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Contingency Assessment of Generators in the 330-Kv Grid and Major Factors Affecting Electricity Generation in Nigeria

James O. Onojo, Kelechi Inyama, Gordon C. Ononiwu, Samuel Okozi

***Abstract*— An over-riding factor in the operation of the power system is the desire to maintain security and expectable reliability level in all the sectors- power generation, transmission and distribution. Steady state power system insecurity such as generator outage causes transmission elements cascade outages which may lead to complete blackout. The security assessment is an essential task as it gives the knowledge about the system state in the event of a contingency. Contingency analysis technique is being widely used to predict the effect of outages like failures of equipment and to take necessary actions to keep the power system secure and reliable. In this paper, the effects of double generator (N-2) outage contingency and simultaneous transfer were considered in Nigerian 330-kV network. The results show that double generator outages can result in an infeasible operating condition (system collapse) of major parts of the Nigerian 330-kV power grid. Also the capacity and major factors affecting electricity generation in Nigeria were highlighted.**

***Index Terms*— Electricity generation, Contingency, Simulation, Double generator outage, Violation**

I. INTRODUCTION

The power systems transmission and generation systems are always designed by engineers with reliability in mind. This means that adequate generation has been installed to meet the load demand and adequate transmission has been installed to deliver the generated power to the load [1]. However, any piece of equipment in the system can fail, either due to internal causes or due to external causes. Two major types of failure events that affect the power system mostly are transmission line outage and generation unit failures. Generation failures can cause flows and voltages to change in the transmission system, and also dynamic problems involving system frequency and operator output [2].

Nigeria uses three types of electricity generation stations namely Hydro generating stations, Steam turbine generating stations and gas turbine generating stations. The electricity generating stations are interconnected in radial form with a single National Control Centre (NCC) in Oshogbo where supervision, control of system and load allocation to the various parts of the country is done [3, 4].

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James O. Onojo, Department of Electrical and Electronic Engineering, Federal University of Technology, Owerri, NIGERIA

Kelechi Inyama, Department of Electrical and Electronic Engineering, Abia State Polytechnic, Aba, NIGERIA

Gordon C. Ononiwu, Department of Electrical and Electronic Engineering, Federal University of Technology, Owerri, NIGERIA

Samuel Okozi, Department of Electrical and Electronic Engineering, Federal University of Technology, Owerri, NIGERIA

The country's peak demand forecast is 17,720MW, while the installed electricity generation capacity stands at 11,165MW, and the network operational capability hovers around 5,500MW, which is too low even at the failure of one or two generators in the grid. This can be attributed to poor power system infrastructure and planning. At July 2016, power generation fell below 3,000MW at a point due to many constrains in power generation [5, 6].

Therefore, it is pertinent to look at power system security, which involves monitoring the generators in the system. It involves the most important function of contingency analysis where the simulation is being carried out on the list of "credible" outage cases so as to give the operators an indication of what might happen to the power system in an event of unscheduled outage of more than one generator, which is common in Nigeria power system. This analysis forewarns the system operator, and allows deciding some remedial action before the outage event [7]. This research also studied the factors affecting the generation companies in Nigeria, which leads to poor electricity generation in the country.

II. ELECTRICITY GENERATION IN NIGERIA

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

Successor Generation Companies (Gencos): There are 6 successor Gencos in Nigeria. Their names and installed capacities are:

Generation Company	Plant type	Capacity (MW)
Afam Power Plc (I-V)	Thermal	987.2
Egbin Power Plc	Thermal	1,320
Kainji/ Jebba Hydro Electric Plc	Hydro	1,330
Sapele Power Plc	Thermal	1,020
Shiroro Hydro Electric Plc	Hydro	600
Ughelli Power Plc	Thermal	942

Independent Power Producers (IPPs): IPPs are power plants owned and managed by the private sector. Although there are Independent Power Producers (IPPs) existing in Nigeria prior to the privatisation process, the Nigerian Electricity

Regulatory Commission (NERC) has recently issued about 70 licenses to Independent Power Producers in order to improve the power situation in the country. The existing IPPs include Shell – Afam VI (642MW), Agip – Okpai (480MW) and AES Barges (270MW).

