ANALYSIS OF THE EFFECT OF FLEXIBLE ALTERNATING CURRENT TRANSMISSION SYSTEM (FACTS) ON THE NIGERIAN 330KV TRANSMISSION NETWORK USING ERACS AND MATLAB SIMULLINK

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ABSTRACT

The increasing demand for electricity in Nigeria has consequently led to the construction of new power stations in different location within the country. This increment results in transmission systems being pushed closer to their stability and thermal limit. This research takes a look at unified power flow controller (UPFC) which is a flexible alternative current transmission system (FACTS) device as a cost effective alternative to upgrading electrical transmission system infrastructure than the traditional form of constructing new transmission line.

Keywords: FACTS, UPFC, Nigerian 330KV Transmission Network.

INTRODUCTION

On-going expansions and growth of electricity industry has pushed transmission system closer to its thermal and stability limits at the same time the quality of power delivered is greater than ever (Peserba, 2005). Nowadays power systems require careful design of new systems due to its complexity especially for transmission systems in new deregulated electricity market (Kalyani& Das, 2008). The demand for a more optimal and profitable operation of power systems has made the need for advanced technologies more paramount in-order to produce a reliable and secure operation of power systems (Peserba, 2005).

The introduction of Flexible alternating current transmission systems (FACTS) in the 1980s has produced a new approach to solving the problem of designing and power system (Hingorani&Gyugi, 2000). This technology allows for the improvement of existing transmission infrastructure with minimal investment, time duration and environmental impact to the traditional mode of upgrading line. This provides a cost effective alternative to the construction of new transmission line (Peserba, 2005).

FACTS technology is based on the use of high speed power electronics to facilitate power control, enhance the capacity to transfer power, improve the system stability, provide security of supply, decrease in the line losses and generation cost (Singh et el, 2008). As such this providing a reliable and efficient means of transmitting power generated from a pool of power plant and load centre at a lower cost (Mahdadet el, 2006).

The research then looked at the different ways of selecting optimum location of the installing a unified power flow controller on the 330kV Nigeria transmission network. The method adopted was the Newton Raphson algorithm which is an algorithm incorporated on computer aided package, in order to compare the findings with a study by Nwosu (2010) which was based on sensitivity analysis in arriving at the optimum location of siting the UPFC. The result of the simulation shows the optimum location of siting the FACTS controller on the transmission line in between Gombe and Jos, thus agreeing with the findings of Nwosu (2010). With the installation of three new power plants on the network the optimum location of siting UPFC changed to the transmission line in between Akanga and Ikeja West.

FLEXIBLE ALTERNATING CURRENT TRANSMISSION SYSTEM (FACTS)

The IEEE defines FACTS as "Alternating Current Transmission Systems incorporating power electronics-based and other static controllers to enhance controllability and power transfer capability." This technology allow for improvement in transmission system operation with minimal infrastructure impact, environment impact and the time frame when compared with the construction of new transmission lines (Paserba, 2005). FACTS technology is a collection of high power controllers which can be applied on individual basis or in coordination with other controllers to control one or more of the interrelated system parameters. The following are the effects of lack of fast reliable controllers:

1. Inability of using transmission line at its thermal limits as a result of transient stability problems.
2. Power flow through unintended lines.
3. Abnormal voltage level and higher losses due to undesirable reactive power flow (Putrus, 2010).

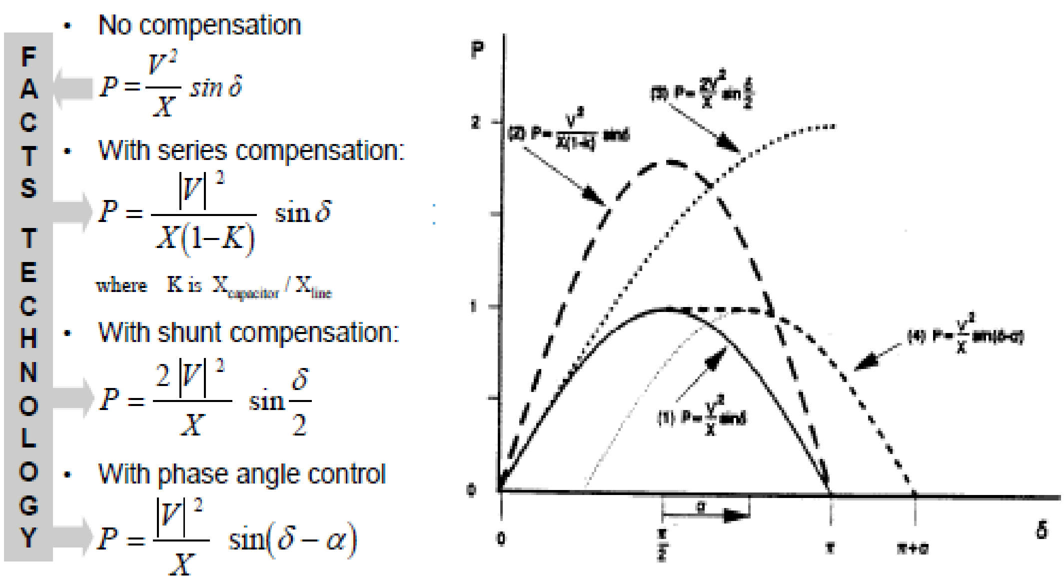

Fig 1: Transmission line compensation (Putrus, 2010)

In general, FACTS controllers can be divided into four categories

- Series Controllers.
- Shunt Controllers.
- Combined Series-shunt controllers.
- Combined Series- series controllers (Hingorani&Gyugyi, 2000).

