International Journal of Scientific Research and Engineering Development-– Volume 5 Issue 3, May-June 2022

Available at www.ijsred.com

RESEARCH ARTICLE OPEN ACCESS

Improving the Transient Stability of a Multi Transmission System Using Static VAR Compensators

Okonkwo Anthony Chibuike*, Prof G N Onoh***

Electrical and Electronics Engineering Department, Enugu State University of Science and Technology, ESUT, Enugu

Email; accurate803@gmail.com,

--************************----------------------------------

Abstract:

This research presents improving transient stability of multi transmission system using static VAR compensator. This was done after the characterization of the Nigerian 30bus 330kv transmission network and identified three buses with low voltage profile due to instability arising from fault. The study developed an SVC and installed at the fault buses to correct the voltage profile from an average of 0.67pu to 1.01pu. This was implemented using Simulink and tested via simulations and the result showed that when fault occurred, power flow is affected in the transmission lines. During excess high voltage, the SVC inductance bank was used to absorb the active power for stability and also when low voltage, the SVC capacitance bank was used to inject the reactive power for stability. The SVC developed after testing was integrated on the three selected bus characterized with instability and comparative analysed. The result showed that with SVC the voltage profile was stable compared to without SVC.

Keywords **— Transmission System, Distribution Network, Static VAR Compensator,**

--************************----------------------------------

I. INTRODUCTION

In recent years, transmission networks are overloaded and are pushed closer to their stability limits. This is as a result of increasing demand for electricity due to growing Nigerian population which as at today to the best of my knowledge is over 200 million. This could have negative effect on the power system security. The security of a power system is regarded as the ability of the network to withstand disturbances without breaking down (Izuegbunam et al., 2019)

One of the indices to assess the state of security of a power system is the transient stability and it involves the ability of power system to remain in equilibrium or return to acceptable equilibrium when subjected to large disturbances. However, there is instability when increase in the load results in uncontrollable decrease in voltage capacity (Onojo et al. 2018). This is usually as a result of the reactive power not equating reactive load. Voltage instability caused by avalanche of voltage unstableness in power system is a subject of great concern in today's power system planning and design. Hence there is need for stability of power system at all times, in the event of credible contingencies.

Secondly, the important operating task of power utility is to maintain voltage within appropriate range for good quality of service. These have not being possible because of increased demand of power over the recent years (Izuegbunam et al., 2019). Due to this continuous increase in power demand, the existing power systems are more and more pressurized such that they operate in a stable limit. Any further pressuring of the system beyond the stability limit may lead to voltage instability and subsequent voltage collapse.

Various methods of determining the transient instability in power system by both the indigenous and foreign based researchers have been proposed to combat this epidermis of transmission instability; some include numerical integration, direct method, probabilistic method and the artificial intelligent methods such as artificial neural networks Onojo et al. (2018), opined that one of the factors to determine the level of integrity of a power system (i.e. transmission capability limit and flexibility of power system) is the level of security of the network based on transient stability assessment. Therefore, power system transmission integrity can be enhanced by devising a means of improving transient stability.

Nigeria power system is faced with series of technical challenges due to long, radial, weak and aging transmission network. Different studies have been done on Nigerian 330kV transmission network by various indigenous researchers with each researcher focusing on different aspect of performance assessment with a view to improving the network:

Powers electronics like shunt static capacitors/reactors and synchronous condensers were extensively used to reduce the level of reactive power flowing in transmission and distribution networks. But these elements are costly, bulky and often relatively inefficient

With the increase in complexity of power system and heavy load demand on the system, coupled with restrain which could be economical and environmental in nature, the challenge of voltage instability increasingly becomes an issue making power systems to operate approaching their limits

The aim of the study is to improve the transient stability of a multi transmission system using static VAR compensators, with the following set out objectives;

i. To perform systematic review of past research works
ii. To characterize the present Nigerian 330KV transmission parameters and improve on it using Simulink
iii. To develop the model of the 330KV interconnected transmission network and study the power flow using load flow analysis
iv. To design a static VAR compensator for the network and ensure transient stability
v. To implement the model using Simulink and evaluate the performance

This project realized will add to the efforts made at improving the stability of the Nigerians 330KV transmission network in the particular and power transmission networks in general. The success of the project will also translate to more available power for both industrial and domestic consumers in Nigeria. This will enhance productivity and quality of life. The research work will also serve as a good reference material to other scholar that will be researching on related area. The 330kv transmission system connects the generating stations and the load centres. Continuous increase in load demand adds stress on the generators, which could lead to system instability, and eventual collapse, the cost of losing synchronism through system collapse is extremely high. These problems must be avoided, hence the need to improve on the loading margin of the Nigeria 30 -bus, 330 KV network.

