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Application of Unified Power Flow Controller in Nigeria Power System for Improvement of Voltage Profile

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ABSTRACT

With the increased rate of urbanization and industrialization, the Nigerian electric power system is being put under pressure, high power losses which has led to fluctuation in voltage level. In this work the Nigeria 330Kv network of 42 bus system was considered. Data for the analysis were obtained from Transmission Company of Nigeria / National Control Centre, Osogbo (TCN) and MATLAB/PSAT software with newton Raphson's solution method embedded in it was used to carry out the analysis. The results of the analysis showed that many of the bus voltages were outside the voltage limits of ±5% i.e 0.95pu- 1.05pu . After compensation with Flexible AC Transmission System devices (FACTs) namely Unified Power Flow Controller (UPFC) which can be used to control power flow on a transmission line, the voltage profile almost flat with bus voltages within acceptable voltage limits. It is also evident that the UPFC is device that can used to combat the voltage problem in the Nigerian electric power system.

1. INTRODUCTION

Electric power generation and transmission is a complex process, wherever power is to be transferred, the two main components are active and reactive power. In a three phase ac power system active and reactive power flows from the generating station to the load centers through different transmission lines and networks buses. The active and reactive power flow in transmission line is called power flow or load flow. The Nigerian power system is characterized by high power loss that affects the reliability and quality of power supply.

Today urbanization and rapid industrialization are putting power utilities under pressure. The consumers at every level including domestic, commercial and industrial users have been on the receiving end of the voltage instability problem in Nigeria electricity grid, experiencing major discomforts in operating their electrical and electronic devices as well as unable to run smoothly their day-to-day activities since they depend largely on stable and quality electricity supply.

Despite the reform exercise and other corrective measures put in place by the Federal Government of Nigeria to address the operational challenges facing her electricity grid, voltage instability problem still persists. Most of voltage instability problems in the Nigeria electricity grid can be traced to inadequate and inefficient reactive power compensation in the system. Therefore, the need to devise means of compensating reactive power in Nigeria electricity supply network becomes highly imperative for efficient operation of the system. To address this, adoption of advanced control technologies such as FACTS is an important option for the Nigeria electricity system reactive power compensation in view of the slow response of the conventional traditional methods for improving power system performance [1,2].

FACTS technology has a lots of benefits, such as greater power flow control ability, increased in the loading of existing transmission circuits, damping of power system oscillations, has the less cost than other alternative techniques of transmission system is used [3,4,5,6,7,8]. The ability of FACTS to control the line impedance and the nodal voltage magnitudes and phase angles at both the sending and the receiving ends of key transmission lines, with almost no delay, has significantly increased the transmission capabilities of the network while considerably enhancing the security of the system. Some of the common FACTS controllers in use are Interphase Power Controller (IPC), Static Synchronous Compensator (STATCOM), Static Var Compensator (SVC), Thyristor Controlled Breaking Reactor (TCR), Thyristor Controlled Series Capacitor (TCSC), Static Synchronous Series Compensator (SSSC), Thyristor Switched Series Reactor (TSSR), Unified Power Flow Controller (UPFC). These controllers have their distinct characteristics which are suitable for different applications and due to these various researches have been carried out to examine their potential applications and benefits [9, 10, 11, 12, 13, 14, 15, 16].

Lots of works have been done to improve the voltage profile of the Nigerian electric power using other conventional methods of compensation, FACTS devices like STATCOM, SSSC, SVC but in this study, our aim is to apply UPFC for improvement of voltage profile in the Nigerian power system.

2. Unified Power Flow Control (UPFC)

Unified Power Flow Controller (UPFC) is power electronics based system that can provide the control of the transmission line impedance, phase angle and reactive power. This versatility of the UPFC makes it a prime FACTS device that can provide many of the control functions required to solve a wide range of dynamic and steady state problems encountered in power systems. Combining the STATCOM and the SSSC into a single device with a common control system represents the third generation of FACTS known as Unified Power Flow Controller (UPFC). It has the unique ability to control real and reactive power flow independently. The basic operation principle diagram of the UPFC is shown in Figure 1, and has been described in open literature [17, 18, 19, 20, 21, 22]. The Unified Power Flow Controller (UPFC) made out of two Voltage Source Converters (VSCs), which are connected through a common DC link capacitor.

From figure 1, the basic function of converter 1 is to supply or absorb the real power demanded by converter 2 at the common dc link. This dc link power is converted back to ac and coupled to the transmission line via a shunt-connected transformer. Converter 1 can also generate or absorb controllable reactive power, if it is desired, and there by it can provide independent shunt reactive compensation for the line. It is important to note that whereas there is a closed "direct" path for the real power negotiated by the action of series voltage injection through Inverters 1 and 2 back to the line, the corresponding reactive power exchanged is supplied or absorbed locally by converter 2 and therefore it does not flow through the line. Thus, converter 1 can be operated at a unity power factor or be controlled to have a reactive power exchange with the line independently of the reactive power exchanged by the by the converter 2. This means there is no continuous reactive power flow through UPFC.

