Static Synchronous Series Compensator with POD Controller for Power System Application

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Abstract— Power engineers consider rising power quality and giving certain power at the lowest cost a major situation. Achievable solutions to power distribution difficulties have been recommended in the form of a number of power electronic based devices for controlling the power flow through transmission line. And enhanced power quality with the use of static synchronous series compensator (SSSC), a voltage sours inverter with battery energy storage system (BESS) with power oscillation damper (POD) as a extra controller devices few of the prominent custom power devices employ at distribution level. This work presents a method capable of designing SSSC to reduce harmonic distortion and improve power transfer capability of the transmission line and improve power quality. The performance of the system is simulated for Linear and Motor load.

Keywords: Programmable Source, SSSC, Capacitive Filter, Power Quality, POD Controller, Motor Load

I. Introduction

The use of alternating current circuits in electrical power system has been a common practice nearly since the very inception of the interconnected power network As a consequence, recently the issue of power quality has become important. Both electric utility and end users of electric power are becoming increasingly concerned about the quality of electric power. The term "power quality" [1] has been used to describe the variation of the voltage, current and frequency on the power system beyond a limit.

Power engineers consider rising power quality and giving certain power at the lowest cost a major situation. Achievable solutions to power distribution difficulties have been recommended in the form of a number of power electronic based devices for enhanced power quality. 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 Distribution Static synchronous Compensator (SSSC) [2] [3] 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 D-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 that 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, a dc energy storage device. A coupling transformer linked in Series with ac system and connected control circuits. The fundamental constriction of SSSC shown in fig.1

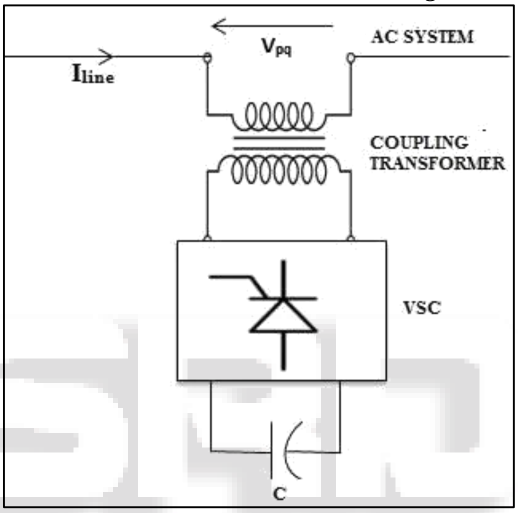

Fig. 1: Basic schematic diagram of SSSC.

If the amplitude of the VSC is reduced, then the current starts flowing from the alternating system to the SSSC and the absorption of power take place. The phase angle and VSC"s magnitude can be changed to control the power flow in the transmission lines. [4]

The injected voltage and phase displacement plays a major role in permitting the real and reactive power exchanges with the power system. Four quadrant operation of SSSC [5] is possible, assuming a DC capacitor connected across the voltage source converter that is shown in the Fig.2

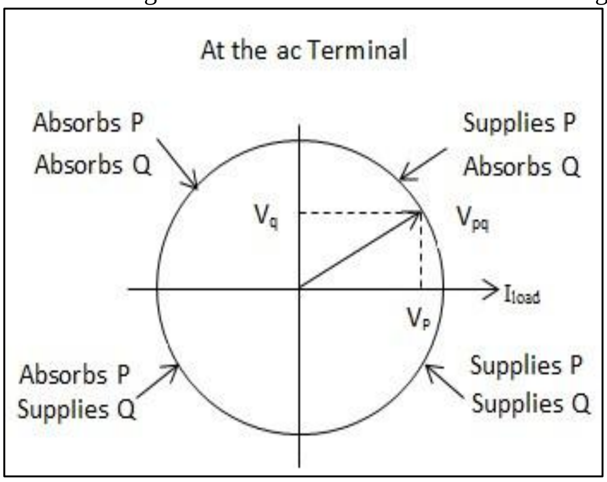

Fig. 2: SSSC phasor diagram

A. Description of Power Quality

Power quality is a term that means different things to different group. Institute of Electrical and Electronic Engineers (IEEE) Standard IEEE1100 defines power quality as "the concept of powering and grounding sensitive electronic equipment in a manner suitable for the equipment." As appropriate as this description might seem, the limitation of power quality to "sensitive electronic equipment" might be subject to disagreement. Electrical equipment susceptible to power quality or more appropriately to lack of power quality would fall within a seemingly boundless domain. All electrical devices are prone to failure or malfunction when exposed to one or more power quality problems. The electrical device might be an electric motor, a transformer, a generator, a computer, a printer, communication equipment, or a household appliance. All of these devices and others react adversely to power quality issues, depending on the severity of problems.

