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Modeling and Simulation of Reactive Power Control of Transmission System using 48-Pulse GTO STATCOM

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ABSTRACT: Active and reactive power losses are always a major challenge in the power system network since beginning. Many techniques have been evolved for reducing these losses and improving voltage profile. Power compensation has become very important aspect of the power system so as to improve power system stability and hence maintain the operation of the system close to the voltage stability boundaries. Reactive power compensation plays a vital role in improving the voltage profile and planning of power system. Reactive power (VAR) compensation is defined as the management of reactive power to improve the performance of ac systems. There are two aspects: a) Load Compensation – The main objectives are to : i) increase the power factor of the system ii) to balance the real power drawn from the system iii) compensate voltage regulation iv) to eliminate current harmonics. b) Voltage Support – The main purpose is to decrease the voltage fluctuation at a given terminal of transmission line. Therefore the VAR compensation improves the stability.

Keywords: Active reactive power, FACTS, Generation, Transmission.

I. INTRODUCTION

The power system is consists of 3 parts Generation, Transmission and Distribution. The power is generated at voltage levels 3.3, 6.6, 11 or 33 KV, most usual value adopted in practice is 11 KV. Electrical system can be transmitted and distributed by either AC or DC but in practice 3-phase 3-wire AC system is universally adopted for transmission of large blocks of power and 3-phase 4-wire AC system is usually adopted for distribution of electrical power.

The transmission system may be further divided into primary and secondary transmission. Generation voltage are 3.3, 6.6, 11or 33 KV, most usual value adopted in practice is 11 KV. The primary transmission voltages are 110, 132, 220 or 400 KV depending upon the distance, the amount of power to be transmitted and the system stability. Secondary transmission voltage is normally of the order of 33 or 66 KV.

Distribution system may be divided into primary and secondary distribution. The voltage of primary distribution are 11, 6.6 or 3.3 KV depending upon the requirement of the bulk consumers and for secondary usable voltage is 415/240V.

Power Generation and Transmission is a complex process, requiring the working of many components of the power system in tandem to maximize the output. One of the main components to form a major part is the reactive power in the system. It is required to maintain the voltage to deliver the active power through the lines. Loads like motor loads and other loads require reactive power for their operation.

A flexible alternating current transmission system (FACTS) is a system composed of static equipment used for the AC transmission of electrical energy. It is meant to enhance controllability and increase power transfer capability of the network. It is generally a power electronics-based system.

FACTS is defined by the IEEE as "a power electronic based system and other static equipment that provide control of one or more AC transmission system parameters to enhance controllability and increase power transfer capability."

According to Siemens "FACTS Increase the reliability of AC grids and reduce power delivery costs. They improve transmission quality and efficiency of power transmission by supplying inductive or reactive power to the grid.

To improve the performance of AC power systems, we need to manage the reactive power in an efficient way and this is known as reactive power compensation. There are two aspects to the problem of reactive power compensation: load compensation and voltage support. Load compensation consists of improvement in power factor, balancing of real power drawn from the supply, better voltage regulation, etc. of large fluctuating loads. Voltage support consists of reduction of voltage fluctuation at a given terminal of the transmission line.

Two types of compensation can be used: series and shunt compensation. These modify the parameters of the system to give enhanced VAR compensation. In recent years, static VAR compensators like the STATCOM have been developed. These quite satisfactorily do the job of absorbing or generating reactive power with a faster time response and come under Flexible AC Transmission Systems (FACTS).

II. REACTIVE POWER COMPENSATION

Need for Reactive power compensation.

The main reason for reactive power compensation in a system is:

1) The voltage regulation;
2) Increased system stability;
3) Better utilization of machines connected to the system;
4) Reducing losses associated with the system, and
5) To prevent voltage collapse as well as voltage sag.

