.1
383	684	777.3	855.1	0	0	0	0	0	137
383	684	777.3	855.1	0	0	0	0	0	137
383	688	777.3	855.1	0	0	0	0	0	89.05
384	782	777.3	855.1	0	0	0	0	0	175
451	457	69.7	76.7	0	0	0	0	0	9
451	457	69.7	76.7	0	0	0	0	0	9
451	457	69.7	76.7	0	0	0	0	0	9
451	457	90.3	99.3	0	0	0	0	0	9
451	476	550	605	0	0	0	0	0	60
451	476	550	605	0	0	0	0	0	60
452	465	90.3	99.3	0	0	0	0	0	62
452	468	125.7	138.3	0	0	0	0	0	140
452	468	125.7	138.3	0	0	0	0	0	140
452	885	777.3	0	0	0	0	0	0	25
452	885	777.3	0	0	0	0	0	0	25
453	483	125.7	138.3	0	0	0	0	0	20
453	483	125.7	138.3	0	0	0	0	0	20
454	461	125.7	138.3	0	0	0	0	0	85
455	462	125.7	138.3	0	0	0	0	0	69
455	481	125.7	138.3	0	0	0	0	0	113
456	469	125.7	138.3	0	0	0	0	0	8
456	469	125.7	138.3	0	0	0	0	0	8
456	469	125.7	138.3	0	0	0	0	0	8
456	472	69.7	76.7	0	0	0	0	0	150
456	478	125.7	138.3	0	0	0	0	0	189
456	478	125.7	138.3	0	0	0	0	0	189
456	480	69.7	76.7	0	0	0	0	0	12
456	480	69.7	76.7	0	0	0	0	0	12
458	459	125.7	138.3	0	0	0	0	0	43
458	482	125.7	138.3	0	0	0	0	0	211
459	470	125.7	138.3	0	0	0	0	0	45
459	471	125.7	138.3	0	0	0	0	0	50.8
459	482	125.7	138.3	0	0	0	0	0	108.5
461	466	90.3	99.3	0	0	0	0	0	110
462	467	125.7	138.3	0	0	0	0	0	80
462	467	125.7	138.3	0	0	0	0	0	80
462	475	550	605	0	0	0	0	0	20
462	475	550	605	0	0	0	0	0	20

From Bus (Number)	To Bus (Number)	Rate A	Rate B	Rate C	Line G From (pu)	Line B From (pu)	Line G To (pu)	Line B To (pu)	Length (Km)
462	883	125.7	138.3	0	0	0	0	0	69.02
462	10002	57.5	0	0	0	0	0	0	71.27
463	464	90.3	99.3	0	0	0	0	0	40
463	480	90.3	99.3	0	0	0	0	0	20
464	465	90.3	99.3	0	0	0	0	0	84.8
465	466	90.3	99.3	0	0	0	0	0	70
469	480	125.7	138.3	0	0	0	0	0	10
469	480	125.7	138.3	0	0	0	0	0	10
469	480	125.7	138.3	0	0	0	0	0	10
469	480	125.7	138.3	0	0	0	0	0	10
471	482	125.7	138.3	0	0	0	0	0	50
472	478	69.7	76.7	0	0	0	0	0	40
472	478	69.7	76.7	0	0	0	0	0	40
473	475	550	605	0	0	0	0	0	40
473	475	550	605	0	0	0	0	0	40
473	477	550	605	0	0	0	0	0	40
473	477	550	605	0	0	0	0	0	40
474	477	550	605	0	0	0	0	0	73
474	477	550	605	0	0	0	0	0	73
481	883	125.7	138.3	0	0	0	0	0	75.98
485	486	777.3	855.1	0	0	0	0	0	230
485	486	777.3	855.1	0	0	0	0	0	230
485	486	777.3	855.1	0	0	0	0	0	230
485	488	777	855.1	0	0	0	0	0	62
485	488	777	855.1	0	0	0	0	0	62
485	594	777.3	855.1	0	0	0	0	0	196
485	594	777.3	855.1	0	0	0	0	0	196
485	594	777.3	855.1	0	0	0	0	0	196
486	487	777.3	855.1	0	0	0	0	0	180
486	487	777.3	855.1	0	0	0	0	0	180
486	490	777.3	855.1	0	0	0	0	0	18
486	490	777.3	855.1	0	0	0	0	0	18
487	490	777.3	0	0	0	0	0	0	160
487	490	777.3	0	0	0	0	0	0	160
487	492	770	855.1	0	0	0	0	0	235.8
487	492	770	855.1	0	0	0	0	0	235.8
488	489	770	855.1	0	0	0	0	0	70
488	489	770	855.1	0	0	0	0	0	70
489	492	770	855.1	0	0	0	0	0	70
489	492	770	855.1	0	0	0	0	0	70
491	492	777.3	855.1	0	0	0	0	0	85
491	492	777.3	855.1	0	0	0	0	0	85
502	563	0	0	0	0	0	0	0	18.9
544	888	0	0	0	0	0	0	0	0
569	573	125.7	138.3	0	0	0	0	0	76
569	574	125.7	138.3	0	0	0	0	0	146
569	579	69.7	76.7	0	0	0	0	0	40
569	591	125.7	138.3	0	0	0	0	0	64
570	574	125.7	138.3	0	0	0	0	0	118
570	574	125.7	138.3	0	0	0	0	0	118
570	589	125.7	138.3	0	0	0	0	0	50
570	589	125.7	138.3	0	0	0	0	0	50

