Indian Journal of Science and Technology, *Vol 10(29), DOI: 10.17485/ijst/2017/v10i29/93658,* August 2017
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Study of Shunt and Series Compensator for Improved VAR Compensation

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Abstract

Objectives: The FACTS devices plays vital role in compensating reactive power for increased power transmission capability and to maintain flat voltage profile in transmission system. The proposed 24 pulse VSC makes it possible to eliminate the need of external filters. **Methods/Analysis:** Power system performance improvement by effective management of reactive power is studied by designing the FACTS devices with the help of simulink in MATLAB. **Findings:** Reactive power control and stability of the transmission line is highly achieved by the STATCOM, a shunt compensator and SSSC, a series compensator. Reactive power control maintains constant voltage profile at all power transmission levels, thereby efficiency of transmission line, power factor and system stability is improved. Series and Shunt VAR compensation modifies the necessary electrical parameters of transmission line. Reactance parameter of the power system is modified by series compensation, while the equivalent load impedance is changed by shunt compensation. The results confirm that the need of external passive filter is eliminated. **Application/Improvement:** The system under consideration can be installed in any type of transmission system irrespective of energy generation method.

Keywords: Flexible AC Transmission System (FACTS), Series Compensation, Shunt Compensation, Static Compensator (STATCOM), Static Synchronous Series Compensator (SSSC), Voltage Source Converter (VSC)

1. Introduction

In modern power system, the power flow in the transmission line can be controlled with the use of power electronics. Power electronics based FACTS technique promotes the control of transmission line. It also increases load on the line up to the thermal limits without having compromise with the reliability[5]. There are large numbers of FACTS controllers in recent advancement in power system of which we use STATCOM for shunt compensation and SSSC for series compensation.

Current is injected at the point of connection in the system by shunt controllers. If variable shunt impedance is connected to line voltage, variable current flows and the current is injected in the line. So long as there is quadrature relationship between voltage and current, these controllers either supply or deal with reactive power[4]. For other phase relationship, active power is also handled.

Voltage is injected in series with the line by series controllers, which is calculated by multiplying current flowing through the line and variable impedance. These controllers supply only reactive power till voltage is in phase quadrature with the line current[9]. Reactive power is handled with real power when the phase relationship between line voltage and line current is different.

2. STATCOM

STATCOM- STATic VAR COMpensator is a shunt connected device in which independent control of capacitive or inductive output current can be done with respect to ac system voltage. While taking an ac system with voltage source converter into account, its output voltage is controlled so that proper reactive current will flow for any bus voltage. The dc capacitor voltage is automatically

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adjusted as per the requirement so that it acts as the voltage source for the converter[2].

In the proposed model as shown in Figure 1 voltage source inverter is 24 pulses cascaded H-bridge inverter driven by voltage across capacitor and the three phase output voltages are in phase with ac system voltages. The difference in the amplitudes of the voltages determines the current flow. The reactive power and its polarity can be changed by controlling the voltage.

With depression in voltage, STATCOM will still supply high reactive power by using it's over current capability[10]. The large capacitor present acts as storage device and can continue to deliver some energy for short duration like synchronous condenser.

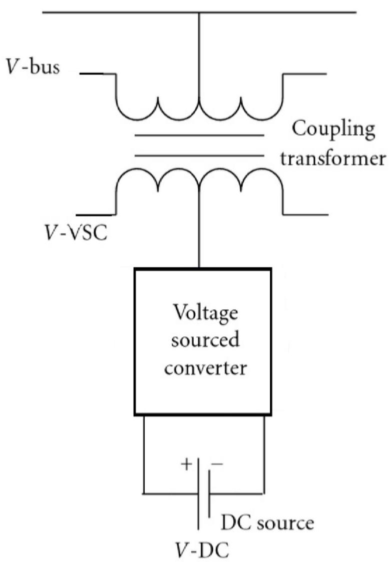

Figure 1. Model of STATCOM.

3. SSSC

Static Synchronous Series Compensator (SSSC) injects voltage containing appropriate phase angle with respect to line current to vary the effective impedance of a transmission line. This injected voltage which is at right angle to line current, imitates an inductive or a capacitive reactance in series with the transmission line[1]. This variable reactance injected by the voltage source in turn influences the electric power flow through the transmission line.

The Voltage Source Converter (VSC) used here is H-bridge converter which is shown in Figure 2. The main feature of this converter is that, for real power conversions from ac to dc and then dc to ac, the cascaded inverter need separate dc sources. The DC energy storage device can be derived from various renewable energy sources[8].

