

Research Article

Ideal Site of Shunt FACTS Devices for Power Flow Control in Long Transmission Line

G. Sundar, M. Thirunavukkarasu and C. Dhinesh Kumar

Department of Electrical and Electronics Engineering, Arulmigu Meenakshi Amman College of Engineering, Kanchipuram, Tamil Nadu, India

Abstract: A Power flow control, in an existing transmission line, plays an imperative role in Power System. This study makes use of the Shunt Attached Compensation (STATCOM) FACTS device for the manipulation of voltage and the power flow in a transmission line. The proposed devices are used in different sites such as sending end of the, middle and receiving end of the transmission line. Simulations were carried out using MATLAB SIMULINK software. The apposite location and the performance of the proposed model were examined. In this study a STATCOM is cast off to standardize voltage in a power system. The STATCOM more proficiently boost the voltage stability and upsurge transmission size in a power system. In this study a semblance is also performed between SVC and STATCOM under burden state and it is shown that STATCOM have the adeptness to take care for more capacitive power during a slip over SVC. It is also shown that STATCOM revelations accelerated retort than SVC.

Keywords: Optimal location, PWM, reactive power, STATCOM, SVC, transmission line

INTRODUCTION

The growth of power electronics brings into operation FACTS devices in power systems. FACTS devices are adept for monitoring the network settings in a very profligate manner and this unique feature of FACTS devices can be put upon to titivate the stability of a system. Power compensation is a critical concern in electrical power systems. For that shunt FACTS devices play a crucial starring role in controlling the reactive power flow to the power network. Hence the system voltage fluctuations and stability remains un-affected. SVC and STATCOM are adherents of FACTS family that are coupled in shunt with the system (Panda and Patel, 2006). Even though the prim devotion of shunt FACTS devices is to support bus voltage by pump out or suck up reactive power, they are also adept of improving the transient stability by increasing or decreasing the power transfer capability when the machine angle increases or decreases, which is realized by operating the shunt FACTS devices in capacitive or inductive mode in a transmission line.

The efficacy of SVC and STATCOM of the identical mark for the augmentation of power flow, they have focused on two or more VSCs are coupled to a DC link modeling converter-based controllers and in their approach they allowed efficient implementation of several VSC in force bounds, where one or more VSCs are loaded to their rated capacity (Hingorani and Gyugyi, 2006). The shunt FACTS devices give

supreme benefit from their alleviated voltage backing when seated at the intermediate of the transmission line. The proof of maximum increase in power transfer ability is based on the cut down model of the line being incurred for resistance and capacitance of the line. However, for long transmission lines, when the definite model of the line is considered, the ravages may deviate think through from those found in the abridged model.

This study consists of the comparison of various results found for the different sites on the shunt FACTS device in a long line in view of the tangible models of the line for a stability study. Computer simulation ravages under a lop off ruckus condition three phase defect for different fault clearing times and different sites of FACTS devices are evaluated. It is felt that for the actual long transmission line model with a predefined direction of real power flow, shunt FACTS device needs to be located slightly off-center. Further the site of these devices hangs down on the amount of local load and through the load (Haque, 2000; Tan, 1999). In this study performance strategy were conducted on SVC and STATCOM at different locations such as sending end, middle and the receiving end of the long distance line. In every part of the location the power flow is tested through and devoid of compensation tactics. A mathematical modeling style and check design are presented in the proposed work. The SIMULINK model of the prevailing system is established and tested using MATLAB SIMULINK environment.

Corresponding Author: G. Sundar, Department of Electrical and Electronics Engineering, Arulmigu Meenakshi Amman College of Engineering, Kanchipuram, Tamil Nadu, India

This work is licensed under a Creative Commons Attribution 4.0 International License (URL: <http://creativecommons.org/licenses/by/4.0/>).

