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Transient Stability Improvement Analysis with UPFC in Nigerian Power System Using PSAT

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ABSTRACT

This paper presents the impact of Unified Power Flow Controller (UPFC) on transient stability improvement in the Nigeria 330KV transmission network. UPFC is a Flexible AC Transmission System controller (FACTS) that can regulate the Power flow through the Line by controlling its Series and shunt reactance. In shunt connection it has Static Synchronous Compensator (STATCOM) and in the series, Static Synchronous Series Compensator (SSSC) is employed and can independently control the Line Power Flow in order to improve transient stability of the system. This network which consist of 17 generating stations, 41 buses and 40 transmission lines was modeled and simulated using PSAT and Matlab Version 7.5. Fault was initiated with and without UPFC and result showed that Transient Stability of the system is improved.

I. Introduction

Recent blackouts in different part of this country have illustrated the need to install UPFC device to improve the power system stability. As a consequence of increasing power demand, some transmission lines are more loaded than was planned when they were built. With the increased loading of transmission lines, the problem of transient stability after a fault can become a transmission limiting factor. FACTS devices are available, to help Power Engineers deal with problems like Large Signal Stability and economic Factors that necessitate improvement of the Stability limit of the System. Facts devices can provide fast control of Active and Reactive power in the Power system. Among the converter based FACTS devices Static Synchronous Compensator (STATCOM) and Unified Power Flow Controller (UPFC) are the popular FACTS devices. They play important role, not only in increasing the amount of energy transported over the lines but also in oscillatory and transient-stability enhancement, system reliability, and controllability.

II. Principle of UPFC

The Unified Power Flow Controller (UPFC), is capable of simultaneously or selectively controlling transmission line power flows, voltage magnitudes and phase angles in a power system. Fig.1 shows the block diagram of UPFC

Figure 1 represents control system (pulse-width modulation (PWM) and phase control). The reactive power is generated/absorbed independently by each converter and does not flow through the dc link. There are two basic control strategies that can be utilized for the switching of the semiconductor in the converters, i.e., PWM and phase controls.

GTO switches operate at "low" switching frequencies required in phase control. However present often high losses at the "high" switching frequencies for PWM control.

However, recent advances in high voltage IGBT technology have led to the development of the Integrated Gate Commutated Thyristor (IGCT), which is basically an optimum combination of thyristor and GTO technology at low cost, low complexity, and high efficiency. It can handle higher switching frequencies with relatively low losses, allowing for the practical implementation of PWM control methodologies.

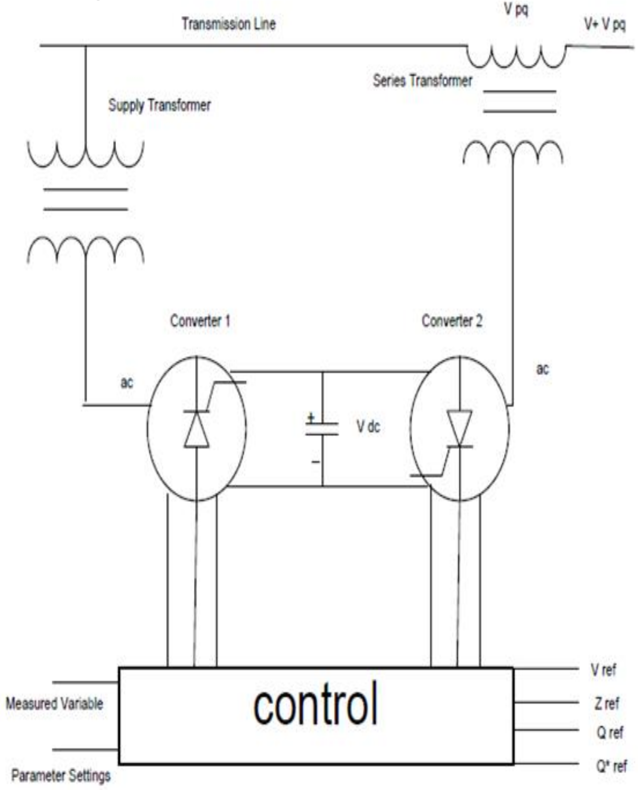

Figure 1. Block Diagram of UPFC.

III. The Nigerian Grid

The increasing demand of electricity in this country has consequently led to THE building of various power stations in different locations within the country.

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Table 1. Power Generation capacity of the current Nigerian grid.