The impedance of transmission lines and the need for lagging VAR by most machines in a generating system results in the consumption of reactive power, thus affecting the stability limits of the system as well as transmission lines. Unnecessary voltage drops lead to increased losses which needs to be supplied by the source and in turn leading to outages in the line due to increased stress on the system to carry this imaginary power. Thus we can infer that the compensation of reactive power not only mitigates all these effects but also helps in better transient response to faults and disturbances. In recent times there has been an increased focus on the techniques used for the compensation and with better devices included in the technology, the compensation is made more effective. It is very much required that the lines be relieved of the obligation to carry the reactive power, which is better provided near the generators or the loads. Shunt compensation can be installed near the load, in a distribution substation or transmission substation.

III. SHUNT COMENSATION

The principles of both shunt and series reactive power compensation techniques are described below: Shunt compensation

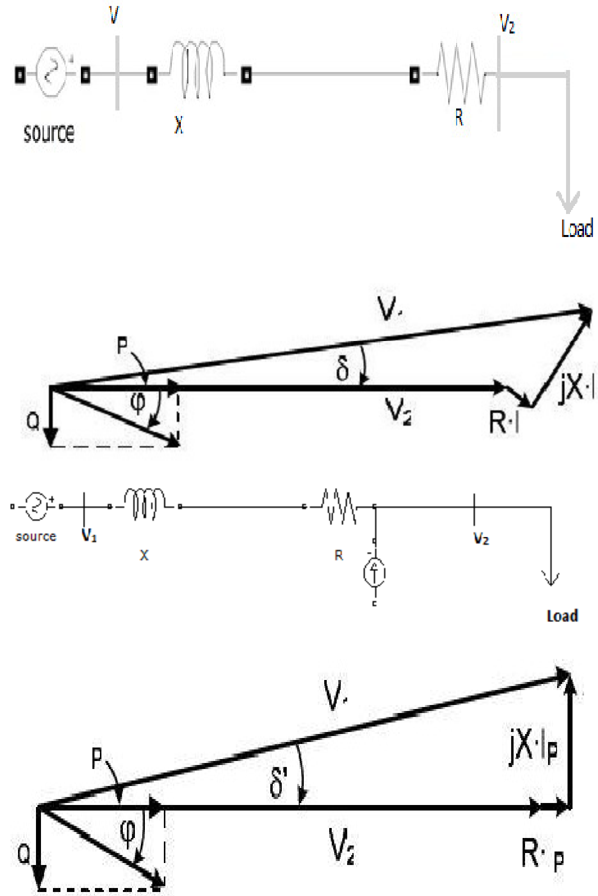

Fig. 1. Shunt Compensation.

The figure 1 comprises of a sourceV_1, a power line and an inductive load. The figure shows the system without any type of compensation. The phasor diagram of these is also shown above. The active current I_p is in phase with the load voltageV_2. Here, the load is inductive and hence it requires reactive power for its proper operation and this has to be supplied by the source, thus increasing the current from the generator and through the power lines. Instead of the lines carrying this, if the reactive power can be supplied near the load, the line current can be minimized, reducing the power losses and improving the voltage regulation at the load terminals.

This can be done in three ways:
1) A voltage source.
2) A current source.
3) A capacitor.

In this case, a current source device is used to compensateI_q, which is the reactive component of the load current. In turn the voltage regulation of the system is improved and the reactive current component from the source is reduced or almost eliminated. This is in case of lagging compensation. For leading compensation, we require an inductor. Therefore we can see that, a current source or a voltage source can be used for both leading and lagging shunt compensation, the main advantages being the reactive power generated is independent of the voltage at the point of connection. In shunt compensation, power system is connected in shunt (parallel) with the FACTS. It works as a controllable current source. Shunt compensation is of two types:

A. Shunt capacitive compensation
This method is used to improve the power factor. Whenever an inductive load is connected to the transmission line, power factor lags because of lagging load current. To compensate, a shunt capacitor is connected which draws current leading the source voltage. The net result is improvement in power factor.