II. MATERIALS AND METHOD

Design Method

The process of interconnecting power source to the grid is called synchronization. This main aim of this process is to contain and manage energy produced to the grid. They re of four classes which are;

i. Direct machine couplings
ii. Partial power electronics couplings
iii. Full electronics coupling
iv. Distribution power electronics couplings

a) Direct machine coupling with the grid: This is a better methodology to transfer mechanical energy to electrical energy without intermediate stages. The machine although depends on the mechanical power supplies. In a case where constant power was used, the synchronous motor is the best; otherwise induction motor is used where variation of power is suitable.

b) Full power electronics coupling with the grid: This process matches the grid requirements with supplied energy to improve the energy sources performance. This has the capabilities to transform power using the control electronics switches called power electronics converter. The converters are mostly used for direct current to alternate current that are compatible with the requirement of the grid.

c) Partial power electronics coupling with the grid: This technique employs smaller size converters using the double feed induction generator to the grid. Converter feed the rotor while the stator is connected to the grid in a variable speed motor (Serge, 2014).

d) Distributed power electronics interface: This is the quantity of distributed machines that are linked to local grids through the power electronics converter. Anumaka (2018) presents the photovoltaic array interfaces through modular conversion process. This distribution active interfering architecture is presented to increase the system reliability and effectiveness of solar power batteries.

Materials

The system contains the following materials;

i. Monitoring PC
ii. Transmission line
iii. Substation
iv. ETP software

Characterization : The Nigerian 30bus, 330kv grid network was characterized. The characterization was done using load flow analysis to collect transmission line parameters line the phase angle, real and reactive power capacity, admittance etc. The parameters were collected from the grid network using load flow analyser tool and recorded as shown below while the load flow model will be presented shortly.

Table.1: Data from the 30 Bus 330KV transmission network

Bus Names	V [p.u]	Phase [rad]	P Flow[p.u.]	Q Flow[p.u.]
ALAOJI	0.981032	-0.73188	5.181951	2.695448
SAPELLE1	1	-0.68211	-36.9771	-23.8358
AKANGBA	0.958026	-0.73967	50.61488	3.753548
AJA	0.998455	-0.69709	-18.8374	-8.02673
JEBBA	1	-0.12629	1.863246	3.194321
KADUNA	0.747704	-0.77868	-18.951	-18.9252
New Haven	0.84567	-0.83531	8.814445	4.154353
SHIRORO	1	-0.50778	-8.63556	-4.18825
UGWUAJI	0.743033	-0.92351	-3.59135	-4.35942
AFAM	1	-0.72005	-11.7188	-12.5704
AJAOKUTA	0.991724	-0.69668	8.85365	4.473013
ALADJA1	0.99764	-0.69409	-5.18134	-1.72711
AYEDE	0.946013	-0.74187	8.85365	4.473013
BENIN1	0.986123	-0.70047	-1.5E-13	8.23E-14
DELTA1	1	-0.69019	-11.2478	-6.07014
EGBIN	1	-0.69434	-19.0858	-1.94633
GEREGU1	1	-0.67187	-25.0724	-18.2424
GOMBE	0.481268	-1.29274	6.132487	4.925603
GWAGWA	0.988903	-0.50997	24.99649	30.9299
IKEJA W	0.960772	-0.73506	10.79445	17.39072
JOS	0.63106	-1.00791	-3.87488	-9.15351
KAINJI	1	0	5.848547	0.426743
KANO	0.69997	-0.87204	-2.20338	-3.89174
KANTANPE	0.988903	-0.50997	8.635562	2.051427
KEBBI	0.993249	-0.01471	3.175867	-0.34198
MAKURDI	0.668612	-0.99161	-6.08653	-6.47034
OKPAI	1	-0.72782	13.33166	8.199671
ONITSHA	0.946346	-0.75562	51.08352	-1.33086
OSHOBO	0.947324	-0.72565	-14.0472	-7.9066
YOLA	0.469706	-1.33806	4.690071	2.10454

The table 1 presents the report of the 30 Bus 330KV transmission network characterized with phasor parameters for real and reactive power, phase magnitude and voltages magnitudes respectively. From the data collected it was observed that certain bus like the Yola, Gombe, Kano, Jos, Ugwualji, New Haven and Markudi all have low voltage profile as a result of transient instabilities and need immediate rectification.