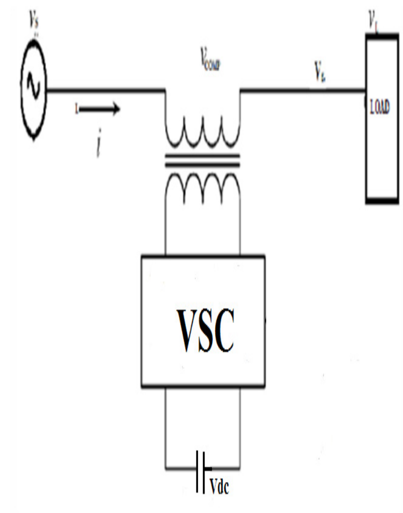

Figure 2. Model of SSSC.

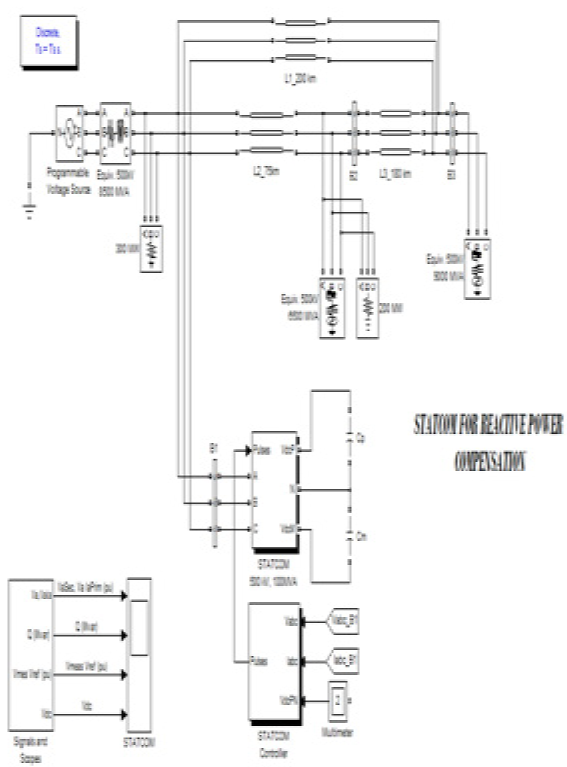

Figure 3. Simulation test diagram for STATCOM.

4. Simulation Results

The simulation work for the STATCOM and SSSC are done with help of simulink in MATLAB. Switches are assumed to be ideal switch that is the switching losses are assumed to be zero. But practically switching devices always has switching losses. The switching losses are referred for selecting the device for switching. In both the cases, the load used is RL load for analysis.

4.1 STATCOM

In the simulation 24 pulse VSC is constructed as shown in Figure 3. The controller output send the controlling signal to pulse generator based on which it generates the pulses. Also controller output decides the switching sequence also. The Pure sine wave output waveform is obtained at the injection point.

When the load is inductive, inductive current flows. In order to make the power factor unity, capacitive current is injected which flows opposite to the inductive current. Similarly when the load is capacitive, capacitive current flows and to make the power factor unity, inductive current is injected which flows opposite to the capacitive current. The compensation scheme controller monitors and processes the line voltage to generate the duty cycle of the switching devices[12].

The pulses are generated by the space vector generator. In simulation output both the positive and negative compensation can be obtained which is shown in Figure 4.

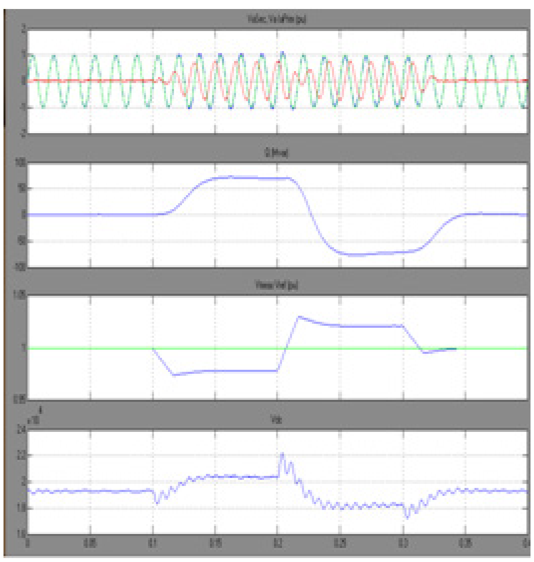

Figure 4. Simulated output of STATCOM.

4.2 SSSC

The cascade H-bridge circuit is constructed using the IGBT switches as shown in Figure 5. The designed system's general notion is to maintain the displacement angle between the line voltage and line current closer to the actual value[3].