From Bus (Number)	To Bus (Number)	Rate A	Rate B	Rate C	Line G From (pu)	Line B From (pu)	Line G To (pu)	Line B To (pu)	Length (Km)
570	590	125.7	138.3	0	0	0	0	0	77
570	590	125.7	138.3	0	0	0	0	0	77
571	579	69.7	76.7	0	0	0	0	0	187
571	582	125.7	138.3	0	0	0	0	0	70
571	582	125.7	138.3	0	0	0	0	0	70
571	586	777.3	855.1	0	0	0	0	0	160
572	573	125.7	138.3	0	0	0	0	0	10
573	577	125.7	138.3	0	0	0	0	0	106
575	585	69.7	76.7	0	0	0	0	0	142
575	591	69.7	76.7	0	0	0	0	0	82
576	589	125.7	138.3	0	0	0	0	0	90
576	589	125.7	138.3	0	0	0	0	0	90
578	579	69.7	76.7	0	0	0	0	0	52
580	581	125.7	138.3	0	0	0	0	0	75
580	581	125.7	138.3	0	0	0	0	0	50
580	592	125.7	138.3	0	0	0	0	0	120
580	592	125.7	138.3	0	0	0	0	0	120
581	582	125.7	138.3	0	0	0	0	0	50
581	582	125.7	138.3	0	0	0	0	0	50
585	587	69.7	76.7	0	0	0	0	0	71
593	594	777.3	855.1	0	0	0	0	0	264
593	594	777.3	855.1	0	0	0	0	0	264
593	595	777.3	855.1	0	0	0	0	0	240
593	598	777.3	855.1	0	0	0	0	0	180
594	686	777.3	855.1	0	0	0	0	0	286
594	686	777.3	855.1	0	0	0	0	0	286
594	686	777.3	855.1	0	0	0	0	0	286
595	597	777.3	0	0	0	0	0	0	159.6
596	598	777.3	855.1	0	0	0	0	0	260
645	658	125.7	138.3	0	0	0	0	0	22.5
645	658	125.7	138.3	0	0	0	0	0	22.5
645	670	125.7	138.3	0	0	0	0	0	18.5
646	653	125.7	138.3	0	0	0	0	0	30
646	653	125.7	138.3	0	0	0	0	0	30
647	650	125.7	138.3	0	0	0	0	0	10
647	655	125.7	138.3	0	0	0	0	0	39
647	655	125.7	138.3	0	0	0	0	0	39
647	659	125.7	138.3	0	0	0	0	0	44.1
647	662	125.7	138.3	0	0	0	0	0	156.1
648	653	125.7	138.3	0	0	0	0	0	13.34
648	659	125.7	138.3	0	0	0	0	0	20.01
649	653	125.7	138.3	0	0	0	0	0	30
650	657	125.7	138.3	0	0	0	0	0	37
651	678	125.7	138.3	0	0	0	0	0	25
652	666	125.7	138.3	0	0	0	0	0	33
654	657	125.7	138.3	0	0	0	0	0	80
654	657	550	605	0	0	0	0	0	80
655	660	125.7	138.3	0	0	0	0	0	54.25
655	660	125.7	138.3	0	0	0	0	0	54.25
655	660	125.7	138.3	0	0	0	0	0	54.25
656	658	125.7	138.3	0	0	0	0	0	22.5
656	658	125.7	138.3	0	0	0	0	0	22.5

