

Optimum Location of Shunt Fact Devices for Transmission Line Compensation

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ABSTRACT – Power flow control, in a current long transmission line, plays an energetic role in Power System area. This paper employs the shunt connected compensation (STATCOM) founded FACTS device for the control of voltage and the power flow in long distance transmission line. The future device is used in different positions such as sending end of the transmission line, middle and receiving end of the transmission line. The PWM control strategy is used to generate the firing pulses of the controller circuit. Simulations were carried out using MATLAB Simulink atmosphere. The suitable location and the recital of the planned typical were examined. Based on a voltage-sourced converter, the STATCOM regulates system voltage by absorbing or generating reactive power. Contrary to a thyristor-based Static Var Compensator (SVC), STATCOM output current (inductive or capacitive) can be skillful independent of the AC system voltage. The simulation consequences discloses that the reactive power generated is improved at the middle of the transmission line when compared with the other ends of the transmission line and also the voltage is controlled at the middle of the line. Henceforth the place of STATCOM is optimum when connected at the middle of the line.

Key Words: FACTS device, STATCOM, SVC, PWM technique, MATLAB Simulink.

1. INTRODUCTION

In modern era the applications of the power electronics devices in power systems are very much augmented. It is an urgent need to control the power flow, in a long distance transmission line. The FACTS devices are introduced in the power system transmission for the reduction of the transmission line losses and also to increase the transfer capability. STATCOM is VSC based controller to regulate the voltage by varying the reactive power in a long transmission line. Tan Y.L., et al [1] have demonstrated the effectiveness of SVC and STATCOM of same rating for the enhancement of power flow. Xia Jiang Xinghao Fang Chow et al [2] have focused on modeling converter-based controllers when two or more VSCs are coupled to a dc link (e.g., unified power-flow controller (UPFC), interline power-flow controller, and a generalized unified power-flow controller) and in their approach they allowed efficient implementation of various VSC operating limits, where one or more VSCs are loaded to their rated capacity. Chandrakar, V.K. et al [3] have investigated the optimal location of shunt FACTS devices in transmission line for highest possible

benefit under normal condition and also they considered three different line models namely, line impedance model, reactance model and π model. Bebic, J.Z. [4] have presented two such topologies, the first one consists of a shunt connected controllable source of reactive power, and two series connected voltage-sourced converters - one on each side of the shunt device which is named as "hybrid power flow controllers", or HPFC.

Johnson, B.K. [5] has presented an overview of how series connected and combined series/shunt connected FACTS controllers are studied in an AC system. Shankaralingappa, C.B. has achieved the optimum required rating of series and shunt flexible ac transmission systems controllers for EHVAC long transmission lines by computing 'optimum compensation requirement' (OCR) for different loading conditions. Shakib, A.D. has defined a sensitivity analysis, which is used to determine the area on which the FACTS device has significant influence, for the detection of sensor nodes and then only this limited area is included in the Optimal Power Flow control. Salemnia, A. et al [8] have proposed the concept of using remote signals acquired through PMU to damp SSR. K.R. Padiyar et al [9] have reflected a series passive compensation and shunt active compensation provided by a static synchronous compensator (STATCOM) connected at the electrical center of the transmission line to minimize the effects of SSR. Prabhu, N. et al [10] has investigated the sub synchronous resonance (SSR) characteristics of the system and proposed a novel method for the withdrawal of sub synchronous component of line current using filter. Zarghami, M. et al [11] has discussed a novel approach for damping interarea oscillations in a large power network using multiple STATCOMs. Yap, E.M. et al [12] have focused on the effective utilization of a flexible alternating current transmission system (FACTS) device called unified power flow controller (UPFC) for power flow control and also demonstrated the use of the latest power system analysis toolbox (PSAT) package for network analysis of alternative means of improving existing transmission capability. Yu Liu Bhattacharya, S. et al [13] have designed a controller in which an optimal combination modulation strategy is used, which leads to some challenges in designing the controller, such as extra switching and the balancing of individual dc capacitor voltages. Larki, F. et al [14] have presented a new approach for identification of optimal locations of STATCOM and SVC and also simulated case studies conducted on Kouzestan power networks in Iran based on the proposed techniques. Albasri, F.A. et al [15] have investigated a comparative study of the performance of distance relays for transmission lines compensated by shunt connected flexible ac transmission system (FACTS) controllers. In this paper performance strategy were

