ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 6, Special Issue , August 2019
International Conference on Recent Advances in Science, Engineering, Technology and Management at Sree Vahini Institute of Science and Technology-Tiruvuru, Krishna Dist, A.P

Design and Brief History of STATCOM

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ABSTRACT: Power disturbances can originate in consumer power systems, consumer loads, or the utility because of non-linear loads, adjustable speed drives, traction drives, start of large motor loads, arc furnace, lightning etc. Typical power quality disturbances are voltage variation (voltage swelling, voltage sag) frequency variation & waveform distortion. In this Paper voltage variation is the focal point. Since the change in voltage at the receiving end of a line depends on reactive power loading, so voltage sag/swell can be reduced by supplying/absorbing reactive power locally rather through transmission line. Number controllers are has been proposed to meet the reactive power of load and allow the source to supply power at unity power factor. In this paper the basic two types of controllers, one being converter based and other being variable impedance or admittance based, the converter based controllers shows good dynamic and steady state behaviour.

I. INTRDUCTION

Now a day due to increased power quality problems by using of switch off/on introduction loads, nonlinear load and induction motor etc in domestic and industries, power-quality (PQ) problems, such as harmonics, flicker, and imbalance have become serious concerns. In addition, lightning strikes on transmission lines, switching of capacitor banks, and various network Faults can also cause PQ problems, such as transients, voltage sag/swell, and interruption. On the other hand, an increase of sensitive loads involving digital electronics and complex process controllers requires a pure sinusoidal supply voltage for proper load operation. To meet power quality to the standard limits need some sort of compensation. In few years back to mitigate the power quality problems in distribution system by using passive filters like capacitor banks. Now these research going very fast to mitigate the power quality problems with help of power conditioning devices [7].

Problems in power quality are usually referred to any electrical problem faced in the frequency, voltage or current deviation which leads to mal-operation of the customer’s equipment.

A.Definition of Power Quality:

A consistent amplitude and one constant frequency sinusoidal signal is considered as an ideal current or voltage signal. Quality of voltage taken from the utility or that delivered to the consumer is referred as voltage or current quality. The fluctuation of voltage, current or frequency from its optimal worth that may prompt mal-operation of the equipment can be considered as issue in the power quality. The term electromagnetic compatibility is also used in place of power quality, they are strongly related but not the exactly same.

As indicated by the IEEE principles, Power quality can be characterized as the technique for grounding and supplying sensitive equipment with power so as to get a reasonable and agreeable performance of the equipment .Overall power quality represents a blend of quality of the current and voltage. Voltage quality at the point of connection is governed by the network operator whereas the quality of current at the connection point is governed by the client's load. Taking into account the prerequisites power quality can have various different meanings and significances. In the view of manufacturer, the term power quality can be characterized as the way in which there ought to be no voltage variety and no noise generation in the system of grounding. In context of utility designer, it can be considered as voltage availability.

Whereas for the end users power quality can be considered as the feasibility of utilising the accessible power for operation of various kinds of loads. Distribution system is worst affected because of the power quality problems.

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Power quality becomes poor at the points where loads are connected with the distribution system. So here we'll try to upgrade the quality of power of the distribution system.

B. Need of Better Power Quality:

Power quality is becoming an important concern because of many reasons. Some major reasons are-

- To increase the efficiency of power system many new devices such as shunt capacitors and adjustable-speed motor drives are gaining popularity. These devices increase the harmonic level of the power system which increases the concern.
- Power electronic devices and loads that make use of control based on microprocessor and microcontroller based are more affected by power quality issues.
- The interconnected networks that are used nowadays are badly affected by the power system disturbances because if any component is failed the entire system is affected.
- The awareness of problems in the quality of power and difficulties faced like under voltage, overvoltage, flickers etc. is among the utility customers or end users is tremendously increasing which arises the demand of a high and better quality of power.

II. STATCOM

STATCOM is one of the standout FACT devices amongst all the FACTS devices. It may contain a voltage source converter or a current source converter and provides a better response. It helps in maintaining a good voltage profile and improves the stability. If we are using this in the distribution system then it can be referred as D-STATCOM i.e. the distribution STATCOM. It mainly consists of an inverter circuit, inductor, a capacitor acting as DC source, control circuit for reference current generation. D-STATCOM helps in compensation of the load harmonic as it acts as a current source. In addition to this it as many more advantages like source current balancing, suppression of DC offset in the load and it helps the load to work at power factor of unity.

A. Operation of STATCOM:

Basic Principle of Operation:

In the case of two AC sources, which have the same frequency and are connected through a series reactance, the power flows will be:

- Active or Real Power flows from the leading source to the lagging source.
- Reactive Power flows from the higher to the lower voltage magnitude source.

