Evaluation of Power System Transient Stability of 330KV Nigeria Network

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Abstract- This paper reviews the evaluation of power system transient stability of 330KV Nigeria network. Transient stability is very important basically from the view of determining the maximum amount of power that can be transmitted without instability being experienced in a steady state condition or as a result of load changes or faults. Prospective stability glitches are still the most critical barriers to maximizing power transfer across interconnected power system like Nigerian national grid. Occurrence of transient instability problems may result to large excursion of the system machine rotor angle, and if remedial action fails, loss of synchronism among generators may result in total system collapse. A fault can occur as a result of short circuits between transmission line phases or between a phase and the ground. The type of fault that was introduced to the network was a three phase fault which was applied on the transmission between Oshogbo to Sapele. During the course of this simulation, it was observed that after the fault has been cleared, it was observed that the speed of the generator dropped below its nominal value (0.99371) against the actual value (0.99417) which also caused the rotor angle to increase. It also caused the system to regain stability after about 18.55 seconds. After connecting the shunt capacitor it was also observed that after the fault has been cleared, the speed, the rotor angle and the real power were operating at nominal values. It is very important to point out here that increasing the number of parallel lines between two points in a common means of reducing reactance. When a parallel transmission lines are used instead of a single line. Some power is transferred over the remaining line even during a three-phase fault on one of the lines unless the fault occurs at a paralleling bus. Finally, reliable and safe power system are critical for any successful operation. A well-designed system ensures robust performance and maximizes plant availability under all operating conditions, including transient conditions like motor starts, non-linear loads and generator loss. Effects of poorly designed systems including outages, faults poor power quality and arc flashes can result in income and production losses, or worse, personnel injuries.

Indexed Terms- Transient Stability, Power Flow, Instability,

I. INTRODUCTION

Electrical energy is an essential ingredient for the industrial and all-round development of any country. The quality of life in any country is highly dependent on a reliable electricity supply. Frequent power system collapse is capable of plunging the entire power system consumers into darkness due to system instability in the electric power system. The epileptic nature of the supply has led to slow economic growth and dissatisfaction among the consumers. The purpose of any electrical power system is to generate electrical energy in ample volumes at most suitable locality, transmit it in a bulk quantity to a load center, which is then distributed to the individual consumers. Fundamentally the power system network is designed to provide uninterrupted power supply that maintains a stable voltage. Synchronism occurs mostly in larger machines in a power system, such as the generators, condensers and considerable part of a motor. In order to achieve consumer standard of service, it is paramount to maintain synchronism in such systems. To assist in overcoming the instability problems, analysis of the Nigerian electric power system transient stability becomes necessary. Improving the stability of a power system under small and large disturbances is one of the most important problems in power system control. This study concentrated on design of advanced controllers for power system stability enhancement.

Power system consists of synchronous machines operating in synchronism. For the stability of the power system, it is essential that they should sustain perfect synchronism in all steady state situations. The ability of the power system to return to its stable conditions after undergoing a disturbance is called stability (Ayodele, 2012). Disturbances in power system may be of various types like abrupt change of load, unexpected short circuit between line and ground, line-to-line fault, all three line faults, switching, etc. Variation of power system connected load causes transient disturbances. Nevertheless, due to unforeseen events these transient disturbances can be caused by loss of excitation, switching operations, lightning, accidents or any other unpredictable events, fault. A fault can occur as a result of short circuits between transmission line phases or between a phase and the ground. Due to fault occurrence, one or more generators may be severely disturbed causing an imbalance between generation and demand. Severe damages can occur when a fault is not cleared at a pre-specified time frame. It may cause serious damage to the equipment which in turn could lead to a power loss and power outage. Protective equipment are therefore installed for fault detection and clearance, also to isolate the faulted parts of the system rapidly before the fault energy spreads to the rest of the system.