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conducted on STATCOM at different locations such as sending end, middle and the receiving end of the long distance transmission line. In every part of the location the power flow is tested with and without compensation strategy. A mathematical modeling approach and control design is presented in the proposed work. The simulink model of the standard system is developed and tested using MATLAB Simulink environment.

2. OPERATING PRINCIPLE

A STATCOM consists of a coupling transformer, an inverter and a DC capacitor is shown in Figure 1. Figure 1. Structure of STATCOM. Figure 2. Equivalent Circuit of STATCOM. For 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. STATCOM is usually used to control transmission voltage by reactive power shunt compensation. Based on the operating principle of the STATCOM [16], the equivalent circuit can be derived, which is given in Figure 2. In the derivation, it is assumed that (a) harmonics generated by the STATCOM are neglected; (b) the system as well as the STATCOM are three phase balanced. Then the STATCOM can be equivalently represented by a controllable fundamental frequency positive sequence voltage source V_{sh} . In principle, the STATCOM output voltage can be regulated such that the reactive power of the STATCOM can be changed.

a. STATIC VAR COMPENSATOR MODEL

The SVC uses conventional thyristors to achieve fast control of shunt-connected capacitors and reactors. The configuration of the SVC is shown in Figure 1. The elements of the SVC shown here consist of the following:

- FC that provides a permanently connected source of reactive power, designed also to act as a harmonic filter
- TCR that consists of bidirectional thyristor valves in series with shunt reactors, usually connected in delta configuration.

Since the firing angle control of the thyristor banks determines the equivalent shunt admittance presented to the power system, the SVC dynamic model can be expressed as follows.

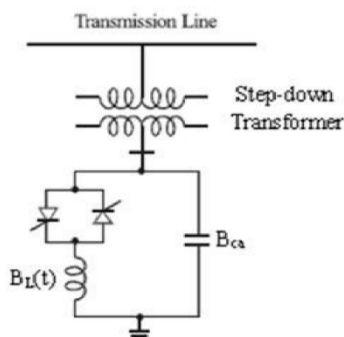


Fig.1 Configuration of an SVC.

b. STATIC SYNCHRONOUS COMPENSATOR MODEL

The static synchronous compensator (STATCOM), previously referred to as a static synchronous condenser (STATCON), resembles in many respects a rotating machine used for reactive compensation. The STATCOM is based on a solid state synchronous voltage source that is analogous to an ideal synchronous machine which generates a balanced set of three sinusoidal voltages, at the fundamental frequency, with rapidly controllable amplitude and phase angle. The configuration of a STATCOM is shown in Figure 2. The real current of the STATCOM is negligible and is assumed to be zero. Control of reactive current, $i_Q(t)$. A positive value of ϕ implies that the STATCOM is in the inductive region while a negative value implies that it is in the capacitive region. By controlling the reactive current of the STATCOM, the susceptance of the STATCOM, $B_Q(t)$, is varied according to the following relationship. Shunt-connected FACTS controllers such as the SVC and STATCOM are traditionally used for injection of reactive power. The sizes of these controllers are Determined from the steady-state requirements, i.e., how much reactive power (Q) is needed. Suppose that in steady-state the amount of Q needed by the power system is zero. In the following, a novel method for the analysis of the effectiveness of an SVC and a STATCOM of the same kvar rating, i.e., $Q = 0.2$ p.u.