Consequently, the phase angle difference between the sources decides the active power flow, while the voltage magnitude difference between the sources determines the reactive power flow. Based on this principle, a STATCOM can be used to regulate the reactive power flow by changing the output voltage of the voltage-source converter with respect to the system voltage.

Modes of Operation:

The STATCOM can be operated in two different Modes:

A. Voltage Regulation

The static synchronous compensator regulates voltage at its connection point by controlling the Amount of reactive power that is absorbed from or injected into the power system through a voltage-source converter.

In steady-state operation, the voltage V2 generated by the VSC through the DC capacitor is in phase with the system voltage V1 (δ=0), so that only reactive power (Q) is flowing (P=0).

1. When system voltage is high, the STATCOM will absorb reactive power (inductive behaviour).
2. When system voltage is low, the STATCOM will generate and inject reactive power into the system (capacitive).

Subsequently, the amount of reactive power flow is given by the equation:

$$Q = [V1\,(V1-V2)] / X$$

B. Var Control:

In this mode, the STATCOM reactive power output is kept constant independent of other system parameter.

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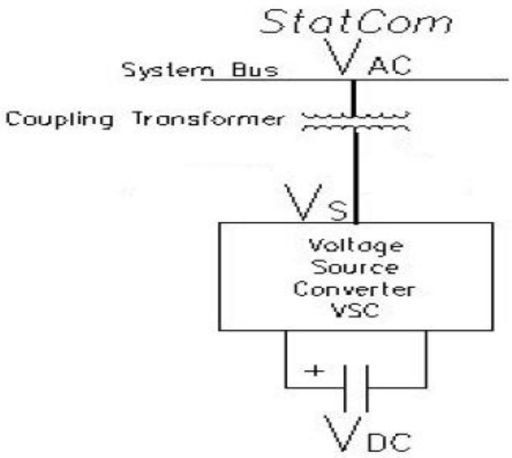

Fig. 1 Static synchronous compensator (STATCM)

In the STATCOM consist of a two voltage source converters and coupling a shunt connected transformer. The configuration of STATCOM is shown in fig. no.1.

The STATCM is a shunt connected device which compensates the reactive power. The STATCOM is capable of generating or absorbing the reactive power. The output of this controller is capable of controlling the specific parameter of electrical power system. Basically the static synchronous series compensator is improve the following such areas.

- Control of voltage flickering.
- Transient stability
- Improve the damping of power transmission system
- The dynamic voltage controlling in the distribution system.

B. Voltage Source Converters (VSC):

Voltage-source converter is a power electronic device, which can generate a sinusoidal voltage with any required magnitude, frequency and phase angle. Voltage source converters are widely used in adjustable-speed drives, but can also be used to mitigate voltage dips. The VSC is used to either completely replace the voltage or to inject the 'missing voltage'. The 'missing voltage' is the difference between the nominal voltage and the actual.

The converter is normally based on some kind of energy storage, which will supply the converter with a DC voltage. The solid-state electronics in the converter is then switched to get the desired output voltage. Normally the VSC is not only used for voltage dip mitigation, but also for other power quality issues, e.g. flicker and harmonics.

C. Series transformer:

The series inverter generates a voltage for maintenance of load voltage sinusoidal at a particular required value. Series inverter helps in injection of this voltage through the series transformer. It is required to maintain a particular turn's ratio in order to maintain a low current flow through the series inverter.

III. SIMULATIN RESULTS

So far in the discussion of STATCOM, it has been focused on the view point of reactive power. The question arises that whether the STATCOM is supplying the required VAR or not, but there is another question which need to be addressed, that is about the current and voltage waveforms, are those purely sinusoidal or not. The answer lies within the converter topology, since six pulse converters are taken, there must be harmonics, which need to be eliminated either by installing filters or by multilevel inverter topology. As far the controller actions are considered the performance of controller can be studied taking an average model of STATCOM, which uses universal bridge (in Simulink library). These bridges don't produce any harmonics and the effect and efficiency of controller can be studied easily. In the control circuits above discussed, the capacitor voltage was varied according to the reactive power demand,

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which slows down the system as the capacitor needs some time to charge or discharge. In the average model PWM technique is inbuilt, which enables
control of voltage through the parameter called modulation index, thereby keeping the capacitor voltage constant and making the system fast. Such a model is also simulated and the simulation was carried out in two modes that are reactive power control mode and voltage control mode.