Power plant	Installed capacity (MW)	Average availability (MW)	Average availability (MVar)	Type/fuel used
Kainji	760	570.0	-105.68	Hydro
Jebba	578.4	578.4	-56.04	Hydro
Shiroro	600	600.0	126.99	Hydro
Egbin	1320	825.1	50.55	Thermal Power Plant
Sapele	720	400.0	-362.66	Thermal Power Plant
Delta II-IV	900	450.0	-82.02	Thermal Power Plant
AfamII,IV,V,VI	1166	450.0	-102.03	Thermal Power Plant
guarara	414	300.0	-111.64	Thermal Power Plant
Olorunshogo I,II	335	60.0	-53.86	Thermal Power Plant
papalanto	710	304.0	-148.74	Thermal Power Plant
Okpai	480	450.0	7.71	Thermal Power Plant
Omoku	150	250.0	48.16	Thermal Power Plant
alaoji	110	0	204.93	Thermal Power Plant
calabar	1000	800.0	-31.31	Thermal Power Plant
egbema	302	250.0	-20.56	Thermal Power Plant
mambiya	300	130.9	-234.67	Thermal Power Plant
geregu	414	414.0	-96.26	Thermal Power Plant
Total	10259.4	6832.4	-967.13	

The power generated is transmitted to different load centers in the county within the national grid. The bulk of electric energy is transferred through the 330 kV and 132 kV transmission lines across the country But the description and analysis of the Nigerian grid system Will be Limited to the 330 kV transmission lines in this study. The 330 kV lines are constructed to have double circuits though on separate towers for reliability and more power transmission capacity. It is only the extension of the 330kV Shiroro substation to Abuja that has a single tower with double Circuits Basically, the means of generating electric energy In Nigeria is principally through thermal and hydro sources. The generating stations installed capacities are as shown in Table I (PHCN 2010), it is observed that the thermal power stations take a greater proportion in power output of Nigerian power system I.e., 67.5% of the total power output. Among the thermal power stations, Egbin thermal power station gives the highest power output. The choice of location of some of these generation stations was obviously due to the existence of a natural falls to their various locations like Kainji, Jebba and Shiroro while the development of other generation stations was determined by the demand and the availability of energy source (natural gas). These were the factors that gave rise to the location of the first gas turbines at Afam and Delta With the developments of all these generation stations, all the electricity produced are pooled together and transmitted to various LoadCentre's within the country. Figure 2 showed the Nigerian network modeled as 41 buses fed by 3 hydro units and 12 thermal units.

IV. PSAT simulation study on Nigeria grid system

In this simulation, a fault was initiated at bus 23 with a fault clearing time of 1.05sec and the system was simulated to get the transient behavior without installing UPFC.