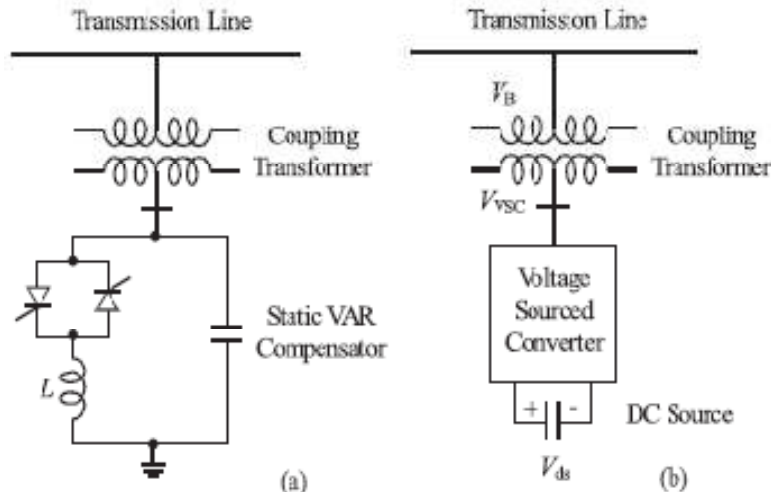


Fig. 1: (a) SVC coupled to the line, (b) STATCOM coupled to the line

METHODOLOGY

Shunt facts devices in power system: Shunt FACTS devices are differentiated into two kinds, namely flexible impedance type and switching converter type.

SVC: The SVC uses conventional Thyristors to attain fast check of shunt coupled capacitors and reactors. The structure of the SVC is shown in Fig. 1a, which comes right down with a Capacitor (C) and a TCR. The SVC makes adequate smoother and clear-cut check. It improves the stability of the network and it can be adapted instantaneously to new situations.

The main applications in transmission, distribution and industrial networks are:

- Keeping of contractual power exchanges with balanced reactive power
- Compensation of Thyristor converters e.g., In conventional HVDC lines
- Improvement of static or transient stability

The firing angle regulation of the thyristor bank firmly decides the peer shunt admittance turned out to the power system (Chandrakar and Kothari, 2003; Masood *et al.*, 2010).

STATCOM: The STATCOM has a characteristic as shown in Fig. 2. The structure of a STATCOM is shown in Fig. 1b. Typically, a STATCOM consists of a coupling transformer, an inverter and a DC capacitor (Johnson, 2004). In such an arrangement, in ideal steady state analysis, it can be assumed that the active power exchange between the AC system and the STATCOM can be neglected and only the reactive power can be exchanged between them. Have a high regard to bus voltage STATCOM can operate in inductive region or capacitive region from Fig. 2 (Sode-Yome and Mithulananthan, 2004).

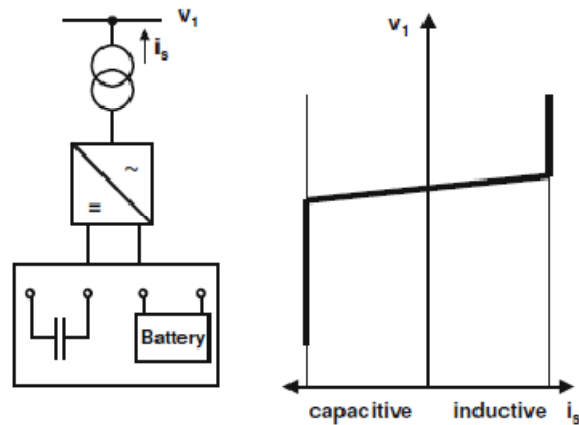


Fig. 2: Equivalent circuit of STATCOM with its VI characteristics

RESULTS AND DISCUSSION

Description of STATCOM and SVC: The power grid made up of two 500 KV counterparts, individually 3000 MVA and 2500 MVA, associated with a 600 km long line. When the STATCOM is not in maneuver, the normal power flow on the line is 925.8 MW from bus B1 to B3. The device has a mark of +/- 100 MVA. This STATCOM is a phase model of a typical three-level PWM STATCOM. STATCOM is coming up through a DC link nominal voltage of 40 KV through a parallel capacitance of 375 μF (Sharma *et al.*, 2007) On the AC side, its total corresponding impedance is 0.22 Pu on 100 MVA. This impedance typifies the transformer trickle reactance and the phase reactor of the IGBT Bridge of a definite PWM STATCOM (Salemmia *et al.*, 2009; Garg and Kumar Agarwal, 2012).