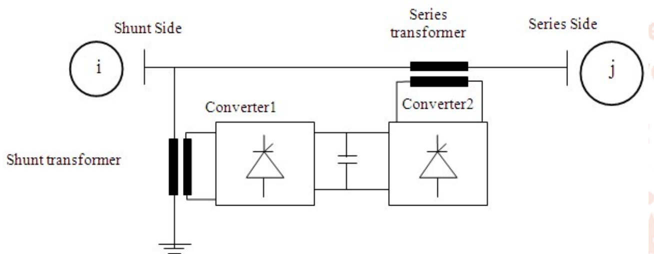


Figure1: Implementation of the UPFC by back to back source converters.

2.1. Mode Of Operation

Operation of the UPFC from the standpoint of conventional power transmission based on reactive shunt compensation, series compensation, and phase shifting, the UPFC can fulfill these functions and thereby meet multiple control objectives by adding the injected voltage V_{pq}, with appropriate amplitude and phase angle, to the terminal voltage V. Using phasor representation, the basic UPFC power flow control functions are illustrated in Figure 2

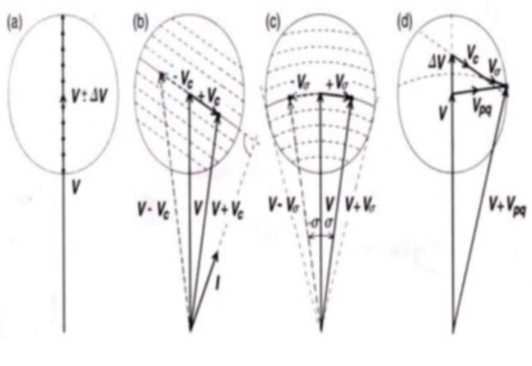


Figure2: Phasor diagram representation of modes of operation of UPFC

A. Terminal Voltage Regulation Terminal voltage regulation, similar to that obtainable with a transformer tap- changer having infinitely small steps. Where $V_{pq} = \Delta V$ is injected in phase or antiphase with V.
B. Line impedance compensation or Series capacitor compensation $V_{pq} = V_c$ is in quadrature with the line current.
C. Transmission angle regulation, (phase shifting)$V_{pq} = V_\sigma$ is injected with angular relationship with respect to V that achieves the desired phase shift (advance or retard) without any change in magnitude.
D. Simultaneous control of voltage, impedance, and angle Multifunction power flow control, executed by simultaneous terminal voltage regulation, series capacitive compensation, and phase shifting where $V_{pq} = \Delta V + V_c + V_\sigma$.

3. Problem Formulation

Due to the complexity that arises in solving the equations, since the functions for real and reactive powers are expressed in terms of non-linear algebraic equations. Iterative methods for solving equations shall be used in solving load flow problems as related to this work. A Newton-Raphson iterative technique was of load flow was used to simulate and investigate the power and voltage at each bus. A MATLAB/PSAT software was also used to run the simulation as it has the Newton-Raphson technique embedded in it.

3.1 Modelling of UPFC for Active and Reactive Power Evaluation

The modelling is carried out for the evaluation of the real and reactive power using the equivalent circuit of figure 3

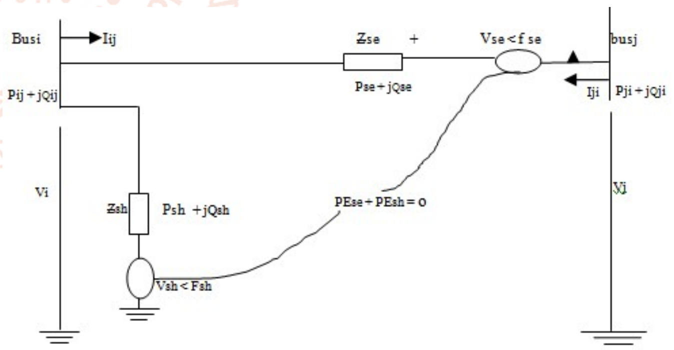


Figure3. Equivalent circuit of a UPFC between two buses i and j

The active and reactive powers of the series convertor (SSSC) are as follow.

$$S_{se} = P_{se} + jQ_{se} = V_{se}I^*j = V_{se}\left[Y^*_{ji}V^*_i + Y^*_{ji}V^*_j + Y_{ij}V^*_{se}\right] \ldots\ldots\ldots (1)$$

