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A Review Article of SSSC based Power Quality Improvement

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***Abstract:** This paper investigate about the power quality improvement in a transmission line with the help of Static synchronous Series Compensator (SSSC). The power engineers consider rising power quality and giving certain power at the lowest cost a major situation. For these power distribution difficulties, it is recommended to achieve some solutions in the form of a number of power electronic based devices to the enhanced the power quality of the system. Distribution Static Compensator (SSSC), Distribution Voltage Regulator (DVR), Unified Power Quality Compensator (UPQC), BESS, HVDC Light are few of the prominent custom power devices employ at distribution level. The most familiar loads on such a system are the constant power, constant impedance and constant current loads. In these cases, the voltage and current waveforms are nearly pure sinusoidal. But this is no longer the case with modern power system. Massive use of the nonlinear and time varying devices in system has led to distortion of voltage and current waveforms. The static synchronous series compensator (SSSC) is capable of delivering a compensating voltage with an inductive and capacitive range which helps to damp out these voltage and power oscillations under any fault conditions.*
***Keywords:** Flexible AC Transmission System, STATCOM, SSSC, Power Quality, PI & Hysteresis controller, Motor load.*

I. INTRODUCTION

A. Preface

In modern power system rising power quality and giving certain power at the lowest cost is considered a major situation. For these power distribution difficulties, it is recommended to achieve some solutions in the form of a number of power electronic based devices to the enhanced the power quality of the system. Static Compensator (SSSC), Distribution Voltage Regulator (DVR), Unified Power Quality Compensator (UPQC), BESS, HVDC Light are few power devices employ at distribution level.

Static Synchronous Compensator (SSSC) is a chief member of the FACTS family of power electronic based controllers. It has been studied for many years, and is probably the most widely used FACTS device in present's power systems. The SSSC voltage and reactive power compensation are normally related through with the magnetic of the SSSC. This traditional power flow framework of the SSSC neglects the impression of the high frequency effects and the switching diagnostics of the power electronics on the active power losses and the reactive power insertion.

The SSSC has appeared as a hopeful device to offering not only for voltage sag reduction but also for a host of other power quality solutions such as voltage stabilization, flicker suppression, power factor correction, and harmonic control.

SSSC is a series device which produces a balanced 3-Φ voltage or current with capability to control the magnitude and the phase angle. Generally, the SSSC configuration consists of a typical 12-pulse inverter arrangement and a dc energy storage device. A coupling transformer linked in series with ac system and connected control circuits.

B. Description of Power Quality

Power quality can be defined as the concept of powering and grounding sensitive electronic equipment in a manner suitable for the equipments. All electrical devices are prone to the failure or malfunction when exposed to one or more power quality problems or due to some unsymmetrical fault in the system. The electrical device might be an electric motor, a transformer, a computer, printer, generator, communication equipment, or a household appliance. Depending on the severity of problems, all of these electric devices reacts adversely to power quality issues.

The role of monitors for troubleshooting power quality problems is undeniable and indubitable. In power plants a disturbance analyzer is used to analyze the quality of power, especially during the installation of new plant equipment when there are number of problems associated with the normal order process. Disturbance analyzers is set to trigger when there are abnormal voltage conditions arises, which allows the troubleshooter to determine if the electric power is to blame for the problem.

C. Power Quality Problems

1) *Voltage Sag:* Voltage sag is the reduction in the RMS voltage value at power frequency for 0.5 cycles duration of 1 minute, the remaining of which has been suggested compliance with the quality of the motion of electric energy. Main causes of voltage sag are failure in the transmission or distribution line, most of the time in the feeder in parallel, consumer installation failure. Heavy connection such as large motor or generator loads. Voltage sag leads to malfunction of information technology equipment, namely, microprocessor-based control systems like PC, PLC etc. that can even lead to a shutdown process. Shooting contactors and electromechanical relays, disconnection and loss of efficiency in rotating electrical machines are the due to voltage sag in the transmission line.