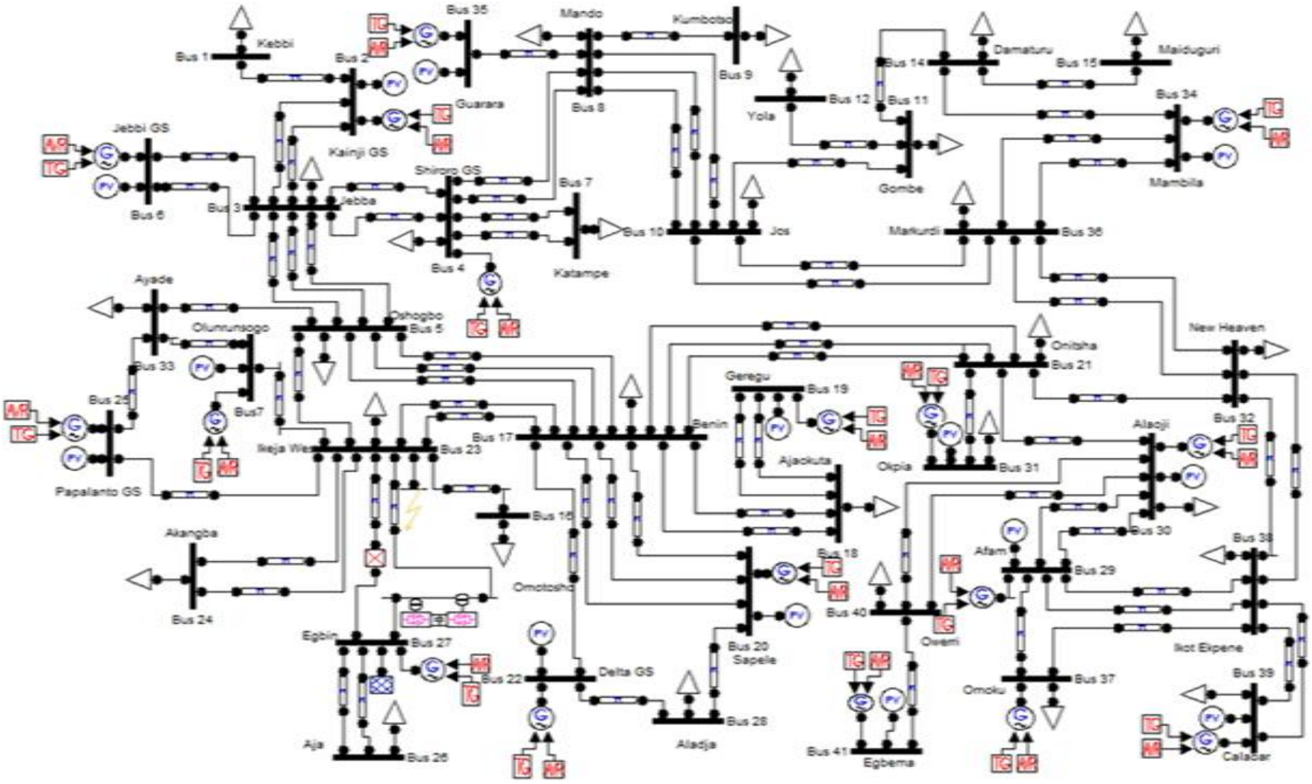

Figure 2. Nigeria System with fault at Bus 23 and UPFC connected between bus 23 and 27.

The same system was simulated with UPFC installed between bus 23 and 27 at the same fault clearing time and the results were compared with the base scenario. Egbin GS was chosen as slack Bus being the generator with the highest capacity. The graphical analysis of the results is done using PSAT plots tool.

Nigeria Gird System (1) Under Study

In this model there are 41 Busses; Bus number 27 is kept as Slack Bus which maintains its voltage at 1 p.u. Fault is simulated at Bus 23 (Ikeja West) at 1 sec. and fault clearing time at 1.05 sec.

All buses connected to each other by π- Section of transmission line.

The automatic voltage regulator used is type 3 in PSAT tool of MATLAB with the range of +500KV to -500KV and having the gain of 200p.u. for maintaining the voltage level as near to 1p.u. Turbine Governor is used of type 2 and having the ref. speed of 1p.u. and the droop is kept at 0.02p.u with max torque and minimum torque limit at1.2p.u and 0.3p.u respectively.

In this Model, Voltage profile at all 41 buses and Rotor angle are studied without any FACTS devices.

Nigeria Gird System (11) Under Study

All the parameters of the Generators, Slack bus, and Load are kept same as were in the System (I) model .UPFC is employed in between Bus 27 and Bus 23 as shown in Fig.2

The Voltage profile of all the buses and Rotor angle are studied at same Fault clearing time with UPFC and their results are compared with the results of system (I) model without any FACTS device.

V. Results of simulation

Fig 3 – 7 show the simulation results of voltage, rotor angle at different buses and angular frequencies in PSAT

Voltage Profile

The graph below show the voltageof buses with and without UPFC at same fault clearing time.