Expanding equation 1 and separating the real and imaginary points we have that

$$P_{se} = /V_{se}/^2 G_{ij} + /V_{se}/\ /V_i\left[G_{ij}\cos(\delta_{se} - \delta_i) + B_{ji}\sin(\delta_{se} - \delta_{se})\right] + /V_{se}//V_j/\left[G_{ij}(\delta_{se} - \delta_j) + B_{ij}\sin(\delta_{se} - \delta_j)\right] \ldots (2)$$

$$Q_{se=} -/V_{se}/^2/B_{ij}/ + /V_{se}//V_i/\left[G_{ji}\sin(\delta_{se} - \delta_i) - B_{ji}\cos(\delta_{se} - \delta i + /Vse//Vj/[Gji\sin\delta se - \delta j + Bji\cos\delta se - \delta j\right] \ldots\ldots (3)$$

Also, the active and reactive power of the shunt controller (STATCOM) are obtained as

$S_{sh} = P_{sh} + jQ_{sh} = V_{sh}I_{sh}^{*} = -V_{sh}Y_{sh}^{*}[V_{sh}^{*}Y_{sh}^{*}]$ ..... (4)

Expanding equation 4 and separating the real and imaginary parts we have

$P_{sh} =$
$-/Vsh/2Gi0 + /Vsh//Vi/Gi0\cos(\delta sh - \delta i + Bi0 sin(\delta sh - \delta j))$ .... (5)

$Q_{sh} = -/V_{sh}/^{2}/B_{i0}/ + /V_{sh}//V_i/[G_{i0}\sin(\delta_{sh} - \delta_i) - B_{i0}\cos(\delta_{sh} - \delta_i)]$ .... (6)

Since we assume lossless converters, the UPFC neither aborts nor injects active power with respect to the AC system. Hence the constraint equation is

$P_{sh} + P_{se} = 0$ .... (7)

Where
P_{se} is the series converter real power flow
P_{sh} is the Shunt converter real power flow
Q_{se} is the Series converter reactive power flow
Q_{sh} is the Shunt converter reactive power flow
V_{se} is the Injected series voltage source
V_{sh} is the Injected shut voltage source
I_{sh} is the Current flowing through the UPFC shut converter
G_{io} is the self conductance of the shunt converter
B_{io} is the self susceptance of the shunt converter
δ_{se} is the Voltage angle of the injected series voltage source
δ_{sh} is the voltage angle of the injected shunt voltage source

3.2 Load Flow Analysis with Newton-Raphson Method

Load flow studies are one of the most important aspects of power system planning and operation. The load flow gives us the sinusoidal steady state of the entire system - voltages, real and reactive power generated and absorbed and line losses. Newton-Raphson's solution method was used to carry out the analysis because of its sparsity, fast convergence and simplicity attribute as compared to other solution methods. Consider the line diagram of a two bus system shown in figure 4

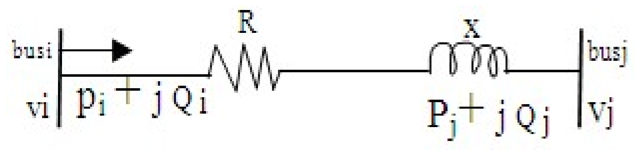


Figure4: Two bus system line diagram o transmission line

The power-flow problem discusse in this section will be presented in terms of the Y_{bus} Ybus matrix whose elements are of the form

$Y_{ij} = |Y_{ij}|e^{j\theta_{ij}} = |Y_{ij}|cos\theta_{ij} + j|Y_{ij}|\sin\theta_{ij} = G_{ij} + jB_{ij}$ .... (8)

For i, k = 1, 2, . . . , N. Let the voltae at bus I be denoted by

$V_i = |V_i|e^{j\delta_i} = |V_i|(cos\delta_i + jsin\delta_i)$ ...... (9)

For i= 1, 2, . . . , N

The net current injected into the etwork at bus I in terms of the elements Y_{in} of the Y_{bus} is determined by

$I_i = Y_{i1}Y_1 + Y_{i2}Y_2 + \dots + Y_{iN}Y_N \sum_{k=1}^{n} Y_{in}$, i=1, 2…,n .... (10)

Let P_i and Q_i denote the net real andreactive power entering the network at bus i. Then the complex conjugate of the power injected at bus is given b $S_i = P_i + jQ_i$ .... (11)

$P_i - jQ_i = V_i^{*}\sum_{n=1}^{N} Y_{in}V_n = V_i I_L^{*}$ .... (12)

Substituting equation 8 and 9 in 12 e have

$P_i - jQ_i \sum_{n=1}^{N}/Y_{in}//V_n/< \theta_{in} + \delta_n - \delta_I$ ....(13)

From the preceding equation we obtain the following form of the power-flow equations:

$P_i = \sum_{n=1}^{n} |Y_{in}V_iV_n cos(\theta_{in} + \delta_n - \delta_i)$ .... (14)

