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Enhancement of Power System Voltage Stability with the Aid of Reactive/Capacitive Power Switching Mechanism (A Case Study of Oweeri Transmission Company of Nigeria)

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ABSTRACT

The focus of this paper is on the application of Static Var Compensator in enhancing voltage stability in power system. In other to achieve this, the Owerri transmission substation is used as a case study. Owerri transmission substation receives its power from Alaoji transmission station at a voltage level of 132kV. This substation is made up of three power transformers, two steady transformers and a mobile transformer with ratings of 60MVA and 40 MVA. ETAP 7.0 was the major tool used in achieving this aim. It was clearly observed that with SVC out of service bus voltage at Owerri was far below regulated value and very high loss occurred along the transmission line leading to high voltage drop. But with the SVC in service the bus voltage experienced a boost in voltage to a regulated value with corresponding reduction in voltage drop, drop in reactive power from the sending end and increase in real power supplied. Also the model was tested with light loads and it was observed that bus voltage was more than the source without the SVC but with the SVC the bus voltage was kept at a regulated value by the reverse flow of reactive power into the SVC. This again showed the dynamic nature of the SVC, absorbing reactive power in period of high voltage and supplying reactive power when low voltage occurs.

Keyword: Static Var Compensator, reactive power, active power, and voltage

INTRODUCTION

The Nigeria power system is associated with epileptic supply, poor system stability, high losses, weak bus voltages, line overloads, inappropriate location of generating stations, long transmission lines among orders (Onohaebi O.S asnd Kuale P.A, 2007). These affect the overall power quality (Omorogiuwa, 2013). Every day, the power transmission and distribution systems face increasing demands for more power, with expecting for better power quality, reliability at lower cost, and as well as low environmental effect. Under these conditions, transmission networks are called upon to operate at high transmission levels, which invariably turn the system to unstable condition. An approach towards solving tackling this problem among others will include placement of Static Var Compensator optimally by the use of any optimization tool.

An inherent characteristic of electric energy transmission and distribution by alternating current (AC) is that real power is generally associated with reactive power. AC transmission and distribution associated with reactive power. AC transmission and distribution lines are dominantly reactive networks, characterized by their per-mile series inductance and shunt capacitance. Thus, load and load power factor changes alter the voltage profile along the transmission lines and can cause large amplitude variations in the receiving end voltage.

For passive compensation, shunt capacitors have been extensively used since the 1930s. They are either permanently connected to the system, or switched, and they contribute to voltage control by modifying characteristics of the network. They are either permanently connected to the system, or switched, and they contribute to voltage control by modifying characteristics of the network (Kundur et al., 1994).

Improvements in the field of power electronics have had a major impact on the development of shunt active compensators, which are Static Var Compensator (SVC) and Static Compensator (STATCOM) devices. One of the most important applications of such devices is to keep system voltage profiles at desirable levels by compensating for the system reactive power. By employing these devices for reactive power compensation, both the stress on the heavily loaded lines and losses are easily reduced as a consequence of line loadability, which is increased.

The Electric Power Research Institute (EPRI) has initiated the development of Flexible AC Transmission Systems (FACTS) in which power flow is dynamically controlled by various power electronic devices. The two main objectives of FACTS are to increase the transmission capacity of lines and control power flow over designated transmission routes (Laszlo, 1994)

Flexible AC Transmission System (FACTS) controllers, such as the Static Var Compensator (SVC), employ the latest technology of power electronic switching devices in electric power transmission systems to control voltage and power-flow, and improve voltage regulation. Static Var Compensators are being increasingly applied in electric transmission systems to economically improve voltage control and post-disturbance recovery voltages that can lead to system instability. An SVC provides such system improvements and benefits by controlling shunt reactive power sources, both capacitive and inductive, with state-of-the-art power electronic switching devices.