For continuous power, power system stability is important and it is thus defined as that property of a power system that enables it to remain in a state of equilibrium under normal operating conditions and to regain an acceptable state of equilibrium after being subjected to a disturbance. Instability of power system can occur in many different situations depending on the system configuration and operating mode. One of the stability problems is maintaining synchronous operation or synchronism especially that power system rely on synchronous machines. This aspect is influenced by the dynamic of generator rotor angles and power-angle relationships. Other instability problem that may be encountered is voltage collapse that is mostly related to load behavior and not synchronous speed of generators.

In order to avoid these unwanted situations, it is of great importance to predict beforehand with accuracy, the extent of voltage, current and power distribution within the system at any time so as to know the protective devices to be integrated to handle the abnormal conditions. Hence under these dangerous situations, the transformers, lines, generators, cables, bus-bars etc. need to be secured (Ikeli, 2009). The transient stability analysis which is the main concern of this work, deals with the state of the synchronous machine during a fault in the system. It gives the state and position of the load. The digital computer is an indispensable tool for power system analysis, computational algorithms for various system studies such as load flow, fault-level analysis, stability studies etc. It gives an acceptable working accuracy to the ever widening complex power system of modern times.

Generally the study of stability is very important basically form the view of determining the maximum amount of power that can be transmitted without instability being experienced under steady state conditions or as a result of load changes or faults. Prospective stability glitches are still the most critical barriers to maximizing power transfers across interconnected power systems like the Nigerian national grid. Occurrence of transient instability problems may result to large excursions of the system machines rotor angle, and if remedial action fails, loss of synchronism among generators may result in total system collapse. Recall that in the summer of 1996, two major transient disturbances occurred in the Western system coordinating council in United States of America which resulted in partial black-outs that cost the power utilities and their customers several Millions Dollars. In Nigeria, two system collapses within a three-day interval in March 2000, and in January 2018 plunged the entire nation into darkness. The nation was without electricity for up to 72 hours in some areas with serious social, economic and security implications. The transient stability of a power system is usually taken important and a major factor of the stability of the power system because of its non-linear character, its fast evolution and its disastrous practical implications (Ikeli, 2009).

So many approaches have been taken by different researchers in the area of transient stability. These approaches can be classified under conventional techniques and computational intelligence techniques. A technique is considered conventional when no renewable energy sources (RES) are involved. conventional techniques make up the greatest part in the literature since they includes techniques with SGs, FACTS and any other approaches that do not involve RES based units (Michael, 2017). Studies on means of reducing power system blackouts are still going all over the world. Lots of people are affected yearly due to power system failures. Incorporating the knowledge of computational intelligence with roots of blackouts can lead us to victory over these great losses. Voltage stability study is a vital aspect as it avoids power system failure. (Fouzul & Zaheeruddin, 2011) Presented a computational intelligence based evaluation for a very important aspect, voltage stability of an electric power system. Large amounts of data, fuzziness of that data, and the endless variations of system configurations are all factors contributing to the complexity of power quality analysis and diagnosis. This complexity has necessitated the need for sophisticated tools to aid system engineers. Artificial Neural Network and Fuzzy Logic have emerged as amongst most suitable tools for voltage stability for power system applications. The combination of two or more intelligent disciplines into one system for power system analysis has proven even more effective (Fouzul & Zaheeruddin, 2011).

The analysis is carried out to determine whether the system loses stability during the first swing or not. In case the power system remains stable, it is assumed that subsequent swings will diminish and that power system will remain stable, as usually happens. However, there is a possibility of power system going unstable in some subsequent swing. For example negative damping is one cause. Control equipment improperly adjusted or applied can produce negative damping (Gupta, 2013).

II. RESEARCH METHOD

In respect of the above the following method were adopted: Newton-Raphson power flow method, Runge-Kutta method, and simulated in PowerWorld software. In this study, the Nigerian power system of 34 buses, 10 generators were used as a case study for the transient stability analysis. Oshogbo to Sapella station was considered during large scale disturbance such as the three phase on the transmission line between Oshogbo to Sapele, the critical clearing time to be determined. This study covers the Nigerian 33KV/34bues power system. All the 34buses in the network were critically examined and analyzed with regard to transient stability.