B. Shunt inductive compensation
This method is used either when charging the transmission line, or, when there is very low load at the receiving end. Due to very low, or no load – very low current flows through the transmission line. Shunt capacitance in the transmission line causes voltage amplification (Ferranti effect). The receiving end voltage may become double the sending end voltage (generally in case of very long transmission lines). To compensate, shunt inductors are connected across the transmission line.

C. Unified Power Flow Controller (UPFC)
Among the available FACTS devices, the Unified Power Flow Controller (UPFC) is the most versatile one that can be used to enhance steady state stability, dynamic stability and transient stability. The basic configuration of a UPFC is shown in Fig. 2.16. The UPFC is capable of both supplying and absorbing real and reactive power and it consists of two ac/dc converters. One of the two converters is connected in series with the transmission constant voltage across the dc capacitor. As the series branch of the UPFC injects a voltage of variable magnitude and phase angle, it can exchange real power with the transmission line and thus improves the power flow capability of the line as well as its transient stability limit. The shunt converter exchanges a current of controllable magnitude and power factor angle with the power system. It is normally controlled to balance the real power absorbed from or injected into the power system by the series converter plus the losses by regulating the dc bus voltage at a desired value.

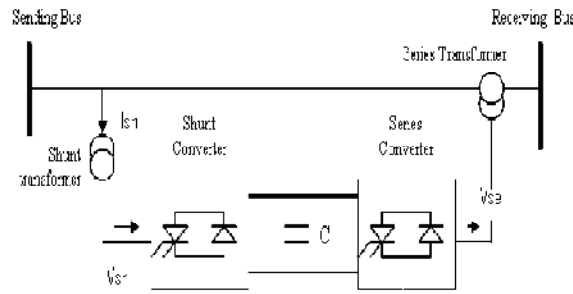

Fig. 2. Configuration of UPFC.

UPFC is one of the unique equipment in FACTS which is used in series and shunt on the transmission line. UPFC is consisted of two VSC and a DC link capacitor. One converter operates in series, the other in s hunt. Shunt converter, in addition to the real power need of series converter, they also can have STATCOM operation modes.

IV. RESULTS

As we run the simulation and observe waveforms on both the STATCOMs scope block. Both STATCOMs are in voltage control mode and their reference voltages are set to V_{ref}=1.0 pu. The voltage droop of the regulator is 0.03 pu/100 VA. Therefore when the STATCOMs operating point changes from fully capacitive (+100 M_{var}) to fully inductive (-100 M_{var}) the STATCOM voltage varies between 1-0.03=0.97 pu and 1+0.03=1.03 pu.

Waveforms showing STATCOM connect at Bus 1 - Dynamic Response to System Voltage Steps

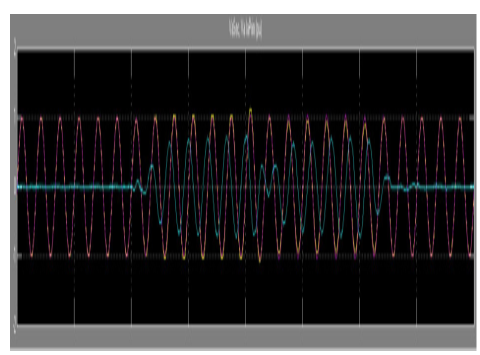

Fig. 3. Waveform of Ia Prim, Va Prim & Va Sec in pu with respect to time in Sec.

V mean V reference in PU

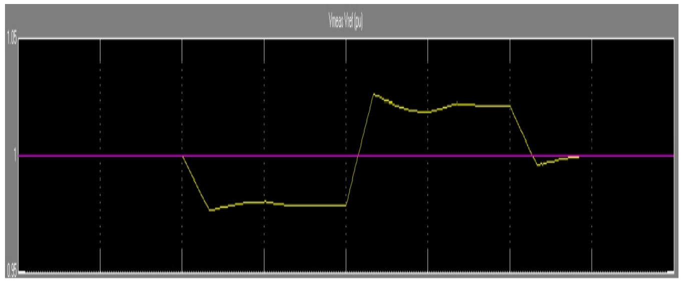

Fig. 4. Waveform of V_{meas} & V_{ref} in pu with respect to time in Sec.