When voltage security or congestion problems are observed during the planning study process, cost effective solutions must be considered for such problems. Traditional solutions to congestion and voltage security problems were to install new costly transmission lines that are often faced with public resistance, or mechanically-switched capacitor banks that have limited benefits for dynamic performance due to switching time and frequency. One approach to solving this problem is the application of "Flexible AC transmission System" (FACTS) technologies, such as the Static Var Compensator (SVC). FACTS technologies are founded on the rapid control response of thyristor-based reactive power controls.

Roberto et al., 2001, investigated increase of voltage stability and power limits using a Static VAR Compensator. The objectives of this study were to increase the transmitted power, under the thermal capacity, through an overhead transmission lines using a voltage stability criterion. The used approach has been the voltages stability, with the purpose of keeping the voltage magnitude on the main buses within the range of 0.8-1.2 p.u., during the transients state and after a fault located anywhere in the systems. In conclusion of this study, Roberto et al., 2001, stated that the application of the dynamic compensator (SVC) for increasing the power flow, under the thermal capacity, through an overhead transmission lines using a voltage stability criterion to achieve the propose target. This was fulfilled by a simulations carried out in the ATP/EMTP program of a model of the power system located in the southeast region of Venezuela, where exist important loads related with the oil industry using as a voltage criterion a specified range of 1.2-0.8 p.u., for the voltage variation.

Alok et al., 2013 studied enhancement of transient stability in transmission line using Static VAR Compensator FACTs controller. The paper discussed and demonstrated how Static VAR Compensator has successfully been applied to control transmission systems dynamic performance for system disturbance and effectively regulate system voltage. Static VAR Compensator is a shunt connected FACTS devices, and plays an important role as a stability aid for dynamic and transient disturbances in power systems. UPFC controller is another FACTS device which can be used to control active and reactive power flows in a transmission line. The damping of power system oscillations after a three phase fault is also analyzed with the analysis of the effects of SVC on transient stability performance of a power system. A general program for transient stability studies to incorporate FACTS devices is developed using modified partitioned solution approach. The modeling of SVC for transient stability evaluation is studied and tested on a 10-Generator, 39 -Bus, New England Test System.

Voltage stability aids have been studied by many power engineers in of which many of their research result implemented. The instability in voltage do creates serious effect on the normal operation of loads as its presence can cause great deterioration in electrical loads. Reactive flow is one of the factors affecting the stability of voltage. Reactive power demand can be from loads, transformers or transmission lines because of there inductive (lagging current) nature. Some of the various techniques for voltage improvement include synchronous condenser, control by transformer, compensation using capacitive / reactive components.

PROPOSED METHOD

The simple circuit of figure 1 shows the relationship between reactive power and real power in an electrical network.

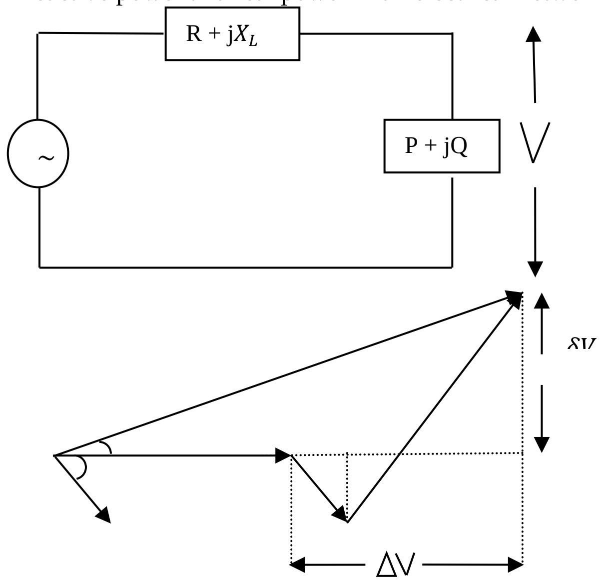

Figure 1: Equivalent circuit of Alternator supplying electrical energy to a practical inductive load and its phasor diagram.