Simulation results: Initially V_{ref} is set to 1 Pu; at $t = 0.2$ sec, V_{ref} is decreased to 0.97 Pu; then at $t = 0.4$ sec, V_{ref} is increased to 1.03; and finally at 0.6 sec, V_{ref}

Table 1: Comparison of P and Q at B1, B2 and B3 with SVC

FACTS devices Position	SVC					
	B1		B2		B3	
	P in MW	Q in MVar	P in MW	Q in MVar	P in MW	Q in MVar
With out	921.8	-119.8	867.9	-33.25	861.4	65.38
Sending end	947.5	-99.10	826.0	-56.35	812.1	67.94
Middle end	940.1	-79.95	820.4	-37.39	806.5	56.34
Receiving end	952.5	-99.59	830.2	-54.77	816.2	70.95

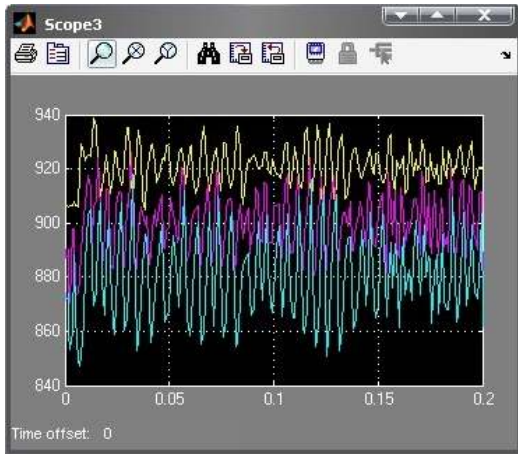


Fig. 3: Real power at B1, B2 and B3 without compensation

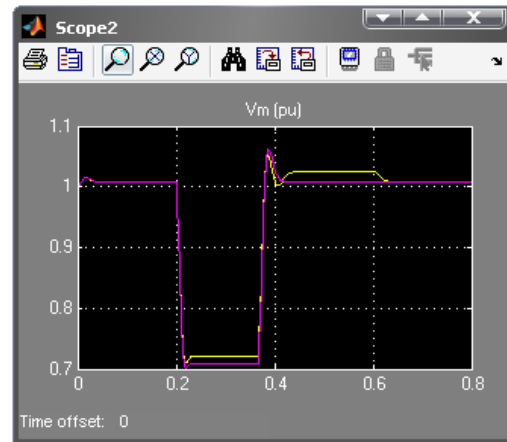


Fig. 5: Voltage V_m of SVC and STATCOM at middle end

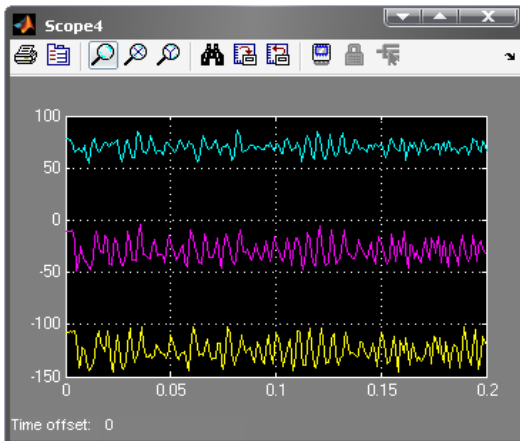


Fig. 4: Reactive power at B1, B2 and B3 without compensation

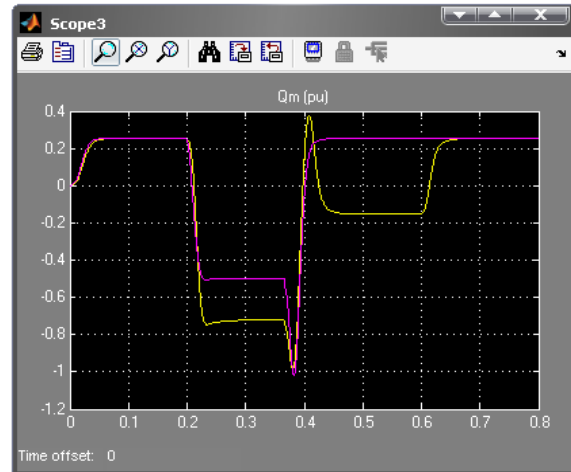


Fig. 6: Reactive power Q_m of SVC and STATCOM at middle end

is set back to 1 Pu. And also the flow breaker at bus B_1 will not function during the bus B_1 will not carry out during the simulation. The ravages were attained through and lacking recompense and also the numerical results were tabulated in Table 1. Figure 3 and 4 highlights the real and reactive power control at the three stages when the STATCOM and SVC is not connected i.e., without compensation. B_1 , B_2 and B_3 and also tabulated the result in Table 1. The circuit diagram when SVC is connected at the sending end of the long transmission line. Similarly the connections are made when the SVC is connected at the middle and receiving end of the long transmission line.