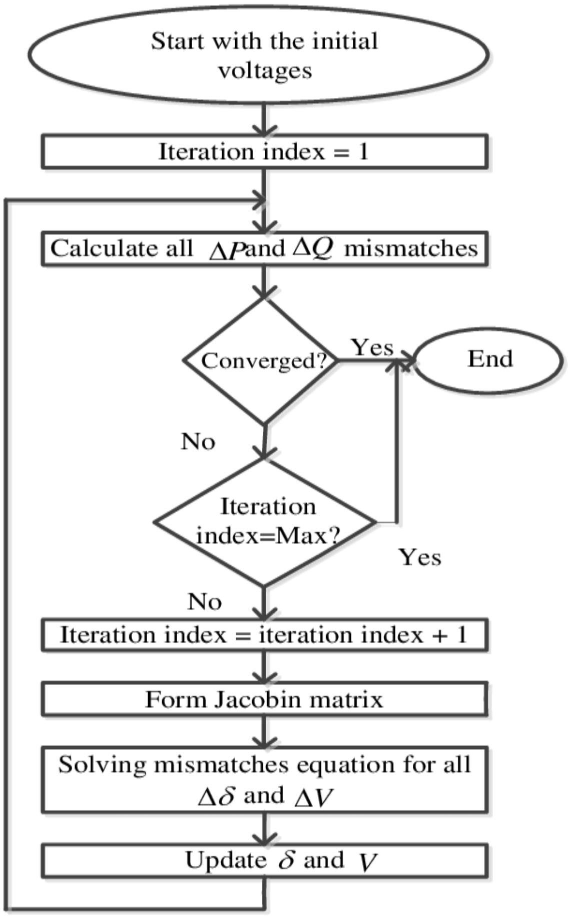

Figure 1: Modeling diagram of the load flow analysis

Modeling and System Design

The system will be designed using the mathematical modelling of the following;

i. Modeling the inter connected transmission lines
ii. Modeling the power flow within the lines
iii. Model of fault causing transient instability
iv. Model of the SVC design

Modeling of the interconnected transmission lines: The model of the three phase transmission line was developed using the Clarke transform model (Mark, 2009). This models the transmission line considering phase self inductance, line to line mutual inductance and resistance, line to line capacitance and line to ground capacitance. To simplify unified this power characters, the Clarke transformation model was adopted considering the power structure in the figure.2 with the respective values presented in the simulation parameters (see table.1).

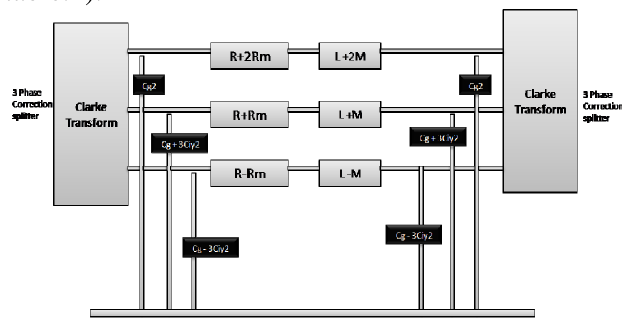

Figure.2: equivalent three phase interconnected transmission line model

Given that:
R is the line resistance for the segment.
R_m is the mutual resistance for the segment.
L is the line inductance for the segment.
C_g is the line-ground capacitance for the segment.
C_l is the line- line capacitance for the segment.
T is the Clarke's transformation matrix.
I1 is the three-phase current flowing into the ~1 port.
I2 is the three-phase current flowing into the ~2 port.
V1 is the three-phase voltage at the ~1 port.
V2 is the three-phase voltage at the ~2 port.

Model of power flow within the 330KV Transmission Network: The model of the power flow was developed using the basic load flow formulation which related the transmission network parameters using Newton Raphson technique as shown below;

$$\Delta P_k = P_{Gk} - P_{Lk} - P_k{}^{cal} = P_k{}^{sp} - P_k{}^{cal} = 0 \quad (.1)$$

$$\Delta Q_k = Q_{Gk} - Q_{Lk} - Q_k{}^{cal} = Q_k{}^{sp} - Q_k{}^{cal} = 0 \quad (.2)$$

The terms ΔP_k and ΔQ_k are the mismatch active and reactive powers at bus k, respectively. P_{Gk} and Q_{Gk} represent, respectively, the active and reactive powers injected by a generator at bus k. P_{Lk} and Q_{Lk} represent the active and reactive powers drawn by the load at bus k, respectively, and are assumed to be known variables.

In principle, at least, the generation and the load at bus k may be measured by the electric utility and their net values are known as the specified active and reactive powers:

$$\Delta P_k = P_{Gk} - P_{Lk} \qquad (.3)$$

$$\Delta Q_k = Q_{Gk} - Q_{Lk} \qquad (.4)$$

The transmitted active and reactive powers, ${P_k}^{cal}$ and ${Q_k}^{cal}$, are functions of nodal voltages and network impedances and are computed using the power flow equations. The algorithm or the Newton Raphson was presented earlier in figure 1.

Description of Fault in the transmission network

This section will describe the most various causes of transient instability on the 330KV network which has been pointed out in the literature review as various types of faults which are the single phase and three phase faults respectively.

a) Single phase or line to ground fault: Line to ground fault is one of the most frequent type of power transmission system faults. The conventional transmission system is equipped with three main live lines of current carrying conductors and a single ground conductor installed at every transmission structure as a multi grounding system. In this transmission network, a line to ground fault is considered when one of the three current carrying conductors using labeled A, B or C operated at a zero potential difference.