From the phasor diagram it can be stated that

$$E^2 = (V + \Delta V)^2 + (\delta V)^2 \qquad 1$$

$$(V + IR\cos\emptyset + IX\sin\emptyset)^2 + (IX\cos\emptyset - IR\sin\emptyset)^2 \qquad 2$$

$$(V + (\frac{RP}{V}) + (\frac{XQ}{V}))^2 + ((\frac{XP}{V} - \frac{RQ}{V})^2 \qquad 3$$

Therefore

$$\Delta V = \frac{(RP+XQ)}{V} \qquad 4$$

$$\delta V = \frac{(XP+RQ)}{V} \qquad 5$$

$$\delta V \lll (V + \Delta V)$$

$$E - V = \Delta V = \frac{RP+XQ}{V} \qquad 6$$

$$\Delta V = \frac{XQ}{V} \quad \text{since } R \lll X \qquad 7$$

i.e., Voltage drop depends on Q. i.e., if reactive power flows over the transmission line, there shall be a voltage drop.

Ampriz-perez et al, 2000, showed the mathematical implementation of firing angle model of SVC which handles the TCR firing angle as a state variable in the power flow formulation. It is expressed as follows:

$$B_{SVC} = \frac{1}{X_c X_l}\left\{X_l - \frac{X_c}{\pi[2(\pi-\alpha)+\sin 2\alpha]}\right\} \qquad 8$$

Where

$X_c = \frac{1}{W_c}$

$X_l = W_l$

α: is the firing angle

$$Q_k = \frac{-V_k^2}{X_c X_l}\left\{X_l - \frac{X_c}{\pi[2(\pi - \alpha) + \sin 2\alpha]}\right\} \qquad 9$$

From equation 9, the linearized SVC equation is given in equation 10.

$$\begin{bmatrix}\Delta P_k \\ \Delta Q_k\end{bmatrix} = \begin{bmatrix}0 & 0 \\ 0 & \frac{2V_k^2}{\pi X_l}(\cos(2\alpha) - 1)\end{bmatrix}\begin{bmatrix}\Delta\delta_k \\ \Delta\alpha\end{bmatrix} \qquad 10$$

At the end of iteration, the variable firing angle is updated according to equation 3.15.

$$\alpha(i) = \alpha(i-1) + \Delta\alpha \qquad 11$$

The Power Flow Studies

Power flow studies are performed to determine voltages, active and reactive power etc. at various points in the network for different operating conditions subject to the constraints on generator capacities and specified net interchange between operating systems and several other restraints. Power flow or load flow solution is essential for continuous evaluation of the performance of the power systems so that suitable control measures can be taken in case of necessity. In practice it will be required to carry out numerous power flow solutions under a variety of conditions.

Necessity For Power Flow Studies

Power flow studies are undertaken for various reasons, some of which are the following:

1. The line flows
2. The bus voltages and system voltage profile
3. The effect of change in configuration and incorporating new circuits on system loading
4. The effect of temporary loss of transmission capacity and (or) generation on system loading and accompanied effects.
5. The effect of in-phase and quadrative boost voltages on system loading
6. Economic system operation
7. System loss minimization
8. Transformer tap setting for economic operation
9. Possible improvements to an existing system by change of conductor sizes and system voltages.

Newton-Raphson (N-R) Nodal Active and Reactive Power Flow Equation Derivation

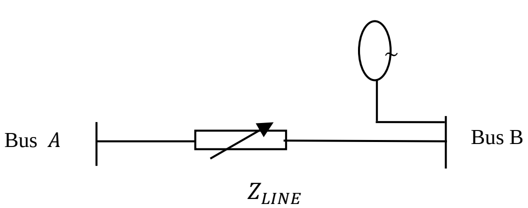

Figure 2: Two bus voltage network.