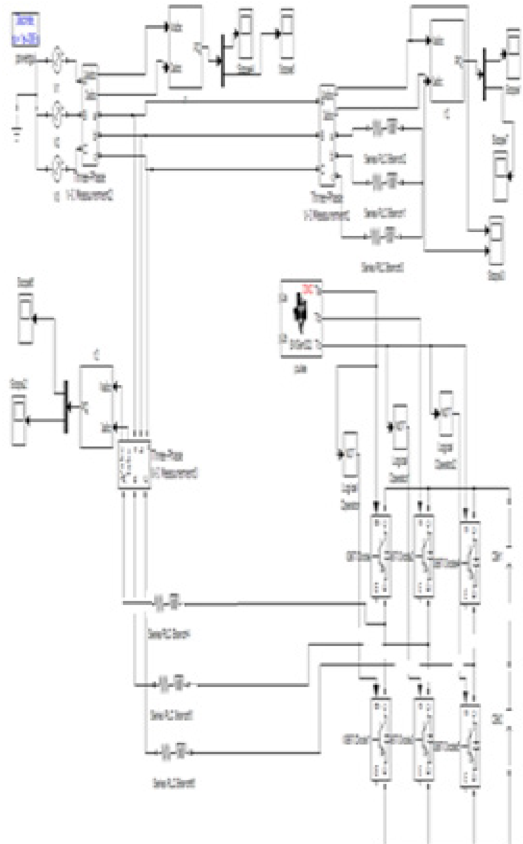

Figure 5. Simulation test diagram for SSSC.

Transmission line voltage compensation method is mainly used to maintain the voltage stability. Control signals are generated based on the grid voltage[7].

Transmission voltage parameters are sensed by potential transformer and the signals are given to the controller in which the control signal generation is decided[6].

DC voltage source is connected based on the transmission voltages. The injecting transformer injects the compensating voltage generated by the cascade bridge circuit in series to transmission line. The output voltage thus generated is a sine wave with reduced harmonics[11]. Thus this system does not need any special filter for harmonic reduction. In case if the transmission line voltage is greater than the actual voltage, controller opt the negative compensation, in which the injected voltage is less than the actual voltage and vice versa.

Harmonics is reduced to a negligible rating when the output is obtained from the injection transformer end as shown in Figure 6 and Figure 7. Also the compensation scheme remains inactive when the actual transmission line voltage equals the reference voltage. Figure 8 shows the reactive power compensated by the SSSC.

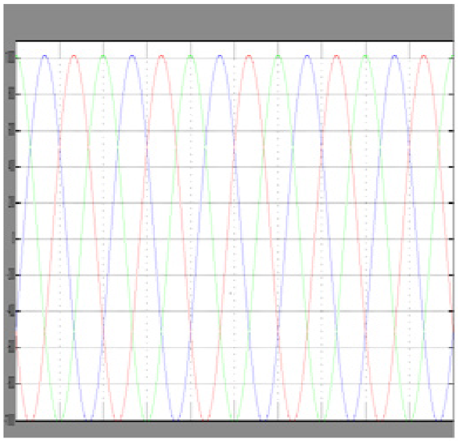

Figure 6. Voltage (V) vs. time (ms).

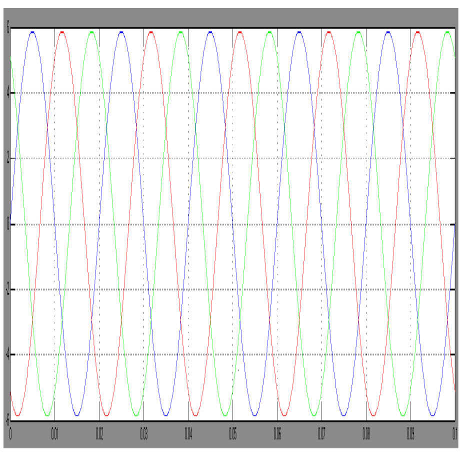

Figure 7. Current (A) vs. time (ms).

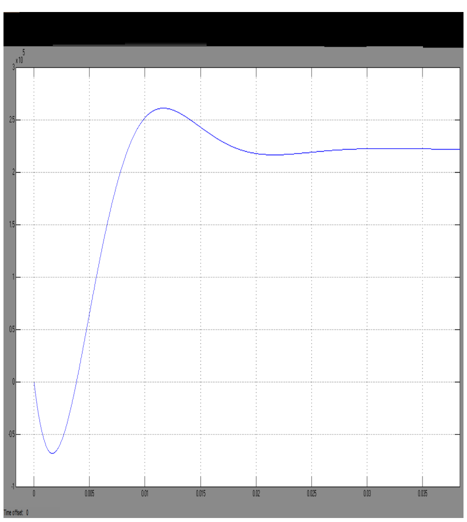

Figure 8. Reactive power (VAR) compensated by SSSC.

5. Conclusion

Results prove that the shunt and series compensation of reactive power is achieved by designing STATCOM and SSSC respectively and system stability is achieved for effective operation of power system. The modeled system enhances reactive power compensation with less harmonics, thus eliminates the need of filter.

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