Q in Mvar :

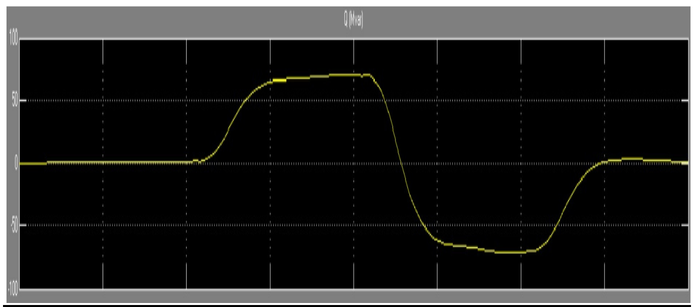

Fig. 5. Waveform of Q in M var with respect to time in Sec.

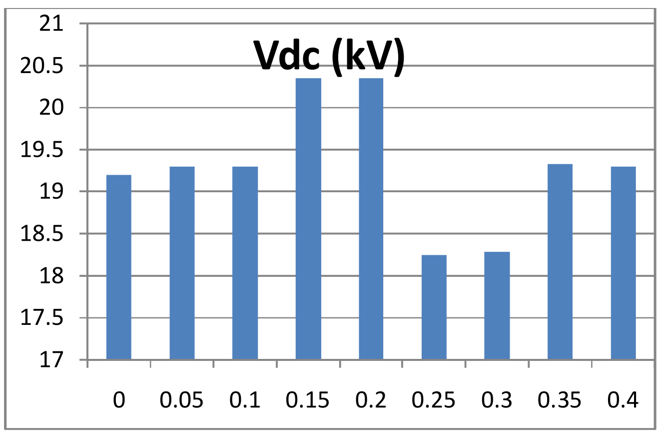

Fig. 6. Bar graph of Vdc in kV with respect to time in Sec.

At first the programmable voltage source is set at 1.0491 pu, resulting in a 1.0 pu voltage at bus B1 when the STATCOM is out of service. As the reference voltage V_{ref} is set to 1.0 pu, the STATCOM is initially floating (zero current). The DC voltage is approx 19.3 kV. At t=0.1s, voltage is suddenly decreased by 4.5% (0.955 pu of nominal voltage). The STATCOM reacts by generating reactive power (Q=+70 M_{var}) to keep voltage at 0.979 pu. The 95% settling time is approximately 56 ms. At this point the DC voltage has increased to 20.35 kV. Then, at t=0.2 s the source voltage is increased to1.045 pu of its nominal value. The STATCOM reacts by changing its operating point from capacitive to inductive to keep voltage at 1.021 pu. At this point the STATCOM absorbs 71.4 M_{var} and the DC voltage has been lowered to 18.3 kV. By examine the first diagram the trace showing the STATCOM primary voltage and current that the current is changing from capacitive to inductive in approximately one cycle.

V. CONCLUSION

Electric generators supply reactive power (in addition to active power) that is consumed by customer load. Synchronous generators, SVC and various types of other Distributed energy resource (DER) equipment are used to maintain voltages throughout the transmission system. Voltage control in an electrical power system is important for proper operation for electrical power equipment to prevent damage such as overheating of generators and motors, to reduce transmission losses and to maintain the ability of the system to withstand and prevent voltage collapse. Decreasing reactive power will cause voltage to fall, while increasing it will cause voltage to rise. The paper work is carried out to minimize the reactive power losses in the 6-Bus test system. With the varying source voltage the transmission system voltage is varied from 0.97 pu to 1.03 pu therefore the STATCOM works in both inductive and capacitive mode to supply and absorb the reactive power of the system. The objective of the thesis is achieved by placing STATCOMs at two buses. The results thus obtained were better as the losses were reduced and the voltage profile also improved.

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