From Bus (Number)	To Bus (Number)	Rate A	Rate B	Rate C	Line G From (pu)	Line B From (pu)	Line G To (pu)	Line B To (pu)	Length (Km)
656	665	125.7	138.3	0	0	0	0	0	22.5
656	665	125.7	138.3	0	0	0	0	0	22.5
656	677	125.7	138.3	0	0	0	0	0	20
656	677	550	605	0	0	0	0	0	20
660	676	550	605	0	0	0	0	0	70
660	676	550	605	0	0	0	0	0	70
660	765	125.7	138.3	0	0	0	0	0	39
660	765	125.7	138.3	0	0	0	0	0	39
661	664	125.7	138.3	0	0	0	0	0	22
661	665	125.7	138.3	0	0	0	0	0	22.5
661	665	125.7	138.3	0	0	0	0	0	22.5
662	678	125.7	138.3	0	0	0	0	0	39.2
663	678	125.7	138.3	0	0	0	0	0	39.2
664	768	125.7	138.3	0	0	0	0	0	25
666	768	125.7	138.3	0	0	0	0	0	40
667	668	125.7	138.3	0	0	0	0	0	60
667	668	125.7	138.3	0	0	0	0	0	60
669	678	125.7	138.3	0	0	0	0	0	47
671	677	550	605	0	0	0	0	0	26.1
671	677	550	605	0	0	0	0	0	26.1
672	674	550	605	0	0	0	0	0	25
672	674	550	605	0	0	0	0	0	25
672	677	550	605	0	0	0	0	0	17.4
672	677	550	605	0	0	0	0	0	17.4
673	674	550	605	0	0	0	0	0	45
673	674	550	605	0	0	0	0	0	45
674	675	550	605	0	0	0	0	0	25
675	681	550	605	0	0	0	0	0	25
679	680	550	605	0	0	0	0	0	21.3
680	682	550	605	0	0	0	0	0	21.3
681	682	550	605	0	0	0	0	0	21.3
683	684	777.3	855.1	0	0	0	0	0	96
684	685	777.3	855.1	0	0	0	0	0	60
684	685	777.3	855.1	0	0	0	0	0	60
684	688	777.3	855.1	0	0	0	0	0	47.95
684	777	777.3	855.1	0	0	0	0	0	138
684	777	777.3	855.1	0	0	0	0	0	138
686	687	777.3	855.1	0	0	0	0	0	47.39
686	687	777.3	855.1	0	0	0	0	0	47.39
686	687	777.3	855.1	0	0	0	0	0	47.39
686	687	777.3	855.1	0	0	0	0	0	47.39
689	690	62.9	69.2	0	0	0	0	0	20
749	750	125.7	138.3	0	0	0	0	0	46
749	754	125.7	138.3	0	0	0	0	0	33
749	759	125.7	138.3	0	0	0	0	0	21.45
750	767	125.7	138.3	0	0	0	0	0	10
750	767	125.7	138.3	0	0	0	0	0	10
750	768	125.7	138.3	0	0	0	0	0	66
750	768	125.7	138.3	0	0	0	0	0	66
750	769	125.7	138.3	0	0	0	0	0	60
750	769	125.7	138.3	0	0	0	0	0	60
751	753	125.7	138.3	0	0	0	0	0	47.36

From Bus (Number)	To Bus (Number)	Rate A	Rate B	Rate C	Line G From (pu)	Line B From (pu)	Line G To (pu)	Line B To (pu)	Length (Km)
751	774	550	605	0	0	0	0	0	5
751	774	550	605	0	0	0	0	0	5
751	774	550	605	0	0	0	0	0	8
751	774	550	605	0	0	0	0	0	8
752	757	125.7	138.3	0	0	0	0	0	46
752	757	125.7	138.3	0	0	0	0	0	46
753	757	125.7	138.3	0	0	0	0	0	18
753	757	125.7	138.3	0	0	0	0	0	18
753	767	125.7	138.3	0	0	0	0	0	85.4
753	774	550	605	0	0	0	0	0	47.36
754	755	125.7	138.3	0	0	0	0	0	3
754	756	125.7	138.3	0	0	0	0	0	3
754	758	125.7	138.3	0	0	0	0	0	10
754	758	125.7	138.3	0	0	0	0	0	10
754	759	125.7	138.3	0	0	0	0	0	11.55
754	759	125.7	138.3	0	0	0	0	0	11.55
758	775	125.7	138.3	0	0	0	0	0	10
760	769	125.7	138.3	0	0	0	0	0	26
760	769	125.7	138.3	0	0	0	0	0	26
761	762	125.7	138.3	0	0	0	0	0	46
761	762	125.7	138.3	0	0	0	0	0	46
761	766	125.7	138.3	0	0	0	0	0	5
761	766	125.7	138.3	0	0	0	0	0	5
762	763	125.7	138.3	0	0	0	0	0	15
762	763	125.7	138.3	0	0	0	0	0	15
762	769	125.7	138.3	0	0	0	0	0	73
762	769	125.7	138.3	0	0	0	0	0	73
764	765	125.7	138.3	0	0	0	0	0	46
764	765	125.7	138.3	0	0	0	0	0	46
764	771	125.7	138.3	0	0	0	0	0	45
764	771	125.7	138.3	0	0	0	0	0	45
770	771	125.7	138.3	0	0	0	0	0	30
770	771	125.7	138.3	0	0	0	0	0	30
773	774	550	605	0	0	0	0	0	5
773	774	550	605	0	0	0	0	0	5
776	777	777.3	855.1	0	0	0	0	0	25
776	777	777.3	855.1	0	0	0	0	0	25
776	779	777.3	855.1	0	0	0	0	0	81
776	782	777.3	855.1	0	0	0	0	0	40
776	782	777.3	855.1	0	0	0	0	0	40
777	779	777.3	855.1	0	0	0	0	0	54.5
777	780	777.3	855.1	0	0	0	0	0	60
777	780	777.3	855.1	0	0	0	0	0	60
778	783	777.3	855.1	0	0	0	0	0	48
778	783	777.3	855.1	0	0	0	0	0	48
779	783	777.3	855.1	0	0	0	0	0	22
779	783	777.3	855.1	0	0	0	0	0	22
779	785	777.3	855.1	0	0	0	0	0	78
779	785	777.3	855.1	0	0	0	0	0	78
780	781	777.3	855.1	0	0	0	0	0	67
780	781	777.3	855.1	0	0	0	0	0	67
781	784	777.3	855.1	0	0	0	0	0	67

