Analysis Of Power Flow of Nigerian 330kv Grid System (Pre and Post) Using MATLAB

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Abstract- This paper assesses the reliability, stability and efficiency of the proposed (post reform) 10,000MW capacity 330kV grid and the extent to which it will provide solution to the numerous problems that presently plague the existing (pre reform) grid. Using MATLAB, load flow studies are first conducted on both the 31-bus system pre reform grid and the 49-bus system post reform grid using both the Gauss-Seidel and Newton-Raphson iteration methods. Furthermore, the grid is subjected to contingency assessment to determine its capacity to withstand various contingencies that practical power systems encounter. The results obtained show that the post reform grid is a great improvement on the pre reform grid.

Indexed Terms- Contingency analysis, MATLAB, Power Flow Analysis, Power losses, Transmission.

I. INTRODUCTION

The on-going reform in the Nigeria Power sector, among its numerous objectives, is to produce radical expansion of the existing grid network. It is expected that in the next few years, a much larger, fortified and stable grid will replace the scanty, unstable and fragile grid that exists presently. This is a major objective of the on-going reform in the power sector. As a solution to the country's present power crisis, caused majorly by a weak grid network, the Nigerian government has mapped out a reform program for the power sector which has in its short term plan the objective of expanding the grid to a total generation capacity of 10,000MW by the year 2011. The proposed grid network has 49 buses, 17 generating stations of 10,000MW total power generation capacity and 9,156km transmission lines. When this is compared with the existing network with only 31 buses, 6,000MW total installed power generation capacity and 4889.2km transmission lines, the expansion process would be regarded as a radical one. The rapid increase in the demand for electricity as a result of population growth, industrial development and rise in consumer electrical appliances have necessitated the stepping up of generation and transmission capabilities of the grid network to deliver quality power supply to the consumers. Various researches have shown that the existing grid network is inadequate and lacks the capacity to provide the right quantity and quality of power for the whole country [1-4]. It must be noted however that most of the solutions proffered by these researcher's demand moderate expansion and changes in the grid network. The detailed load flow study of the emerging grid was carried out on the Nigerian power grid with focus on the 330kV power transmission lines, all generating stations and 330kV substations.

II. METHODOLGY

Power flow, commonly known as load flow is a vital tool for power system analysis and design. They are necessary for planning, operation, economic scheduling, transient stability, contingency studies and control of an existing system as well as planning its future expansion. The power flow solution is used to evaluate the bus voltage, branch current, real power flow and reactive power flow for the specified generation and load conditions. The results are used to evaluate the line or transformer loading and the acceptability of bus voltages. A 4-bus system was used for this analysis while MATLAB was used to generate the admittance matrix for the 31-bus transmission line for pre-existing 330kV and 49-bus transmission line for the proposed network.

III. MODELLING OF THE NETWORK

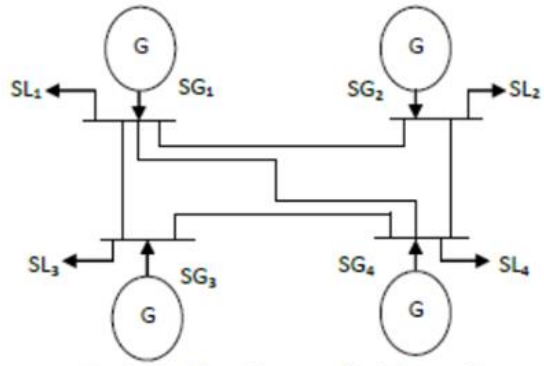

Fig. 1: One line diagram of a 4-bus system

	Pre- 330kV Network	Post- Reform 330kV Netwo
Number of Generators	11	17
Total capacity(MW)	6,000	10,000
Number of Buses	31	49
Length of Transmission Lines	4889	9156
Number of Single Lines	16	37
Number of Double Lines	13	27
Number of Loops	3	9

Table1: Pre and Post reform 330kV network

SGi denote the 3-phase complex generator power flowing into the ith bus and SLi denote the 3-phase complex power drawn from ith bus.

SGi = PGi + jQGi --------------------- 1

SLI = PLi + jQLi ----------------------- 2

Where P and Q denote the real and reactive powers in each bus. The generator and load are combined so that the net 3 phase complex power flowing into the iih bus can be written as;

Si=(SGi – jSLi)=(PGi+jPLi) + j(QGi – jQLi) ---3

If the sources are connected to a common reference of ground potential and the shunt admittances at the buses have been lumped, the equivalent circuit reduces to Fig. 2.

