International Journal of Electrical and Power Engineering 5 (1): 13-17, 2011
ISSN: 1990-7958
© Medwell Journals, 2011

Effects of Static Synchronous Compensator (STATCOM) on Voltage Stability and Transmission Losses of Electric Power Systems

Nwohu Mark Ndubuka
Department of Electrical/Electronics Engineering, Federal University of Technology,
P.M.B. 65, Minna, Niger State, Nigeria

Abstract: This study investigates the effects of applying Static Synchronous Compensator (STATCOM) to electric power systems with losses. The northeast and part of northwest of the Nigerian grid system is chosen for a case study in order to characterize the performance of the entire power systems and infer at what point or under what condition, the system can suffer from emergency voltage instability. The intent is to examine whether such FACTS (Flexible AC Transmission System) device can be effective in minimizing the transmission losses and improve the voltage stability. Simulation results carried out in the PSCAD/EMTDC environment are presented to show the significant reduction of power losses in transmission lines and improvement of voltage stability with STATCOM.

Key words: Electric power systems, FACTS devices, STATCOM, transmission losses, voltage stability, Nigeria

INTRODUCTION

With the ever increasing complexities in power systems across the globe and the growing need to provide stable, secure, controlled, economic and high-quality electric power, it is envisaged that Flexible AC Transmission System (FACTS) controllers are going to play a critical role in power systems (Arnold, 2001). FACTS devices can be used to influence power flows to support voltages to increase transmission capacity over an existing transmission corridor to damp system oscillations and to increase stability margins. Due to the fast control characteristics and continuous compensating capability of these FACTS devices, it is imperative that they should be made with high precision to ensure correct behaviour on power systems.

Otherwise, they could quickly initiate system instabilities which can lead to power system outages, loss of generation or unacceptable voltage fluctuations (Gyugi, 1994). Basically, Static Synchronous Compensator (STATCOM) is a voltage-sourced converter which is connected in shunt with the transmission line through a shunt transformer.

It is voltage favourable and can generate full capacitive output at low voltage (Canizares, 2000; Sadikovic *et al*., 2004; Song and Johns, 1999).

Usually, a long and loaded overhead transmission line is characterized as an inductive reactance (i.e., consumes reactive power as it transmits the active power) resulting in power losses. But the connection of STATCOM to the transmission line will increase, its transmission capacity and will produce more reactive power to provide voltage and transient stability and hence reducing the power losses on transmission lines.

Many studies have been carried out and reported in literature on the use of STATCOM in improving voltage and transient stability (Canizares *et al*., 2003; Mathur and Varma, 2002; Scarfone *et al*., 2003). However, not much has been reported on the minimization of power losses on transmission line by the use of STATCOM. This study studies the effects of applying STATCOM to electric power systems with the intent to minimize the transmission losses and improve voltage stability under contingency conditions.

MATERIALS AND METHODS

STATCOM modeling and its control system: In order to investigate the impact of STATCOM on power systems effectively, appropriate STATCOM model is very important.

STATCOM is a voltage sourced converter which is connected in shunt with the transmission line through a shunt transformer.

Thus, it is modeled using a voltage source $V_{STATCOM}$ and V_{shunt}. During the steady state and dynamic analysis, the control variables $V_{STATCOM}$ and V_{shunt} are transformed into injected nodal currents according to Eq. 1. The mathematical model of STATCOM is shown in Fig. 1.