From Bus (Number)	To Bus (Number)	Rate A	Rate B	Rate C	Line G From (pu)	Line B From (pu)	Line G To (pu)	Line B To (pu)	Length (Km)
781	784	777.3	855.1	0	0	0	0	0	67

III. C

From Bus (Number)	To Bus (Number)	R-Zero (pu)	X-Zero (pu)	B-Zero (pu)	Zero Seq G From (pu)	Zero Seq B From (pu)	Zero Seq G To (pu)	Zero Seq B To (pu)
2	12	0	0	0	0	0	0	0
2	12	0	0	0	0	0	0	0
2	12	0	0	0	0	0	0	0
2	14	0	0	0	0	0	0	0
2	16	0	0	0	0	0	0	0
2	16	0	0	0	0	0	0	0
2	19	0	0	0	0	0	0	0
2	19	0	0	0	0	0	0	0
3	17	0	0	0	0	0	0	0
3	17	0	0	0	0	0	0	0
4	7	0	0	0	0	0	0	0
4	7	0	0	0	0	0	0	0
4	11	0	0	0	0	0	0	0
4	11	0	0	0	0	0	0	0
4	18	0	0	0	0	0	0	0
4	18	0	0	0	0	0	0	0
4	25	0	0	0	0	0	0	0
4	25	0	0	0	0	0	0	0
4	29	0	0	0	0	0	0	0
4	29	0	0	0	0	0	0	0
5	13	0	0	0	0	0	0	0
5	13	0	0	0	0	0	0	0
5	14	0	0	0	0	0	0	0
6	24	0	0	0	0	0	0	0
6	24	0	0	0	0	0	0	0
6	28	0	0	0	0	0	0	0
6	28	0	0	0	0	0	0	0
6	28	0	0	0	0	0	0	0
7	20	0	0	0	0	0	0	0
7	20	0	0	0	0	0	0	0
8	9	0	0	0	0	0	0	0
8	16	0	0	0	0	0	0	0
8	25	0	0	0	0	0	0	0
8	25	0	0	0	0	0	0	0
9	16	0	0	0	0	0	0	0
9	21	0	0	0	0	0	0	0
9	21	0	0	0	0	0	0	0
10	23	0	0	0	0	0	0	0
10	23	0	0	0	0	0	0	0
11	23	0	0	0	0	0	0	0
11	23	0	0	0	0	0	0	0

From Bus (Number)	To Bus (Number)	R-Zero (pu)	X-Zero (pu)	B-Zero (pu)	Zero Seq G From (pu)	Zero Seq B From (pu)	Zero Seq G To (pu)	Zero Seq B To (pu)
12	15	0	0	0	0	0	0	0
12	15	0	0	0	0	0	0	0
13	14	0	0	0	0	0	0	0
13	14	0	0	0	0	0	0	0
13	20	0	0	0	0	0	0	0
13	20	0	0	0	0	0	0	0
15	32	0	0	0	0	0	0	0
15	32	0	0	0	0	0	0	0
17	22	0	0	0	0	0	0	0
17	22	0	0	0	0	0	0	0
17	27	0	0	0	0	0	0	0
18	22	0	0	0	0	0	0	0
18	22	0	0	0	0	0	0	0
21	31	0	0	0	0	0	0	0
21	31	0	0	0	0	0	0	0
23	24	0	0	0	0	0	0	0
24	32	0	0	0	0	0	0	0
24	32	0	0	0	0	0	0	0
25	29	0	0	0	0	0	0	0
25	29	0	0	0	0	0	0	0
26	32	0	0	0	0	0	0	0
26	32	0	0	0	0	0	0	0
27	192	0	0	0	0	0	0	0
33	35	0	0	0	0	0	0	0
33	35	0	0	0	0	0	0	0
33	39	0	0	0	0	0	0	0
33	39	0	0	0	0	0	0	0
33	41	0	0	0	0	0	0	0
33	41	0	0	0	0	0	0	0
34	36	0	0	0	0	0	0	0
34	36	0	0	0	0	0	0	0
35	36	0	0	0	0	0	0	0
35	40	0	0	0	0	0	0	0
35	40	0	0	0	0	0	0	0
35	383	0	0	0	0	0	0	0
36	38	0	0	0	0	0	0	0
36	40	0	0	0	0	0	0	0
36	40	0	0	0	0	0	0	0
36	198	0	0	0	0	0	0	0
36	199	0	0	0	0	0	0	0
36	1000	0	0	0	0	0	0	0
38	197	0	0	0	0	0	0	0
39	41	0	0	0	0	0	0	0
39	41	0	0	0	0	0	0	0
169	683	0	0	0	0	0	0	0
169	683	0	0	0	0	0	0	0
169	687	0	0	0	0	0	0	0
169	687	0	0	0	0	0	0	0
169	779	0	0	0	0	0	0	0
169	779	0	0	0	0	0	0	0
169	779	0	0	0	0	0	0	0
169	779	0	0	0	0	0	0	0