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

NIPP's	Capacity (MW)
Alaoji Generation Company Limited	1131
Benin Generation Company Limited	508
Calabar Generation Company Limited	634
Egbema Generation Company Limited	381
Gbarain Generation Company Limited	254
Geregu Generation Company Limited	506
Ogorode Generation Company Limited	508
Olorunsogo Generation Company Limited	754
Omoku Generation Company Limited	265
Omotosho Generation Company Limited	513

III. CONTINGENCY ANALYSIS

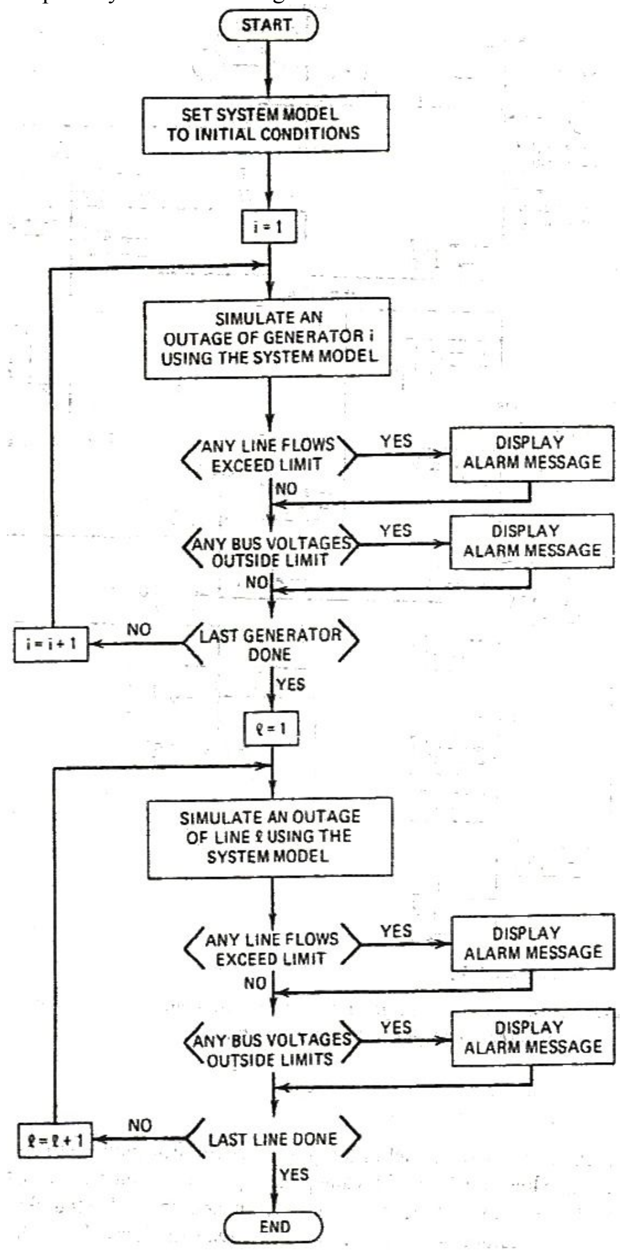
Contingency Analysis actually provides and prioritizes the impacts on an electric power system when problems occur. A contingency is the loss or failure of a small part of the power system, or an individual equipment failure (such as a generator or transformer). This is also called an unplanned "outage". Contingency analysis is a computer application that uses a simulated model of the power system, to evaluate the effects, and calculate any overloads resulting from each outage event. In other word, Contingency Analysis is essentially a "preview" analysis tool that simulates and quantifies the results of problems that could occur in the power system in the immediate future [7].

There are various methods of contingency analysis which include the following:

a. AC Load flow method
b. DC Load flow method
c. Z-Matrix method
d. Performance Index method

Of all the above listed methods, methods based on AC power flow calculations are considered to be deterministic methods which are accurate compared to DC power flow methods. In deterministic methods line outages are simulated by actual removal of lines instead of modelling [1].