Unified Power Flow Controller (UPFC)

This is the combination of static synchronous compensator (STATCOM) and a static series compensator (SSSC) which is coupled via a common dc link, in order to allow bidirectional flow of real power between the series output terminals of the SSSC. The shunt output terminals of STATCOM are controlled to provide concurrent real and reactive series line compensation without an external electric energy source. Using angularly unconstrained series voltage injection, the UPFC is able to control, either concurrently or selectively, the transmission line voltage, impedance, and angle, or alternatively, the real and reactive power flow in the line (Hingorani&Gyugyi, 2000).
The UPFC fulfils the function of reactive shunt compensation, active and reactive series compensation as well as phase shifting. Besides, it also provide stability control to suppress power System oscillations, improve the transient stability of power system (Donsion, 2007).

In principle, of the all FACTS devices the unified power flow controller (UPFC) is only controller that can provide control to all transmission line parameter:

- Voltage (|V|)
- Phase angle (δ)
- Impedance (X)

Operation of UPFC
The basic component of UPFC consist of two voltage source inverters (VSIs) sharing a common dc storage capacitor (Agelidis&Xu, 2003). One of the VSI is connected to the transmission system via a shunt transformer, while the other one is connected in series through a series transformer (Gupta, 2010).

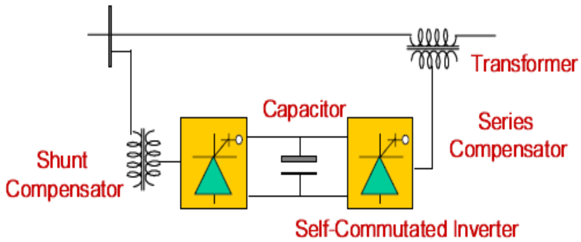

Fig 2: Circuit for a Unified Power Flow Controller (UPFC) (Pasera, 2005).

The series inverter is controlled to inject a symmetrical three phase voltage system (Vc), of controllable magnitude and phase angle in series with the line in order to control active and reactive power flow on the transmission line. As such, the series inverter is provided with reactive power electronically and the active power is transmitted to the dc terminals. The two VSI's can work independently of each other by separating the dc side. The shunt inverter which operates as a STATCOM (Static Synchronous Compensators) generates or absorbs reactive power to regulate the voltage magnitude at the connection point. While the series inverter operates as an SSSC (Static synchronous series compensators) generates or absorbs reactive power to regulate the current flow and hence the power flows on the transmission line (Gupta, 2010).

Mathematical modelling of UPFC

A UPFC can be represented by two voltage sources representing fundamental components of output voltage waveforms of the two converters and impedance being leakage reactance of the two coupling transformers. Fig. 2 depicts two voltage source model of UPFC.

System voltage is taken as reference vector $V_i = V_i0$ and $V^1_i = V_{se} + V_i$ the voltage source $V_{se}$and V_{sh} are controllable in both their magnitude and phase angles. r and θ are respectively the pu magnitude and phase angle of series voltage source, operating within the following specified limits given by Eq. (2).

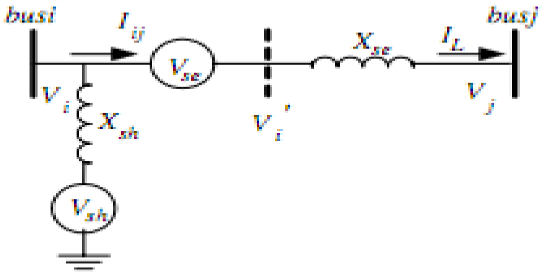

Fig 3: Two voltage-source model of UPFC (Vural&Tümay 2007).

$0 \le r \le r_{max}$and $0 \le \gamma \le 2\pi$ (2)

V_{se} should be defined as:

$V_{se}=rVie^{j\gamma}$ (3)

The model is developed by replacing voltage source V_{se} by a current source I_{se} parallel with the transmission line as shown in Fig 4, where $b_{se} = 1/X_{se}$

$I_{se} = -jb_{se}V_{se}$ (4)

The current source I_{se} can be modelled by injection powers at the two auxiliary buses i and j.

$S_{is} = V_i\ (-I_{se})^*$ (5)

$S_{js} = V_j(I_{se})^*$ (6)

Injected powers S_{is} and S_{js} can be simplified according to the following operations by substituting Eqs. (3) and (4) into Eq. (5).

$S_{is} = V_i(jb_{se}rV_ie^{j\gamma})^*$ (7)

By using Euler Identity, ($e^{j\gamma} = \cos\gamma + j\sin\gamma$), Eq. (7) takes the form of

$S_{is} = V_i(e^{-(\gamma+90)}\ b_{se}rV^*i)$ (8)

$S_{is} = V^2_ib_{se}r\ [\cos(-\gamma - 90) + j\sin(-\gamma - 90)]$ (9)

By using trigonometric identities, Eq. (9) reduces to

$S_{is} = -rb_{se}V^2_i\mathrm{Sin}\gamma - jrb_{se}V^2_i\mathrm{Cos}\gamma$ (10)

Eq. (10) can be decomposed into its real and imaginary components, $S_{is} = P_{is} + jQ_{is}$, where

$P_{is} = -\ rb_{se}V^2_i\mathrm{Sin}\gamma$ (11)

$Q_{is} = -\ rb_{se}V^2_i\mathrm{Cos}\gamma$ (12)

Similar modifications can be applied to Eq. (6), final equation takes the form of,

$S_{js} = V_iV_jb_{se}r\mathrm{Sin}\ (\theta_i - \theta_j + \gamma) + jV_iV_jb_{se}r\mathrm{Cos}\ (\theta_i - \theta_j + \gamma)$ (13)

Eq. (13) can also be decomposed into its real and imaginary parts, $S_{is} = P_{is} + jQ_{is}$,

$P_{js} = V_iV_jb_{se}r\mathrm{Sin}\ (\theta_i - \theta_j + \gamma)$ (14)

$Q_{js} = V_iV_jb_{se}r\mathrm{Cos}\ (\theta_i - \theta_j + \gamma)$ (15)

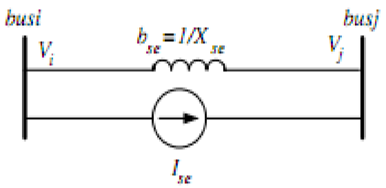

Fig 4: Replacement of series voltage source by a current source (Vural&Tümay 2007).