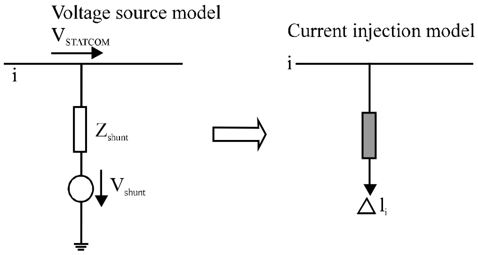

Fig. 1: STATCOM mathematical model

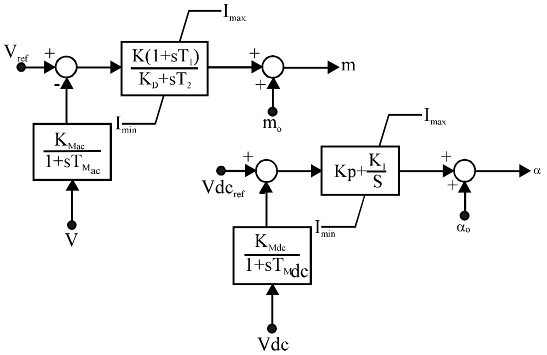

Fig. 2: Basic STATCOM pulse width modulation voltage control

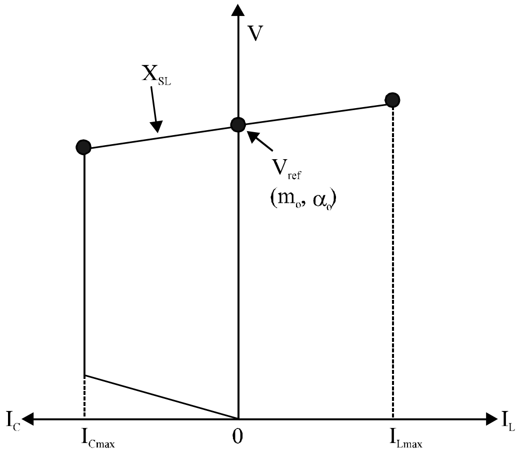

Fig. 3: The voltage/current characteristics of a STATCOM

$$\Delta I_i = \frac{\overline{V}_{statcom} - \overline{V}_{shunt}}{Z_{shunt}} \qquad (1)$$

A simple pulse width modulation voltage controller of STATCOM is shown in Fig. 2 (Uzunovic *et al.*, 1999; Reeve *et al.*, 1999). The ac bus voltage magnitude is controlled through the modulation index, m since this has a direct effect on the ac side Voltage Sourced Inverter (VSI) voltage magnitude. The phase angle α, determines the active power flowing into the controller which charges and discharges the capacitor. This phase angle is used to directly control the dc voltage magnitude. The controller limits are defined in terms of the controller current limits (i.e., maximum and minimum converter currents $I_{max}(I_{Lmax})$ and $I_{min}(Ic_{max})$, respectively.

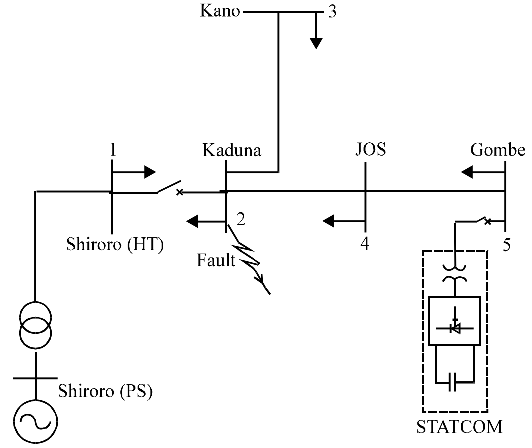

Fig. 4: Northeast and part of Northwest Nigeriar grid system

Figure 3 shows the controller current limits in the voltage/current characteristic of the STATCOM which illustrates how the STATCOM offers better voltage support and improve voltage stability margin by providing more reactive power at lower voltages (Garcia-Gonzalez and Garcia-Cerrada, 1999; Wang *et al.*, 1998).

Studied system: The northeast and part of Northwest of the Nigerian grid system (330 kV) is used to validate the STATCOM model discussed in this study. The network is modeled with 5 buses, 4 branches and 1 hydro-unit as shown in Fig. 4. The parameters of the system are obtained from Power holding company of Nigeria. STATCOM is optimally sited at bus 5.

RESULTS AND DISCUSSION

Simulation results: At steady state, the network in Fig. 4 was evaluated and observed to be prone to voltage instability at loads above 200 MW. This network is used to validate the STATCOM model into the PSCAD (Power System Computer Aided Design) based on detailed EMTDC (Electromagnetic transients) simulation results. The EMTDC is used to simulate the STATCOM operating under phase control.