How contingency analysis can be performed is described in a simple way in the following flowchart:



IV. SIMULATION AND RESULTS

The run mode of the power world simulator software is the mode where the actual power flow or load flow simulation and the voltage stability analysis was done. This mode allowed in performing a load flow analysis in other to produce some unknown variables such as the active and the reactive power for the slack bus, the reactive power for the generator buses, the voltages in the load buses and the angles for the whole bus in the whole network [9, 10].

During the double (N-2) generator outage contingency simulation of the Nigeria 330kv grid, violations were observed in a lot of buses in the network. Severe violations were observed in many buses. Five of the (N-2) generator outage contingencies with the most severe violations will be used as case study in this work. These are:
Kanji & Jebba, Kainji & Mambilla, Jebba & Manbilla, Shiroro & Mando, Ajaokuta(Geregu) & Mambilla.
These generators were practically shut down respectively on the simulator, and the load flow analysis was performed to reproduce the unknown variables and to note the effect of these contingencies on the network. The following data were obtained;

A. Violation summary during Kainji and Jebba outage.

TABLE 1: Line Violations during Kainji and Jebba outage.

Element	Value(MVA)	Limit(MVA)	Percentage(%)
Ikeja west to Egbin (Line 1)	945	777.3	126
Ikeja west to Egbin (Line 2)	945	777.3	126

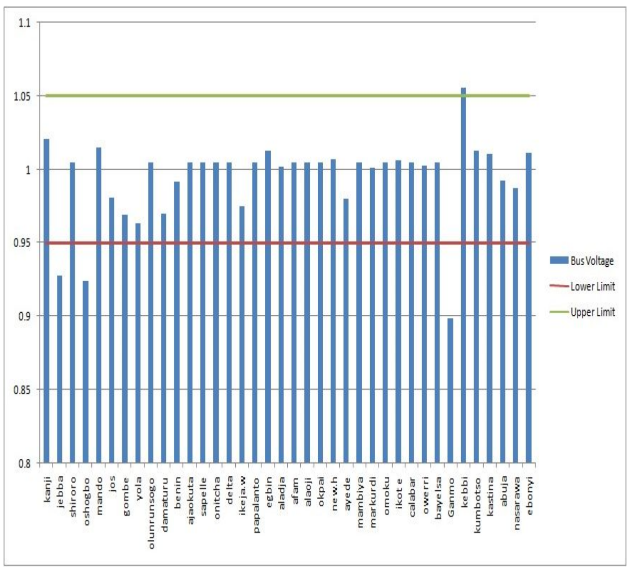


Fig 1: PU Voltage during Kainji and Jebba outage.

B. Violation summary during Kainji and Mambilla outage

TABLE 2: Line Violations during Kainji and Mambilla outage

Element	Value(MVA)	Limit(MVA)	Percentage (%)
Ikeja west to Egbin (Line 1)	862	777.3	114.1
Ikeja west to Egbin (Line 2)	862	777.3	114.1

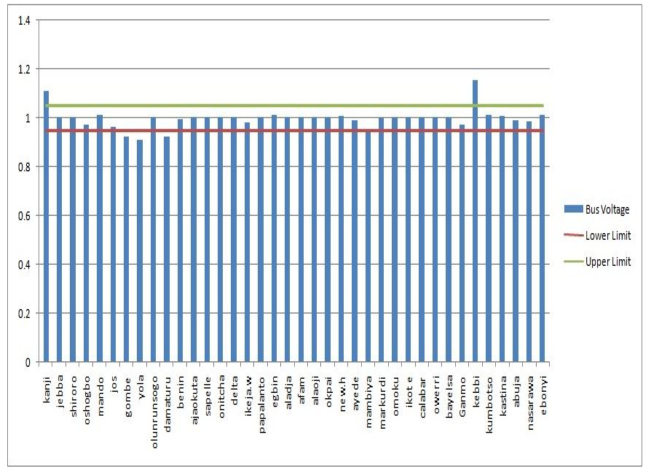


Fig 2: PU Voltage during Kainji and Mambilla outage.