From Bus (Number)	To Bus (Number)	R-Zero (pu)	X-Zero (pu)	B-Zero (pu)	Zero Seq G From (pu)	Zero Seq B From (pu)	Zero Seq G To (pu)	Zero Seq B To (pu)
170	176	0	0	0	0	0	0	0
170	182	0	0	0	0	0	0	0
170	192	0	0	0	0	0	0	0
171	175	0	0	0	0	0	0	0
171	175	0	0	0	0	0	0	0
171	183	0	0	0	0	0	0	0
171	188	0	0	0	0	0	0	0
171	188	0	0	0	0	0	0	0
171	194	0	0	0	0	0	0	0
171	194	0	0	0	0	0	0	0
171	195	0	0	0	0	0	0	0
171	196	0	0	0	0	0	0	0
171	196	0	0	0	0	0	0	0
172	175	0	0	0	0	0	0	0
172	178	0	0	0	0	0	0	0
173	180	0	0	0	0	0	0	0
173	180	0	0	0	0	0	0	0
173	188	0	0	0	0	0	0	0
173	188	0	0	0	0	0	0	0
173	191	0	0	0	0	0	0	0
173	191	0	0	0	0	0	0	0
174	175	0	0	0	0	0	0	0
174	175	0	0	0	0	0	0	0
176	178	0	0	0	0	0	0	0
177	179	0	0	0	0	0	0	0
177	187	0	0	0	0	0	0	0
177	194	0	0	0	0	0	0	0
178	181	0	0	0	0	0	0	0
179	194	0	0	0	0	0	0	0
180	183	0	0	0	0	0	0	0
183	185	0	0	0	0	0	0	0
185	190	0	0	0	0	0	0	0
186	187	0	0	0	0	0	0	0
192	193	0	0	0	0	0	0	0
197	198	0	0	0	0	0	0	0
198	200	0	0	0	0	0	0	0
198	288	0	0	0	0	0	0	0
198	288	0	0	0	0	0	0	0
198	389	0	0	0	0	0	0	0
199	383	0	0	0	0	0	0	0
200	288	0	0	0	0	0	0	0
257	270	0	0	0	0	0	0	0
257	271	0	0	0	0	0	0	0
257	271	0	0	0	0	0	0	0
257	273	0	0	0	0	0	0	0
258	260	0	0	0	0	0	0	0
258	260	0	0	0	0	0	0	0
258	262	0	0	0	0	0	0	0
258	262	0	0	0	0	0	0	0
258	262	0	0	0	0	0	0	0
258	265	0	0	0	0	0	0	0
258	265	0	0	0	0	0	0	0

From Bus (Number)	To Bus (Number)	R-Zero (pu)	X-Zero (pu)	B-Zero (pu)	Zero Seq G From (pu)	Zero Seq B From (pu)	Zero Seq G To (pu)	Zero Seq B To (pu)
258	273	0	0	0	0	0	0	0
258	275	0	0	0	0	0	0	0
258	275	0	0	0	0	0	0	0
259	266	0	0	0	0	0	0	0
259	266	0	0	0	0	0	0	0
259	272	0	0	0	0	0	0	0
259	272	0	0	0	0	0	0	0
259	10003	0	0	0	0	0	0	0
260	273	0	0	0	0	0	0	0
261	268	0	0	0	0	0	0	0
261	282	0	0	0	0	0	0	0
262	267	0	0	0	0	0	0	0
262	267	0	0	0	0	0	0	0
262	279	0	0	0	0	0	0	0
262	279	0	0	0	0	0	0	0
263	271	0	0	0	0	0	0	0
264	265	0	0	0	0	0	0	0
264	265	0	0	0	0	0	0	0
267	268	0	0	0	0	0	0	0
268	281	0	0	0	0	0	0	0
268	285	0	0	0	0	0	0	0
269	270	0	0	0	0	0	0	0
269	277	0	0	0	0	0	0	0
270	283	0	0	0	0	0	0	0
271	273	0	0	0	0	0	0	0
271	273	0	0	0	0	0	0	0
272	284	0	0	0	0	0	0	0
272	454	0	0	0	0	0	0	0
275	280	0	0	0	0	0	0	0
275	280	0	0	0	0	0	0	0
277	278	0	0	0	0	0	0	0
281	285	0	0	0	0	0	0	0
286	292	0	0	0	0	0	0	0
286	294	0	0	0	0	0	0	0
286	294	0	0	0	0	0	0	0
287	290	0	0	0	0	0	0	0
287	291	0	0	0	0	0	0	0
287	291	0	0	0	0	0	0	0
288	289	0	0	0	0	0	0	0
288	289	0	0	0	0	0	0	0
288	290	0	0	0	0	0	0	0
288	290	0	0	0	0	0	0	0
288	294	0	0	0	0	0	0	0
288	294	0	0	0	0	0	0	0
291	492	0	0	0	0	0	0	0
291	492	0	0	0	0	0	0	0
292	293	0	0	0	0	0	0	0
292	293	0	0	0	0	0	0	0
292	294	0	0	0	0	0	0	0
292	294	0	0	0	0	0	0	0
292	387	0	0	0	0	0	0	0
292	387	0	0	0	0	0	0	0