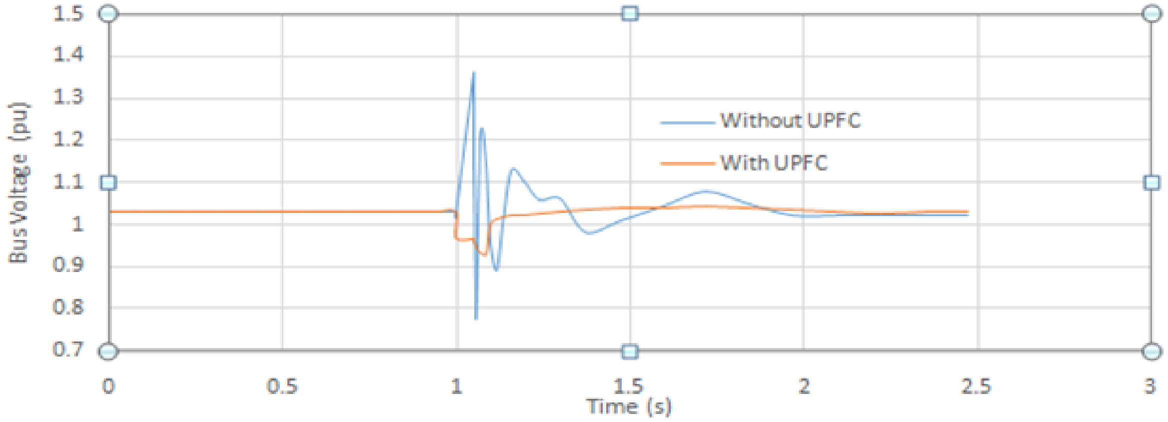

Figure 3. Voltage Profile with and without UPFC.

Rotor Angle

The graphs show the generator (within Area 3) rotor angles against time in case with and without UPFC.

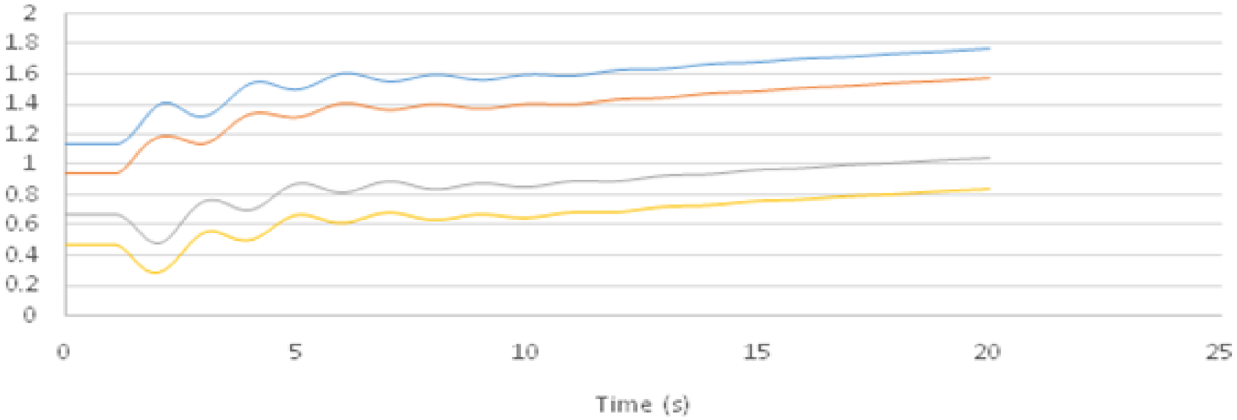

Figure 4. Rotor angle without UPFC.

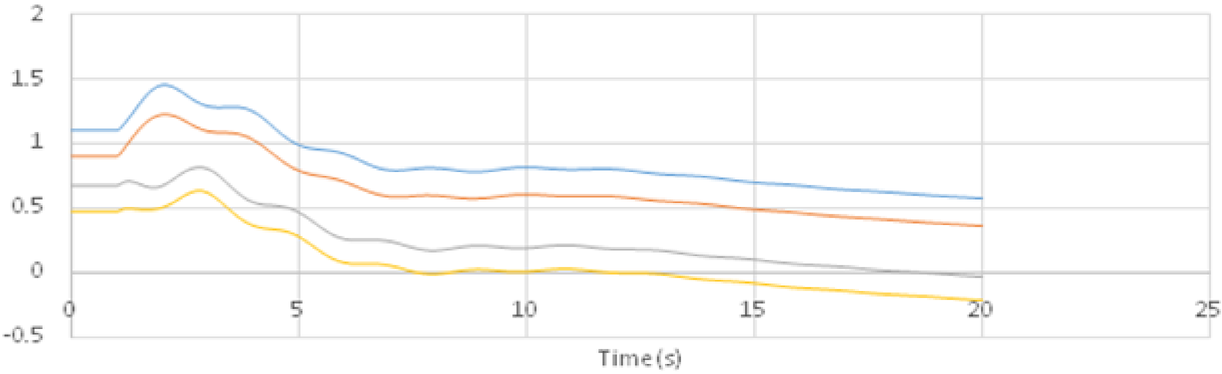

Figure 5. Rotor angle with UPFC.