$Q_i = \sum_{n=1}^{n} |Y_{in}V_iV_n|\sin(\theta_{in} + \delta_n - \delta_i)$ .... (15)

Where
V_i is the voltage at bus i
V_j is the voltage at bus j
δ_i is the voltage angle at bus i
δ_j is the voltage angle at bus j

Expanding equation 13, we have

$$P_i - jQ_i = V_iG_{ij} - [V_iV_jcos(\delta_i - \delta_j) - V_iV_j\sin(\delta_i - \delta_j)]G_{ij} + V_i^2 jB_{ij} - [V_iV_jcos(\delta_i - \delta_j) + V_iV_jj\sin(\delta_i - \delta_j)]jB_{ij}$$

$= V_i^2G_{ij} - V_iV_jG_{ij}cos(\delta_i - \delta_j) + V_iV_j[G_{ij}sin(\delta_i - \delta_j) + V_i^2 jB_{ij} - V_iV_jjB_{ij}cos(\delta_i - \delta_j) + V_iV_jB_{ij}sin(\delta_i - \delta_j)$......(16)

Separating the real and imaginary parts from both sending and receiving end we have that:

For sending Bus

$P_{ij} = V_i^2G_{ij} - V_iV_j[G_{ij}cos(\delta_i - \delta_j) + B_{ij}\sin(\delta_i - \delta_j)]$ .... (17)

$Q_{ij} = -V_i^2B_{ij} - V_iV_j[G_{ij}sin(\delta_i - \delta_j) - B_{ij}\cos(\delta_i - \delta_j)]$ .... (18)

Similarly, for the receiving bus

$P_{ji} = V_j^2G_{ji} - V_iV_j[G_{ji}\cos(\delta_j - \delta_i) - B_{ji}\cos(\delta_j - \delta_i)]$ .... (19)

$Q_{ji} = -V_j^2B_{ji} - V_{ji}[G_{ji}\cos(\delta_j - \delta_i) - B_{ij}\cos(\delta_i - \delta_j)]$ .... (20)

The objective of the Newton-Raphson method is to produce values for $|V_i|$ and δ_i that will match the prescribed P_{di} and Q_{di} as determined from Equations (14) and (15). At each iteration of the method, new estimates of $|V_i|$ and δ_i for the non-slack buses (i= 2, 3, ... , N) are generated. At the end of each iteration, the power mismatch is given by

$\Delta P_i = P_{i,sch} - P_i$, ...(21)

$\Delta Q_i = Q_{i,sch} - Q_i$. ....(22)

The complex power flow equations for uncompensated transmission system in solved by Newton –Raphson's iterative method are defined thus.

$P_n = P_i - P_{di} = \sum_{n=i}^{n}/V_i//V_n//Y_{in}/Cos(\theta_{in} + \delta_n - \delta_i)$ i = 1,2..n ......(23)

$Q_n = Q_i - P_{di} = \sum_{n=i}^{n} / V_i // V_n // Y_{in} / Cos\,(\theta_{in} + \delta_n - \delta_i)$ i $= 1,2, \ldots n$... (24)

For compensated transmission system, equation 24 is modified and is defined by

$Q_n = Q_i - Q_{di} + Q_{ci} = -\sum_{n=i}^{N} / V_i // V_n // Y_{in} / sin\,(\theta_{in} + \delta_n - \delta_i)$ .... (25)

Where

P_i = Real power generated at the i^th bus

Q_i = Reactive power generated at the i^th Bus

P_{di} = Real power consumed at the i^th bus

V_n = Voltage of the n^th bus.

Q_{di} = Reactive power consumed at the i^th bus

V_i = Voltage at bus i

Y_{in} = element of the bus admittance matrix

δ_i = Voltage angle at bus i

δ_n = Voltage angle at nth Bus

θ_{in} = Angle associated with Y_{in}

Then the new estimates for the bus voltages are

$\delta_i^{(k=1)} = \delta_i^{(k)} + \Delta\delta_i^{(k)}$ ....(26)

$|V_i^{k+1}| = |V_i^{(D)}| + \Delta|V_i^{(k)}|$ .... (27)

The solution of equation enables us to identify weak points in the system where the voltages magnitude lies outside the voltage limits of ±5%.