Figure 3 provides a visual representation of a hypothetical point on a transmission line in which a phase A to ground fault has occurred. The Zf fault impedance represents the fault impedance through the current carrying conductor to grounded equipment. This Zf impedance value can vary depending on the physical condition that is causing the fault.

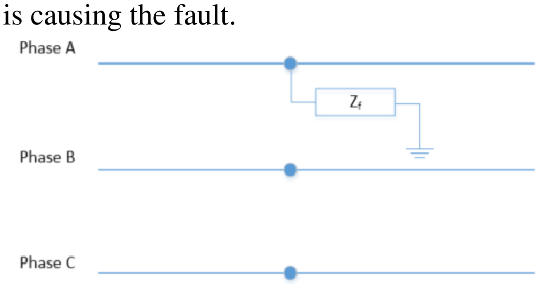

Figure.3: Equivalent model of Line to Ground Fault

b) Three phase fault: The three-phase fault is a last fault type that will be studied within this dissertation. This fault type is also the rarest of all faulted conditions to occur. Three-phase fault conditions occur when all three current carrying conductors have become in contact with each other. The only possible faulted combination that can happen on a three-phase system is when phases A, B, and C come in contact with each other. These faults, as with the other three fault classifications we have discussed previously, will contain some amount of fault impedance. The fault impedance, Zf, within the three-phase fault condition is modeled such that the fault current in each phase must flow through the fault impedance within each phase. Figure 3.4 provides a visual representation of the three-phase fault classification.

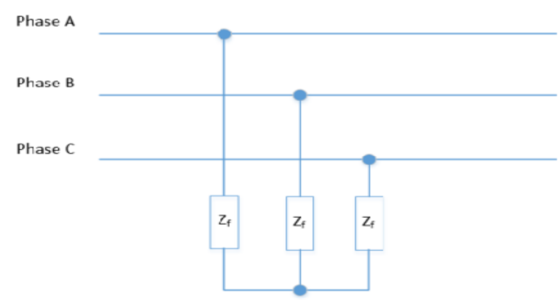

Figure 4: Equivalent model of the Three Phase Fault

Development of the SVC compensator

The Static VAR Compensator (SVC) is a shunt device of the flexible AC transmission system family using power electronics to control the flow of power and improve transient stability in the power grid. The SVC regulates voltage through the control of reactive power injected (SVC capacitive) or absorbed (Inductive) from the power system depending on the voltage condition (high or low). The capacitive bank is designed by a power electronic device (thyristor switches) which can act as a switch, reactor or phase controller. The SVC has four main sections which are used to design the block diagram in figure.5

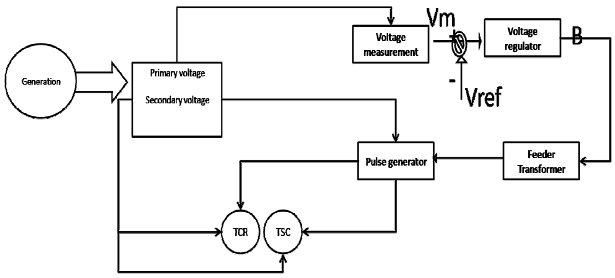

Figure 5: Block diagram of SVC

Block diagram of SVC as shown in figure.5 consists of the measurement system, the pulse generator, feeder unit and the regulator unit respectively.

i. Measurement System: measures the positive-sequence primary voltage. This system uses discrete Fourier computation technique to evaluate fundamental voltage over a one-cycle running average window.
ii. Voltage Regulator uses a PI regulator to regulate primary voltage at the reference voltage
iii. Feeder Unit uses the primary susceptance B_{svc} computed by the voltage regulator to determine the TCR firing angle α and the status (on/off) of the three TSC branches.
iv. The firing angle α as a function of the TCR susceptance

The feeder Unit consists of three independent subsystems, one for each phase (AB, BC and CA). Each subsystem consists of a PLL synchronized on line-to-line secondary voltage and a pulse generator for each of the TCR and TSC branches. The pulse generator uses the firing angle α and the TSC status coming from the Distribution Unit to generate pulses. The firing of TSC branches can be synchronized (one pulse is sent at positive and negative thyristor at every cycle) or continuous.

The SVC model is represented by the approximation of simple transfer functions that yields the correct output of a system fundamental frequency as follows;

H(s) $\frac{1}{1+s\,Tm}$: transfer function of the phasor parameters .5

$G_R(s) = \frac{Ksl}{1+s\,T}$: transfer function of the voltage regulator and slope unit .6

$G_B(s) = \frac{1}{1+s\,Td}$: transfer function of the compensator main circuit .7

$G_N(s) = X_e$: Transfer function of the network.