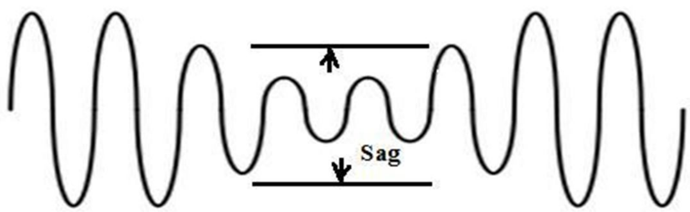

Fig1. Voltage Sag

2) *Voltage Swell:* Voltage swell can be defined as the transient increment of the voltage, at the power frequency, outside the ordinary resilience, with length of time of more than one cycle and regularly not as much as a few moments. Sudden start/stop of heavy machines, seriously dimensioned power sources, gravely controlled transformers (for the most part amid off-crest hours). Voltage swell leads to data misfortune, glinting of lighting and screens, stoppage or harm of touchy hardware, if the voltage qualities are too high.

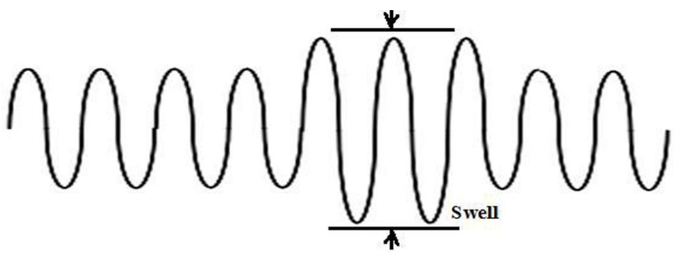

Fig 2. Voltage Swell

3) *Interruption:* Interruption is the complete loss of supply voltage or load current in power transmission line. Contingent upon its duration, an intrusion is arranged as instantaneous, momentary, temporary, or sustained. Span range for interference types are as per the following:

Instantaneous 0.5 to 30 cycles
Momentary 30 cycles to 2 seconds
Temporary 2 seconds to 2 minutes
Sustained greater than 2 minutes

The reasons for interruptions can change, however are generally the after effect of some kind of electrical supply matrix harm, for example, lightning strikes, creatures, trees, vehicle mishaps, damaging climate (high winds, substantial snow or ice on lines, and so on.), gear disappointment, or an essential electrical switch stumbling. While the utility foundation is intended to naturally adjust for a large portion of these issues, it is not reliable.

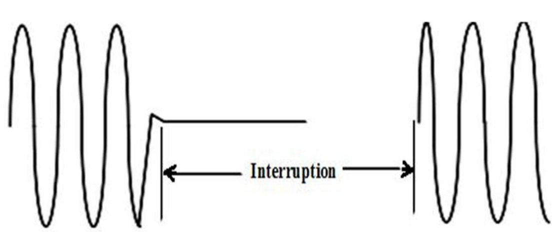

Fig 3. Interruption

4) *Over Voltage:* Over voltages can be the consequence of long-haul issues that make swells. An over voltage can be considered as an expanded swell. Over voltages are likewise basic in zones where supply transformer tap settings are set inaccurately and load have been lessened. This is basic in occasional districts where groups diminish in force utilization amid off-season and the yield set for the high use piece of the season is as yet being supplied despite the fact that the force need is much littler. It's similar to putting your thumb over the end of a patio nursery hose. The weight increments in light of the fact that the gap where the water turns out has been made littler, despite the fact that the measure of water leaving the hose continues as before. Over voltage conditions can make high current draw and reason the superfluous stumbling of downstream circuit breakers, and overheating and putting weight on equipment.