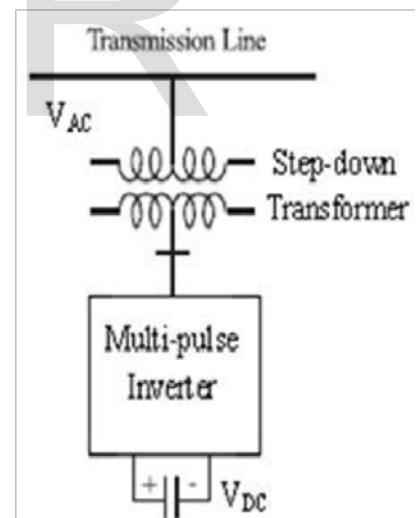


Fig.2 Configuration of an STATCOM

3. SIMULATION OF STATCOM

A. Circuit Description

The power grid consists of two 500-KV equivalents, respectively 3000 MVA and 2500 MVA, connected by a 600 km long transmission line. When the STATCOM is not in operation, the "natural" power flow on the transmission line is 925.8 MW from bus B1 to B3. STATCOM has a rating of +/- 100MVA. This STATCOM is a phasor model of a typical three-level PWM STATCOM. STATCOM is having a 155 DC link nominal

voltage of 40 KV with an equivalent capacitance of 375 μ F. On the AC side, its total equivalent impedance is 0.22 pu on 100 MVA. This impedance represents the transformer leakage reactance and the phase reactor of the IGBT bridge of an actual PWM STATCOM. Figure3 explains about the circuit diagram without compensation. In this circuit the power is directly measured in the 600km long transmission line at the three stages like B1,B2 explains about the circuit diagram when STATCOM is connected at the sending end of the long transmission line. Similarly the connections are made when the STATCOM is connected at the middle and receiving end of the Compensation Circuit Diagram of STATCOM at long transmission line. Figure(3),(4). Circuit Diagram without sendingend

Initially Vref is set to 1 pu; at t=0.2 s, Vref is decreased to 0.97 pu; then at t=0.4 s, Vref is increased to 1.03; and finally at 0.6s, Vref is set back to 1 pu. And also the fault breaker at bus B1 will not operate during the simulation. The results were obtained with and without compensation and also the numerical results were tabulated in table 1. Figure5 and Figure6 highlights the real and reactive power control at the three stages when the STATCOM is not connected i.e. without compensation.