Based on Eqs. 11, 12, 14, and 15, power injection model of the series-connected voltage source can be seen as two dependent power injections at auxiliary buses i and j as shown in Fig. 5. In UPFC, shunt branch is used mainly to provide both the real power, $P_{series,}$ which is injectedto the system through the series branch, and the total losseswithin the UPFC. The total switching losses of the twoconverters is estimated to be about 2% of the power transferred for thyristor based PWM converters (Mohan, 1992). If thelosses are to be included in the real power injection ofthe shunt-connected voltage source at bus i, $P_{shunt}$is equalto 1.02 times the injected series real power P_{series} through the series-connected voltage source to the system.

$P_{shunt} = -1{:}02 P_{series}$

The apparent power supplied by the series converter is calculated as

$S_{series} = V_{se} I^{*}_{ij} = r e^{j\gamma} V_i \, (Vi - V_j / jX_{se})$ (17)

Active and reactive power supplied by the series converter can be calculated from Eq. (17).

$S_{series} = jeV_i r e^{j\gamma} V_i((re^{j\gamma} V_i + V_i - V_j) / jX_{se})^*$ (18)

$S_{series} = rV_i e^{j(\theta i+\gamma)} \, ((rV_i \, e^{-(\theta i+\gamma)} + V_i e^{-j\theta i} - V_j e^{-j\theta j}) / -jX_{se})$ (19)

$S_{series} = jb_{se} r^2 V^2_i + jb_{se} r V^2_i e^{j\gamma} - jb_{se} V_i V_j e^{j(\theta i - \theta j + \gamma)}$ (20)

$S_{series} = jb_{se} r^2 V^2_i + jb_{se} r V^2_i \, (\mathrm{Cos}\,\gamma + j\mathrm{Sin}\,\gamma) - jb_{se} r V_i V_j \mathrm{Cos}\,(\theta_i - \theta_j + \gamma) + j\mathrm{Sin}\,(\theta_i - \theta_j + \gamma)$ (21)

Final form Eq. (21) takes the form of

$S_{series} = P_{series} + jQseries$ Where

$P_{series} = rb_{se} V_i V_j \mathrm{Sin}\,(\theta_i - \theta_j + \gamma) - rb_{se} V^2_i \mathrm{Sin}\,\gamma$ (22)

$Q_{series} = rb_{se} V_i V_j \mathrm{Cos}(\theta_i - \theta_j + \gamma) + rb_{se} V^2_i \mathrm{Cos}\,\gamma + r^2 b_{se} V^2_i$ (23)

The reactive power delivered or absorbed by converter 1is not considered in this model, but its effect can be modelled as a separate controllable shunt reactive source. In this case main function of reactive power is to maintain the voltage level at bus i within acceptable limits. In view of the above explanations, Q_{shunt} can be assumed to be 0.

Consequently, UPFC mathematical model is constructed from the series-connected voltage source model with the addition of a power injection equivalent to P_{shunt} + j0 to bus i, as depicted in Fig 5. Finally, UPFC mathematical model can be constructed by combining the series and shunt power injections at both bus i and bus j as shown in Fig. 13.

The elements of equivalent power injections in Fig. 13 are,

$P_{i,upfc} = 0{:}02 rb_{se} V^2_i \mathrm{Sin}\gamma - 1.02 rb_{se} V_i V_j \mathrm{Sin}\,(\theta_i - \theta_j + \gamma)$ (24)

$P_{j,upfc} = rb_{se} V_i V_j \, \mathrm{Sin}(\theta_i - \theta_j + \gamma)$ (25)

$Q_{i,upfc} = rb_{se} V^2_i \mathrm{Cos}\,\gamma$ (26)

$Q_{j,upfc} = rb_{se} V_i V_j \mathrm{Cos}\,\gamma\,(\theta_i - \theta_j + \gamma)$ (27)

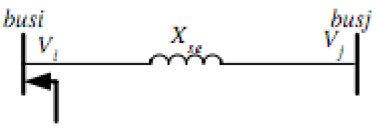

Fig 5 Equivalent power injection of shunt branch (Vural&Tümay 2007)

General nodal power flow equations and linearized power system model can be expressed in rectangular form by the following equations:

$P = f_1\,(V,\theta,G,B)$ (28)

$Q = f_2\,(V,\theta,G,B)$ (29)

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$$\begin{pmatrix} \Delta P \\ \Delta Q \end{pmatrix}^n = \begin{pmatrix} H & N \\ J & L \end{pmatrix}^n \begin{pmatrix} \Delta\theta \\ \Delta V/V \end{pmatrix}^n \quad (30)$$ (Vural&Tümay 2007)

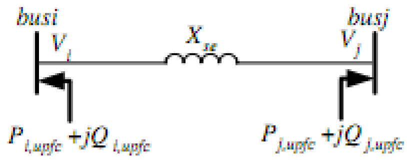

Fig 6: UPFC mathematical model (Vural&Tümay 2007).