Where K_i is the voltage regulator for the integrator gain, T_m is the measurement time constant, X_{SL} is the steady gain error, T_b is the firing delay for the thyristor and T_d the gating delay

Location of the SVC

The placement of SVC is based on acceleration of generators. The equation of the generators without damping is given as

δ = ώΔP/ 2H 8

Here δ denotes the machine's rotor angle, H is inertial constant and ΔP gives the mismatch between the mechanical power into the machine and its electrical output. The machine which needs to be controlled through SVC is determined on the basis of oscillation made by it. The acceleration of the two machines at node I, j is given by;

δ_{IJ}= $ώ_o$/2(ΔPi/ Hi – ΔPj/ Hj) = EF_{ij} 9

This equation is called 'effectiveness factor' and is used to find the location of SVC. The higher the value of this factor will give best location for SVC connection Made. SVC is a controlled Static VAR compensator can deliver or absorb the reactive power at its point of connection. SVC is also used for voltage control in power system

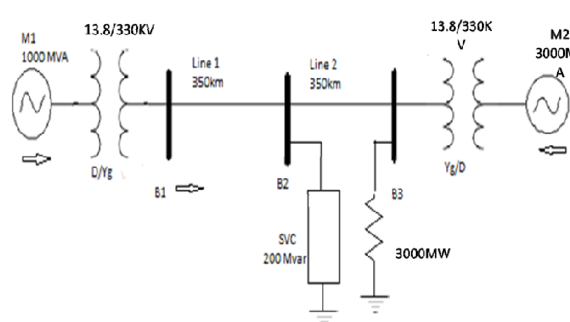

Figure 6: The single line diagram of the system

Implementation of the model

The models were implemented using the mathematical equations developed from equation .1 to 7 and the equivalent modeling circuits used to model the various components within the 30Bus, 330KV interconnected transmission network. Recall in the characterization that some bus line like the Newhaven, Ugwuaji among other are characterized with instabilities. The Simulink diagram in figure 6 presented the implementation of the interconnected 330KV Bus networks with the SVC for power control. The source codes are presented in appendix A.

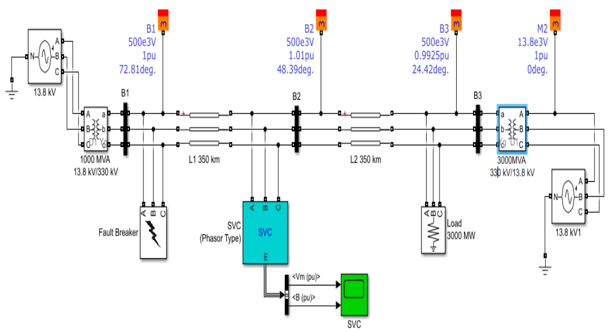

Figure 7: Simulink model of the SVC interconnected transmission lines

III. RESULT AND DISCUSSIONS

The results of the simulation performance of the new system developed and simulation parameters are presented below in **table. 2**

Table 2: simulation parameters

Parameters	Values
Number of buses	3
Transmission lines (KV)	330
Number of faults	2
Thyristor control	0.001s
Steady state error	0.01- 0.05 p.u
Capacity of generator 1	1000MVA
SVC rating	200Mvar
Capacity of generator 2	2000MVA

The simulation of the model implemented was done to test the performance of the 330KV transmission network under transient instability using fault conditions. The result was presented as shown below.

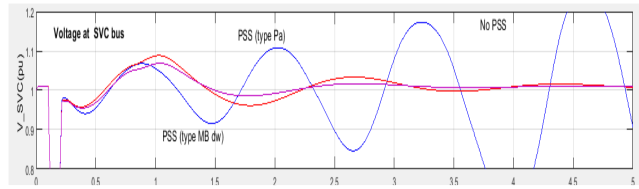

Figure 8: the performance of the network under transient instability

From the result presented in the figure 8 the behaviour of the load flow performance of the transmission network under transient instability using faults were presented. From the result was observed that when fault was induced, the lines became very unstable due to the presented of active and reactive power fluctuations, thus leading to unstable voltage magnitude. To rectify this challenge an SVC was installed at the bus point of the transmission lines and the effect presented the result as shown below;

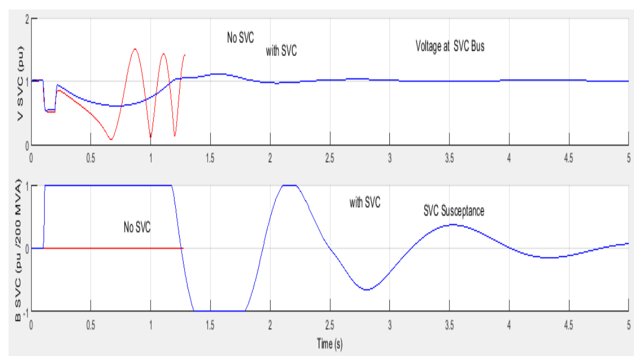

Figure 9: performance of the SVC at the transmission system

The result in figure 9 presented the performance of the SVC when single phase fault was induced to cause instability. It was revealed at after 1.3s which is the time of the fault occurrence, the SVC was able to control the fault and immediately restored normalcy by absorbing reactive power using the inductance. It was revealed that with fault the voltage magnitude dropped and changes continuously which indicated instability. However, with the SVC the voltage magnitude was restored to stableness after the inductance absorbs the reactive power due to fault.