A. Power Flow analysis by Newton Raphson Method

$$P_i = |V_i|^2|Y_{ii}|\cos\theta_{ii} + |V_i|\sum_{k\neq i}^{n}|V_k||Y_{ik}|\cos(\theta_{ik} - \delta_i + \delta_k) \quad (1.35)$$

$$Q_i = -|V_i|^2|Y_{ii}|\sin\theta_{ii} + |V_i|\sum_{k\neq i}^{n}|V_k||Y_{ik}|\sin(\theta_{ik} - \delta_i + \delta_k) \quad (1.36)$$

Where

P_i and Q_i= Real power and reactive power of bus i respectively

$|V_i|$ and $|V_k|$= Voltage magnitude of buses i and k respectively

$|Y_{ik}|$= Bus admittance

θ_{ik}= phase angle between bus i and k

δ_i and δ_k= Volage angle of bus i and bus k

The first derivatives of equations 1.35 and 1.36 with respect to bus voltage magnitudes and angles and expanded by Taylors' series with higher terms neglected gives the expression below

$$\begin{bmatrix} \Delta P_2{}^r \\ \vdots \\ \Delta P_n{}^r \\ - \\ \Delta Q_2{}^r \\ \vdots \\ \Delta Q_n{}^r \end{bmatrix} =$$

$$\begin{bmatrix} \frac{\partial P_2{}^r}{\partial \delta_2} & \cdots & \frac{\partial P_2{}^r}{\partial \delta_n} & | & \frac{\partial P_2{}^r}{\partial |V_2|} & \cdots & \frac{\partial P_2{}^r}{\partial |V_n|} \\ \vdots & \ddots & \vdots & | & \vdots & \ddots & \vdots \\ \frac{\partial P_n{}^r}{\partial \delta_2} & \cdots & \frac{\partial P_n{}^r}{\partial \delta_n} & & \frac{\partial P_n{}^r}{\partial |V_2|} & \cdots & \frac{\partial P_n{}^r}{\partial |V_n|} \\ & - & & \cdot & & - & \\ \frac{\partial Q_2{}^r}{\partial \delta_2} & \cdots & \frac{\partial Q_2{}^r}{\partial \delta_n} & & \frac{\partial Q_2{}^r}{\partial |V_2|} & \cdots & \frac{\partial Q_2{}^r}{\partial |V_n|} \\ \vdots & \ddots & \vdots & | & \vdots & \ddots & \vdots \\ \frac{\partial Q_n{}^r}{\partial \delta_2} & \cdots & \frac{\partial Q_n{}^r}{\partial \delta_n} & & \frac{\partial Q_n{}^r}{\partial |V_2|} & \cdots & \frac{\partial Q_n{}^r}{\partial |V_n|} \end{bmatrix} \begin{bmatrix} \Delta \delta_2{}^r \\ \vdots \\ \Delta \delta_n{}^r \\ - \\ \Delta |V_2|^r \\ \vdots \\ \Delta |V_n|^r \end{bmatrix} \quad (1.37)$$

$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_4 \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \Delta |V| \end{bmatrix} \quad (1.38)$$

$$\begin{bmatrix}\Delta P\\ \Delta Q\end{bmatrix} = J\begin{bmatrix}\Delta\delta\\ \Delta|V|\end{bmatrix} \quad (1.39)$$

Where
ΔP is the mismatch active power vector
ΔQ is the mismatch reactive power vector
$\Delta|V|$ is the unknown voltage magnitude vector
$\Delta\delta$ is the unknown voltage angle correction vector
J is the Jacobian matrix of partial derivatives of equations (1.35) and (1.36)

J_1, J_2, J_3 *and* J_4 as the first, second, third and fourth partition of the Jaobian matrix J

Therefore, differentiating equation (1.35) with respect to δ_i and δ_k gives

$$\frac{\partial P_i}{\partial \delta_i} = \sum_{k=1}^{n} |V_i|\,|V_k|\,|Y_{ik}|\sin(\theta_{ik} - \delta_i + \delta_k) \quad (1.40)$$

$$\frac{\partial P_i}{\partial \delta_k} = -|V_i|\,|V_k||Y_{ik}|\sin(\theta_{ik} - \delta_i + \delta_k)\,, k \neq i \quad (1.41)$$

Equations (1.40) and (1.41) are respectively the diagonal and off-diagonal elements of J_1, the first partition of the Jacobian matrix.