A 3 phase to ground fault was initiated at bus 2 at 300 ms which triggers the circuit breaker at 400 ms to clear the fault without STATCOM and the voltages obtained were as shown in Table 1. Consequently, the

Table 1: Bus voltage profile with and without STATCOM

Bus no.	Bus name	Load demand (MW)	Without STATCOM (kV)	With STATCOM (kV)
1	Shiroro	61.5	332.87	327.8
2	Kaduna	166.2	315.00	314.4
3	Kano	184.9	309.40	310.8
4	JOS	58.4	302.10	313.6
5	Gombe	102.9	268.90	330.0

Table 2: Transmission losses with and without STATCOM

			Real power losses (MW)		Reactive power losses (MVar)	
Lines	Names	Distance (km)	With STATCOM	Without STATCOM	With STATCOM	Without STATCOM
1-2	Shiroro-Kaduna	96	0.873	1.047	2.11	7.87
2-3	Kaduna-Kano	230	2.980	3.137	11.46	23.59
2-4	Kaduna-JOS	197	1.098	2.274	6.89	17.13
4-5	JOS-Gombe	265	3.512	4.738	11.86	35.57

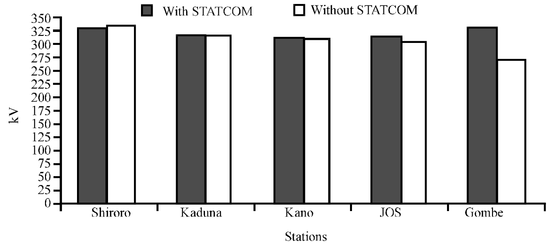

Fig. 5: Voltage output with and without STATCOM (kV)

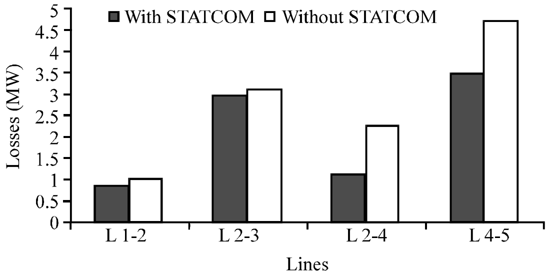

Fig. 6: Real power losses with and without STATCOM

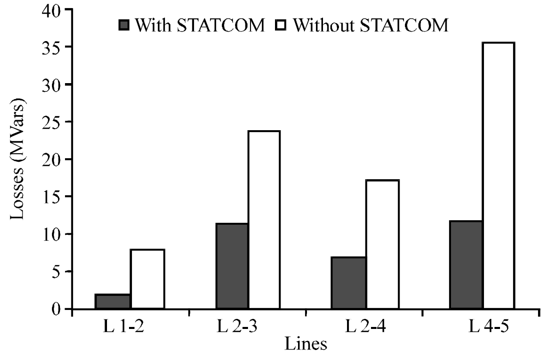

Fig. 7: Reactive power losses with and without STATCOM

Table 3: Voltage output with variation in load demand at Gombe bus

Buses	Stations	Load demand (MW)	Without STATCOM	With STATCOM	Load demand (MW)	Without STATCOM	With STATCOM
1	Shiroro	61.5	333.1	332.4	61.5	330.9	330.0
2	Kaduna	166.2	312.6	311.8	166.2	308.6	306.8
3	Kano	184.9	289.5	303.6	184.9	300.3	301.6
4	JOS	58.4	327.4	329.7	58.4	301.7	310.4
5	Gombe	67.9	323.7	330.4	215.0	221.4	329.9