The next result presented the performance of the SVC when signal phase fault occurred. This lead to the inducement of active and reactive power in the system leading to unstable voltage profile as shown below;

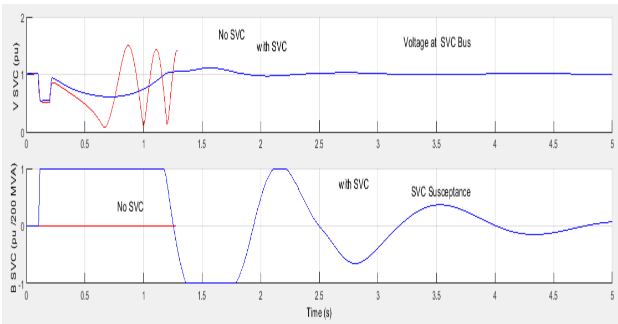

Figure 10: SVC performance during single phase fault

In the result of figure 10, when single phase fault occurred on the transmission network, this resulted to nonlinearity within the first 1.3s at the bus voltage magnitude. However with the installation of the SVC, the instability was controlled and the voltage magnitude was restored to stability. This effect of this result on the load flow analyser was presented on the figure 11 below;

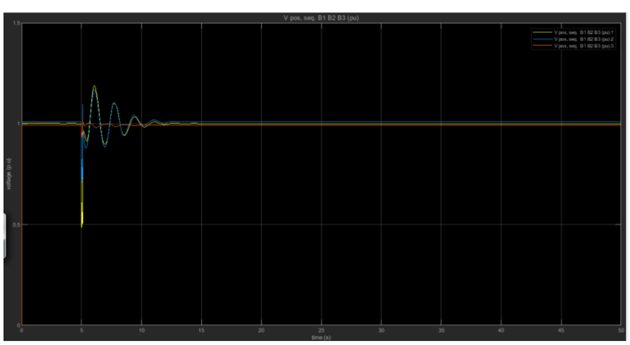

Figure 11: three phase fault control on the transmission line

The figure 11 presented the performance of the SVC as a controller to absorb fault current as shown. The fault occurred at 5s but was controlled after 6s of its occurrence. The figure showed that during the time of fault that nonlinearity occurred in the voltage magnitude as 5 to 11s, but the SVC was able to control the fault and restored the voltage magnitude which is stable (constant). The next result presented the load flow performance during transient due to single phase fault.

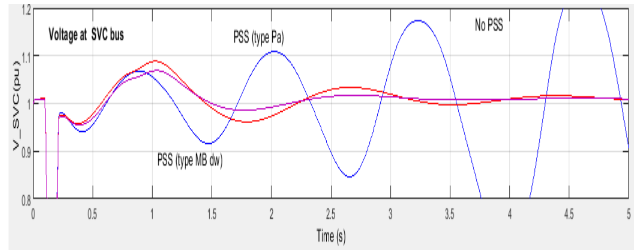

Figure 12: single phase fault on the transmission line

The figure 12 presented the performance of the load flow during single phase fault. The result showed how the voltage magnitude was affected due to the fault resulting to transient instability. This fault induced reactive power on the line leading to instability. To rectify this challenge, the SVC was installed on the line Bus and used to control the instability via the inductance to absorb reactive power as a result of the fault. The control response is presented below;

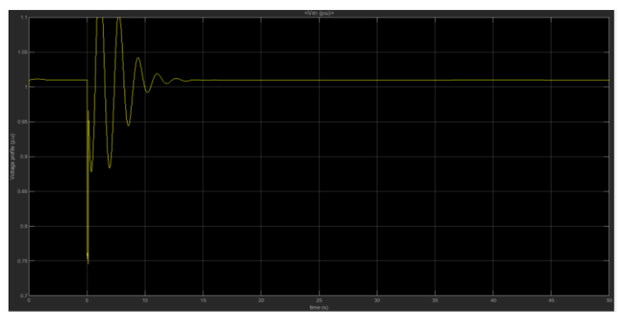

Figure 13: SVC during single phase fault

From the result it was observed that the voltage profile was restoring to stability as the SVC was able to inject active power by the capacitance when that of the load flow was low and also absorbs reactive power using the inductance when the flow rate was high as a result of fault. The new voltage magnitude was restored to an average of 1.01 (p.u).