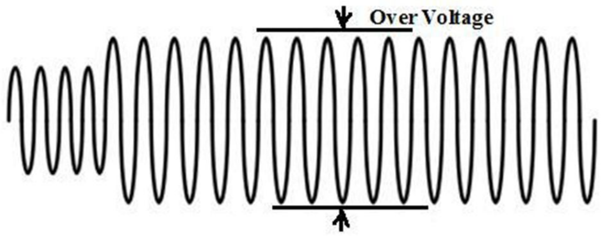

Fig 4. Over Voltage

II. SSSC

A. *Principle of SSSC*

The heavy demand on power system has initiated the system to load heavily leading to voltage unbalance conditions and power quality issues. The static synchronous series compensator (SSSC) is a series FACTS device and is capable of delivering a compensating voltage with an inductive and capacitive range. The complete simulation is done in the MATLAB/Simulink background. From simulation result it is concluded that under various unsymmetrical fault conditions the voltage and power oscillations can be damped well by using Static Synchronous series Compensator (SSSC) with a POD controller. The transient mode is created by L-G, LL-G or three phase fault. In order to tune the circuit and also to provide zero steady state error PID Controller is used here.

The SSSC has emerge as a hopeful device to offer not only for voltage sag mitigation but also for a host of additional power quality solutions such as voltage stabilization, flicker suppression, power factor correction, and harmonic control.

SSSC is a Series device that generates a balanced 3-Φ voltage or current with capability to control the magnitude and the phase angle. SSSC usually consists of a classic 12-pulse inverter arrangement, a capacitor as a dc energy storage device; a coupling transformer linked in series with ac system, and related control circuits, the configurations that are further complicated use multi pulse and/or multilevel configurations. The VSC converts the dc voltage across the storage device into a set of 3-Φ ac output voltages. These voltages are in phase and coupled with the ac arrangement of network through the reactance of the coupling transformer. The SSSC is fundamentally a DC-AC voltage source converter with an energy storage part, typically a DC capacitor. It operates as a controlled Synchronous Voltage Source (SVS) linked to the line through a coupling transformer. The controlled output voltage is maintained in phase with the line voltage, and can he manage to draw either capacitive or inductive current from the line in a related style of a synchronous condenser, but much further quickly.

SSSC has the capability to keep full capacitive output current at low system voltage, which also makes it more effective than SVC in improving the transient stability.

B. *Brief Methodology*

SSSC mainly suppress voltage variant and it controls reactive power in phase with system voltage. It can compensate for inductive and capacitive currents linearly and continuously. Figure 5.2 shows the vector diagram at the basic frequency for capacitive and inductive modes and for the transition state from capacitive to inductive and vice versa. The terminal voltage V_{bus} is equal to the sum of the voltage across the coupling transformer reactive V_L and inverter voltage V_{VSC} in both capacitive and inductive mode. If output voltage of SSSC V_{vsc} is in phase with bus terminal voltage (V_{bus}) and V_{vsc} is greater than V_{bus}, SSSC provides reactive power to system. And if V_{vsc} is smaller than V_{bus}, then SSSC absorbs reactive power from power system. V_{bus} and V_{vsc} have the same phase, but in reality, they contain a little phase difference due to the inverter switching and loss of transformer winding therefore absorbs some real power from system.

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Figure 5.1 is SSSC vector diagrams, which illustrate inverter output voltage V_I, system voltage V_T, reactive voltage V_L and line current I in association with magnitude and phase δ. Figure 5.2 a and b explain how V_I and V_T generate capacitive or inductive power by controlling the magnitude for inverter output voltage V_I in phase with each other. Figure 5. 1 c and d illustrate SSSC produces or absorbs real power with V_I and V_T having phase ±δ. The shift from inductive to capacitive mode occurs by charging angle δ from zero to a negative value. The active power is transferred from the AC terminal to the DC capacitor and reasons of the DC link voltage to increase. The active and reactive power might be expressed by the subsequent equations:

P $= (V_{bus}V_{vsc}/X_L) \sin \delta$

Q $= (V2_{bus}/X_L) - (V_{bus}V_{vsc}/X_L) \cos \delta$

In several practical SSSC there are losses in the transformer windings and in the converter switches. These losses use active power from the ac terminals, which always leads to a small phase variation all times present between the VSC voltage and the ac system voltage. This review paper proposed a detail study of the power interactions between the SSSC and the AC system as a purpose of the SSSC output voltage V_{vsc} and the AC system voltage V_{bus}.