3.3. Modelling load Flow Equations with UPFC

The linearized system of power flow equations for UPFC in connection with the rest of the network in obtained using Newton-Raphson power flow equation given by

[F (x)] = [J] [ΔX] .... (28)

Where

F (x) is the Power and control mismatch vectors

Δx is the Incremental vector of state variables Where ΔX is the solution vector and it is given by

$$\Delta X = \begin{pmatrix} \Delta\delta_i \\ \Delta\delta_j \\ \Delta/V_{sh} \\ \Delta/V_j/ \\ \Delta\,\delta_{se} \\ \Delta V_{se} \\ \Delta\delta_{sh} \end{pmatrix} \quad \ldots\ldots\ 29 \qquad [FX] = \begin{pmatrix} \Delta P_i \\ \Delta P_j \\ \Delta\, Q_i \\ \Delta Q_j \\ \Delta P_{ji} \\ \Delta Q_{ji} \\ \Delta P \end{pmatrix} \quad \ldots\ldots\ 30$$

J is the matrix of partial derivative of F(x) with respect to x,

Let us assume the UPFC is connected to node i and the power and the power system is connected to node j. UPFC is required to control voltage magnitude of node i and active power low from node j to node i. Reactive power is infected at node j. Here we can re-write equation 28 as

$$\begin{matrix} \Delta P_i \\ \Delta P_j \\ \Delta Q_i \\ \Delta Q_j \\ \Delta P_{ji} \\ \Delta Q_{ji} \\ \Delta P \end{matrix} = \begin{pmatrix} \frac{\partial P_i}{\partial\delta_i} & \frac{\partial P_i}{\partial\delta_j} & \frac{\partial P_i}{\partial/V_{sh}/} & \frac{\partial P_i}{\ } & \frac{\partial P_i}{\partial/V_j/} & \frac{\partial P_i}{\partial\delta_{se}} & \frac{\partial P_i}{\partial/V_{se}/} \\ \frac{\partial P_j}{\partial\delta_i} & \frac{\partial P_j}{\partial\delta_j} & & \frac{0}{\partial/V_j/} & \frac{\partial P_j}{\ } & \frac{\partial P_j}{\partial\delta_{se}} & \frac{\partial P_j}{\partial/V_{se}/} \\ \frac{\partial Q_i}{\partial\delta_i} & \frac{\partial Q_i}{\partial\delta_j} & \frac{\partial Q_i}{\partial/V_{sh}/} & \frac{\partial Q_i}{\partial/V_j} & \frac{\partial Q_i}{\partial\delta_{se}} & \frac{\partial Q_i}{\partial/V_{se}/} & \frac{\partial Q_i}{\partial\delta_{sh}} \\ \frac{\partial Q_j}{\partial\delta_i} & \frac{\partial Q_j}{\partial\delta_j} & 0 & \frac{\partial Q_j}{\partial/V_j/} & \frac{\partial Q_j}{\partial\delta_{se}} & \frac{\partial Q_j}{\partial/V_{se}/} & 0 \\ \frac{\partial P_{ji}}{\partial\delta_i} & \frac{\partial P_{ji}}{\partial\delta_j} & 0 & \frac{\partial P_{ji}}{\partial/V_j/} & \frac{\partial P_{ji}}{\partial\delta_{se}} & \frac{\partial P_{ji}}{\partial/V_{se}/} & 0 \\ \frac{\partial Q_{ji}}{\partial\delta_i} & \frac{\partial Q_{ji}}{\partial\delta_j} & 0 & \frac{\partial Q_{ji}}{\partial/V_j/} & \frac{\partial Q_{ji}}{\partial\delta_{se}} & \frac{\partial Q_{ji}}{\partial/V_{se}/} & 0 \\ \frac{\partial P}{\partial\delta_i} & \frac{\partial P}{\partial\delta_j} & \frac{\partial P}{\partial/V_j/} & \frac{\partial P}{\partial\delta_{se}} & \frac{\partial P}{\partial/V_{se}/} & \frac{\partial P}{\partial\delta_{sh}} & \frac{\partial P}{\partial\delta_{sh}} \end{pmatrix} \begin{matrix} \partial\delta_{sh} \\ \begin{pmatrix} \Delta\delta_i \\ \Delta\delta_j \\ \Delta/V_{sh}/ \\ \Delta/V_j \\ \Delta\,\delta_{se} \\ \Delta/V_{se}/ \\ \Delta\,\delta_{sh} \\ \partial_{sh} \end{pmatrix} \end{matrix} \quad \ldots\ldots\ 31$$

4. SIMULATION AND RESULT ANALYSIS

Overview of Nigeria 330kV Transmission Network used for the case study

The input data for the power flow analysis include the bus data that is real and reactive powers of the generator buses, transmission line data (impedance of lines), voltages and transformer/load data obtained from Power Holding Company of Nigeria (PHCN) are as presented in Tables contained in the appendix. They are used to carry out the analysis. The single-line diagram of the existing 330kV Nigeria transmission network used as the case study is as shown in Figure 5. It has 42 buses with nine generating station. The Egbin power station was chosen as the slack bus because it has the highest generating capacity of 1320MW.

4.1 SIMULATION STEPS

MATLAB/PSAT software was used to simulate the proposed model. The model of simulation of the proposes model using the developed MATLAB code are as follows. The algorithm is represented in figure 4

- Run load flow on the proposed model before and after incorporation with UPFC.
- Plot the graph of voltages (p.u) against the buses.
- Compare the result in graph.

