An Analysis of Transient Stability Enhancement Capability of UPFC in a Multi-machine Power System

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Abstract— This study presents the transient stability enhancement capability of Unified power flow controller (UPFC) as an effective Flexible AC Transmission System (FACTS) device in a multi-machine power system. The test system was a reduced Nigerian 330kV power system and the focus was on the effect of disturbances on the largest generating unit (Egbin) in the system. The analysis was conducted by simulating a 3-phase fault at two locations; on the terminal of the largest generator unit at Egbin bus and the bus with the largest load at Ikeja–west. The response of the system in both cases was compared with and without the device in operation. Simulations were carried out using the Power System Simulation for Engineering (PSS/E) software. Results showed that, with the UPFC in the network, system transient stability was enhanced considering that critical clearing time of the system was increased from 380ms to 590ms when the fault was at Egbin generator terminal and from 470ms to 510ms following the fault at Ikeja-west. In addition, the device was able to damp power oscillations resulting from the disturbance created by the faults.

Keywords— Flexible AC Transmission Systems, Power System Simulation for Engineering, Power Systems, Transient Stability, Unified Power Flow Controller,

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1 INTRODUCTION

Deregulation of power system around the world has brought to the forefront the issue of power system stability. The stability issue stems from new regulatory requirements, economic/environmental factors, and increase demand without a corresponding increase in generation and transmission line reinforcement. All these results in power systems being stressed beyond the capacity they were originally built to handle. Considering that some generators are far from the load centres, the problem of transient stability following a major disturbance will be a threat to the security of supply. Stressed power systems are known to exhibit nonlinear behaviour (Januszewski, Machowski, &Bialek, 2004) and the interactions among power systems components results in various modes of oscillations. These oscillations if not properly damped, may be sustained for several minutes affecting power flows and may even increase to cause loss of synchronism between systems and ultimately lead to total or partial system outage.

While Braking resistors and Power system stabilizers are amongst the fore-most measures used to enhance the damping of power swings, the advent of Flexible AC Transmission System (FACTS) controllers has changed the way power systems are operated and controlled at steady states and during network contingencies. Advancement in power electronic devices for high power application indicates that they will continue to find application in electric power transmission and distribution systems; particularly, in this era of a deregulated market. The Unified Power Flow Controller (UPFC) is a FACTS device which is, technically, the most versatile and effective because, it combines the functionality of a series Static Synchronous Series Compensator (SSSC) and shunt STATicCOMpensator (STATCOM).

A UPFC fundamental frequency state-space model under balanced operating conditions is reported by Nabavi-Niaki&Iravani, (1996), the work however focused mainly on the technical feasibility of UPFC in damping torsional oscillatory modes as a result of series capacitor compensated transmission system. Meng& So, (2000) proposed a current injection model for UPFC using the speed/rotor angle deviations and active power/reactive power deviations as input signals to the UPFC controller. However, the choice of input signals of the later means that the location of the device is restricted to a point that allows for such signals to be measured.

The effect of UPFC on a heavily disturbed generator is reported by Ravi Kumar &Nagaraju, (2007) using the 10-generator 39-bus New England as test system. In Omoigui, Komolafe, &Olorunfemi, (2007), a reinforced Nigerian 330kV transmission network showed improved voltage profiles and system stability with a STATCOM and UPFC installed. However, the effect of the UPFC series device in damping power oscillation could have been better utilised if the device was located at a point farther from the end of a radial line. Various FACTS devices were used on Kundur inter-area power system by Murali, Rajaram, &Reka, (2010) to improved power system stability. Comparative result revealed that UPFC provided better performance than these other devices during the post fault period. They, however, did not take into consideration the equivalent rating of the devices when they were compared.

Nwohu, (2011) investigated the use of UPFC to improve the damping of low frequency power oscillations in the Nigerian grid system. Although results obtained showed that the rotor angle of the generator (closest to fault) located at Shiroro was the most affected and the UPFC's (located at Ikeja west) effectiveness in damping power oscillation was shown, the work restricted the fault location to just one bus and the impact of the fault location

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and its distance from the UPFC as it relates to the network behaviour was not revealed. A two-machine system was used to investigate the effect of UPFC on transient stability under various fault conditions by Thakur &Ghawghawe, (2012). The fault conditions had increased critical clearing time, hence the transient stability; although, the 3L-G fault has the lowest margin.