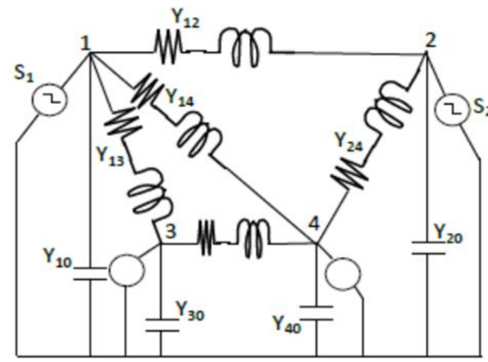

Fig. 2: One-line diagram of a 4-bus system

Applying KCL to the four nodes of Fig. 2, Ibus = YbusVbus ----------------------------4. The bus admittance matrix can be calculated according to the flow chart below;

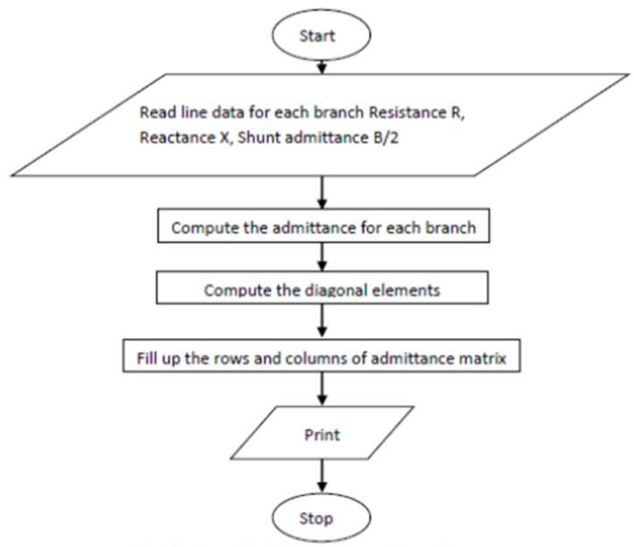

Fig. 3: Flow chart for computing the admittance matrix

IV. DATA PREPARATION

In order to perform a power flow analysis by the Newton-Raphson method in the MATLAB environment, the following variables must be defined: power system base MVA, power mismatch accuracy, acceleration factor and maximum number of iterations.The name (in lower case letters) reserved for these variables are base MVA accuracy and maxiter respectively. The value used here are: Basemva = 100; accuracy = 0.001; maxiter = 100. The initial step in the preparation of input file is the numbering of each bus. Buses are numbered sequentially. Although the numbers are sequentially assigned, the buses need not be entered in sequence. In addition, bus data file and line data file are required.

- BUS DATA FILE

The format for the bus entry is chosen to facilitate the required data for each bus in a single row. The information required must be included in a matrix called bus data. Column 1 is the bus number. Column 2 contains the bus code. Columns 3 and 4 are the voltage magnitude in p.u and phase angle in degrees respectively. Columns 5 and 6 are load MW and Mvar respectively. Columns 7 through 10 are MW, Mvar, minimum Mvar and maximum Mvar of generation, in that order. The bus code entered in column 2 is used for identifying load, voltage-controlled and slack buses as outlined below;

1. This code is used for the slack bus. The only necessary information for this bus is the voltage magnitude and its phase angle.
2. This code is used for the voltage-controlled buses. For this bus, voltage magnitude, real power generation in megawatts, and the minimum and maximum limits of the megavar demand must be specified.

This code is used for the load buses. The loads are entered positive in megawatts and Mega Vars. For this bus, initial voltage estimate must be specified. This is usually 1 and 0 for voltage magnitude and phase angle, respectively. If voltage magnitude and phase angle for this type of bus are specified, they will be taken as the initial starting voltage for the bus instead of a flat start of 1 and 0.

- LINE DATA FILE

Lines are identified by the mode-pair method. The information required must be included in a matrix called line data. Columns 1 and 2 are the line bus numbers. Columns 3 through 5 contain the line resistance, reactance, and one-half of the total line charging susceptance in p.u on the specified MVA base. The last column is for the transformer tap setting. The lines may be entered in any sequence or order with the only restriction being that if the entry is a transformer, the left bus number is assumed to be the tap side of the transformer.

V. POWER FLOW PROGRAMS

Power flow programs are the programs that have been developed for the power flow solution of practical system. Each method of solution consists of four programs. The program for the Newton-Raphson method is newtonrap, which is then preceded by building bus and is followed by busout and lineflow. Programs ifybus, busout and lineflow are designed to be used with the power flow programs.