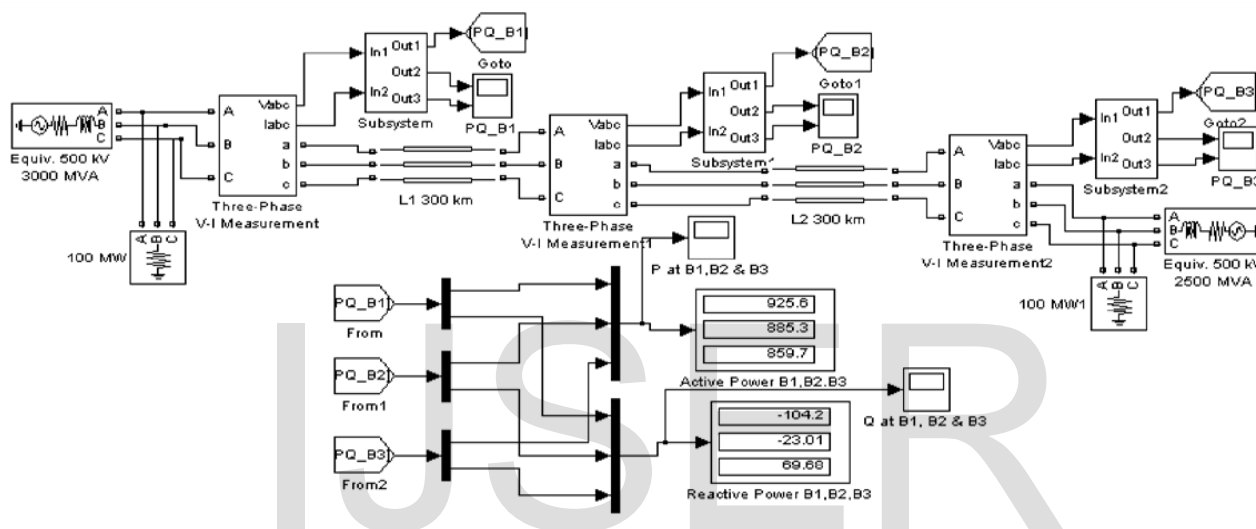


Fig 3 Circuit Description

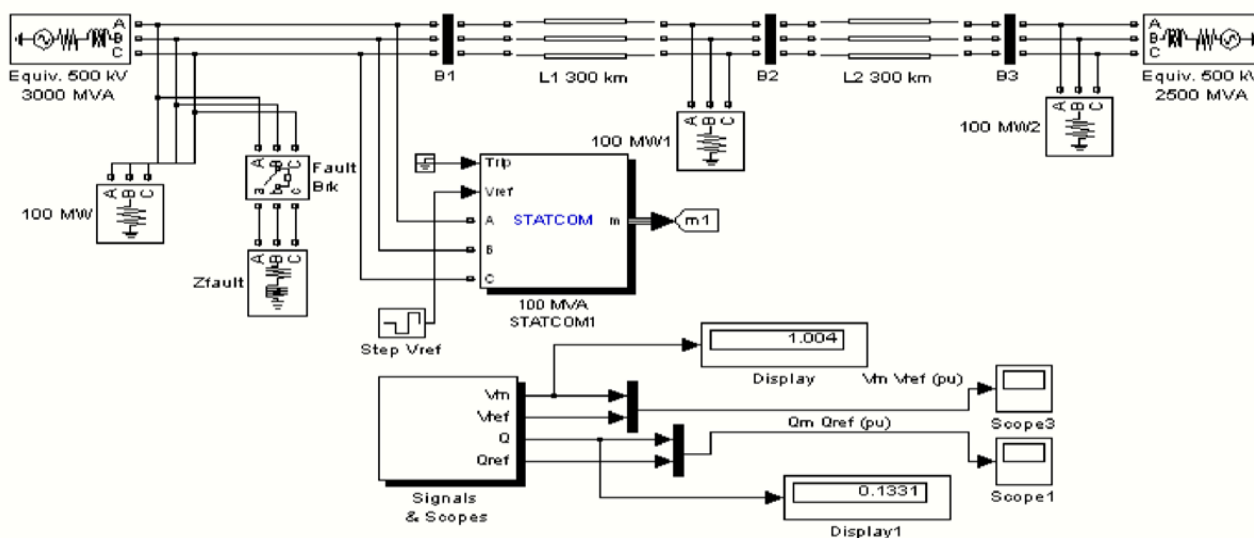


Fig 4 Circuit Description

3. SIMULATION RESULTS

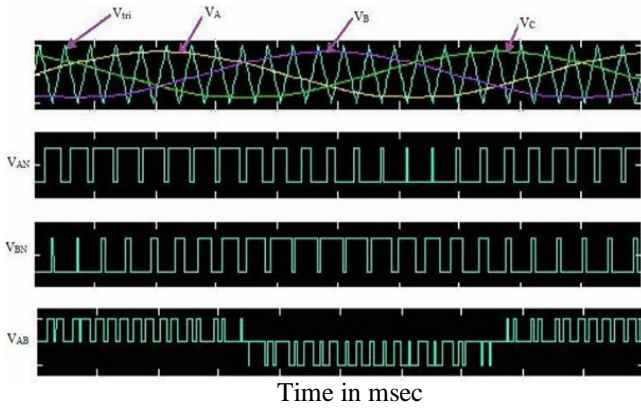


Figure5. Real Power at B1,B2& B3 without compensation

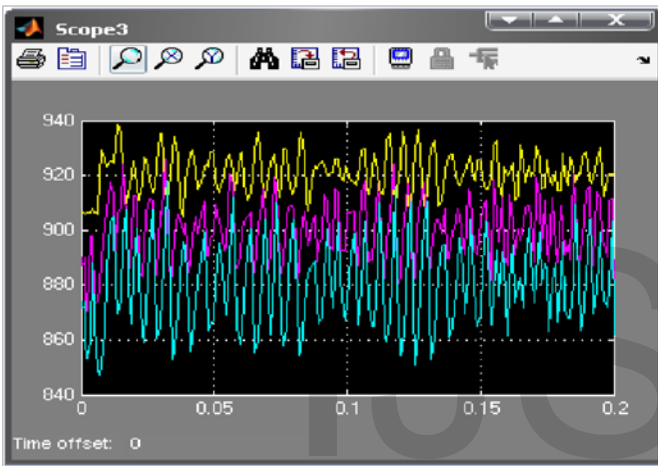


Figure6. Reactive Power at B1,B2& B3 without compensation