This paper adopts the study of transient stability of an electrical power system under severe disturbances by considering how a UPFC responds to a disturbance affecting power supply from a critical (largest) generating unit in a network. The multi-machine power system used in the study is a reduced Nigerian 330kV transmission system. The Power System Simulator for Engineering (PSS/E) developed by Siemens PTI (Power Technologies International) is used for this study. PSS/E is composed of an all-inclusive set of programs for studies of power system transmission network and generation performance in both steady-state and dynamic conditions.

2 STUDY SYSTEM

Figure 1 (Sanni et al., 2015) shows a reduced Nigerian 330kV transmission network including the UPFC used for this study. It’s a 5 generator system with a particular interest on the generator at Egbin as the critical generator. This generator is the single largest unit in the network hence, its critical nature. The system is subjected to credible disturbance and the response of the critical generator is compared for the case when the UPFC is present and when it is absent.
Sample Preparation

3 SYSTEM MODEL

3.1 UPFC Principle of Operation

The UPFC is conceptually seen as a synchronous voltage source (SVS) at the fundamental frequency. Consider a simple two machine system interconnected by a transmission line in series with a voltage phasor with controllable magnitude V_{pq} ($0 \leq V_{pq} \leq V_{pqmax}$) and angle ρ ($0 \leq \rho \leq 2\pi$) as shown in Figure 2.

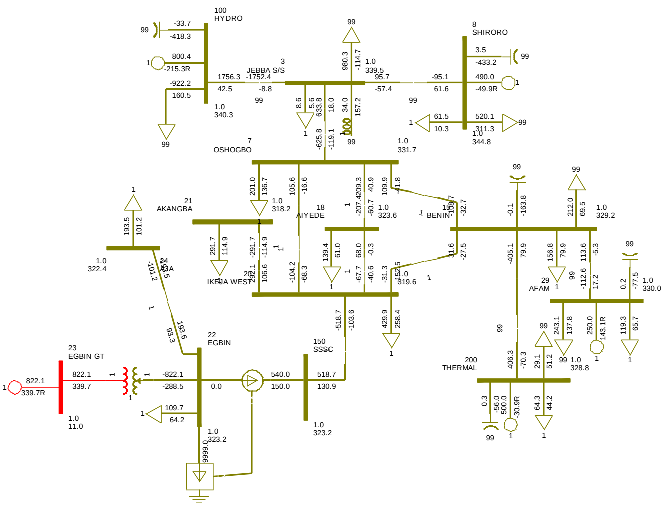

Fig. 1.The Reduced Nigerian 330kv Transmission Network Including UPFC Modelled in PSS/E

In this functionally unrestricted operation, which clearly includes voltage and angle regulation, the SVS generally exchanges both reactive (Q_{pq}) and real (P_{pq}) power with the transmission system. Since the SVS primarily is able to generate only the reactive power exchange, the real power must be supplied to it, or absorbed from it, by a suitable power supply or sink (Hingorani & Gyugyi, 2000). In the UPFC arrangement the real power exchanged is provided by one of the end buses usually the sending-end bus (V_s).

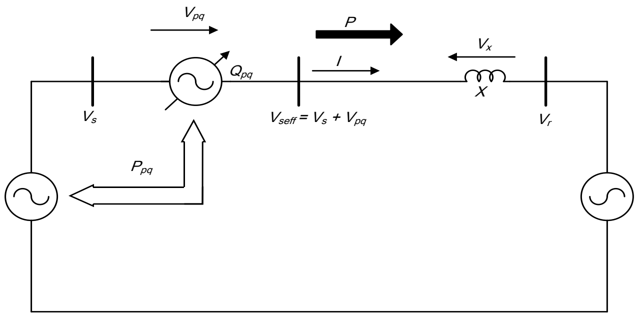

Fig. 2. Conceptual Representation of the UPFC in a Two-machine Power System (Hingorani&Gyugyi, 2000)

Fig. 3 shows the practical implementation schematic diagram of the power circuit of a UPFC which is composed of an excitation transformer (ET), a boosting transformer (BT), two voltage source converters (VSCs) and a dc link capacitor. The VSC on the side of the boosting transformer (VSC-B) controls the magnitude and phase angle of injected voltage (V_B) by means of amplitude modulation index (m_B) and phase-angle (δ_B) respectively. Fig. 4 shows the phasor relationship which indicates that depending upon the magnitude and/or phase-angle of V_B, angle δ can be controlled. Thus real and reactive power flow through the line can be regulated. Furthermore, the magnitude of receiving end voltage (V_2) could also be controlled by V_B. Therefore; the UPFC can also be used for reactive power flow regulation (voltage control).