$$P_A + jQ_A = V_A I_A^* \qquad 12$$

Referring to figure 3.3, at Node A, the following parameters are defined:

S_A = *Complex injected power*

P_A = *Active Injected power*

Q_A = *Reactive Injected powe*

V_A = *Complex voltage*

I_A = *Complex injected current*

Injected current I_A expressed as a function of current flow from branch A – B is given as

$$I_A = \sum_{B=1}^{n} Y_{AB} V_B \qquad 13$$

Where $Y_{AB} = G_{AB} + jB_{AB}$ and Y_{AB}, G_{AB} and jB_{AB} are the admittance, conductance and susceptance of branch A – B respectively. Substituting equation 12 into 13 gives equation 3.14

$$P_A + jQ_A = V_A \sum_{B=1}^{n} Y_{AB}^* V_B^* \qquad 14$$

In other to find equation for the active and reactive power, the complex voltages must be expressed in polar form.

$$V_A = |V_A| e^{j\theta_A} \qquad 15$$

$$V_B = |V_B| e^{j\theta_B} \qquad 16$$

$$P_A + jQ_A = |V_A| \sum_{B=1}^{n} |V_B| G_{AB} - jB_{AB} e^{j(\theta_A - \theta_B)} \qquad 17$$

$$P_A + jQ_A = |V_A| \sum_{B=1}^{n} |V_B||G_{AB} - jB_{AB}|(\cos(\theta_A - \theta_B) + j\sin(\theta_A - \theta_B)) \qquad 18$$

$$P_A = |V_A| \sum_{B=1}^{n} |V_B||G_{AB}|(\cos(\theta_A - \theta_B) + B_{AB}\sin(\theta_A - \theta_B)) \qquad 19$$

$$Q_A = |V_A| \sum_{B=1}^{n} |V_B||G_{AB}|\left(\sin(\theta_A - \theta_B) + B_{AB}\cos(\theta_A - \theta_B)\right) \qquad 20$$

The voltages at the nodes and phase angles are given as V_A *and* V_B *and* θ_A *and* θ_B respectively. Equations 19 and 20 are solved using Newton-Raphson method by making the set of equations linear. This takes the form of an n- node network. At node A

$$\begin{pmatrix}\Delta P_2 \\ \Delta P_3 \\ \vdots \\ \Delta P_n \\ \Delta Q_2 \\ \Delta Q_3 \\ \vdots \\ \Delta Q_n\end{pmatrix} = \begin{pmatrix}
\frac{\partial P_2}{\partial e_2} & \frac{\partial P_2}{\partial e_3} & \cdots & \frac{\partial P_2}{\partial e_n} & \frac{\partial P_2}{\partial f_2} & \frac{\partial P_2}{\partial f_3} & \cdots & \frac{\partial P_2}{\partial f_n} \\
\frac{\partial P_3}{\partial e_2} & \frac{\partial P_3}{\partial e_3} & \cdots & \frac{\partial P_3}{\partial e_n} & \frac{\partial P_3}{\partial f_2} & \frac{\partial P_3}{\partial f_3} & \cdots & \frac{\partial P_3}{\partial f_n} \\
\frac{\partial P_n}{\partial e_2} & \frac{\partial P_n}{\partial e_3} & \cdots & \frac{\partial P_n}{\partial e_n} & \frac{\partial P_n}{\partial f_2} & \frac{\partial P_n}{\partial f_3} & \cdots & \frac{\partial P_n}{\partial f_n} \\
\frac{\partial Q_2}{\partial e_2} & \frac{\partial Q_2}{\partial e_3} & \cdots & \frac{\partial Q_2}{\partial e_n} & \frac{\partial Q_2}{\partial f_2} & \frac{\partial Q_2}{\partial f_3} & \cdots & \frac{\partial Q_2}{\partial f_n} \\
\frac{\partial Q_2}{\partial e_2} & \frac{\partial Q_2}{\partial e_3} & \cdots & \frac{\partial Q_2}{\partial e_n} & \frac{\partial Q_2}{\partial f_2} & \frac{\partial Q_2}{\partial f_3} & \cdots & \frac{\partial Q_2}{\partial f_n} \\
\frac{\partial Q_n}{\partial e_2} & \frac{\partial Q_n}{\partial e_3} & \cdots & \frac{\partial Q_n}{\partial e_n} & \frac{\partial Q_n}{\partial f_2} & \frac{\partial Q_n}{\partial f_3} & \cdots & \frac{\partial Q_n}{\partial f_n}
\end{pmatrix} \qquad 21$$