Table 4: Transmission losses with variation in load demand at Gombe bus

			Real power losses		Reactive power losses	
Lines	Names	Load demand @ bus 5	With STATCOM	Without STATCOM	With STACOM	Without STACOM
1-2	Shiro-Kad.	67.9	0.098	0.176	0.647	3.698
2-3	Kad.-Kano		1.437	2.178	4.021	18.948
2-4	Kad.-JOS		0.426	1.058	1.692	12.354
4-5	JOS-Gomb		1.637	3.352	7.501	27.183
L1-2	Shiro-Kad.	215.0	1.098	3.176	1.647	13.698
L2-3	Kad-Kano		3.437	4.178	5.021	38.948
L2-4	Kad-JOS		1.426	2.058	3.692	22.354
L4-5	JOS-Gombe		4.637	6.352	17.501	87.183

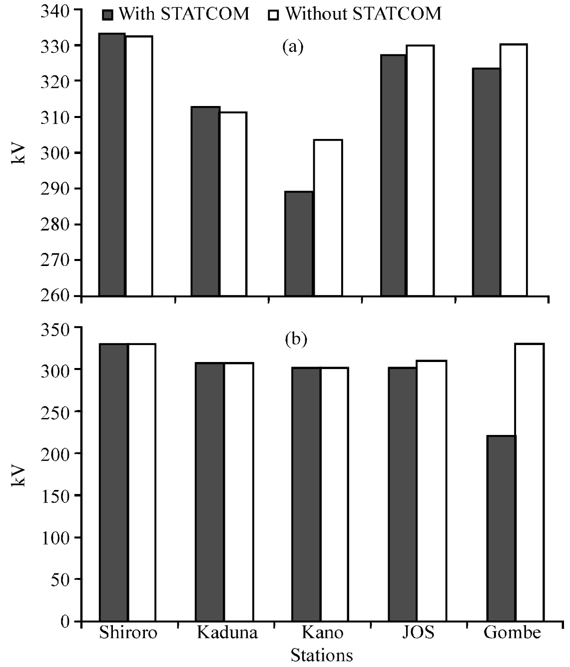

Fig. 8: Voltage output at the load of; a) 67.9 MW; b) 215.0 MW (Gombe bus)

power losses along the transmission line were also read and recorded as shown in Table 2. It is generally observed that the voltage at which bus 5 operated was very low but considerably improve at the connection of STATCOM (Fig. 5). However, the transmission line losses were reasonably high.

But with the STATCOM embedded on the line, the losses were drastically reduced as shown in Fig. 6 and 7. Furthermore, the loading of the system was varied at bus 5 in order to examine the robustness of the