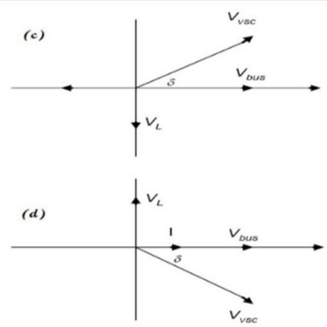

Fig.5.1 (c) Active power release and (d) Active power absorption

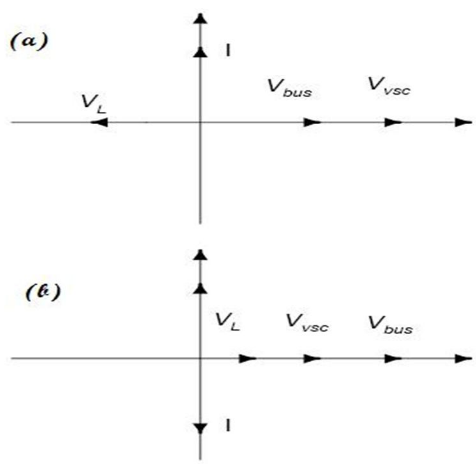

Fig.5.2 Vector dig. of SSSC (a)capacitive mode, (b) Inductive mode

C. V-I Characteristic's

A typical V-I characteristic of a SSSC is describing in Fig. 3.2. As can be seen, the SSSC can supply mutually the capacitive and the inductive compensation and is capable to control its output current over the rated excessive capacitive or inductive range irrespective of the quantity of ac-system voltage. Specifically, the SSSC can recommend entire capacitive-reactive power at any system voltage even as low as 0.15 pu.

The characteristic of a SSSC reveals strong point of this technology: that it is skilled of yielding the full output of capacitive generation approximately freely of the system voltage (Constant-current output at of poorer quality voltages).

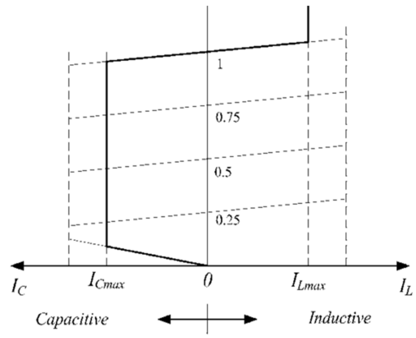

Fig. 6 V-I Characteristics of the SSSC

D. Application of SSSC

1) Typically, a SSSC is installed to support electricity networks that have a reduced power factor and often poor voltage regulation.
2) The most common employ is for voltage stability. A SSSC is a voltage source converter (VSC) based apparatus, with the voltage source after a reactor.
3) The voltage source is produced from a DC capacitor and so a SSSC has very small active power capability. Still, its active power capability can be amplified if a appropriate energy storage device is linked across the DC capacitor.

E. Advantages of SSSC

1) The characteristics of SSSC are higher.
2) The output current of SSSC can be controlled up to the rated highest capacitive or inductive range.
3) Control of Power flow
4) Increase the power transmission capability, increase the loading capability
5) Reactive power compensation with controllers and provide system security
6) Provides greater flexibility
7) The problem of voltage fluctuation and oscillations can be reduced.
8) Decrease of size of high value air-cored reactor.

III. CONCLUSION

A. A model of SSSC has been developed in MATLAB environment using Power System Block-set. The performance of the developed model is tested under a wide variety of loading conditions.
B. It is found that SSSC is capable of minimizing the harmonics and reactive power compensation.
C. Indirect current control technique has been applied over the sensed and reference supply currents for SSSC and it has been found to be a simple technique.
D. PI controller is required to regulate terminal voltage and to eliminate the steady state error thus reduces computation effort. The future work can be extended in SSSC modeling by replacing the PI Controller with some other controllers to provide voltage stability and respective power in the power systems and a comparative study can be performed. And to analyze the effect of non-linear loads and Motor loads on distribution system when feeding a generation with wind and solar.

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