ΔP_A = Active power mismatch;

ΔQ_A = Reactive power mismatch;

P^{Gen} *and* Q^{Gen} = active and reactive power generated;

P^{load} and Q^{load} active and reactive power consumed;

$\Delta\theta_A$ and ΔV_A are the incremental nodal voltage change.

Differentiating equations 19 and 20, the Jocabian matrix element becomes for two possible conditions of both equal and unequal bus voltages at both ends.

If A = B, then

$$\frac{\partial P_A}{\partial \theta_A} = |V_A| \sum_{B=A}^{n} |V_A| - |G_{AB}| \left(\sin(\theta_A - \theta_B) + B_{AB}\cos(\theta_A - \theta_B)\right) - |V_A^2||B_{AA}| \quad 22$$

$$\frac{\partial P_A}{\partial \theta_A} = -Q_A - |V_A^2||B_{AA}| \quad 23$$

$$\frac{\partial P_A}{\partial |V_A|} = |V_A| \sum_{B=1}^{n} |V_A| - |G_{AB}|(\cos(\theta_A - \theta_B) + B_{AB}\sin(\theta_A - \theta_B) - |V_A||B_{AA}| \quad 24$$

$$\frac{\partial P_A}{\partial |V_A|} = \frac{P_A}{|V_A|} + |V_A||B_{AA}| \quad 25$$

$$\frac{\partial Q_A}{\partial |\theta_A|} = |V_A| \sum_{B=1}^{n} |V_A| - |G_{AB}|(\cos(\theta_A - \theta_B) + B_{AB}\sin(\theta_A - \theta_B) - |V_A^2||B_{AA}|$$

$$= P_A - |V_A^2||B_{AA}| \quad 26$$

$$\frac{\partial Q_A}{\partial V_A} = |V_A| \sum_{B=1}^{n} |V_A| - |G_{AB}|\left(\sin(\theta_A - \theta_B) + B_{AB}\cos(\theta_A - \theta_B)\right) - |V_A||B_{AA}|$$

$$\frac{\partial Q_A}{\partial |V_A|} = \frac{Q_A}{|V_A|} - |V_A||B_{AA}| \quad 27$$

If $A \neq B$, then

$$\frac{\partial P_A}{\partial \theta_A} = |V_A||V_B||G_{AB}|\left(\sin(\theta_A - \theta_B) + B_{AB}\cos(\theta_A - \theta_B)\right) \quad 28$$

$$\frac{\partial P_A}{\partial |V_A|} = |V_B||G_{AB}|(\cos(\theta_A - \theta_B) + B_{AB}\sin(\theta_A - \theta_B) \quad 29$$

$$\frac{\partial P_A}{\partial |V_A|} = \frac{-\partial Q_A}{|V_B|\partial|\theta_B|} \quad 30$$

$$\frac{\partial Q_A}{\partial \theta_B} = -|V_A||V_B||G_{AB}|\left(\sin(\theta_A - \theta_B) + B_{AB}\cos(\theta_A - \theta_B)\right) \quad 31$$

$$\frac{\partial Q_A}{\partial |V_B|} = |V_A||G_{AB}|\left(\sin(\theta_A - \theta_B) + B_{AB}\cos(\theta_A - \theta_B)\right) \quad 32$$

$$\frac{\partial Q_A}{\partial |V_B|} = \frac{\partial P_A}{|V_B|\partial\theta_B} \quad 33$$