Performance at the 30 Bus 330Kv network

When the SVC was installed at the selected buses with low voltage magnitude from the characterized bus 330kv transmission lines network to ensure power flow control during fault conditions, the following result was achieved.

Table 3: result of the corrected buses using SVC

Bus Names	V [p.u.]
UGWUAJI	1.04345
New Haven	1.05563
GOMBE	1.08138
JOS	1.06041
KANO	1.03201

The result in table 3 presented the performance of the corrected buses using SVC. The SVC was used to absorb excess reactive power from the bus using inductance and also control active power flow using capacitance during the time of transient instability. The result achieved an average voltage magnitude of 1.01.

Comparative analysis

Comparative analysis was performed to evaluate the performance of the SVC and the characterized system. The data collected using the load flow analyzer is presented below;

Table 4. Comparative result

Bus Names	V [p.u.] without SVC	V [p.u.] with SVC
UGWUAJI	0.743033	1.04345
New Haven	0.84567	1.05563
GOMBE	0.481268	1.08138
JOS	0.63106	1.06041
KANO	0.69997	1.03201

The data collected from the table 4. was analysed using the load flow analyser tool and the result presented as shown below;

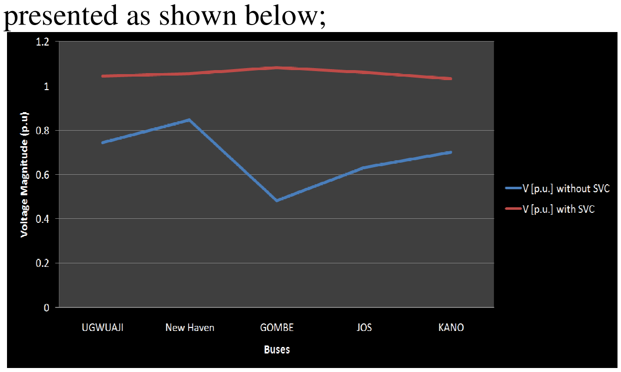

Figure 14: comparative result

From the result a comparative analysis was performed on the buses identified for the study and the result showed that with SVC a stable voltage magnitude was achieved with an average of 1.01000pu when compared the characterized bus with an average voltage magnitude of 0.68032pu.

IV. CONCLUSIONS AND RECOMMENDATION

This research has sucessfully improved the stabikity prfomance of the Nigerian 30Bus, 330Kv transmission network using SVC. This research charcaterized the national grid and identified certian bus like the kano, newhaven, ugwuaji, markurdi, gombe and yola as buses with challenges of transcient instability as at the time of charcaterization. The research developed an SVC and then installed at the bis level of the transmission lines for each of the identified transient chalenges. The result was tested and it was revealed that the voltage magnitudes was improved from average of 0.67pu to 1.01pu.

Conclusion

This project work have studies and analyzed the performance of the nigerian 330KV grid system considering the reactive power compnsation charcateristics. This was done using amthlab and the neceaasry power syste, optimization toolbox to acheive the propsed aim.

By nature the electrical power system is dynamic and presents a compex nonlinear load and instantaneous quantities to predict the relationship between the simulated and real data collections. The previosu chapter presents the performance of the system using SVC for the power flow analysis so as to optimzie the system behaviour. The aim was to ensure at reactiev power is generated and stable voltage profile. This was employed for the stability of compex power system and snusre the desired votlage instability and pahse angle result is acheived.

Recommendation

Having concluded this research, the folowing are recommended

i. Artificial intelligence tehcnique can use use to improve the sensing time of the SVC for transcient instability
ii. Adaptive fault protection sstem can be installed on the nased to protect the netowkr against fault

Finding

i. SVC can act as both regulator and controller for power flow lines
ii. Six buses of the 30 bus 330kv transmission network of Nigeria is characterized with poor voltage magnitude

ACKNOWLEDGMENT

My first and foremost acknowledgement goes to the alpha and Omega, God Almighty for his inspiration and guidance throughout this research work from the beginning up to this final stage. To him is all the glory.

I sincerely wish to express profound gratitude to all who contributed one way or the other towards this reality research work making, most especially to my able supervisor; Prof. G. Onoh, .

My special gratitude goes to my Wife, Mrs Okonkwo for her financial and moral support throughout my days in the schools, and I also acknowledged mostly the indefectible work of my friend, Nwabueze Charles N, for his assistant toward my Education.

I just want to say thanks to you all.

REFERENCES

[1] Anumaka M C, 2018. Analysis of technical losses in electrical power system (nigerian 330kv network as a case study) IJRRAS , 12, 320-327.