Similarly, differentiating equation (1.35) with respect to $|V_i|$ and $|V_k|$ gives

$$\frac{\partial P_i}{\partial |V_i|} = 2|V_i||Y_{ii}|\cos\theta_{ii} + \sum_{k\neq i}^{n}|V_k||Y_{ik}|\cos(\theta_{ik} - \delta_i + \delta_k) (1.42)$$

$$\frac{\partial P_i}{\partial |V_k|} = |V_i||Y_{ik}|\cos(\theta_{ik} - \delta_i + \delta_k), k \neq i \quad (1.43)$$

Equations (1.42) and (1.43) are respectively the diagonal and off-diagonal elements of J_2, the second partition of the Jacobian matrix.

In the same vein, differentiating equation (1.36) with respect to δ_i and δ_k gives

$$\frac{\partial Q_i}{\partial \delta_i} = \sum_{k\neq i}^{n} |V_i|\,|V_k|\,|Y_{ik}|\cos(\theta_{ik} - \delta_i + \delta_k) \quad (1.44)$$

B. $\frac{\partial Q_i}{\partial \delta_k} = -|V_i|\,|V_k||Y_{ik}|\cos(\theta_{ik} - \delta_i + \delta_k)\,, k \neq i$ (1.45)

Equations (1.44) and (1.45) are respectively the diagonal and off-diagonal entries of J_3, the third partition of the Jacobian matrix.

Finally, differentiating equation (1.36) with respect to $|V_i|$ and $|V_k|$ gives

$$\frac{\partial Q_i}{\partial |V_i|} = -2|V_i||Y_{ii}|\sin\theta_{ii} - \sum_{k\neq i}^{n}|V_k||Y_{ik}|\sin(\theta_{ik} - \delta_i + \delta_k) (1.46)$$

$$\frac{\partial Q_i}{\partial |V_k|} = -|V_i||Y_{ik}|\sin(\theta_{ik} - \delta_i + \delta_k), k \neq i (1.47)$$

Equations (1.46) and (1.47) are respectively the diagonal and off-diagonal entries of J_4, the fourth partition of the Jacobian matrix.

The Jacobian matrix gives the linearized relationship between small changes in voltage angle $\Delta\delta_i^{(r)}$ and voltage magnitude $\Delta\left|V_i^{(r)}\right|$ with the small changes in real and reactive power, $\Delta P_i^{(r)}$ and$\Delta Q_i^{(r)}$ respectively. Elements of the Jacobian matrix are the partial derivatives of equations 1.24 and 1.25, evaluated at $\Delta\delta_i^{(r)}$ and $\Delta|V_i^{(r)}|$, where *r* is the iteration count.

For voltage-controlled buses, the voltage magnitudes are known. Therefore, if *m* buses of the system are voltage controlled, *m* equations involving ΔQ and ΔV and the corresponding columns of the Jacobian matrix are eliminated. The terms $\Delta P_i^{(r)}$ and $\Delta Q_i^{(r)}$ are the difference between the scheduled and calculated values, known as power mismatch (or residuals) given by:

$$\Delta P_i^{(r)} = P_i^{sch} - P_i^{(r)} (1.48)$$

and

$$\Delta Q_I^{(r)} = Q_I^{sch} - Q_I^{(r)} (1.49)$$

The new estimate for bus voltages are

$$\delta_i^{(r+1)} = \delta_i^{(r)} + \Delta\delta_i^{(r)} (1.50)$$

$$\left|V_i^{(r+1)}\right| = \left|V_i^{(r)}\right| + \Delta\left|V_i^{(r)}\right| \quad (1.51)$$