Since after iteration, the initial estimated voltages and specified power will always not agree with obtained voltage and injected power, then the mismatch power vectors is defined as

$$\Delta P = P^{Gen} - P^{load} - P^{cal} = P^{net} - P^{cal} \quad 34$$

$$\Delta Q = Q^{Gen} - Q^{load} - Q^{cal} = Q^{net} - Q^{cal} \quad 35$$

Thus the Jacobian element is calculated and the linearized equation (8) is solved to obtain vectors of updated voltages.

$$\theta^{(z+1)} = \theta^{z} + \Delta\theta^{z} \quad 36$$

$$|V|^{(z+1)} = |V|^{z} + \Delta|V|^{z} \quad 37$$

SIMULATION RESULT

The simulation in this paper is carried out using ETAP 7.0. The network consists of a total number of five (5) buses. These buses are analysed using the package. All the necessary data are well considered.

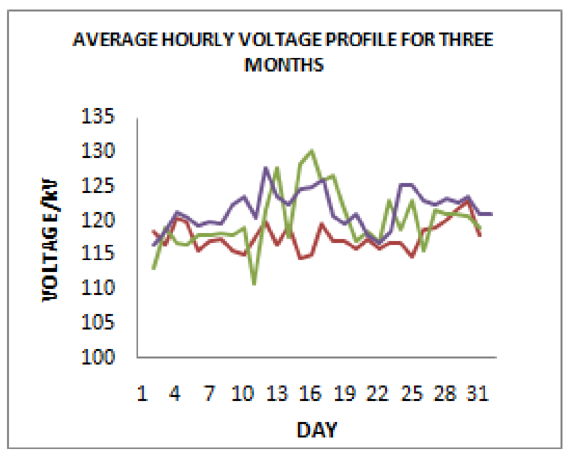

Figure 2: Average Hourly voltage profile for September, November and December

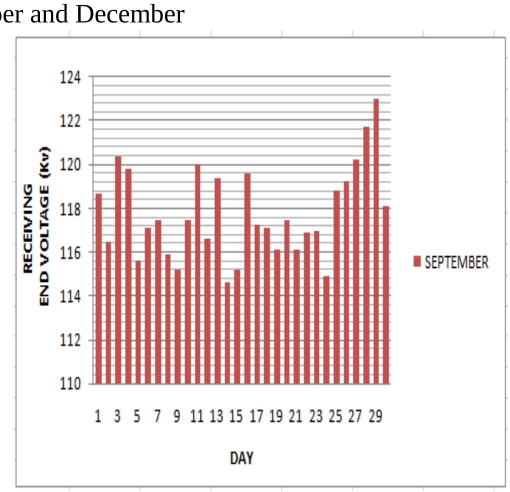

Figure 3: Average Hourly voltage profile for September only

Firstly, the network simulation was done without SVC in operation. The load flow report was noted.

Secondly, in order to achieve the voltage improvement and loss reduction, the SVC was placed randomly at each bus. The load flow report for each of these was noted. The bus at which these aim was more effective was noted. This bus signified the optimal location of for the placement of this SVC.

Table 1. Mean Value for each day in three months (Egbu Feeder).