[2] Breuer, D. Povh, D. Retxmann, E. Teltsch, " Trends for Future HVDC Applications", 16th Conference of Electric Power Supply Industry, November 2016.

[3] Hingorani G. and Gyugyi Lazlo (2016) " Understanding FACTS: Concepts & technology of flexible AC Transmission Systems" ISBN 0-7803-3455-8.

[4] Izuegbunam F I, Duruibe S I, and Ojukwu G G, 2019. Power flow and contingency assessment simulation of the expanding 330kv nigeria grid using power world simulator. Journal of Emerging Trends in Engineering and Applied Sciences , 2, 1002-1008.

[5] Kumar S V R and Nagaraju S S, 2017. Transient stability improvement using upfc and svc. ARPN Journal of Engineering and Applied Sciences , 2, 1-6.

[6] Kaur T and Kakran S, 2012. Transient stability improvement of long transmission line system by using svc. International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering , 4, 218-227.

[7] Ogunjuyigbe A S O and Ayodele T R, 2015. Technoeconomic analysis of stand-alone hybrid energy system for nigerian telecom industry. Int. J. Renewable Energy Technology , in Press,

[8] Anumaka M C, 2018. Analysis of technical losses in electrical power system (nigerian 330kv network as a case study) IJRRAS , 12, 320-327.

[9] Onojo O J, Ononiwu G C, and Okozi S O, 2017. Analysis of power flow of nigerian 330kv grid system (pre and post) using matlab. European Journal of Natural and Applied Sciences , 1, 59-66.

[10] Izuegbunam F I, Duruibe S I, and Ojukwu G G, 2019. Power flow and contingency assessment simulation of the expanding 330kv nigeria grid using power world simulator. Journal of Emerging Trends in Engineering and Applied Sciences , 2, 1002-1008.

[11] Onohaebi O S and Igbinovia S O, 2018. Voltgae dip reduction in he nigerian 330kv trasmission grid.

[12] Jody Verboomen, Dirk Van Hertem, Pieter H. Schavemaker, Wil L. Kling, Ronnie Belmans, " Phase Shifting Transfomers: Princples and Application", IEEE.

[13] K. R. Padiyar, A. M. Kulkarni, "Flexible AC transmission systems: A status review", Sadhana, Vol.22, Part 6, pp. 781-796, December 2017.

[14] Kaur T and Kakran S, 2012. Transient stability improvement of long transmission line system by using svc. International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering , 4, 218-227.

[15] Laszlo Gyugyi, Colin D. Schauder, Kalyan K. Sen, (2017) " Static Synchronous Series Compensator: A Solid-State Approach To The Series Compensation of Transmission Lines", IEEE Transaction on Power Delivery, Vol.12, January 1997.

[16] Mark Ndubuka NWOHU, " Voltage Stability Improvement using Static Var Compensator in Power Systems", Leonardo Journal of Sciences, Issue 14, p 167-172, January-June 2009.

[17] Mazilah Binti and Ahab Rahman, (2013)"Overview of Thyristor Controlled Series Capacitor (TCSC) In Power Transmission System".

[18] Nadarajah Muthulananthan, Arthit Sode-yome, Mr. Naresh Acharya, "Application of FACTS Controllers in Thailand Power Systems", Asian Institute of Technology, Jan 2005.

[19] Nitus Voraphonpiput, Teratam Bunyagul and Somchai Chatratana (2013), Power Flow Control with Static Synchronous Series Compensator (SSSC)".

[20] Ogunjuyigbe A S O and Ayodele T R, 2015. Technoeconomic analysis of stand-alone hybrid energy system for nigerian telecom industry. Int. J. Renewable Energy Technology , in Press,

[21] Onohaebi O S and Igbinovia S O, 2018. Voltgae dip reduction in he nigerian 330kv trasmission grid.

[22] Onojo O J, Ononiwu G C, and Okozi S O, 2017. Analysis of power flow of nigerian 330kv grid system (pre and post) using matlab. European Journal of Natural and Applied Sciences , 1, 59-66.

[23] Rajiv K. Varma, M. Noroozian, C. W. Taylor, (2018); "Benefits of SVC and STATCOM for Electric Utility Application".3122153829, Introduction to FACTS Controllers", Member, IEEE.

[24] Sidhartha Panda and N. P. Padhy (2013, "Thyristor Controlled Series Compensator- based Controller Design Employing Genetic Algorithm: A Comparative Study", International Journal of Electronics, Vol. 1.

[25] Umar S V R and Nagaraju S S, 2017. Transient stability improvement using upfc and svc. ARPN Journal of Engineering and Applied Sciences , 2, 1-6.

[26] Zhang X. "Robust modeling of the interline power flow controller and the generalized unified power flow controller with small impedances in power flow analysis", Electrical Engineering, Vol. 89, pp 1-9, 2016.