Nigerian Grid System

Introduction

(PHCN, 2004) news bulletining shows that a greater proposition of power generated are from thermal power station which accounts for about 67% of the total power output, out of which Egbin thermal power station accounts for the highest power output. The other form of power generating is the Hydro power station; these are Kainji, Jebba and Shiroro. These power stations are located at different part of the country which has natural falls.

Power stations	Year commissioned	Type/fuel used	Installed capacity (MW)	No. of turbines	Percent in national grid	Available capacity as at 30/12/2003 (MW)
Kainji	1968	Hydro	760.0	8	12	410
Jebba	1986	Hydro	578.0	6	9	540
Shiroro	1990	Hydro	600.0	4	10	600
Egbin	1985	Thermal steam/NG, HPFO	1320.0	6	22	1170
Sapele	1978	Thermal steam/HPFO,	720.0	10	17	170
	1981	NG Thermal gas/HPFO, NG	300.0	-	-	-
Ijora	1978	Thermal gas turbine/Na	60.0	3	1	15
Delta	1966	Thermal gas turbine/Na	942.0	20	13	5288
Afam	1965	Thermal gas turbine/Na	986.6	17	16	325
Total of installed generative capacity			6136.0	.	.	.

PHCN (formerly called, NEPA) NEWS bulletin (2004) PHCN (2004)

The increasing demand of electricity has led to the construction of various power stations in different locations within the country. This power is hence transmitted to different load centres in the country through the national grid. The bulk of electric energy transferred in Nigeria is either 330kV or 132kV transmission line. (Nwohu, 2010).

The transmission grid system is predominantly characterised by radial, fragile and very long transmission lines. It comprises of 11,000 km of 330 and 132kV, 24000 km of sub-transmission line of 33kV and 19000km of distribution line of 11kV with 22500 substations (Sadoh, 2005). This project is limited to the 330kV. These transmission lines were constructed to have double circuits though on separate towers for purpose of reliability and power transmission capacity except the extension of the 330kV shiroro substation to Abuja that has a single tower with double circuits (Nwosu, 2010). The 330kV employs 350mm^2 Aluminium conductor steel re-enforced (ACSR) known as BISON. The supporting structure are made of steel towers are spanned at an average distance 500 metres apart., with a height of 75metres for the double circuits and 54 metres for the single circuit (Sunday & Emmanuel, 2010).

Fig 7: Map of Nigeria showing the 330kV and 132kV Transmission line
(Hon. Minister of Power & Steel and Chairman of the NEPA Technical Committee, 2004).

Optimization of Power Flow

They are different modes of selecting the optimal location of siting FACTS device, but this study will be limited to few of these methods such as the following:

- Genetic Algorithm.
- Newton-Raphson Algorithm.
- Sensitivity Analysis.
- Differential Evolution
- Linear Programming Algorithm.

Linear Programming Algorithm

Linear programming (LP) is a technique that converts the objective function and constraints of power system optimization have linear form, it is essentially used to linearize the non-linear power system optimization process. In solving LP problem, simplex method is known to be effective. Some advantages of linear programming are:

- It is reliable, especially regarding convergence properties.
- It identifies infeasibility quietly, so that appropriate strategies can be put into effect.
- LP accommodates a large variety of power system operating limit.
- Convergence to engineering accuracy is rapid and also accepted when changes in control are small.

But this technique provides inadequate evaluation of losses and insufficient ability to locate an exact solution with an accurate non-linear power system model.

Large scale application of this technique has being limited to network constraint real and reactive power dispatch calculations with the objective of comprising the sum of convex curves which can lose the accuracy of calculation when the approximation is oversimplified. A great deal of applications shows that the LP generally meets the requirement for engineering precision as such used to solve power system problems such as optimal power flow, steady state security regions, reactive power optimization and lots more (Zhu, 2009)

DESIGN

Network Design

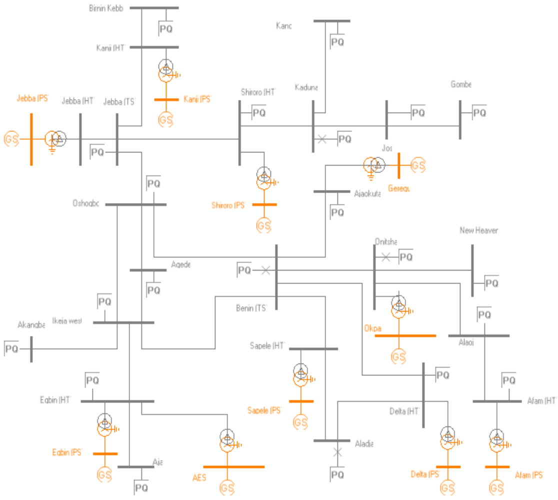

Fig 8: The Network of 330kV Nigerian Grid System (Nwosu, 2010).

EXPERIMENTAL METHODOLOGY

This research is based on quantitative approach of investigation. There are two main classes of research methods: qualitative and quantitative. Quantitative research is a systematic investigation of social phenomena via statistical, mathematical or computational techniques, while qualitative research methods are used to study social and cultural phenomenon (Hohmann, 2006). Several simulations were conducted with the computer aided application ERACS and MATLAB/SIMULINK. These software were run at a frequency of 50Hz

ERACS

Four simulations were run at this stage. At the initial stage of modelling, the network was simulated with 31 buses and 33 branches which included seven (7) power stations providing electric supply to different load centres. This configuration was used to simulate the load flow analysis of the network before and after load shedding. This was done due to greater load demand than the generating stations could handle.

With the installation of three (3) new power plants to the network, three (3) more buses were added to the grid. The purpose of this was to investigate the significances of installing new power plant on the network and how it affects the optimum location of siting a unified power flow controller.