Fig. 4 also shows that control of the apparent power (S) in the line is accompanied by the exchange of real power $(|V_B||I| \cos\theta)$ between the VSC-B and the system. This power exchange results in either the discharge or overcharge of the dc link capacitor. This power exchange is compensated by VSC on the excitation transformer (VSC-E) to maintain the capacitor at the required value, and assure proper operation of the VSCs. Phase angle of the control signal of VSC-E (δ_E) is used to control the real

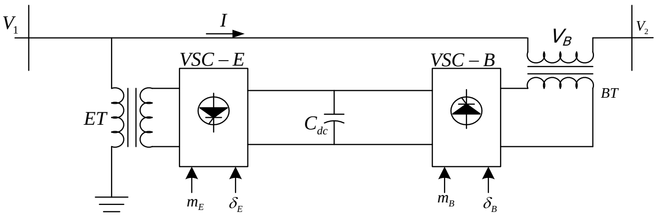

Fig. 3.UPFC Schema (Nabavi-Niaki & Iravani, 1996)

power exchange between VSC-E and the system so as to control the dc link voltage. Therefore, neglecting losses, the UPFC is neither a source nor a sink of energy (Nabavi-Niaki & Iravani, 1996).

3.2 Mathematical model of a Multi-machine Power system

Transient stability analysis requires the appropriate modelling of critical components like generators, transmission lines, loads etc. This section outlines how the multi-machine network is handled during dynamic simulation.

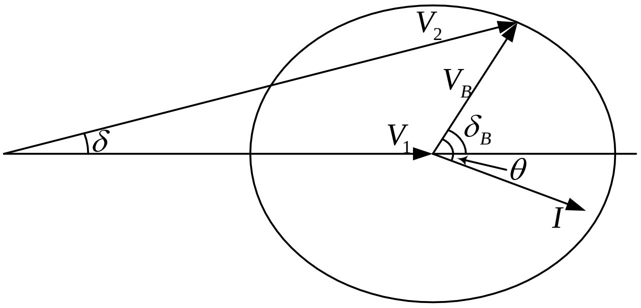

Fig. 4. Phasor Representation of UPFC operation in a System (Nabavi-Niaki&Iravani, 1996)

The steady state operation of a power system is determined by solving the initial power flow of the network to determine the initial bus voltages and angles. (1) defines the injected currents at the generator buses prior to a disturbance.

Where n is the number of generators, V_i is the terminal voltage of the ith generator, P_i and Q_i are the generator real and reactive powers. The generator voltage behind transient reactance is obtained from (2)

$$I_i = \frac{S_i^*}{V_i^*} = \frac{P_i - jQ_i}{V_i^*},\ i = 1,2,\ldots\ldots n \qquad (1)$$

Once the Y matrix for each network condition (pre-fault, during and after fault) is calculated, all nodes except for the internal generator nodes are eliminated to obtain the Y matrix for the reduced network. The reduction can be achieved by matrix operation bearing in mind that all the nodes have zero injection currents except for the internal generator nodes. In a power system with n generators, the nodal equation can be written as:

$$E' = V_i + jX'_d I_i \qquad (2)$$

Loads are converted to equivalent admittance using (3)

$$y_{j0} = \frac{S_j^*}{|V_j|^2} = \frac{P_j - jQ_j}{|V_j|^2} \qquad (3)$$

The equivalent network with all load converted to admittances is shown in Fig. 5

The reduced bus admittance matrix has the dimensions (n x n), where n is the number of generators. The network reduction as illustrated by (4) to (8) is a convenient analytical technique that can be used only when the loads are treated as constant impedances. The electrical power output of each machine can now be expressed in terms of the machine's internal voltages. The power into the network at node i which is the electrical power output of the ith machine is given by (9)

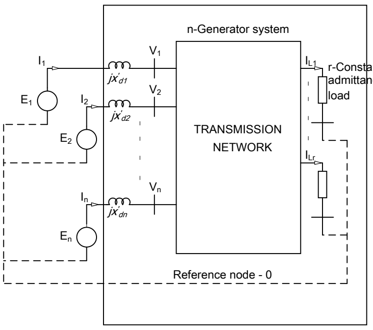

Fig. 5. Multi-machine system representation

$$\lfloor 0 \rfloor \quad \lfloor Y_{rn} \quad Y_{rr} \rfloor \lfloor V_r \rfloor \qquad (4)$$

Where the subscript n represents generator nodes and the subscript r represent all other nodes.