C. Violation Summary during Jebba and Mambilla outage

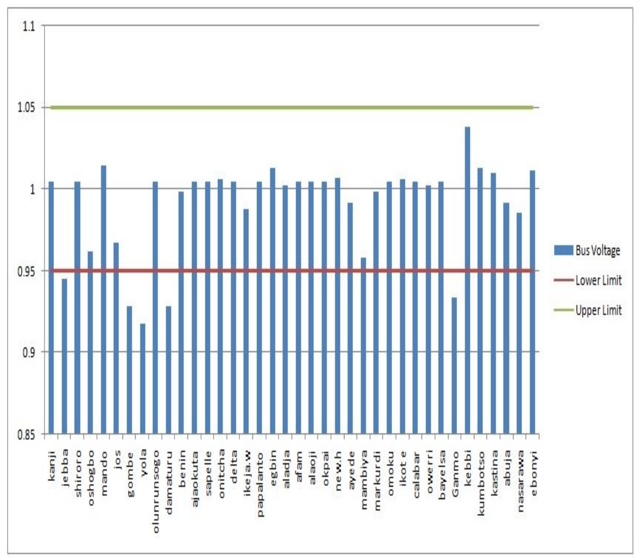


Fig 3: PU Voltage during Jebba and Mambilla outage.

D. Violation Summary during Shiroro and Mando outage

TABLE 3: Line Violations during Shiroro and Mando outage

Element	Value(MVA)	Limit(MVA)	Percentage (%)
Ajaokuta to Makurdi	783.5	777.3	101.8

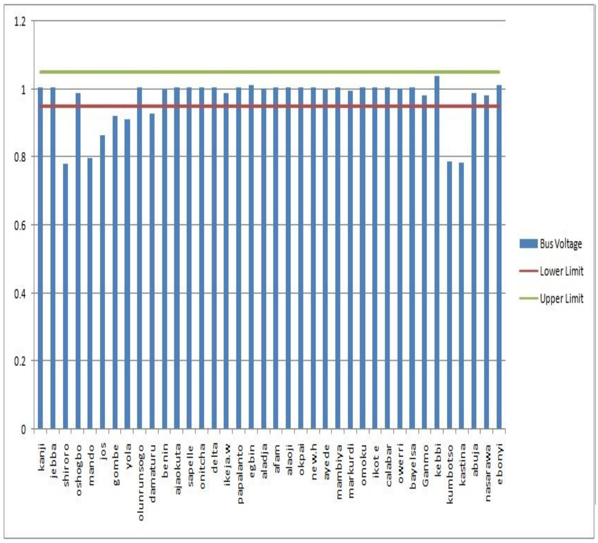


Fig 4: PU Voltage during Shiroro and Mando outage

E. Violation summary during Ajaokuta and mambilla outage

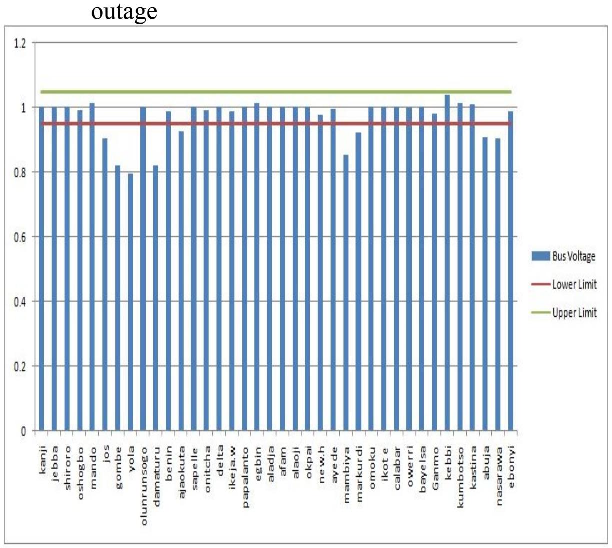


Fig 5: PU Voltage during Ajaokuta and mambilla outage

Line MVA limits violations: This type occurs in the system when the MVA rating of the line exceeds given rating. This is mainly due to the increase in the amplitude of the current flowing in that line.

Voltage Violations: This type of violation occurs at the buses. This suggests that the voltage at the bus is less or higher than the specified value. Using the standard voltage limit of ±5%, it was observed that;

During Kainji and Jebba generators outage, there were violations at Jebba, Oshogbo, ganmo and kebbi load buses.