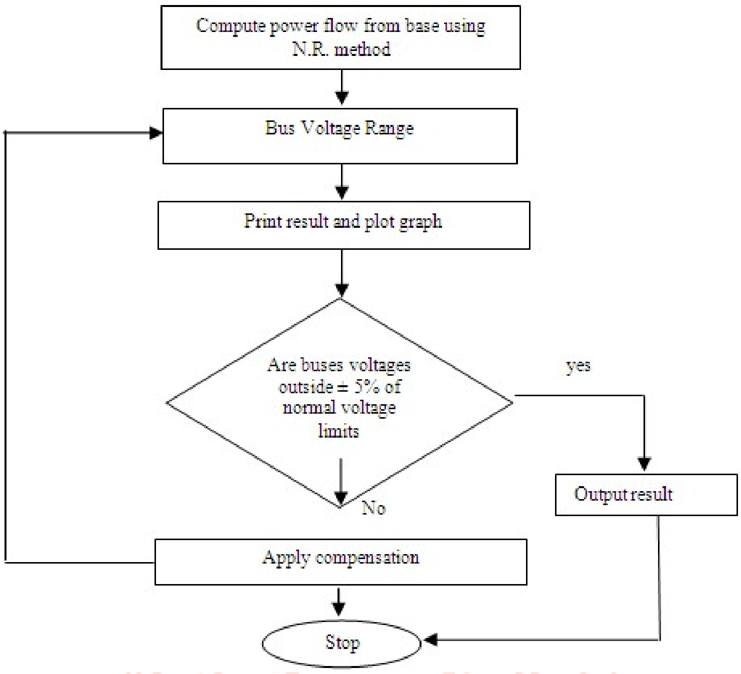


Figure4: Flow Chart for the Analysis of UPFC Compensation Algorithm.

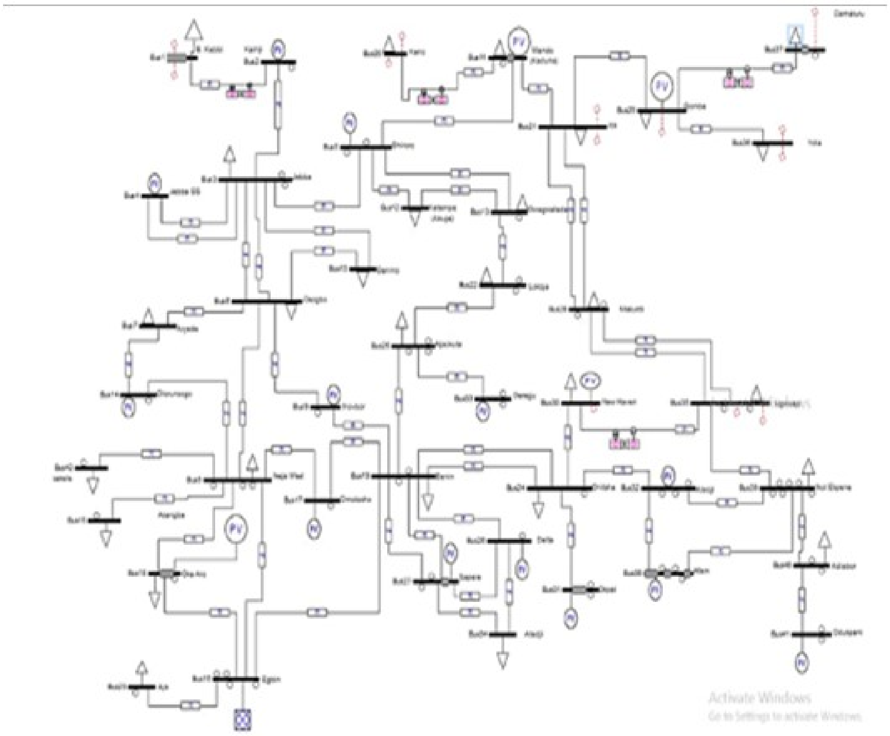


Figure5: Modelled Nigerian 330kV power system on PSAT

5. RESULTS

Load flow analysis was carried out on the network to investigate the buses outside voltage limits and also losses along the lines. Results of the simulations are in figures 5, 6, 7 and table 1.