The whole simulations were run at a study base of 100MVA with all generators simulated as slack except Egbin Power station which was assigned power. All the generators produced power at 11kV before it was stepped up to 330kV for onward transmission. The configuration of the some of the bus bars, load, lines, transformers and generators are clearly illustrated in Appendix A.

MATLAB/SIMULINK

The simulation was carried out using the ode45 numerical integration routine. The UPFC is used to control the power flow of the 330kV /132 kV transmission systems which is connected in a loop configuration. This model consists of five bus bar (B1 – B5) which is interconnected through transmission line (L1- L3), two 330/132kV transformer (tr1 & tr2), and two power plants (PP1 & PP2). The two power plants supplies power to a 330kV, 15000MVA equivalent voltage source and also to a 700MW load connected close to bus 3. The settings up of all this parameter are clearly illustrated at appendix B.

Before running the simulation the initial configuration was carried at the Phasors powergui. The analysis tool is used to set the initial state of the model, this displays the measurement, sources and nonlinear element result of the steady state voltage and current of the various components as shown in Fig 9 below. In the UPFC dialog the series and shunt converter were rated at 100MVA with the series converter having a maximum voltage injection of 0.1 pu.

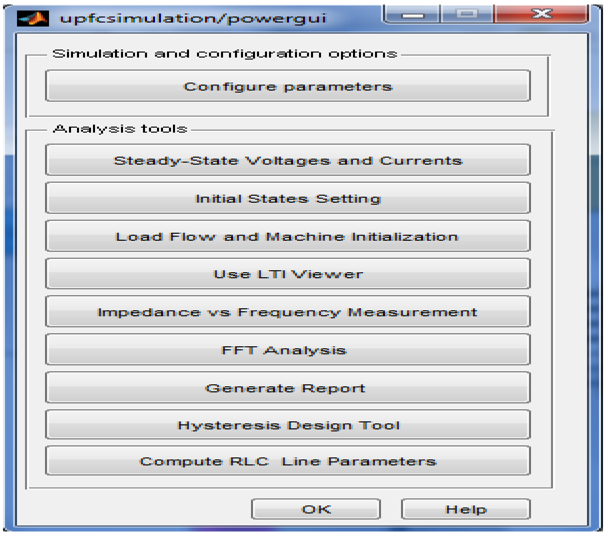

Fig 9: MATLAB/SIMULINK configuration tool bar

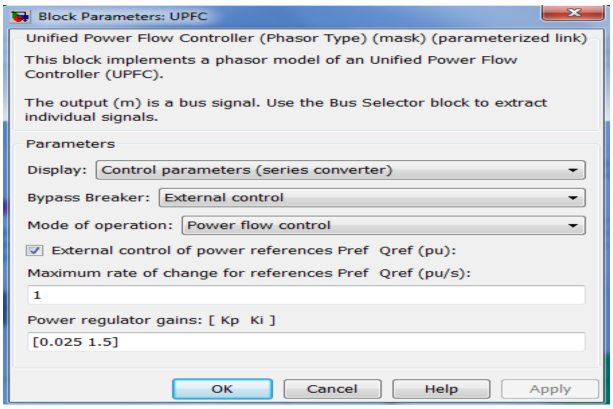

Fig 10: Block parameter of UPFC.

The use of Bypass breaker in the system is to connect or disconnect the UPFC block from the power system in-order to show the effect of the controller.

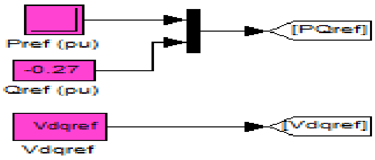

Fig 11: Reference Power flow control and Voltage Injection.

PQref and Vdqref are reference power flow control and voltage injection. Pref and Qrefare used to set the UPFC reference of active and reactive powers respectively. The Pref block was programmed with an initial active power of 5.87pu corresponding to natural power flow while Qref was kept constant at -0.27pu.

ANALYSIS AND RESULTS

The equipment *and the method used in obtaining the results were discussed. This chapter present the result obtained for the simulation ran from the two different computer aided programs.*

Load Flow Analysis Result

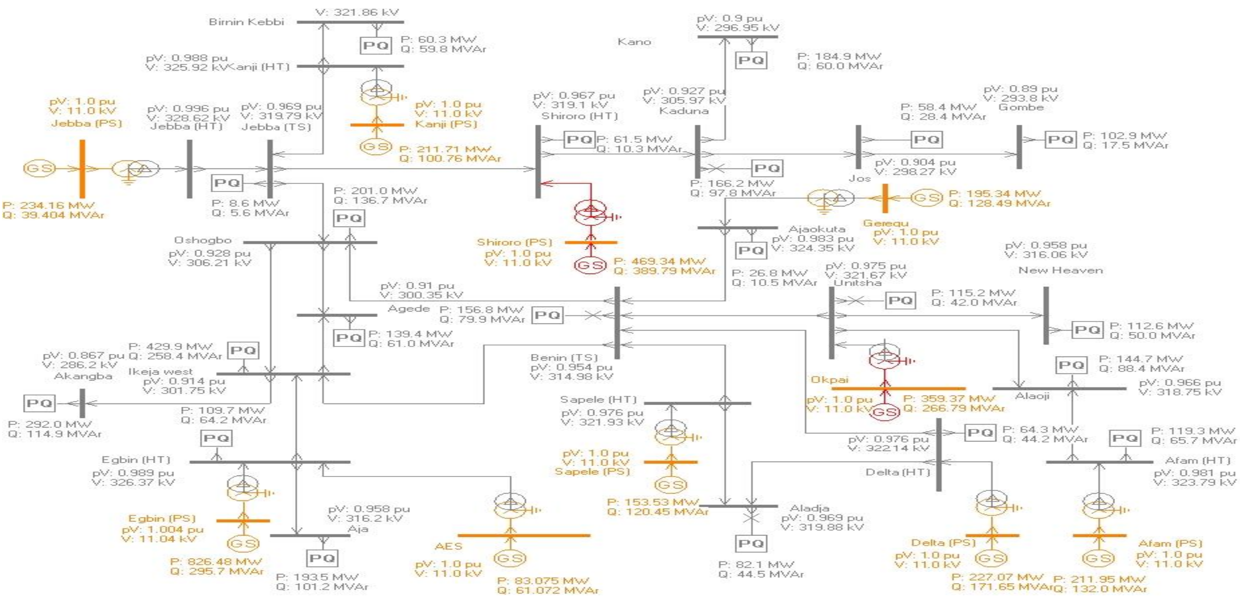

Fig 12: The result of load flow simulated in ERACS

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LOADFLOW STUDY ON NETWORK: NIGERIA