From Bus (Number)	To Bus (Number)	R-Zero (pu)	X-Zero (pu)	B-Zero (pu)	Zero Seq G From (pu)	Zero Seq B From (pu)	Zero Seq G To (pu)	Zero Seq B To (pu)
292	387	0	0	0	0	0	0	0
292	387	0	0	0	0	0	0	0
292	388	0	0	0	0	0	0	0
294	485	0	0	0	0	0	0	0
294	485	0	0	0	0	0	0	0
294	485	0	0	0	0	0	0	0
294	485	0	0	0	0	0	0	0
370	374	0	0	0	0	0	0	0
371	372	0	0	0	0	0	0	0
371	372	0	0	0	0	0	0	0
371	372	0	0	0	0	0	0	0
371	372	0	0	0	0	0	0	0
371	376	0	0	0	0	0	0	0
371	376	0	0	0	0	0	0	0
371	376	0	0	0	0	0	0	0
371	377	0	0	0	0	0	0	0
372	373	0	0	0	0	0	0	0
372	373	0	0	0	0	0	0	0
372	377	0	0	0	0	0	0	0
373	375	0	0	0	0	0	0	0
374	375	0	0	0	0	0	0	0
379	380	0	0	0	0	0	0	0
379	380	0	0	0	0	0	0	0
381	383	0	0	0	0	0	0	0
381	383	0	0	0	0	0	0	0
381	386	0	0	0	0	0	0	0
381	386	0	0	0	0	0	0	0
381	387	0	0	0	0	0	0	0
381	387	0	0	0	0	0	0	0
381	387	0	0	0	0	0	0	0
381	387	0	0	0	0	0	0	0
381	388	0	0	0	0	0	0	0
382	384	0	0	0	0	0	0	0
382	385	0	0	0	0	0	0	0
383	384	0	0	0	0	0	0	0
383	385	0	0	0	0	0	0	0
383	385	0	0	0	0	0	0	0
383	385	0	0	0	0	0	0	0
383	389	0	0	0	0	0	0	0
383	684	0	0	0	0	0	0	0
383	684	0	0	0	0	0	0	0
383	688	0	0	0	0	0	0	0
384	782	0	0	0	0	0	0	0
451	457	0	0	0	0	0	0	0
451	457	0	0	0	0	0	0	0
451	457	0	0	0	0	0	0	0
451	457	0	0	0	0	0	0	0
451	476	0	0	0	0	0	0	0
451	476	0	0	0	0	0	0	0
452	465	0	0	0	0	0	0	0
452	468	0	0	0	0	0	0	0
452	468	0	0	0	0	0	0	0

From Bus (Number)	To Bus (Number)	R-Zero (pu)	X-Zero (pu)	B-Zero (pu)	Zero Seq G From (pu)	Zero Seq B From (pu)	Zero Seq G To (pu)	Zero Seq B To (pu)
452	885	0	0	0	0	0	0	0
452	885	0	0	0	0	0	0	0
453	483	0	0	0	0	0	0	0
453	483	0	0	0	0	0	0	0
454	461	0	0	0	0	0	0	0
455	462	0	0	0	0	0	0	0
455	481	0	0	0	0	0	0	0
456	469	0	0	0	0	0	0	0
456	469	0	0	0	0	0	0	0
456	469	0	0	0	0	0	0	0
456	472	0	0	0	0	0	0	0
456	478	0	0	0	0	0	0	0
456	478	0	0	0	0	0	0	0
456	480	0	0	0	0	0	0	0
456	480	0	0	0	0	0	0	0
458	459	0	0	0	0	0	0	0
458	482	0	0	0	0	0	0	0
459	470	0	0	0	0	0	0	0
459	471	0	0	0	0	0	0	0
459	482	0	0	0	0	0	0	0
461	466	0	0	0	0	0	0	0
462	467	0	0	0	0	0	0	0
462	467	0	0	0	0	0	0	0
462	475	0	0	0	0	0	0	0
462	475	0	0	0	0	0	0	0
462	883	0	0	0	0	0	0	0
462	10002	0	0	0	0	0	0	0
463	464	0	0	0	0	0	0	0
463	480	0	0	0	0	0	0	0
464	465	0	0	0	0	0	0	0
465	466	0	0	0	0	0	0	0
469	480	0	0	0	0	0	0	0
469	480	0	0	0	0	0	0	0
469	480	0	0	0	0	0	0	0
469	480	0	0	0	0	0	0	0
471	482	0	0	0	0	0	0	0
472	478	0	0	0	0	0	0	0
472	478	0	0	0	0	0	0	0
473	475	0	0	0	0	0	0	0
473	475	0	0	0	0	0	0	0
473	477	0	0	0	0	0	0	0
473	477	0	0	0	0	0	0	0
474	477	0	0	0	0	0	0	0
474	477	0	0	0	0	0	0	0
481	883	0	0	0	0	0	0	0
485	486	0	0	0	0	0	0	0
485	486	0	0	0	0	0	0	0
485	486	0	0	0	0	0	0	0
485	488	0	0	0	0	0	0	0
485	488	0	0	0	0	0	0	0
485	594	0	0	0	0	0	0	0
485	594	0	0	0	0	0	0	0