Table1: Bus voltages and angles with and without UPFC

Bus Number	Bus Name	Voltage (p.u) without UPFC	Voltage (p.u) with UPFC	Voltage angle without UPFC	Voltage angle with UPFC
Bus1	B. Kebbi	0.92327917	0.98177	-0.26392	-0.12408
Bus10	Ganmo	0.993467034	0.99455	-0.13674	-0.12508
Bus11	Mando	0.936016761	0.989	-0.40837	-0.37615
Bus12	Katampe	0.96932409	0.97002	-0.30952	-0.28767
Bus13	Gwagwalada	0.972349829	0.9732	-0.29775	-0.27645
Bus14	Olorunsogo	1	1	-0.09085	-0.08538
Bus15	Akangba	0.967384227	0.98276	-0.10562	-0.10388
Bus16	Egbin	1.012	1.012	0	0
Bus17	Omotosho	1	1	-0.0174	-0.01423
Bus18	Oke-Aro	0.980006451	1	-0.07579	-0.07584
Bus19	Benin	1.01126355	1.0143	-0.01387	-0.01021
Bus2	Kainji	1	1	-0.10788	-0.09377
Bus20	Kano	0.912025045	0.98415	-0.42084	-0.3865
Bus21	Jos	0.876609365	0.98555	-0.47534	-0.42692
Bus22	Lokoja	0.967875943	0.96994	-0.21473	-0.1999
Bus23	Aja	1.00915049	1.0092	-0.00437	-0.00437
Bus24	Onitsha	0.989343263	1.0043	0.006314	0.005664
Bus25	Ajaokuta	0.97281235	0.97499	-0.18027	-0.16727
Bus26	Delta	1.012	1.012	0.009153	0.013138
Bus27	Sapele	1.012	1.012	0.000476	0.004477
Bus28	Makurdi	0.893989619	0.98314	-0.29127	-0.26873
Bus29	Gombe	0.812150442	0.99	-0.71929	-0.61011
Bus3	Jebba	0.999264259	0.99943	-0.13043	-0.11731
Bus30	New Haven	0.916384533	0.98	-0.10314	-0.10298
Bus31	Okpai	1.012	1.012	0.044018	0.044556
Bus32	Alaoji	1	1	0.172816	0.168112
Bus33	Geregu	1	1	-0.1154	-0.10237
Bus34	Aladji	1.007415339	1.0074	-0.00267	0.00132
Bus35	Ugwuaji	0.914546079	0.97883	-0.10913	-0.1066
Bus36	Yola	0.801049641	0.98458	-0.75828	-0.63654
Bus37	Damaturu	0.804956113	0.9833	-0.75371	-0.62535
Bus38	Afam	1.003	1.003	0.196087	0.191143
Bus39	IkotEkpene	0.980610751	0.9889	0.145729	0.139584
Bus4	Jebba GS	1	1	-0.12617	-0.11303
Bus40	Adiabor	0.986716932	0.98844	0.19726	0.191375
Bus41	Odukpani	0.991	0.991	0.214988	0.209277
Bus42	Sakete	0.954470925	0.97019	-0.13171	-0.12916
Bus5	Shiroro	1	1	-0.27781	-0.25354
Bus6	Osogbo	0.996650962	0.99881	-0.11878	-0.109
Bus7	Aeyede	0.972034158	0.97309	-0.12932	-0.12185
Bus8	Ikeja West	0.973856683	0.98913	-0.09482	-0.09342
Bus9	Ihovbor	1	1	0.049304	.056249