MEAN VOLTAGE FOR EACH DAY IN THREE MONTH kV.............(EGBU FEEDER)			
MONTH/ DATE	SEPTEMBER	NOVEMBER	DECEMBER
1	118.68	113.00	116.58
2	116.48	118.96	118.41
3	120.38	116.61	121.417
4	119.84	116.48	120.50
5	115.64	117.90	119.50
6	117.12	117.96	120.00
7	117.44	118.13	119.60
8	115.87	117.79	122.42
9	115.17	119.05	123.59
10	117.44	110.79	120.54
11	120.04	121.48	127.71
12	116.63	127.73	123.67
13	119.40	117.58	122.38
14	114.64	128.38	124.54
15	115.17	130.32	125.00
16	119.60	125.92	125.96
17	117.28	126.63	120.75
18	117.12	121.50	119.67
19	116.08	117.13	121.08
20	117.48	118.31	117.92
21	116.08	116.60	116.85
22	116.92	122.82	118.54
23	117.00	118.61	125.25
24	114.88	123.05	125.13
25	118.84	115.53	122.92
26	119.22	121.67	122.54
27	120.24	121.00	123.17
28	121.71	120.96	122.58
29	123.00	120.75	123.50
30	118.08	119.08	121.08
31			121.04

Table 2: Average Maximum Load Demand, from Jan-Jul, Year 2011

MONTH/ TRAN-SFORMERS	TR1 60MVA 132/33kV	TR2 60MVA 132/33kV	MOB 40 MVA 132/33kV
kV/MW			
JAN	30/47	32/48	33/30
FEB	32/37.6	34/42	31.5/20.5
MAR	34/49	32/44	31/43
APR	31.5/48	34/44	30/30
MAY	34/48	32/40	31/32
JUN	31/45.5	31.2/42	32.32
JUL	31/20	31.5/42.5	32/32

Table 3: Load Flow Summary with and without SVC (Voltage)

	VOLTAGE kV(%)	
YEAR	SVC	
	ABSSENT	PRESENT
2011	110.09(83.4)	124.6(94.4)
2012	111.94(84.8)	125.4(95.0)
2013	109.56(83.0)	124.65(94.3)

Table 4: Load Flow Summary with and without SVC (Line Losses)

	LINE LOSSES (MVA)	
YEAR	SVC	
	ABSSENT	PRESENT
2011	11.6353+j15.2061	10.921+J13.593
2012	9.9341+12.3702	9.2413+j10.8206
2013	12.1516+j16.066	11.4177+j14.4128

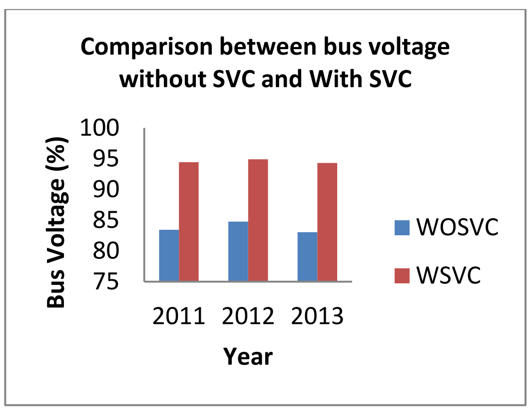

Figure 4: Plot of values in table 3 (WOSVC mean without SVC, while WSVC mean with SVC)

CONCLUSION

This work involved the use of Static Var Compensator in enhancing voltage stability considering Owerri transmission substation, Nigeria as a case study. From the resultant analysis it can conclude that voltage stability can be enhanced using SVC which controls the flow of reactive power in the line. Also the reduction in reactive power flow gives rise to more flow of Active power, thus, load shedding in the system will reduce as more real power is made available.