Where

$\delta_i^{(r+1)}$ is the new bus voltage angle and

$\left|V_i^{(r+1)}\right|$ is the new bus voltage magnitude

III. RESULT

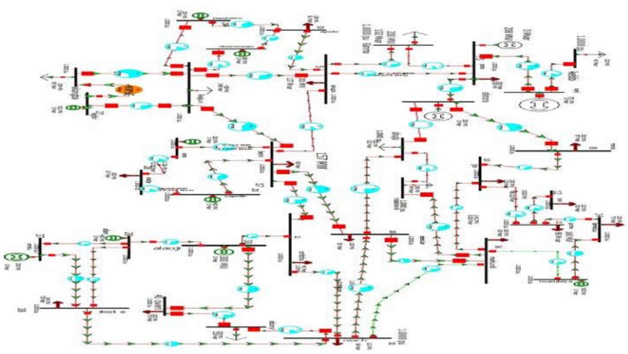

Figure 1:34 Bus, Nigeria Grid network.

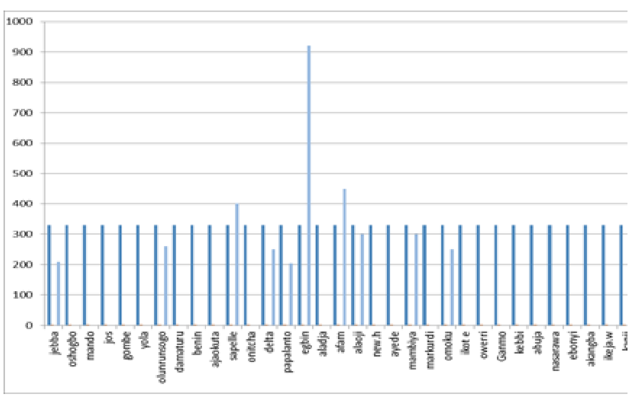

Figure 1.2: showing the bus data

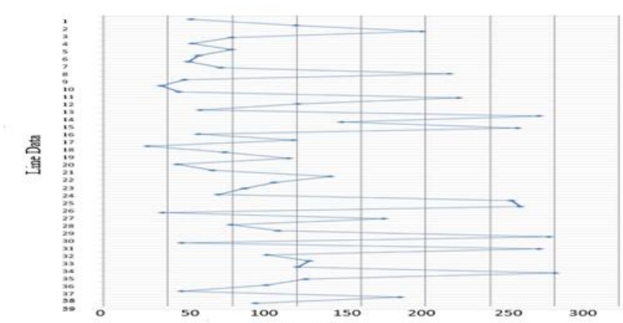

Figure1.3: showing the line data.

Simulation of Transient Stability Study Based On the Application of a Three-Phase Fault

Simulations were carried out using Power world simulation software package environment to examine the behavior of Nigeria 330KV power system network during large scale disturbance such as the three phase fault on the transmission line between Oshogbo to Benin the critical clearing time was determined at 0.085sec after the fault has been cleared. The simulation results are shown in figure 1.4, 1.5 and 1.6 are the generator´s real power, rotor angle and speed. The result of the simulation is shown that the generators were in synchronism after the fault has been cleared. So it was decided that we analyze one of the generators which was the generator at Sapele.

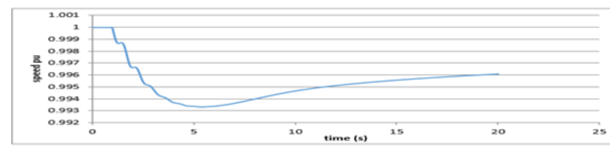

Figure 1.4: a plot of speed against time.