ERACS Loadflow Module by Cobham Technical Services - ERA Technology. ERACS Version:
3.9.0. Loadflow Version: 3.9.0
Run on 25-Aug-2011 by student from data set up on 25-Aug-2011 by student
Network Name     : Nigeria
Data State Name  : ISO 749
At Iteration: 1
Voltage range:
From   0.867pu at busbar with ID Akangba
To     1.004pu at busbar with ID Egbin (PS)
At Iteration: 2
At Iteration: 3
At Iteration: 4
At Iteration: 5
Voltage range:
From   0.867pu at busbar with ID Akangba
To     1.004pu at busbar with ID Egbin (PS)
Calculation Successful
Iterations at study end = 5
Convergence = 0.2146E-05 pu
Current in winding 1 of transformer with ID TRX 5 exceeds 100.00 % of its rating
Current in winding 2 of transformer with ID TRX 5 exceeds 100.00 % of its rating
Current in winding 1 of transformer with ID TX 8 exceeds 100.00 % of its rating
Current in Synchronous Machine with ID Shiroro connected to busbar Shiroro (PS)
exceeds 100.00% of its rating
Current in Synchronous Machine with ID Okpai connected to busbar Okpai
exceeds 100.00% of its rating
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Fig 13: Summary of result to the Load Flow study on the Nigerian Network.

From the above load flow results the following observation were made.

- ➢ The load requirement has surpassed the power generation from the power station at Shiroro and Okpai.
- ➢ The voltage profile at the bus bar ranges from 0.876pu at Akanga to 1.004pu in Egbin.
- ➢ The current in the transformers has exceeded its rating.

As a result of the problems observed above, loading shedding was introduced at Onitsha and Kaduna bus bar and the following result was obtained.

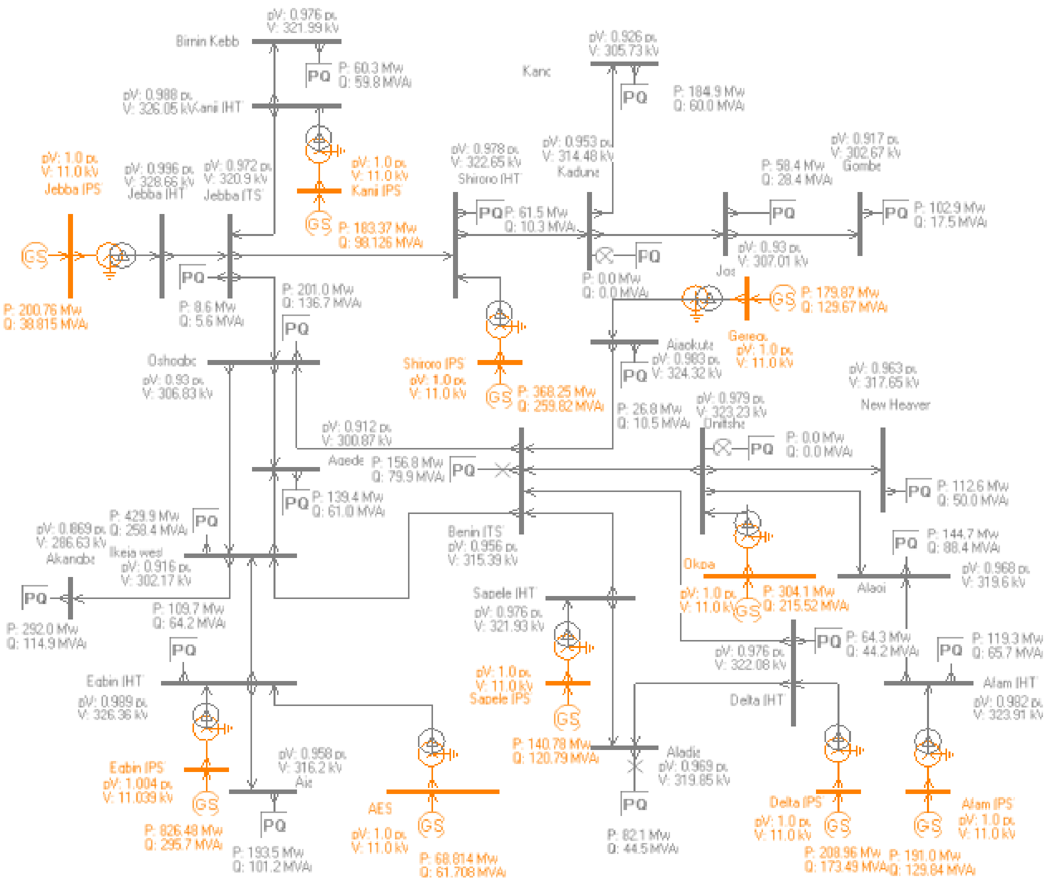

Fig 14: Load flow analysis after load shedding

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LOAD FLOW STUDY AFTER LOAD SHEDDING @ ONITSHA AND KADUNA
ERACS Loadflow Module by Cobham Technical Services - ERA Technology. ERACS Vers:
3.9.0. Loadflow Version: 3.9.0
Run on 25-Aug-2011 by student from data set up on 25-Aug-2011 by student
Network Name    : Nigeria
Data State Name : ISO 749
At Iteration: 1
At Iteration: 2
At Iteration: 3
At Iteration: 4
At Iteration: 5
Voltage range:
From  0.869pu at busbar with ID Akangba
To    1.004pu at busbar with ID Egbin (PS)
Calculation Successful
Iterations at study end = 5
Convergence = 0.1907E-05 pu
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Fig 15: Summary of Result to load flow study after shedding