The Real power across buses B_1 , B_2 and B_3 without compensation is shown in Fig. 3. The Real power is occurring at sending end B_1 (921.8 MW), Middle end B_2 (867.9 MW) and receiving end B_3 (861.4 MW) buses, as indicated in Fig. 3.

The Reactive power across buses B_1 , B_2 and B_3 without compensation is shown in Fig. 4. The reactive power is occurring at sending end B_1 (-119.8 MVAR), Middle end B_2 (-33.25 MVAR) and receiving end B_3 (65.38 MVAR) buses, as indicated in Fig. 4.

The Voltage V_m of SVC and STATCOM at middle end is shown in Fig. 5. The measured voltages V_m of

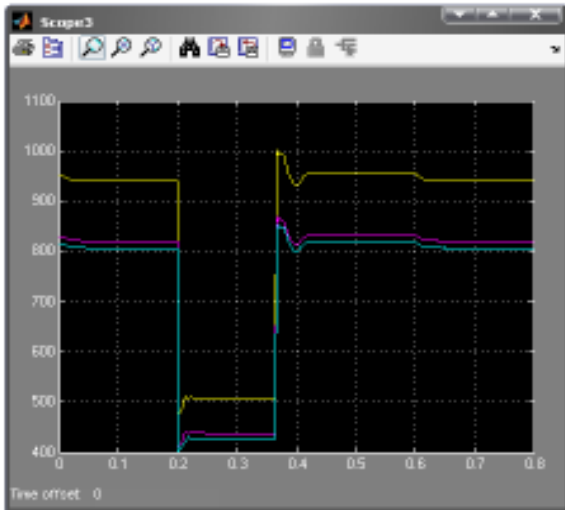


Fig. 7: Real power at B1, B2 and B3 with STATCOM at middle end

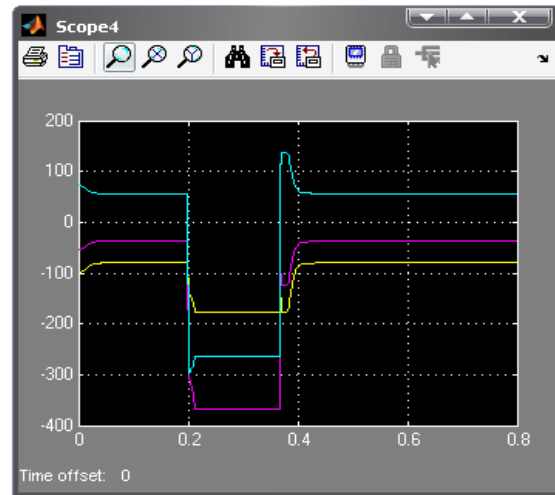


Fig. 10: Reactive power across B1, B2 and B3 with SVC at middle end

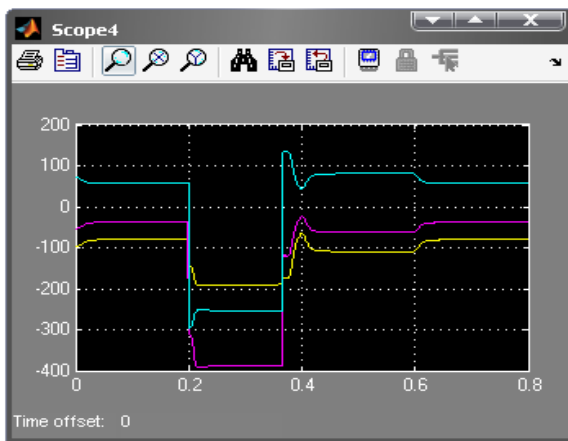


Fig. 8: Reactive power at B1, B2 and B3 with STATCOM at middle end

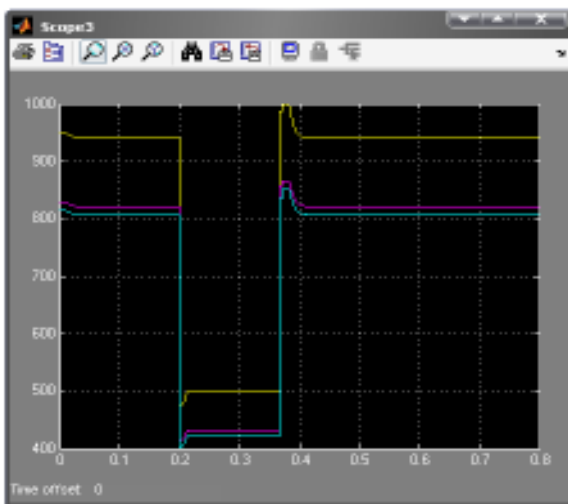


Fig. 9: Real power across B1, B2 and B3 with SVC at middle end

both devices are represented as magenta trace of SVC and yellow trace of STATCOM in Fig. 5.

The Reactive Power Q_m of SVC and STATCOM at middle end is shown in Fig. 6. The measured Reactive Power Q_m of both devices are represented as magenta trace of SVC and yellow trace of STATCOM in Fig. 6.

The Real power across buses B1, B2 and B3 with STATCOM at middle end, is shown in Fig. 7. The Real power is occurring at sending end B1 (940.1 MW), Middle end B2 (820.5 MW) and receiving end B3 (806.5 MW) buses, as indicated in Fig. 7.

The Reactive power across buses B1, B2 and B3 with STATCOM at middle end, is shown in Fig. 8. The reactive power is occurring at sending end B1 (-79.97 MVAR), Middle end B2 (-37.43 MVAR) and receiving end B3 (56.36 MVAR) buses, as indicated in Fig. 8.