Expanding (4),

$$I_n = Y_{nn} V_n + Y_{nr} V_r \qquad (5)$$

$$0 = Y_{rn} V_n + Y_{rr} V_r \qquad (6)$$

Eliminating Vr to find

$$I_n = (Y_{nn} - Y_{nr} Y_{rr}^{-1} Y_{rn}) V_n = Y_R V_n \qquad (7)$$

Thus the reduced matrix can be written as:

$$Y_R = (Y_{nn} - Y_{nr} Y_{rr}^{-1} Y_{rn}) \qquad (8)$$

$$P_{ei} = \sum_{j=1}^{n} |E_i E_j Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j) \ i = 1,2,3 \ldots\ldots, n \qquad (9)$$

The dynamics of the rotor angle δ and speed ω as described by the swing equations is given as

$$\frac{d\Delta\omega}{dt} = \frac{1}{2H}[T_m - T_e - D\Delta\omega] \qquad (10)$$

$$\frac{d\delta}{dt} = \omega_0 \Delta\omega \qquad (11)$$

Where $\Delta\omega = \omega - \omega_0$ is the speed deviation of rotor angular speed from the synchronous speed ω_0, H is the per-unit inertia constant, T_m and T_e are the per-unit mechanical and electrical torque respectively and D is the damping factor.

For the ith machine, the swing equation becomes

$$\frac{2H_i}{\omega_0}\frac{d\Delta\omega_i}{dt} + D_i\Delta\omega_i = P_{mi} - \left[\sum_{j=1}^{n} |E_i E_j Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j) \ i = 1,2,3 \ldots\ldots, n\right] \qquad (12)$$

$$\frac{d\delta_i}{dt} = \omega_i - \omega_0 \quad i = 1,2,\ldots\ldots, n \qquad (13)$$

Prior to disturbance, the mechanical input power is at equilibrium with the electrical power output, and we have:

$$P_{mi}^{pf} = \sum_{j=1}^{n} |E_i E_j Y_{ij}^{pf}| \cos\left(\theta_{ij}^{pf} - \delta_i^{pf} + \delta_j^{pf}\right) \ i = 1,2,3 \ldots\ldots, n \qquad (14)$$

The superscript pf is used to indicate the pre-transient conditions. As the network changes due to switching during the fault, the corresponding values will be used in the above equations.

4 SIMULATION

4.1 Transient Stability Simulation

An indicator of system stability is given by the rotor angle plot (swing curves) of the machines and the critical clearing time (CCT) of the system before instability occurs. The critical clearing time is the maximum allowable time that a fault can be sustained without the synchronous generator becoming unstable. In the analysis, the generator models selected in PSS/E was the classical model GENCLS, except for the generator at Egbin modelled with a wound rotor model GENROU used for thermal plants. These generator models are able to reflect the characteristics of the actual generators based on the actual parameters. Since the response of Egbin generator to the device during severe disturbance was of concern, the UPFC in the network was located between the buses at Egbin and Ikeja-west as illustrated in Fig. 1.

4.2 UPFC Model Implementation in PSS/E

PSS/E is used to model and study power systems in static and dynamic conditions and it is the tool of choice by most utility companies around the world. PSS/E model library however, does not have a dynamic model for the series component of the UPFC to be used in this investigation and a user defined model was developed.
This was achieved using the Application Program Interface routines (APIs) developed in Python programming language to control the operation of the program during the dynamic simulation and solving for the SSSC model. The python programme interpreter is an embedded program within PSS/E.

The series device model developed is based on the works of Hernández et al., (2011), where the VSC switching dynamics of SSSC was neglected for the time scale of transient stability analysis, and the SSSC can be represented as a controllable voltage source behind an equivalent transformer reactance. This study uses the same variable impedance model for the SSSC component of the UPFC. In PSS/E it is modelled as a zero impedance line connecting the sending and receiving end bus (i.e. Egbin Sub-station and Ikeja-west). This way, the impedance imposed in series with the transmission line where it is connected varies based on the variation of the power flowing in the line from the steady state value. The flow of control during the dynamic simulation and modelling of series part of the UPFC is illustrated in fig. 6. However, the available dynamic model in PSS/E was used for the STATCOM component of the UPFC.