REFERENCES

1. Alok Kumar, and Surya Bhushan Dubey "Enhancement of Transient Stability in Transmission Line Using SVC Facts Controller" International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878, Volume-2, Issue-2, May 2013 51
2. Arti Pateriya and Nitin Saxena "Transfer Capability Enhancement of Transmission Line Using Static VAR Compenstator" (Received 15 October, 2012 Accepted 10 January, 2013)
3. Avneesh Kumar Vishwakarma, Dhaneshwari Sahu "Efficient Voltage Regulation in Three Phase A.C. Transmission Lines Using Static VAR Compensator" International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol. 2, Issue 5, May 2013
4. Chowdhury K. R., Di Felice M. , "Search: a routing protocol for mobile cognitive radio ad hoc networks," Computer Communication Journal, vol. 32, no. 18, pp. 1983-1997, Dec.20
5. De Kock, Jan; Strauss, Cobus .Practical Power Distribution for Industry . Elsevier.pp. 74–75. ISBN 978-0-7506-6396-0,2004.
6. Deb, Anjan K. Power Line Ampacity System . CRC Press. pp. 169–171.ISBN 978-0-8493-13066
7. Donald Fink, Wayne Beaty (ed) StandardHandbook for Electrical Engineers Eleventh Edition ,Mc Graw Hill, 1978, ISBN 0-07-020974-X ,page14-33
8. Entsoe "definition of a set of requirements to generating units," technical paper 2008.
9. Hingorani N.G, Gyugyi L., Understanding FACTS, Concepts and Technology of Flexible AC Transmission systems, IEEE Press 2000
10. Mark Ndubuka NWOHU " Voltage Stability Improvement using Static Var Compensator in Power Systems" Leonardo Journal of Sciences 1583-0233 Issue 14, January-June 2009 p. 167-172
11. Md M. Biswas, Kamol K. Das Voltage Level Improving by Using Static VAR Compensator (SVC) Global Journal of researches in engineering: J General Engineering Volume 11 Issue 5 Version 1.0 July 2011
12. Naseer M. Yasina and Mostafa Al-eedanya "Enhancement of Power System Transient Stability Using Static Var Compensator" International Journal of Current Engineering and Technology ISSN 2277 - 4106, Vol.3, No.2 ,June 2013
13. Omorogiuwa Esosa, Use of Flexible AC transmission system (FACT) devices in enhancing the efficiency of an electrical Network. 2013
14. Padiyar, K. R. Analysis of Sub-synchronous Resonance in Power Systems .Springer. pp. 169–177. ISBN 978-0-7923-8319-2, 1998.
15. Padiyar, K. R. Analysis of Sub-synchronous Resonance in Power Systems .Springer. pp. 169–177. ISBN 978-0-7923-8319-2, 1998.
16. Paserba, J.J.; "How FACTS controllers benefit AC transmission systems", Power Engineering Society General Meeting, IEEE, Vol.2, June 2004, pp:1257 – 1262
17. Prakash Mahela & Sheesh Ram Ola "comparison of ht shunt capacitors and svc for active and reactive power flow control in transmission line" International Journal of Electrical and Electronics Engineering (IJEEE) ISSN 2278-9944 Vol. 2, Issue 1, Feb 2013, 49-58 , IASET
18. Roberto Alves, Miguel Montilla, Ernesto Mora " increase of voltage stability and power limits using a static var compenstor"
19. Ryan, H.M. High Voltage Engineering and Testing . IEE. pp. 160–161.ISBN 978-0-85296-775-1, 2001
20. Sreenivasulu, Gouse Basha. Enhancement of Voltage Stability in Power System with Optimal Location of Static VAR Compensator International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering Vol. 2, Issue 7, July 2013
21. Sullivan, D.J., Paserba, J.J., Reed, G.F., Croasdaile, T., Pape, R., Shoup, D., et. al., "Design and Application of a Static VAR Compensator for Voltage Support in the Dublin, Georgia Area," FACTS Panel Session, IEEE PES T&D Conference and Exposition, Dallas Texas, May 2006
22. Taylor C., "Power System Voltage Stability," textbook ISBN 0-07-113708-4, McGraw Hill, 1994.
23. Van T. Custem, C.Vournas, Voltage stability of electric power system, Kluwer Academic publishers, Boston. 1998
24. Weedy B.M., (1979), Electric power systems , John Wiley, pg 149 second edition.
25. Zhang, B.M.; Ding, Q.F "The development of FACTS and its control", Advances in Power System Control, Operation and Management, APSCOM-97. Fourth International Conference, Vol.1, Nov. 1997, pp: 48 – 53

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