The above result shows a slight increment on the overall voltage profile at the various bus bars as a result of the introduction of loading shedding at the Onitsha and Kaduna bus bars. It can also be observed that the power stations can now adequately handle the load requirement.

Selection of the Optimum Location

In the selection of the optimum location of siting the unified power flow controller on the 330kV Nigerian grid system, two different simulations were carried out. This is done in order to compare this study and a similar study carried out by Nwosu (2010) with both studies undertaking different approaches in achieving the goal. The technique abducted in this paper is the newton-raphson algorithm which is one of the different techniques discussed in earlier under the optimization of power flow controller.

1) In the initial stage the load flow analysis was carried out on the 330kV before the construction of the AES, Geregu and Okpai power station.
2) The other stage is the simulation of network with installation of AES, Geregu and Okpai Power stations

First Simulation

Nwosu (2010) carried out a study of locating the optimum location of UPFC in Nigerian grid system. The study was based on the sensitivity analysis technique in selecting the optimum location of siting a UPFC. This technique which is another mode of selecting the optimal location shows the critical point of power system during time domain voltage collapse scenario (Wang, 1999). The result of the study shows the optimum location of siting the controller is on the transmission line located between Jos and Gombe which has the highest index with 2.4712. While this study uses newton raphson approach, an optimization technique incorporated on a computer aided program. The result of simulation in fig 16 below shows Egbin power plant will the maximum voltage of 1 pu while Gombe having the minimum voltage at the bus bar with 0.844 pu. This clearly shows the optimum location of siting a UPFC in between Jos and Gombe. Thus, this illustrates at total agreement to the result of Nwosu (2010).

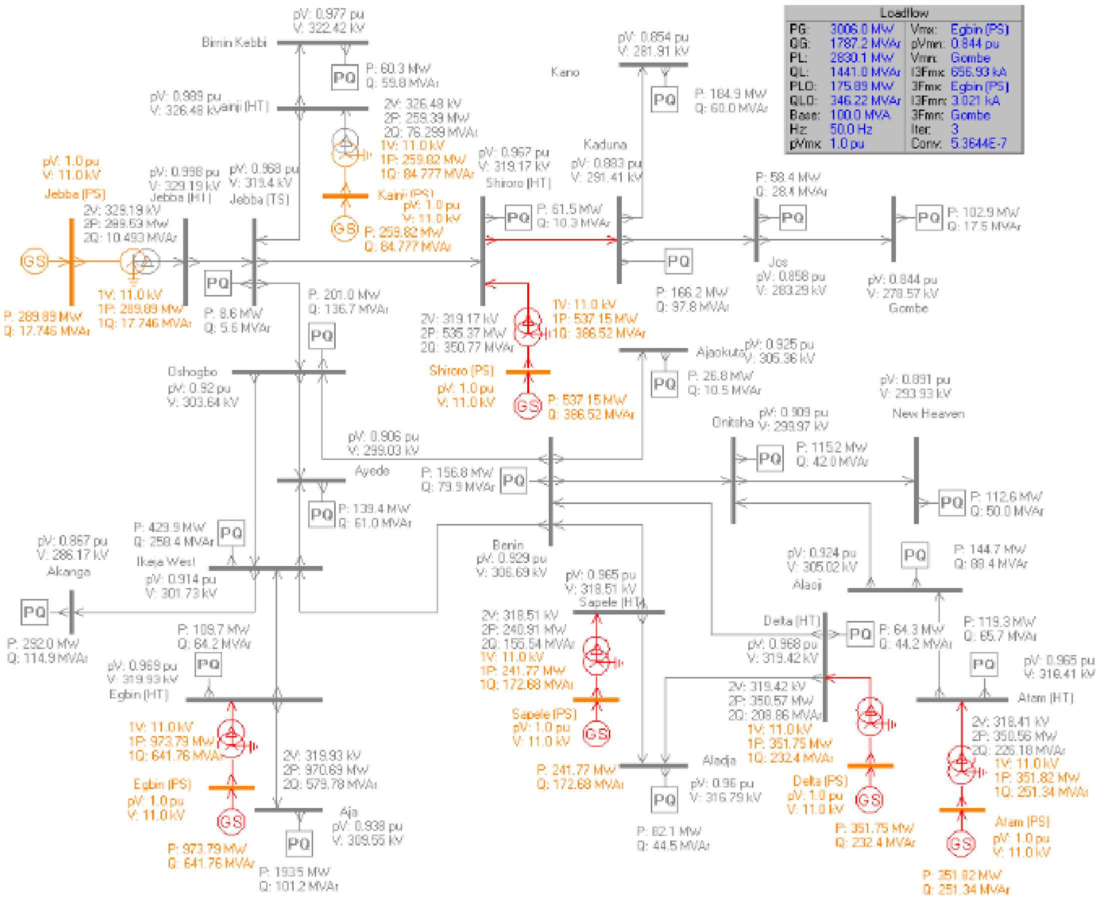

Fig 16: load flow result at the initial stage before installation of new power plant.