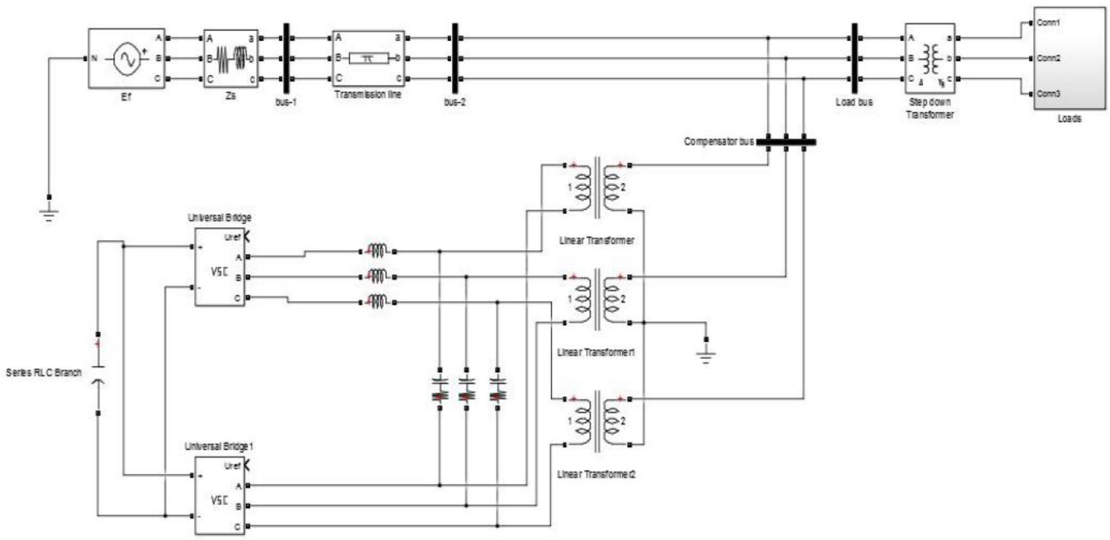

Fig. 2 STATCOM Power circuit

In reactive power control mode the reactive power of STATCOM becomes equal to load reactive power. The load reactive power varies in steps in both ways (both capacitive and inductive) and the source delivers power at unity power factor.
The waveform for this mode is shown below.

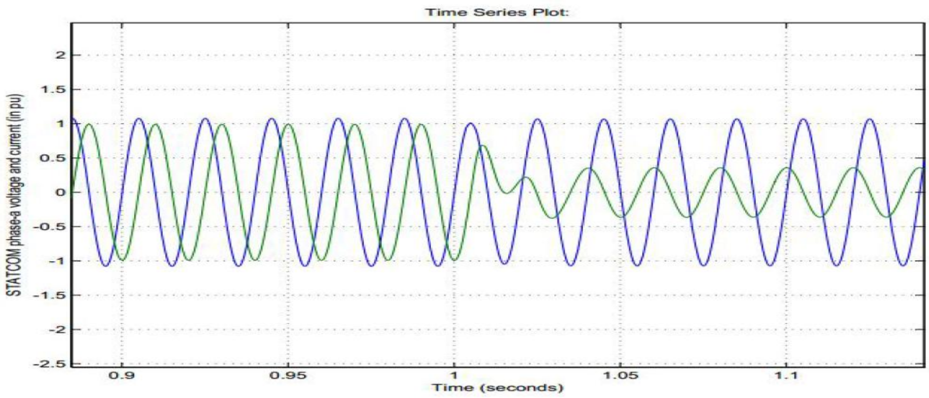

Fig. 3 STATCOM operation in both inductive and capacitive region

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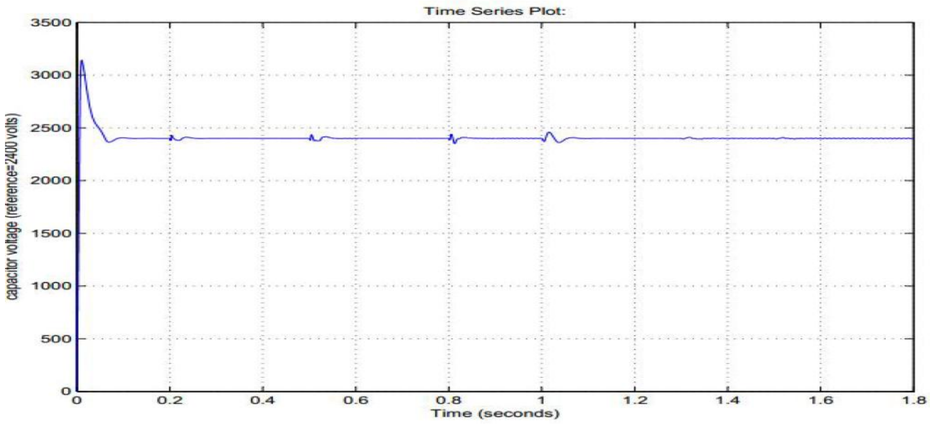

Fig. 4 Capacitor voltage

In voltage control mode of operation, it is desired that the STATCOM maintains the voltage of the bus equal to reference voltage (1 pu) by supplying/absorbing the reactive power. To obtain the performance the generator emf is perturbed around 1pu, and the effect of STATCOM is studied as shown next.