Figure7, Figure8 and Figure9 exhibits the active power at the three stages of the transmission line when STATCOM is connected at the sending end, middle and receiving end.

Figure7. Real Power at B1,B2& B3 when STATCOM is Sending End

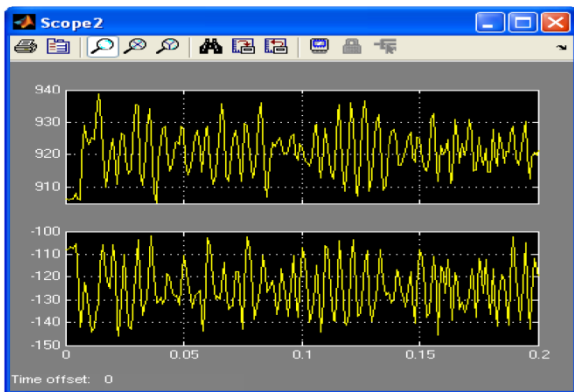


Figure8. Real Power at B1,B2& B3 when STATCOM is Middle

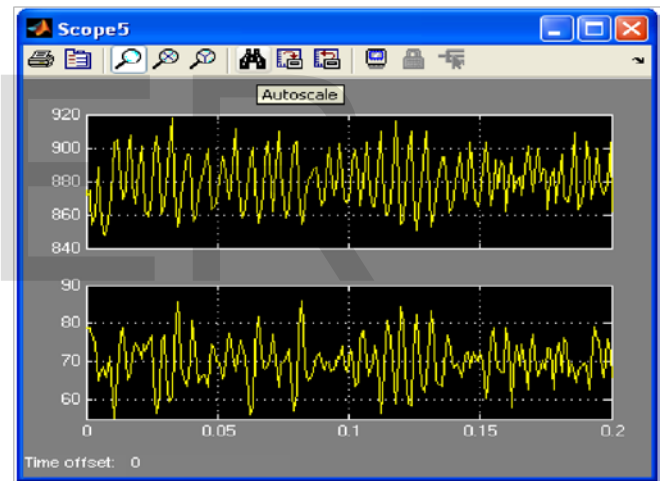
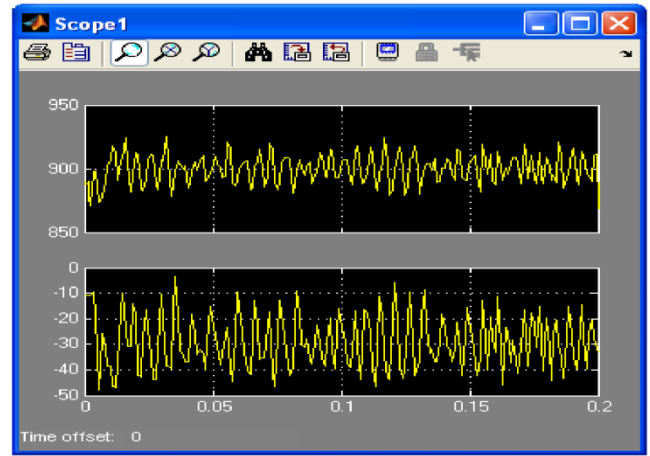