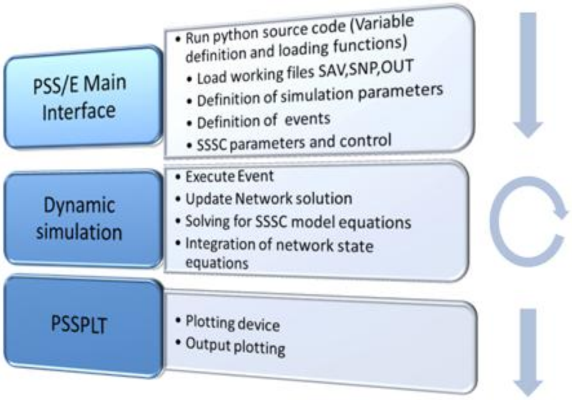

Fig. 6.Structure of Python code integration within PSS/E (Hernández et al., 2011)

5 Results and Analysis

The system was subjected to a three phase fault at:

i. The terminal of the generator at Egbin.
ii. Ikeja-west Bus (as the bus with the largest load)

In all cases, the system was operating at the steady state and the fault was simulated at 0.1seconds. The fault was cleared after five cycles by the removal of the fault. The evaluation of the system response with and without the UPFC device in the network is described in the subsequent sections.

5.1 Fault on Egbin Generator terminal

The response of the system to a three-phase fault on the terminal of the generator at Egbin was considered to examine both transient stability and power oscillation damping capabilities of the UPFC. The swing curves of the 5 generators are shown in fig. 7 and it is observed that the generator at Egbin was the most severely disturbed considering that it was the faulted bus. Fig. 8 gives a comparison of the response of the rotor angle for the generator at Egbin when the UPFC operation was activated for the same fault scenario. It could be observed the rotor angle excursion is reduced when the UPFC is in operation. The terminal voltage profile of the generator at Egbin with and without the UPFC is shown in Fig. 9. While the voltage returned to pre-fault steady state value at about 5.5 seconds when the UPFC was in the system, some oscillations could be observed without it, showing the effectiveness of the shunt part of the UPFC in voltage control.

The effect of the series part of the device can be observed in Fig. 10 where the oscillation of the power flowing through the Egbin - Ikeja-west line was damped with the UPFC in service. The initial power flowing through the line was 540MVA from Egbin to Ikeja-west. This steady state flow was restored at about 10 seconds after some oscillations that resulted from the applied disturbance.

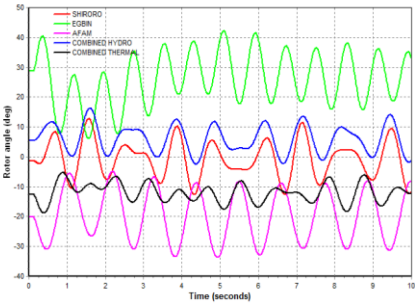

Fig. 7.Swing Curves of Generators in the Network Following a Three-Phase Fault at Egbin Generator Terminal

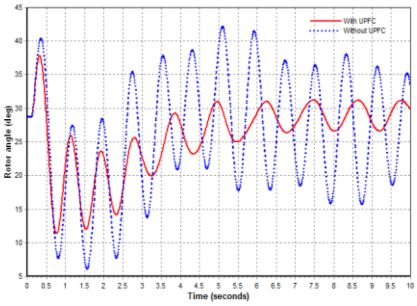

Fig. 8.Swing Curve of the Generator at Egbin with and without UPFC in the System Following a Three-Phase Fault at Egbin Generator Terminal

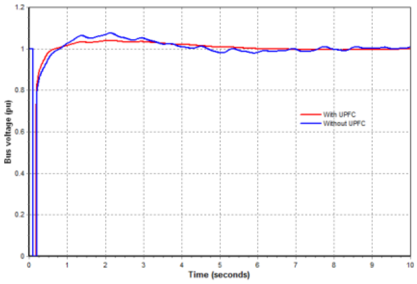

Fig. 9.Terminal Voltage Response of the Generator at Egbin with and Without UPFC in the System Following a Three-Phase Fault at Egbin Generator Terminal

The implication is that more power can be delivered to the load within a short period of time when there is a UPFC in the system. The system was, however, subjected to an extended period of fault clearing time to determine the critical clearing time (CCT) of the system before instability. It was revealed that without the UPFC in operation the critical clearing time of the system was 380ms while it increased to 590ms when the UPFC was in operation.