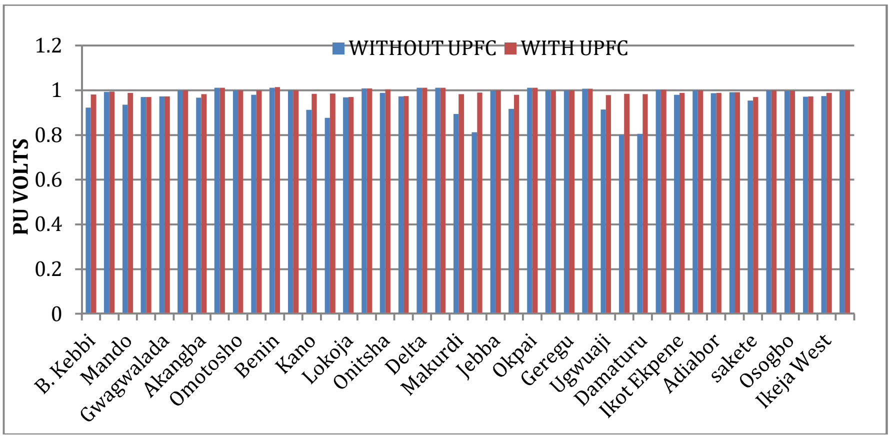
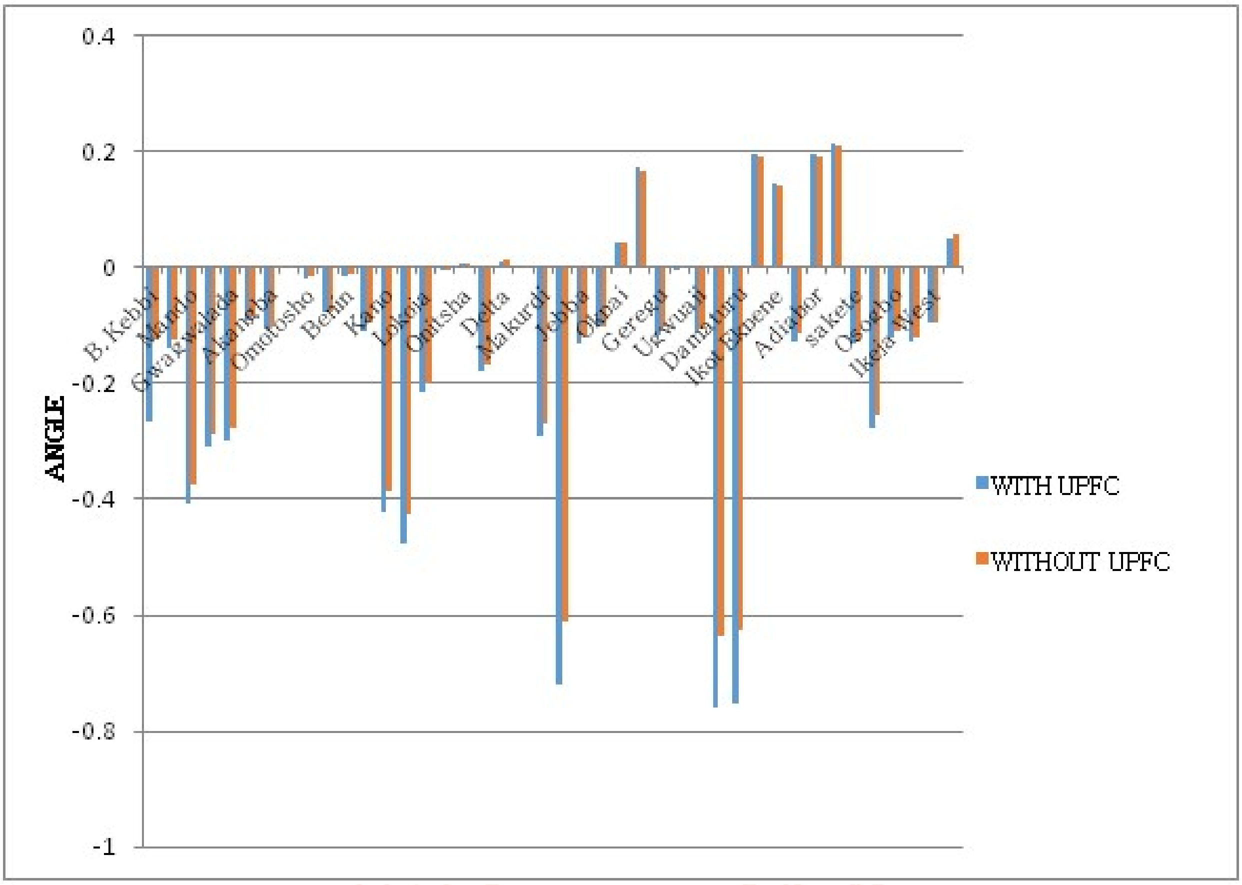


Figure6: Bar plot of bus voltage with and without UPFC



6. DISCUSSION

The analysis of Nigeria 330kV 42 bus network using Newton- Raphson's power flow solution algorithm with MATLAB/PSAT software was successfully completed. The results obtained revealed the weak buses with values outside the statutory limit of 0.95p.u. (313.5kV) and 1.05p.u. (346.kV). Four (4) UPFC devices where placed at some weak buses in the network namely Birnin Kebbi, Kano, New haven and Gombe which resulted to almost a flat voltage profile with all the buses within voltage limits as in figure 6. The bar plot in the figure 6, shows the comparism of the bus voltages before and after compensation by UPFC while figure 7 is the corresponding voltage angle of the bus voltages before and after compensation. The voltage profile of the system was improved as a result of the series compensation voltages added to the system with controllable magnitude by the UPFC.

7. CONCLUSION

The Nigerian 330kV transmission system associated with various challenges like instability of the system as a result of voltage profile violation, transmission line inefficiency, problem of long transmission lines, network being stretched beyond thermal limit, and poor power quality that causes constant power failure in Nigeria power system were discussed. Newton-Raphson's solution method because of its sparsity, fast convergence and simplicity attributes compared to other solution methods was chosen. UPFC was used because of its ability control the network parameters which are voltage magnitude, phase angle and impedance simultaneously and independently. In the simulation study MATLAB/PSAT simulation tool was used for the analysis. The result of the simulation of the uncompensated and compensated network were recorded in table 1. It was found that the UPFC improved the voltages at the bus of the power system.

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