Angular Frequency

Fig. 7 shows Angular frequency atgenerator Buses (in Area 3) without UPFC. The fault is simulated at 1sec and cleared at 1.05sec

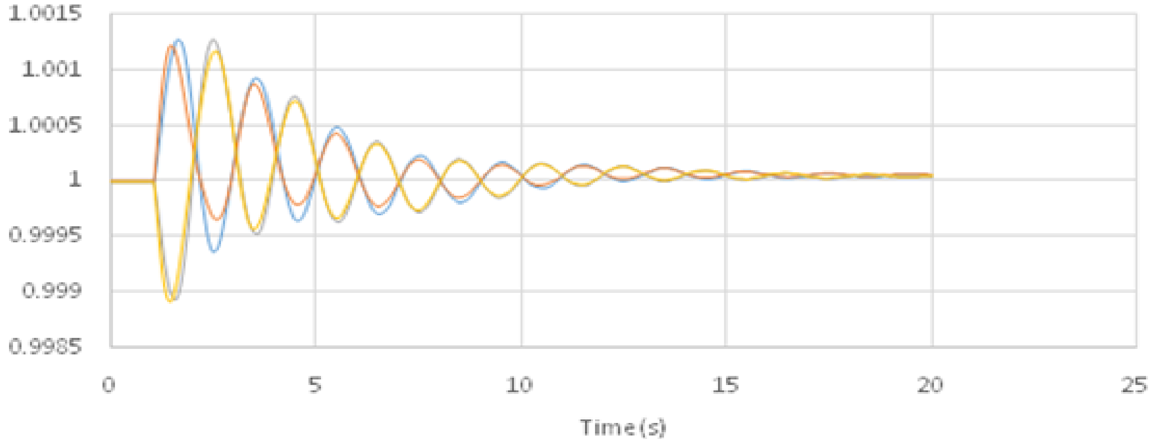

Figure 6. Angular Frequency without UPFC.

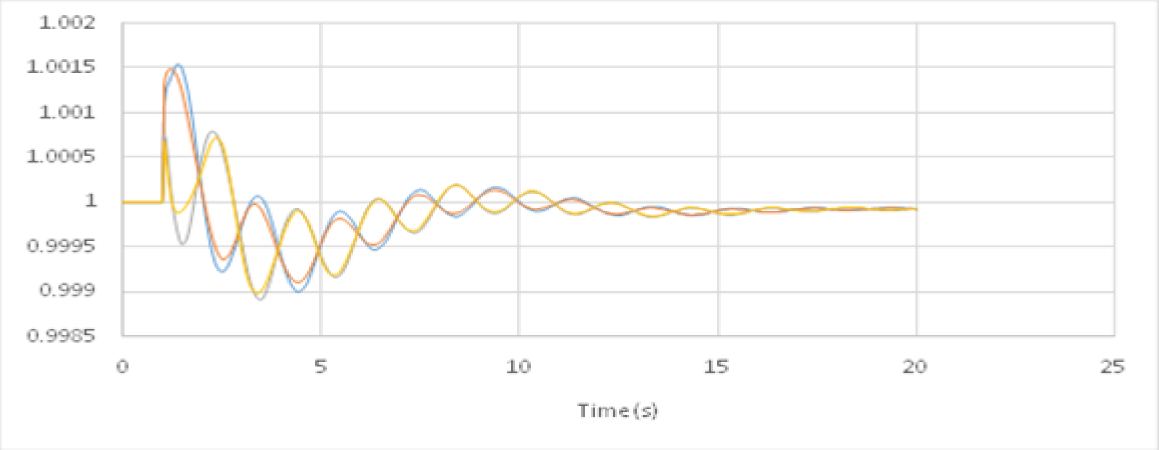

Figure 7. Angular Frequency with UPFC.

VI. Conclusion

This paper investigates the capability of UPFC on transient stability of Nigeria power system. The analysis of Generator Rotor angle, Voltage Profile and Angular Frequency are done with and without UPFC at the same fault clearing time.

The Buses of Area 3 i.e. Buses 5,7,16,17,20,22,24,28,33 their settling time is more than 2secs without UPFC. With the application of UPFC the settling time is reduced to 1.18 sec. for all buses.

Without UPFC the Rotor angle of all the buses increases and will lead the system out of synchronism whereas with UPFC they are decreasing and settling down. System will remain in synchronism.

The Angular Frequency without UPFC settles at 1p.u. value after 20secs. With UPFC Angular frequency starts settling down after 15sec. at fault clearing time 1.05secs.

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