Fig. 11 is the rotor angle response of the generator at Egbin showing the first swing instability when the CCT was 380ms. The origin of this instability can be traced to the response of the electrical and mechanical power output of the generator as shown in Fig. 12 and Fig. 13. Fig. 13 shows that at the point of instability the synchronizing torque in the form of mechanical power generated was insufficient to sustain the electrical power requirement of the available loads leading to instability without the UPFC device. Conversely, with the UPFC device, the mechanical power output is able to relatively sustain the loads, albeit, oscillating and over time will eventually return to pre steady state value.

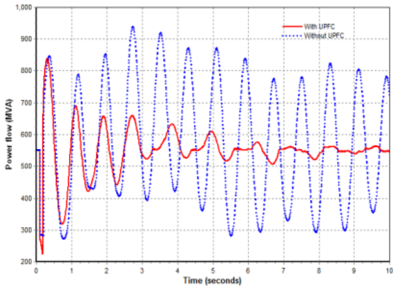

Fig. 10.Power Flow in the Line between Egbin and Ikeja-West Showing the Oscillation Damping Effect of UPFC Following a Three-Phase Fault at Egbin Generator Terminal

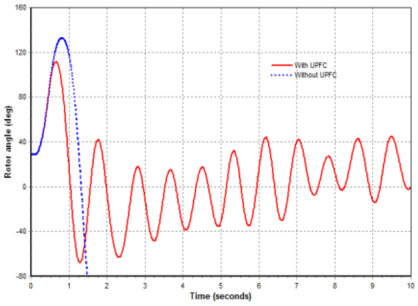

Fig. 11.Swing Curve of the Generator at Egbin Showing Instability Following a Three-Phase Fault at Egbin Generator Terminal

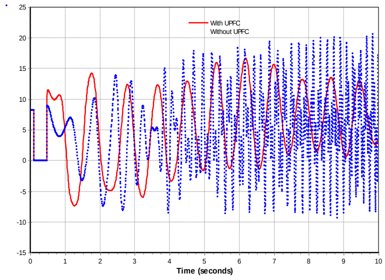

Fig. 12.Egbin Generator Electrical Power Output During Instability Following a Three-Phase Fault at Egbin Generator Terminal

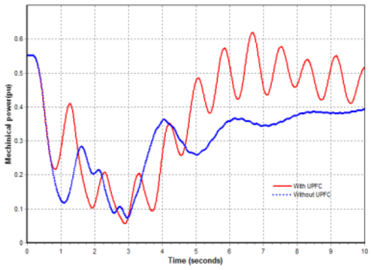

Fig. 13.Egbin Generator Mechanical Power Output During Instability Following a Three-Phase Fault at Egbin Generator Terminal

B. Fault on Ikeja-west Bus

For a bus with the largest load of 430MWon the network, the system response to a 3 phase fault on the network was important. The performance of the UPFC during such disturbance was even more critical due to the size of the load on the bus. The swing curves of the 5 generators for fault duration of 5 cycles are shown in Fig.14. Fig.15 gives a comparison of the response of the rotor angle for the generator at Egbin when the UPFC operation was activated for the same fault scenario. It could be observed the rotor angle oscillation is reduced when the UPFC is in operation. Although, in comparison with when the fault was at Egbin, the maximum angle in reduced. As the faulted bus, the voltage of the bus at Ikeja-west falls to zero for the fault duration as shown in Fig. 16. This means that the largest load on the system momentarily lost power for that duration which could be far-reaching if the loads are critical, emphasizing the need for equipments that will not allow for such fault to be sustained. In addition, the bus voltage was increase from about 0.94pu without UPFC to 0.98pu with UPFC and the level of oscillation following the disturbance is reduced with the device. As the most significant generator in this study, the terminal voltage of the generator at Egbin with and without the UPFC is shown in Fig.17. While some oscillations can be observed without UPFC, the effect of shunt part (STATCOM) of the UPFC in voltage control is shown when the voltage of the Egbin generator returned to pre-fault steady state value at about 6.0 seconds when the UPFC was in the system.

Fig.18 shows the power flowing through the transmission line between Egbin and Ikeja-west where the UPFC is connected. There is a marked difference in the power oscillating in the line following the disturbance, showing the effect of the series part (SSSC) of the UPFC. Having subjected the system to a prolonged period of fault clearing time to determine the CCT of the system before instability, it was discovered that the CCT of the system was increased to 510ms from 470ms with UPFC in the system. Fig.19 shows the rotor angle response of the generator at Egbin showing the first swing instability when the CCT was 470ms. During this instability the electrical and mechanical power response is given by Fig. 20 and Fig. 21 respectively. It is obvious that the inadequate mechanical power to balance the electrical power output is a factor in the instability that occurred. It could be interpreted that a disturbance on a bus with a large load which is also the receiving end bus of the UPFC could be more severe than the same fault on the largest generating unit.