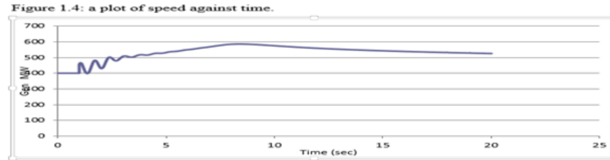

Figure 1.5 showing the plot of power against time

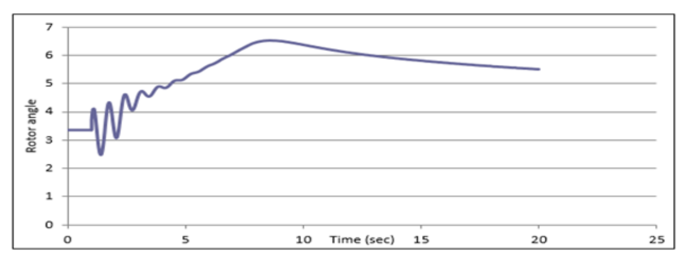

Figure 1.6 showing the plot of rotor angle against time.

Figure 1.4, 1.5, 1.6 shows the behavior of the generator in relation to speed, Real power and rotor angle when the three phase fault and cleared by the relay. It is observed that the speed of the generator recovered below its normal operating speed while the generator´s real power and rotor angle above it operating value before stabilizing after 18.55 seconds.

Simulation of Transient Stability Study Based on the Application of a Three-Phase Fault after Capacitor was connected.

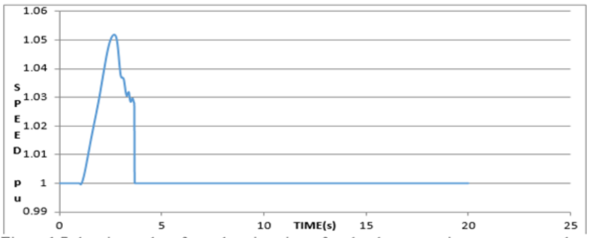

Figure 1.7 showing a plot of speed against time after the shunt capacitor was connected.

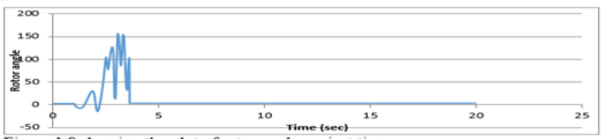

Figure 1.8 showing the plot of rotor angle against time

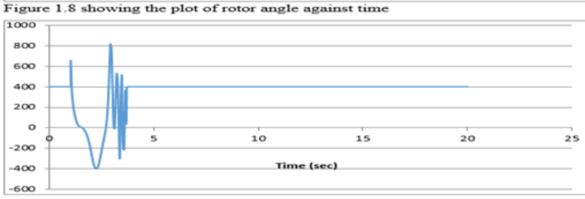

Figure 1.4, 1.5, 1.6 shows the behavior of the generator in relation to speed, Real power and rotor angle when the three phase fault and cleared by the relay and when the shunt compensator such as the shunt capacitor. We could observe that the disturbance lasted for about 3 seconds before stabilizing to normal operation.

IV. CONCLUSION

In this work, an attempt was made to determine the transient stability of the 34bus in Nigeria power system under fixed load condition. A load flow was carried out in the network to determine unknown variables such as bus voltages and angle at the load bus the reactive power at the generator bus. The technique used to solve this problem is the Newton-Raphson technique. In this study in order to run transient analysis on the network, a disturbance such as a three phase fault is applied on the network. The critical clearing time was set at 0.08 seconds this was set to clear the fault in order to return the system to normalcy. When the relay acted due to the presence of a fault it was observed that the speed which had a nominal value of 1PU was stabilizing below the nominal value and it took 18.55 seconds for it stabilize. After the shunt capacitor was connected to the network at the bus in Yola and Damaturu. It was observed that the shunt capacitor brought stability to the system. The speed of the generator was able to normalize at 1PU. It took about 3 seconds for disturbance to occur before the system came back to normalcy.

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