Second Simulation

The second stage of this simulation was carried out after the installation of three new power plants at different location on the network. These power plants are AES, Geregu and Okpai. The result of the simulation illustrate a change to the optimum location of siting a controller with the weakest bus bar located at Akanga with 0.869 pu as such the optimum location of siting the UPFC is between Akanga and Ikeja west.

Effect of UPFC on Transmission

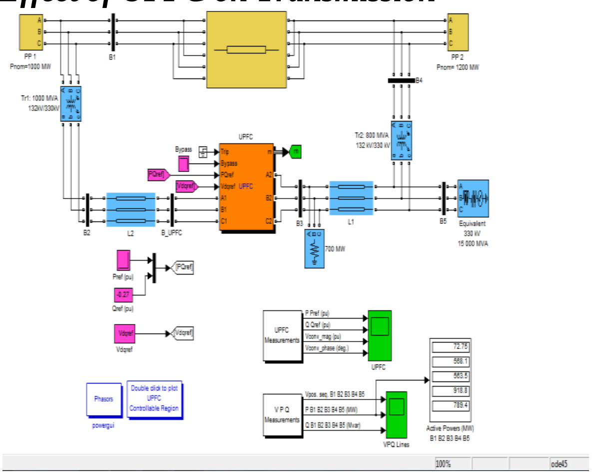

Fig 17: MATLAB SIMULINK Model

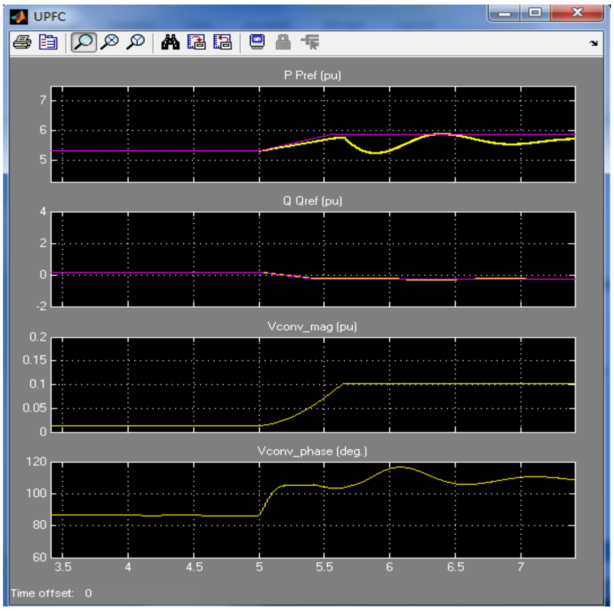

Fig 18:Result of Simulation indicating the reference power in per unit

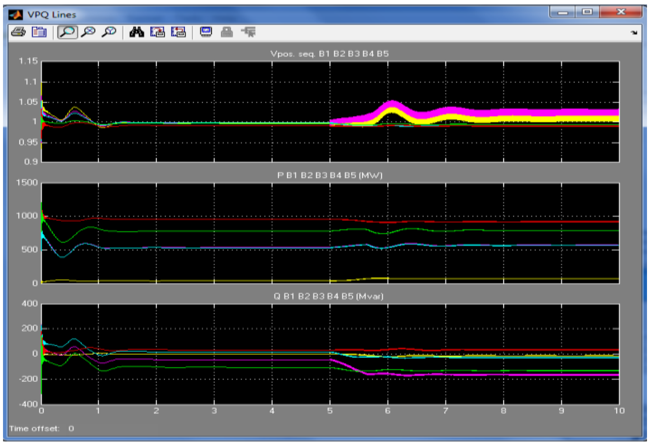

Fig 19: Result of Active and Reactive power of the Bus bars.

Fig 18 and 19 shows the result of simulating fig 17. This is in compliance with the UPFC characteristics. The real power of the UPFC has increased when the breaker was opened. The voltage at the bus bars are: B1 **72.75** B2 **568.** power led to a decrease in congestion on bus 5 which can be seen from the graph above as power variation is noticed on every bus.**1** B3 **563.5** B4 **918.8** B5 **789.4** This increase in real

CONCLUSION

This research is conducted to study the load flow analysis of the 330kV transmission line of the Nigerian grid. The study looks at the some different mode of selecting the optimum location of siting a FACTS controller on transmission line. It also evaluated the performance of installing the FACTS controller UPFC on the network as a cost effective alternative of upgrading existing network infrastructure as compare to the traditional mode of upgrading transmission line.

The technique used in the selection of the optimum location is based on the Newton Raphson algorithm, which is a widely used method for solving non-linear equation (El-Hawary, 2008) incorporated on work stations or personal computers (Pritchard &Pottle, 1982). The simulation of the load flow analysis was in two stages:

- The simulation was run before the Installation of three powers: AES, Geregu&Okpai power station.
- The Second simulation was after the installation of the new power plants.

The first simulation was run in-order to compare the work ran by Nwosu (2010) which used sensitivity analysis as a way of selecting the optimum location of siting a UPFC and also how the of installation of new power station at different location s affect the optimum position of installing a FACTS controller.

The result of the first simulation as shown in fig 16 indicates the transmission line in between Jos and Gombe as the optimum location of siting the FACTS controller. The second simulation indicate a shift in the optimum location after the installation of new powerplants as illustrated in fig 4-3 above to new located on the transmission line in between Akanga and Ikeja West.

In Power system transmission, it is always desirable to maintain the voltage magnitude, phase angle and line impedance therefore power flow control is paramount. The result of simulation from the model in fig 17 illustrates that power flow control is achieved with less congestion, there is an improvement of transient stability, faster steady state achievement and an overall improvement of the voltage profile.

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