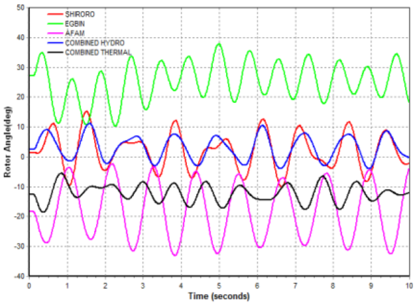

Fig.14. Swing Curves of Generators in the Reduced Network Following a Three-Phase Fault at Ikeja-West Bus

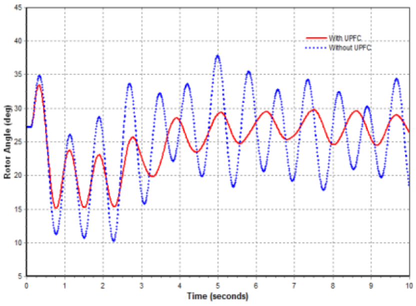

Fig. 15.Swing Curve of the Generator at Egbin With and Without UPFC in the System Following a Three-Phase Fault at Ikeja-West Bus

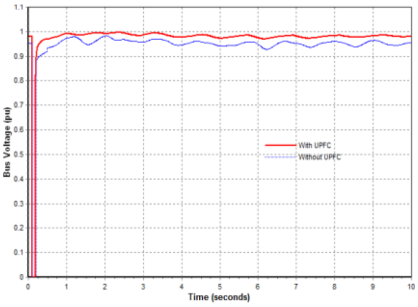

Fig. 16.Bus Voltage Response at Ikeja-west With and Without UPFC in the System Following a Three-Phase Fault at Ikeja-West Bus

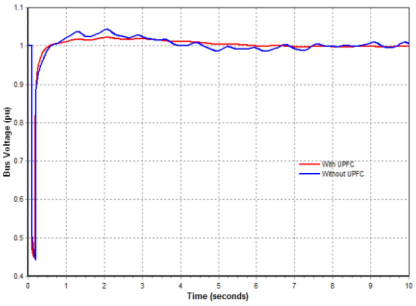

Fig. 17.Terminal Voltage Response of the Generator at Egbin with and Without UPFC in the System Following a Three-Phase Fault at Ikeja-West Bus

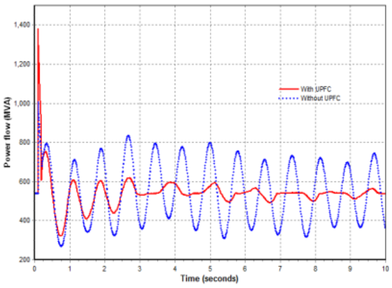

Fig. 18.Power Flow in the Line between Egbin and Ikeja-West Showing the Oscillation Damping Effect of UPFC Following a Three-Phase Fault at Ikeja-West Bus

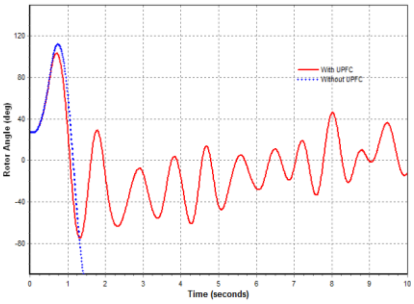

Fig. 19.Swing Curve of the Generator at Egbin Showing Instability Following a Three-Phase Fault at Ikeja-West Bus

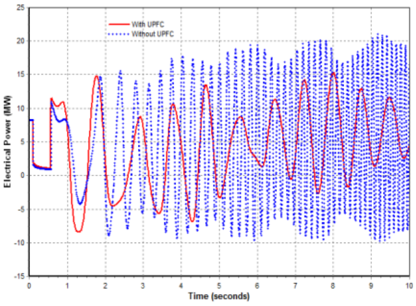

Fig. 20.Egbin Generator Electrical Power Output During Instability Following a Three-Phase Fault at Ikeja-West Bus