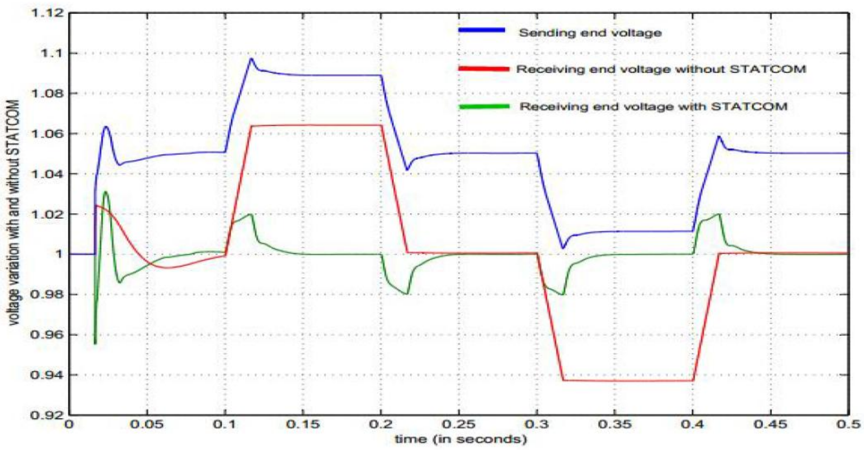

Fig. 5 Response of average model in voltage control mode to step inputs

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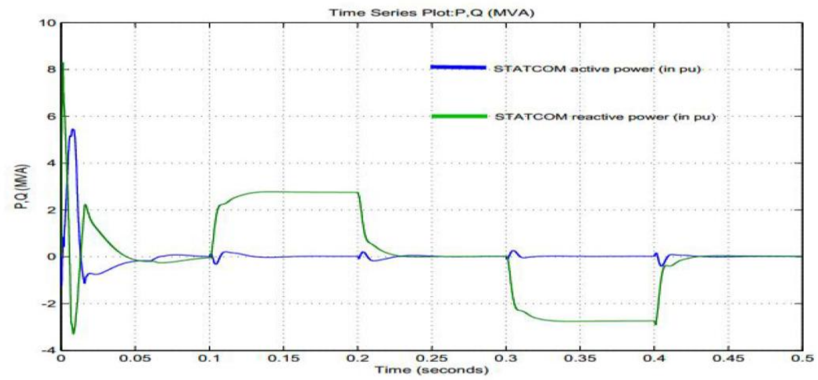

Fig. 6 Reactive power variation to step inputs while maintaining the voltage constant

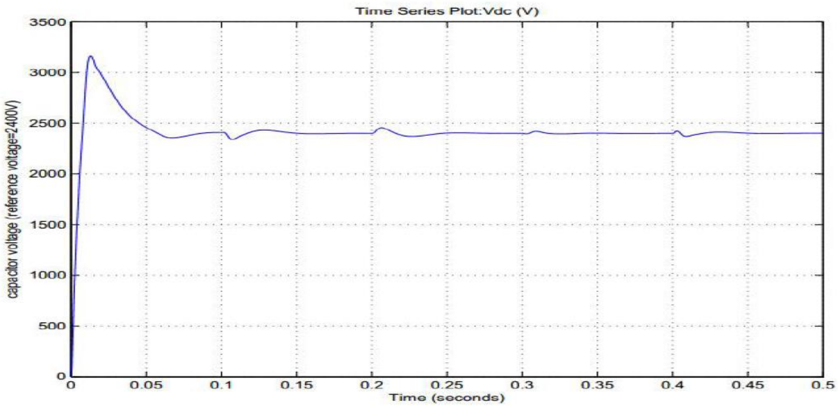

Fig. 7 Capacitor voltage

IV. CONCLUSION

The detailed model of STATCOM for single phase as well as three phases contains harmonic, which needs to be eliminated, but as said earlier the average model doesn't contain any harmonic. The detailed model shows slow response due to the use of six pulse converter and also due to charging and discharging the capacitor. It is worthwhile to note that in voltage control mode of operation, to compensate only 0.06 pu it requires 1 pu of reactive power injection in to the network, so it implies that this mode has a narrow range of control. For system where there is always some minimum lagging reactive power demand/voltage sag, the STATCOM should accompanied by one or more TSC, to shift the characteristic towards capacitive region, for systems suffering from overvoltage/leading reactive power the STATCOM should accompanied by one or more reactor.

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