The Real power across buses B1, B2 and B3 with SVC at middle end, is shown in Fig. 9. The Real power is occurring at sending end B1 (940.1 MW), Middle end B2 (820.4 MW) and receiving end B3 (806.5 MW) buses, as indicated in Fig. 9.

The Reactive power across buses B1, B2 and B3 with SVC at middle end, is shown in Fig. 10. The reactive power is occurring at sending end B1 (-79.95 MVAR), Middle end B2 (-37.39 MVAR) and receiving end B3 (56.34 MVAR) buses, as indicated in Fig. 10.

The results were getting along and default of compensation. The simulation ravages reveal that the reactive power spawned is outdo at the middle of the transmission line when contrast by means of the further terminates of the line and also the voltage is controlled at the middle of the line. So, the location of SVC is optimum when connected in the middle of the line. SVC performs at the middle end of transmission line. The numerical results of the system analysis were elaborated in the Table 1.

The results were obtained with and without recompense. The simulation outcome reveals that the

Table 2: Comparison of P and Q at B1, B2 and B3 with STATCOM

FACTS devices Position	STATCOM					
	B1		B2		B3	
	P in MW	Q in MVAr	P in MW	Q in MVAr	P in MW	Q in MVAr
With out	921.8	-119.8	867.9	-33.25	861.4	65.38
Sending end	947.5	-99.11	826.0	-56.35	812.1	67.94
Middle end	940.1	-79.97	820.5	-37.43	806.5	56.36
Receiving end	952.5	-99.60	830.2	-54.78	816.2	70.94



Fig. 11: Archetype module with source



Fig. 13: Archetype module with compensation

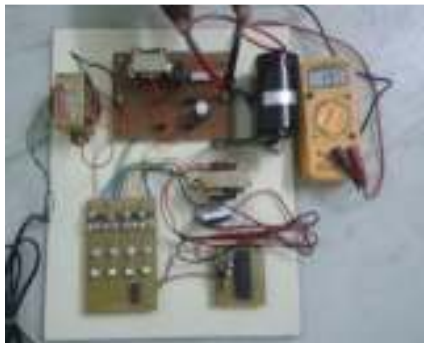


Fig. 12: Archetype module without compensation

voltage to load is shown in Fig. 12. Here have some loss of voltage due to the core and copper loss of grid transformer. The output voltage 19.5 V neglecting with losses has obtained in driver circuit is shown in Fig. 12.