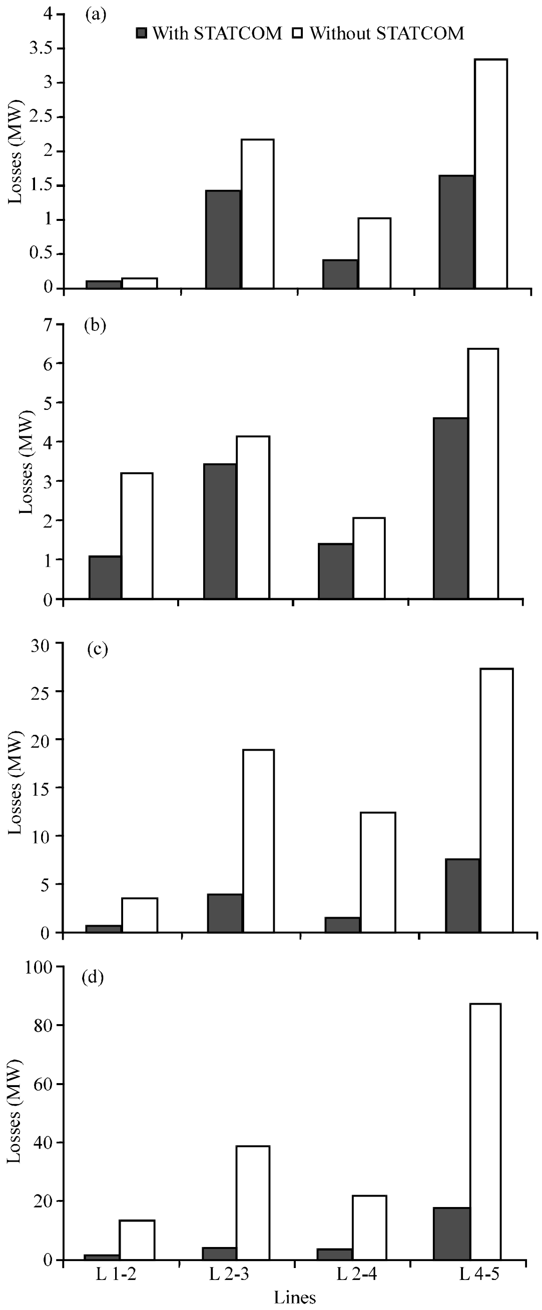

Fig. 9: Real power losses at; a) 67.9MW load; b) 215.0 MW; c) Reactive power losses at 67.9 MW; d) 215.0 MW load (Gombe bus)

STATCOM in the reduction of the system losses and voltage stability enhancement. The system was then results in system voltages and losses as shown in Table 3 and 4, respectively. The effects of STATCOM can be appreciated as it is connected at the variation of the load at Gombe (Fig. 8a, b and 9a, b).

CONCLUSION

Evaluations of the electric power network at steady state showed that Gombe in Northeast region of the Nigerian grid system is vulnerable to possible voltage collapse. Simulations confirmed that a dynamic reactive compensator such as a STATCOM could provide the fast acting voltage support necessary to prevent the possibility of voltage collapse and minimize the power losses along the transmission lines.

It is observed that the reduction of reactive power losses along the transmission lines is more pronounced than the active power losses with consequent improvement of the system voltage profiles as the STATCOM is connected to the system.

REFERENCES

Arnold, R., 2001. Solutions to the power quality problem. Power Eng. J., 15: 65-73.

Canizares, C.A., 2000. Power flow and transient stability models of FACTS controllers for voltage and angle stability studies. Proceedings of the Power Engineering Society Winter Meeting, Jan. 23-27, USA., pp: 1447-1454.

Canizares, C.A., M. Pozzi, S. Corsi and E. Uzunovic, 2003. STATCOM modeling for voltage and angle stability studies. Int. J. Electrical Power Energy Syst., 25: 431-441.

Garcia-Gonzalez, P. and A. Garcia-Cerrada, 1999. Control system for a PWM-based STATCOM. Proceedings of the Power Engineering Society Summer Meeting, July 18-22, Edmonton, AB Canada, pp: 1140-1145.

Gyugi, L., 1994. Dynamic compensation of AC transmission lines by solid state synchronous voltage sources. IEEE Tran. Power Delivery, 9: 904-911.

Mathur, R.M. and R.K. Varma, 2002. Thyristor-based FACTS Controllers for Electrical Transmission Systems. 1st Edn., Wiley-Interscience, New York, USA., ISBN: 978-0-471-20643-9, pp: 495.

Reeve, J., A. Canizares and E. Uzunovic, 1999. Transient stability model of unified power flow controllers and control comparisons. Submitted for Publication in IEEE Transaction Power Delivery and Available Upon Request, pp: 1-11.

Sadikovic, R., G. Andersson and P. Korba, 2004. Power flow control with FACTS devices. Proceedings of the World Automation Congress, (WAC'04), Seville, Spain, pp: 91-95.

Scarfone, A.W., B.K. Oberlin, J.P. di Luca, D.J. Hanson and C. Horwill, 2003. A ±150 MVAr STATCOM for Northeast utilities glenbrook substation. Proceedings of the Power Engineering Society General Meeting, July 13-17, USA., pp: 132-141.

Song, Y.H. and A.T. Johns, 1999. Flexible AC Transmission Systems. IEE Press, London, ISBN: 0852967713.

Uzunovic, E., A. Canizares and J. Reeve, 1999. EMTP studies of UPFC power oscillation damping. Proceedings of the North American Power Symposium (NAPS), October 1999, San Luis Obispo, California, pp: 405-410.

Wang, H.F., F.J. Swift and M. Li, 1998. An unified model for the analysis of FACTS devices in damping power system oscillations. II. multi-machine power systems. IEEE Trans. Power Delivery, 13: 1355-1362.