On Kainji and mambilla generators outage, there were violations at Kainji, gombe, yola, damaturu and kebbi load buses.

On Jebba and mambilla generators outage, there were violations at Jebba, gombe, yola, damaturu and ganmo load buses.

On shiroro and mando generators outage, there were violations at shiroro, mando, jos, gombe, yola, damaturu, kumbosto and katsina load buses.

Then, during Ajaokuta and mambilla generators outage, there were violations at jos, gombe, yola, damaturu, ajaokuta, mambilla, makurdi, Abuja and nasarawa load buses.

V. MAJOR FACTORS AFFECTING ELECTRICITY GENERATION IN NIGERIA.

There are many factors that affect electricity generation in Nigeria, the major ones include but not limited to:

a. Huge debts owed to generation companies by some government agencies and some other companies: The continued existence of generation companies in Nigeria is being threatened by huge unpaid debts by some stakeholders in the power industry. Most of the generation companies are now running their operations at a huge loss [11].

b. Stranded power: Stranded power is electricity that is generated but wasted or unable to be used because of where its source is located. One of the major causes of the lingering epileptic power supply in the country is the cumulative stranded capacity from generation companies which they record daily [12].

c. Shortage of gas supply: Majority of the generation companies generates power from gas turbines. But in recent times, there is reduction in the supply of gas to these power plants, thereby crippling the system. This is as a result of the rising cases of pipeline vandalism and insecurity around gas producing and transportation assets.

d. Declining value of Naira: When the generation companies, (GENCOs) acquired the power assets, the exchange rate of the United States Dollar to Nigerian Naira was $1/N157. About three years down the line, the cost of the equipment needed to carry out repairs of turbines and associated auxiliaries remain the same on the international market but has increased by about 100 percent in the last three years, arising from the devaluation of the Naira. Given the fact that majority of parts and equipments procured by GENCOs are sourced from outside the country, this has had significant impact on the GENCOs' purchasing power and inevitably on their ability to upgrade and maintain their various power plants. Furthermore, as at the time of paying for the power assets in 2013, some of the acquisition financing were sourced by GENCOs in dollars. The cost of repaying those facilities has significantly increased by about 100 percent in the last three years arising from the devaluation of Naira as well. This has resulted in additional huge losses with suffocating effects on the GENCOs [13].

e. Low tariffs: The electric power market rules recognize three critical factors that drive tariffs; exchange rate, cost of inflation and gas prices. In recent times, these three drivers have significantly risen by over 100% without commensurate increase in tariff. This has ensured that cost reflective tariffs, which are clearly provided for in the Electricity Power Sector Reform Act, have not been achieved till date.

VI. CONCLUSION

The supply of adequate and stable electricity to consumers is the back born of socio-economic growth of any nation and Nigeria is not an exception. But the Nigeria power system has remained weak due to constant obstructions like failure of equipments which do cause overloads to other equipments. The problem of studying thousands of possible outages becomes very difficult to solve if it is desired to present the results quickly. So it is very important to have a system which can detect the possible future outages and prioritize among them to determine the most critical cases for detailed analysis. This is done by Contingency Analysis which allows operators to be better prepared to react to outages by using pre-planned recovery scenarios [14].

To maintain adequate power supply to the consumers in any part of the globe is a very challenging task. For the Nigeria power generating sector to function effectively and deliver adequate electricity supply, the following is recommended:

a. The Government should diversify the sources of fuel for electricity generating stations. Nigeria has abundance coal reserve, Uranium, bio-mass, wind and solar potentials, which can be used for generating electricity instead of relying only on gas and hydro potentials.
b. Distribution companies can supply stranded electricity to consumers directly from GENCOs within their vicinity owing till when the transmission grid can be fortified evacuate all electric power generated.
c. The electricity consumers in Nigeria should show patriotism through prompt settlement of electricity bills.
d. The restructuring of the Nigerian radial interconnected electricity generation station grid system which has National Control Centre at Oshogbo and replace it with a regional interconnected grid system in order to reduce transmission line losses and improve reliability of the Nigerian grid system.

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