1. Buildybus: This program requires the line and transformer parameters and transformer tap setting specified in the input file named line data. It converts impedances to admittances and obtains the bus admittance matrix.
2. Bus data: This program produces the bus output result in a tabulated form. The bus output result includes the voltage magnitude and angle, real and reactive power of generators and loads, and the shunt capacitor/reactive Mvar.
3. Loadflow: This program prepares the line output data. It is designed to display active and reactive power flow entering the line terminals and line losses as well as the net power at each bus. Also included are the total real and reactive losses in the system.
4. Newtonrap: This program obtains the power flow solution by the Newton-Raphson method and requires the bus data and line data files. It is designed for the direct use of load and generation in MW, bus voltages in p.u, and angle in degrees, loads and generation are converted to p.u quantities on the base MVA selected. A provision is made to maintain the generation reactive power of the voltage-controlled buses within their specified limits. The violation of reactive power limit may occur if the specified voltage is either too high or too low. In the iteration, the Var calculated at the generator buses are examined.

```
>> % matlab input file power flow program
>>basemva = 100; maxiter = 100; accuracy = 0.001
>>clc
>>linedatas
>>buildybus
>>busdata
>>gaussp
>>newtonrap
>>loadflow
```

VI. RESULTS AND DISCUSSION

- THE NETWORK ON CAPACITY

The load flow analysis shows the proposed or post-reform network as a significant improvement on the existing network. MATLAB simulation of the proposed network recorded a lot of improvement in bus voltage, line and system stability. However, the network was discovered to have significant deficiencies in voltage level and power flow along the transmission lines. The network experienced high voltage at buses 18, 19, 21, 22, 23, 24, 25, 26, 28, 29 and 37 which represent Damaturu, Maiduguri, Gombe, Yobe, Jalingo, Jos, Makurdi, Alaide, Katampe, Sokoto, and BirninKebbi. Most of these buses are located at the northern areas where load consumption is low. This coupled with the fact that most lines connecting these buses are very long transmission lines, results in high voltages in these buses due to reactive power build-up. Also, lines 31-32, 27-31, 26-37- 11-41, 11-44 and 2-49 experienced heavy loading with excessive power losses. From the result, these lines were discovered to be loaded beyond their thermal capacity. As a solution, the affected lines which are single circuits were replaced with double circuit transmission lines with only lines 11-41, 26-27 and 11-44, with the highest loadings in the network further strengthened with additional double circuit lines each. The simulation result showed that this was able to lower the power evacuation burden on these lines well below their thermal ratings, it also showed reduction in line losses. This is illustrated in Fig. 4. Reactive power compensations were also made at the buses that experienced high voltages. The results revealed very high improvement in voltage levels at affected buses as no bus voltage exceeded acceptable limits (-15% to +10% of nominal value) after compensation. These are shown in Fig. 4 and Fig. 5.