From Bus (Number)	To Bus (Number)	R-Zero (pu)	X-Zero (pu)	B-Zero (pu)	Zero Seq G From (pu)	Zero Seq B From (pu)	Zero Seq G To (pu)	Zero Seq B To (pu)
485	594	0	0	0	0	0	0	0
486	487	0	0	0	0	0	0	0
486	487	0	0	0	0	0	0	0
486	490	0	0	0	0	0	0	0
486	490	0	0	0	0	0	0	0
487	490	0	0	0	0	0	0	0
487	490	0	0	0	0	0	0	0
487	492	0	0	0	0	0	0	0
487	492	0	0	0	0	0	0	0
488	489	0	0	0	0	0	0	0
488	489	0	0	0	0	0	0	0
489	492	0	0	0	0	0	0	0
489	492	0	0	0	0	0	0	0
491	492	0	0	0	0	0	0	0
491	492	0	0	0	0	0	0	0
502	563	0	0	0	0	0	0	0
544	888	0	0	0	0	0	0	0
569	573	0	0	0	0	0	0	0
569	574	0	0	0	0	0	0	0
569	579	0	0	0	0	0	0	0
569	591	0	0	0	0	0	0	0
570	574	0	0	0	0	0	0	0
570	574	0	0	0	0	0	0	0
570	589	0	0	0	0	0	0	0
570	589	0	0	0	0	0	0	0
570	590	0	0	0	0	0	0	0
570	590	0	0	0	0	0	0	0
571	579	0	0	0	0	0	0	0
571	582	0	0	0	0	0	0	0
571	582	0	0	0	0	0	0	0
571	586	0	0	0	0	0	0	0
572	573	0	0	0	0	0	0	0
573	577	0	0	0	0	0	0	0
575	585	0	0	0	0	0	0	0
575	591	0	0	0	0	0	0	0
576	589	0	0	0	0	0	0	0
576	589	0	0	0	0	0	0	0
578	579	0	0	0	0	0	0	0
580	581	0	0	0	0	0	0	0
580	581	0	0	0	0	0	0	0
580	592	0	0	0	0	0	0	0
580	592	0	0	0	0	0	0	0
581	582	0	0	0	0	0	0	0
581	582	0	0	0	0	0	0	0
585	587	0	0	0	0	0	0	0
593	594	0	0	0	0	0	0	0
593	594	0	0	0	0	0	0	0
593	595	0	0	0	0	0	0	0
593	598	0	0	0	0	0	0	0
594	686	0	0	0	0	0	0	0
594	686	0	0	0	0	0	0	0
594	686	0	0	0	0	0	0	0

From Bus (Number)	To Bus (Number)	R-Zero (pu)	X-Zero (pu)	B-Zero (pu)	Zero Seq G From (pu)	Zero Seq B From (pu)	Zero Seq G To (pu)	Zero Seq B To (pu)
595	597	0	0	0	0	0	0	0
596	598	0	0	0	0	0	0	0
645	658	0	0	0	0	0	0	0
645	658	0	0	0	0	0	0	0
645	670	0	0	0	0	0	0	0
646	653	0	0	0	0	0	0	0
646	653	0	0	0	0	0	0	0
647	650	0	0	0	0	0	0	0
647	655	0	0	0	0	0	0	0
647	655	0	0	0	0	0	0	0
647	659	0	0	0	0	0	0	0
647	662	0	0	0	0	0	0	0
648	653	0	0	0	0	0	0	0
648	659	0	0	0	0	0	0	0
649	653	0	0	0	0	0	0	0
650	657	0	0	0	0	0	0	0
651	678	0	0	0	0	0	0	0
652	666	0	0	0	0	0	0	0
654	657	0	0	0	0	0	0	0
654	657	0	0	0	0	0	0	0
655	660	0	0	0	0	0	0	0
655	660	0	0	0	0	0	0	0
655	660	0	0	0	0	0	0	0
656	658	0	0	0	0	0	0	0
656	658	0	0	0	0	0	0	0
656	665	0	0	0	0	0	0	0
656	665	0	0	0	0	0	0	0
656	677	0	0	0	0	0	0	0
656	677	0	0	0	0	0	0	0
660	676	0	0	0	0	0	0	0
660	676	0	0	0	0	0	0	0
660	765	0	0	0	0	0	0	0
660	765	0	0	0	0	0	0	0
661	664	0	0	0	0	0	0	0
661	665	0	0	0	0	0	0	0
661	665	0	0	0	0	0	0	0
662	678	0	0	0	0	0	0	0
663	678	0	0	0	0	0	0	0
664	768	0	0	0	0	0	0	0
666	768	0	0	0	0	0	0	0
667	668	0	0	0	0	0	0	0
667	668	0	0	0	0	0	0	0
669	678	0	0	0	0	0	0	0
671	677	0	0	0	0	0	0	0
671	677	0	0	0	0	0	0	0
672	674	0	0	0	0	0	0	0
672	674	0	0	0	0	0	0	0
672	677	0	0	0	0	0	0	0
672	677	0	0	0	0	0	0	0
673	674	0	0	0	0	0	0	0
673	674	0	0	0	0	0	0	0
674	675	0	0	0	0	0	0	0