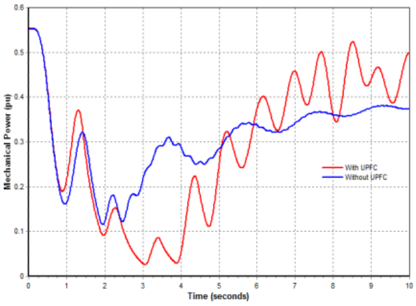

Fig. 21.Egbin Generator Mechanical Power Output During Instability Following a Three-Phase Fault at Ikeja-West Bus

4 CONCLUSION

In this study, an investigation of the capability of UPFC in enhancing the transient stability of a typical multi machine power system is presented. The power oscillation damping capability of UPFC was also examined. For the analysis, a reduced Nigerian 330kV network was used as the study system with a three-phase fault was simulated at the terminal of the largest generator unit in the system at Ebgin and the bus with the largest at Ikeja-west. The dynamics of the system were compared with and without the presence of UPFC in the system in the time immediately following the disturbance. It was revealed that in all cases, the UPFC was able to damp the resulting power oscillations and by extension increased the system stability derived from an increase in the critical clearing time for the system before instability.

The Modelling and simulation of the network including the UPFC was implemented in PSS/E using python programming and the application program interface. With the fault at Egbin the critical clearing time was extended by 210ms, while the margin of stability at Ikeja-west it was 40ms. It is believed that the Nigerian power system can benefit significantly from the utilization of FACTS technologies to solve some of the problems associated with the network.

REFERENCES

Hernández, A., Eguía, P., Torres, E., & Rodríguez, M. Á. (2011, June). *Dynamic simulation of a SSSC for power flow control during transmission network contingencies.* Paper presented at the IEEE Trondheim PowerTech, 2011, Trondheim, Norway.

Hingorani, N. G., & Gyugyi, L. (2000). *Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems.* NJ: IEEE Press, Piscataway.

Januszewski, M., Machowski, J., & Bialek, J. W. (2004). Application of the direct Lyapunov method to improve damping of power swings by control of UPFC. *IEE Proceedings on Generation, Transmission and Distribution* , 151 (2), pp. 252-260.

Meng, Z. J., & So, P. L. (2000). A current injection UPFC model for enhancing power system dynamic performance. *IEEE Power Engineering Society Winter Meeting.* 2, pp. 1544 - 1549. IEEE.

Murali, D., Rajaram, M., & Reka, ,. N. (2010). Comparison of FACTS Devices for Power System Stability Enhancement. *International Journal of Computer Applications*, 8 (4) pp. 30 - 35.

Nabavi-Niaki, S. A., & Iravani, M. R. (1996). Steady-state and dynamic models of unified power flow controller (UPFC) for power system studies. *IEEE Transactions on Power Systems* , 11 (4), pp. 1937 - 1943.

Nwohu, M. N. (2011). Low-frequency power oscillation damping enhancement and voltage improvement using unified power flow controller (UPFC) in multi-machine power system. *Journal of Electrical and Electronics Engineering Research* , 3 (5), pp. 87-100.

Omoigui, M. O., Komolafe, O. A., & Olorunfemi, J. O. (2007). Reinforcing the Nigerian 330kV Electric Power Network to Increase Power Delivery and Improve Steady-State and Transient Stability. *Ife Journal of Technology, OAU, Ile-Ife* , pp. 87-98.

Power Holding Company of Nigeria Plc (PHCN). (2009). *Natinal Control Center Oshogbo Generation and Transimission Grid Operations. Oshogbo:* General Manager (S/O) National Control Center Oshogbo.

Power Technology International (PTI). (2015). *PSS/E 34 Program Application Guide. Vol. I and II.* Siemens Energy.

Power Technology International (PTI). (2015). *PSS/E 34 Program Operation Manual.* Siemens Energy.

Ravi Kumar, S. V., & Nagaraju, S. S. (2007). Transient Stability Improvement Using UPFC and SVC. *ARPN Journal of Engineering and Applied Sciences* , 2 (3) pp. 38 - 45.

Sanni, S. O., Haruna, J. O., Jimoh, B., & Aliyu U. O. (2015). *Coherency based dynamic reduction of Nigerian power system in PSS/E.* Paper Presented at the International Engineering Conference (IEC) 2015 (pp. 194 - 199). Minna: IEC.

Thakur, R. V., & Ghawghawe, N. D. (2012). Enhancement of transient stability of system using Unified Power Flow Controller (UPFC) under fault conditions. *Proc. 2012 International Conference on Computing, Electronics, and Electrical Technologies (ICCEET)* (pp. 198 - 202). IEEE.