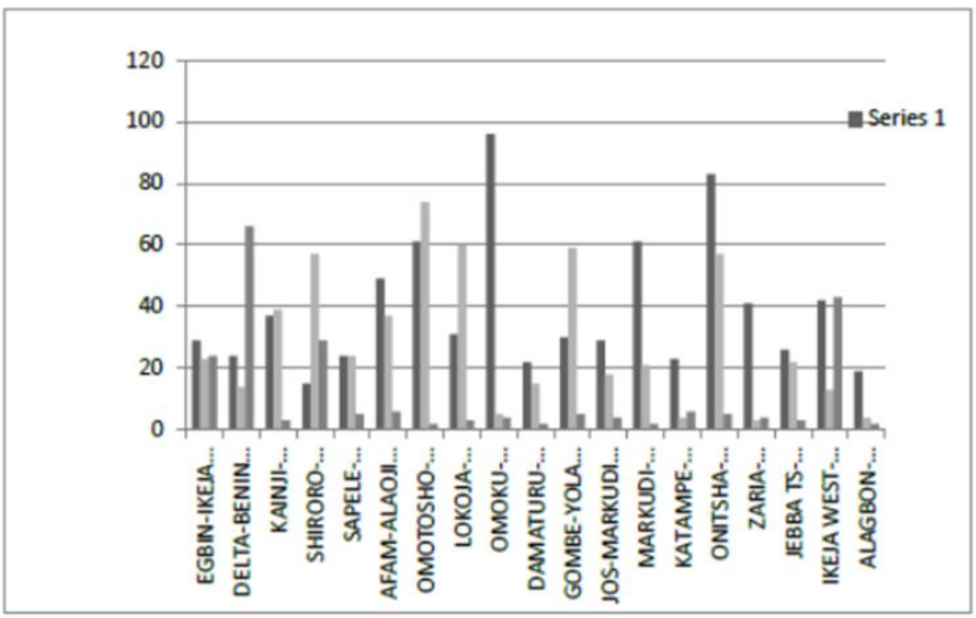

Fig. 4: Percentage line loading after compensation and lines fortification

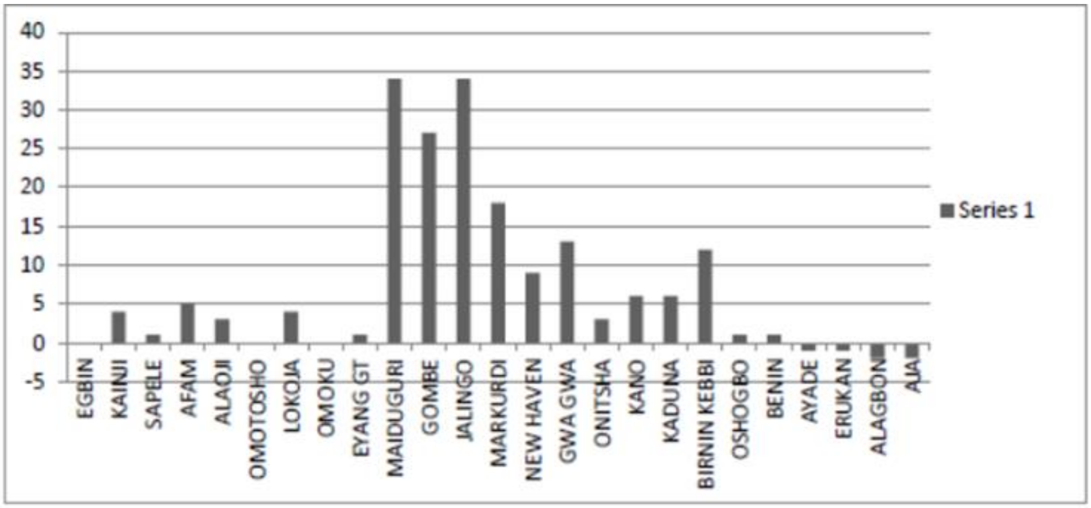

Fig. 5: Voltage Violation Profile before Compensation (+10% and -15% limit)

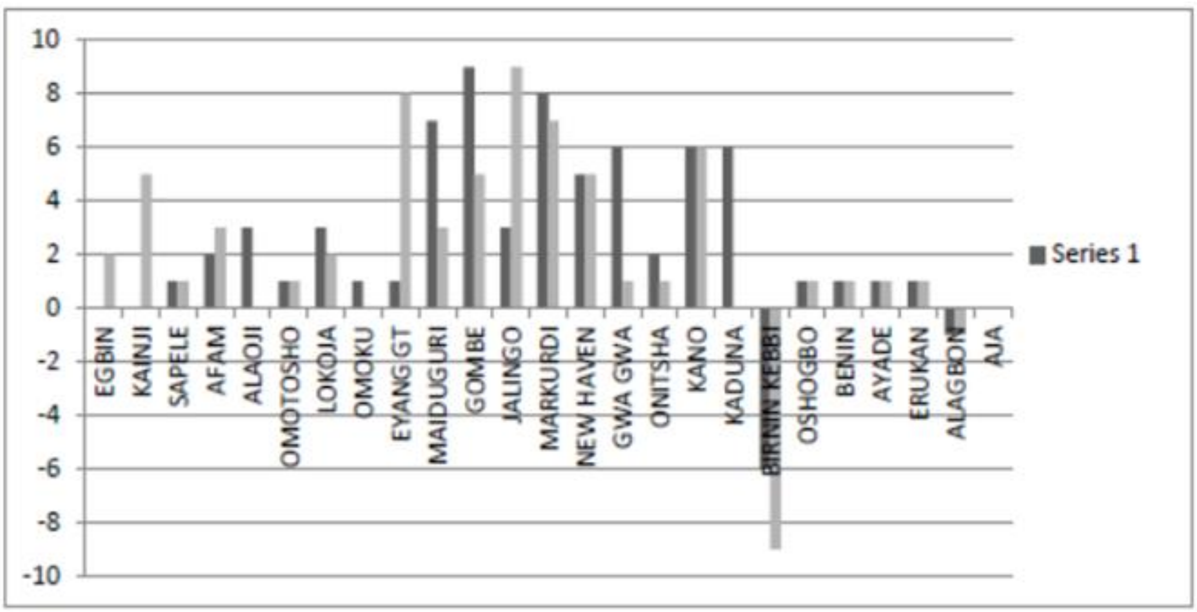

Fig. 6: Voltage Violation Profile after Compensation (+10% and -15% limit)

CONCLUSION

In the post-reform grid, Nigeria has a power network which unlike the pre-reform (existing) network, offers higher power generation capacity, stability, efficiency and reliability. The network which is made up of 18 generators of 10000 MW total generation capacity, 9,156km length of transmission lines and 49 substations, is no doubt a radical expansion of the pre-reform grid network, which has 7 generators of 6000 MW total installed capacity, 4889.2km length of transmission lines and 32 substations. It also has a higher percentage of double circuit and short transmission lines with more loops thereby reducing transmission losses and improving the reliability and efficiency of the network.

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