Figure9. Real Power at B1,B2& B3 when STATCOM is Receiving End

4. CONCLUSION

The vital role of shunt FACTS devices, which are connected in long distance transmission lines, are to improve the power transfer capability and also to control the power flow in the power system network. In this proposed work STATCOM is employed as a shunt FACTS device. STATCOM is connected at the various locations such as sending end, middle and receiving end of the transmission line. The results were obtained with and without compensation. The simulation results reveals that the reactive power generated is better at the middle of the transmission line when compared with the other ends of the transmission line and also the voltage is controlled at the middle of the line. So, the location of STATCOM is optimum when connected at the middle of the line. The numerical results of the

system analysis were elaborated in the table 1. The simulation results were carried in MATLAB Simulink environment.

REFERENCES

- [1] Tan, Y.L., "Analysis of line compensation by shunt connected FACTS controllers: a comparison between SVC and STATCOM", IEEE Transactions on Power Engineering Review, Vol.19, pp 57-58, Aug 1999.
- [2] Xia Jiang Xinghao Fang Chow, J.H. Edris, A.-A. Uzunovic, E. Parisi, M. Hopkins, L. "A Novel Approach for Modeling Voltage-Sourced Converter-Based FACTS Controllers", IEEE Transactions on Power Delivery, Vol.23(4), pp 2591-2598, Oct 2008.
- [3] Chandrakar, V.K. Kothari, A.G. "Optimal location for line compensation by shunt connected FACTS controller", The Fifth International IEEE Conference on Power Electronics and Drive Systems", Vol 1, pp 151-156, Nov 2003.
- [4] Bebic, J.Z. Lehn, P.W. Iravani, M.R. "The hybrid power flow controller - a new concept for flexible AC transmission", IEEE Power Engineering Society General Meeting, DOI10.1109/PES.2006.1708944, Oct 2006.
- [5] Johnson, B.K. "How series and combined multiterminal controllers FACTS controllers function in an AC transmission system", IEEE Power Engineering Society General Meeting, Vol.2, pp 1265-1267, June 2004.
- [6] Shankaralingappa, C.B. Jangamashetti, S.H. "FACTS Controllers to Improve Voltage Profile and Enhancement of Line Loadability in EHV Long Transmission Lines", International IEEE Conference on POWERCON, pp 1-5, Oct 2008.
- [7] Shakib, A.D. Balzer, G. "Optimal location and control of shunt FACTS for transmission of renewable energy in large power systems", 15th IEEE Mediterranean Electrotechnical Conference, MELECON 2010, pp 890-895, Apr 2010. [8] Salemnia, A. Khederzadeh, M. Ghorbani, A. "Mitigation of subsynchronous oscillations by 48-pulse VSC STATCOM using remote signal", IEEE Transactions on Power Tech, pp 17, June 2009.
- [9] K.R. Padiyar N. Prabhu "Design and performance evaluation of subsynchronous damping controller with STATCOM", IEEE Transactions on Power Delivery, Vol.21(3), pp 1398-1405, July 2006.
- [10] Prabhu, N. Janaki, M. Thirumalaivasan, R. "Damping of subsynchronous resonance by subsynchronous current injector with STATCOM", IEEE Conference on TENCON 2009, pp 1-6, Jan.2009.
- [11] Zarghami, M. Crow, M.L. "Damping inter-area oscillations in power systems by STATCOMs", 40th North American Symposium 2008, pp 1- 6, 978-1-4244-4283-6, Sept 2008.