From Bus (Number)	To Bus (Number)	R-Zero (pu)	X-Zero (pu)	B-Zero (pu)	Zero Seq G From (pu)	Zero Seq B From (pu)	Zero Seq G To (pu)	Zero Seq B To (pu)
675	681	0	0	0	0	0	0	0
679	680	0	0	0	0	0	0	0
680	682	0	0	0	0	0	0	0
681	682	0	0	0	0	0	0	0
683	684	0	0	0	0	0	0	0
684	685	0	0	0	0	0	0	0
684	685	0	0	0	0	0	0	0
684	688	0	0	0	0	0	0	0
684	777	0	0	0	0	0	0	0
684	777	0	0	0	0	0	0	0
686	687	0	0	0	0	0	0	0
686	687	0	0	0	0	0	0	0
686	687	0	0	0	0	0	0	0
686	687	0	0	0	0	0	0	0
689	690	0	0	0	0	0	0	0
749	750	0	0	0	0	0	0	0
749	754	0	0	0	0	0	0	0
749	759	0	0	0	0	0	0	0
750	767	0	0	0	0	0	0	0
750	767	0	0	0	0	0	0	0
750	768	0	0	0	0	0	0	0
750	768	0	0	0	0	0	0	0
750	769	0	0	0	0	0	0	0
750	769	0	0	0	0	0	0	0
751	753	0	0	0	0	0	0	0
751	774	0	0	0	0	0	0	0
751	774	0	0	0	0	0	0	0
751	774	0	0	0	0	0	0	0
751	774	0	0	0	0	0	0	0
752	757	0	0	0	0	0	0	0
752	757	0	0	0	0	0	0	0
753	757	0	0	0	0	0	0	0
753	757	0	0	0	0	0	0	0
753	767	0	0	0	0	0	0	0
753	774	0	0	0	0	0	0	0
754	755	0	0	0	0	0	0	0
754	756	0	0	0	0	0	0	0
754	758	0	0	0	0	0	0	0
754	758	0	0	0	0	0	0	0
754	759	0	0	0	0	0	0	0
754	759	0	0	0	0	0	0	0
758	775	0	0	0	0	0	0	0
760	769	0	0	0	0	0	0	0
760	769	0	0	0	0	0	0	0
761	762	0	0	0	0	0	0	0
761	762	0	0	0	0	0	0	0
761	766	0	0	0	0	0	0	0
761	766	0	0	0	0	0	0	0
762	763	0	0	0	0	0	0	0
762	763	0	0	0	0	0	0	0
762	769	0	0	0	0	0	0	0
762	769	0	0	0	0	0	0	0

From Bus (Number)	To Bus (Number)	R-Zero (pu)	X-Zero (pu)	B-Zero (pu)	Zero Seq G From (pu)	Zero Seq B From (pu)	Zero Seq G To (pu)	Zero Seq B To (pu)
764	765	0	0	0	0	0	0	0
764	765	0	0	0	0	0	0	0
764	771	0	0	0	0	0	0	0
764	771	0	0	0	0	0	0	0
770	771	0	0	0	0	0	0	0
770	771	0	0	0	0	0	0	0
773	774	0	0	0	0	0	0	0
773	774	0	0	0	0	0	0	0
776	777	0	0	0	0	0	0	0
776	777	0	0	0	0	0	0	0
776	779	0	0	0	0	0	0	0
776	782	0	0	0	0	0	0	0
776	782	0	0	0	0	0	0	0
777	779	0	0	0	0	0	0	0
777	780	0	0	0	0	0	0	0
777	780	0	0	0	0	0	0	0
778	783	0	0	0	0	0	0	0
778	783	0	0	0	0	0	0	0
779	783	0	0	0	0	0	0	0
779	783	0	0	0	0	0	0	0
779	785	0	0	0	0	0	0	0
779	785	0	0	0	0	0	0	0
780	781	0	0	0	0	0	0	0
780	781	0	0	0	0	0	0	0
781	784	0	0	0	0	0	0	0
781	784	0	0	0	0	0	0	0