In Fig. 13, the hardware circuit consists of driver circuit which is used to overcome the grid transformer loss and it is used to produce amplified voltage to the load from 19.5 to 23.2 V. The driver circuit is switched the led indicator will glow the output voltage given to the load a 230 V AC linear motor. Moreover, 230 V of supply is required to run, but the circuit could produce 23.2 V. Due to this voltage range, the motor could not run and it is simply vibrated.

reactive power bred is outdo at the middle of the transmission line when contrasted with the other ends of the transmission line and also the voltage is restrained in the middle of the line. Hence, the site of STATCOM is ideal when coupled at the middle of the line. STATCOM performs better reactive power compensation than SVC which is evident from the Table 2. The numerical results of the system analysis were elaborated in the Table 1 and 2.

Archetype implementation: The Archetype module with source is shown in the Fig. 11. It comprises of 230/24 volt step-down transformer, 24 volt grid transformer, Driver circuits (microcontroller PIC 16F874A/877A), STATCOM model, Load (motor), Multi meter for output measurement. The output voltage is displayed with the help of multi meter is shown in Fig. 12.

The input voltage from step down transformer (24 volt) given to grid transformer which is used to pass the

CONCLUSION

To improve the power transfer capability and to control the power flow in the power system network shunt FACTS devices, connect with long distance transmission lines. In this study STATCOM is employed as the shunt FACTS device. SVC is connected at several locations like sending end, middle and receiving end of the transmission line. The ravages were attained through and devoid of compensation. The replications ravage reveals that the reactive power spawned and the voltage control is better in the middle of the line when contrasted with the other ends of the transmission line. The statistical analysis of the system was elaborated in the Table 1 and 2. The Hardware implementation of the optimum location of the shunt FACTS devices for power flow control in long transmission line was done and the results are presented.

REFERENCES

- Chandrakar, V.K. and A.G. Kothari, 2003. Optimal location for line compensation by shunt connected FACTS controller. Proceeding of 5th International IEEE Conference on Power Electronics and Drive Systems, 1: 151-156.
- Garg, A. and S. Kumar Agarwal, 2012. Voltage control and dynamic performance of power transmission system using STATCOM and its comparison with SVC. *Int. J. Adv. Eng. Technol.*, 1(1): 437-442.
- Haque, M.H., 2000. Optimal location of shunt FACTS devices in long transmission lines. *IEEE T. Generat. Transm. Distribut.*, 147(4): 218-222.
- Hingorani, N.G. and L. Gyugyi, 2006. Understanding FACTS-concepts and technology of flexible ac transmission system. IEEE Power Engineering Society.
- Johnson, B.K., 2004. How series and combined multi terminal controllers FACTS controllers function in an AC transmission system. *IEEE Power Eng. Soc. General Meeting*, 2: 1265-1267.
- Masood, T., R.K. Aggarwal, S.A. Qureshi and R.A.J. Khan, 2010. STATCOM model against SVC control model performance analyses technique by MATLAB. Proceeding of International Conference on Renewable Energies and Power Quality (ICREPQ'10).
- Panda, S. and R.N. Patel, 2006. Improving power system transient stability with an off-centre location of shunt FACTS devices. *J. Elect. Eng.*, 57(6): 365-368.
- Salemnia, A., M. Khederzadeh and A. Ghorbani, 2009. Mitigation of Sub synchronous oscillations by 48-pulse VSC STATCOM using remote signal. *IEEE Bucharest on PowerTech*, pp: 1-7.
- Sharma, P.R., A. Kumar and N. Kumar, 2007. Optimal location for shunt connected FACTS devices in a series compensated long transmission line. *Turk. J. Elect. Eng.*, 15(3).
- Sode-Yome, A. and N. Mithulananthan, 2004. Comparison of shunt capacitor, SVC and STATCOM in static voltage stability margin enhancement. *Int. J. Elect. Eng. Edu.*, 41(2): 158-171.
- Tan, Y.L., 1999. Analysis of line compensation by shunt-connected FACTS controllers: A comparison between SVC and STATCOM. *IEEE T. Power Eng. Rev.*, 19: 57-58.