B. Power Quality Stride

Why interested in power quality, and why is the anxiety? Since the quest of electricity four hundred years past, the generation, distribution, and the use of electricity is growing faster.

Latest and upgraded methods to make and there has been a revolution in the use of electricity in industries, and since then scientists, engineers, and amateurs have share to its continuing development. Initially, electrical machines and devices were basic at best but none the less very functional. They addicted large amounts of electricity and performed quite well. The machines were conventionally designed with cost concern only secondary to performance consideration. They were probably susceptible to whatever power quality anomaly existed at the time, but the effects were not readily noticeable, due partly to the forcefulness of the machines and partly to the lack of effective ways to compute power quality parameters. However, in the last fifty years or so, the industrial age lead to the necessitate for products to be economically competitive, which meant that electrical machines were becoming smaller and more efficient and were designed without performance margins. At the same time, other factors were coming into play. Increased demands for electricity formed extensive power generation and distribution grids. Industries demand larger and larger shares of the generated power, which, along with the rising use of electricity in the inhabited sector, extended electricity generation to the limit. Today, electrical utilities are no longer separately operated entities; they are part of a huge network of utilities joined together in a complex grid. The blend of these factors has created electrical systems requiring power quality.

C. Power Quality Problems

1) Voltage Sag:

Defined sag voltage in IEEE1159-1995 is, IEEE is the reduction in the RMS voltage 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 It was reported that tension. Cause: Failure in the transmission or distribution (most of the time in the feeder in parallel). Consumer installation of failure. Heavy connection and commissioning of large motor loads. Outcome: Malfunction of information technology equipment, namely, microprocessor-based control systems (PC, PLC, TEA, etc) that can lead to a shutdown process. Shooting contactors and electromechanical relays. Disconnection and loss of efficiency in rotating electrical machines

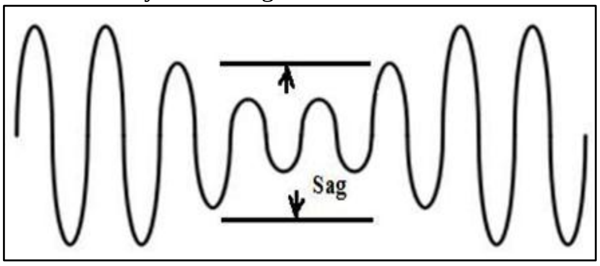

Fig. 3: Voltage Sag.

And Voltage swell, Interruption, overvoltage Electric noise, Oscillation, Harmonics etc. are the power quality problem.

D. Reactive Power Effect SSSC

We generally by and by to decrease reactive power to enhance system efficiency.[6] These are satisfactory at some level. In the event that system is absolutely resistive or capacitive it make because some issue in Electrical system. Alternating systems supply or consume two kind of power: real power and reactive power.

Real power performs helpful work while receptive power underpins the voltage that must be controlled for system dependability. Reactive power has a significant impact on the security of force system in light of the fact that it influences voltages all through the system.
Find vital talk with respect to significance about Reactive power and how it is helpful to keep up System voltage healthy.

1) Important to Control of Voltage and Reactive Power:

- Voltage control and reactive power administration are two parts of a solitary action that both backings unwavering quality and encourages business exchanges crosswise over transmission systems.
- On a rotating current (AC) power system, voltage is controlled generation and retention of reactive power.
- There are three reasons why it is important to oversee reactive power and control voltage.

2) Fundamental idea of Reactive Power:

- Why We Require Reactive Power:-
- Active power is the energy supplied to run a motor, heat a home, or illuminate an electric light bulb. Reactive power provides the important function of regulating voltage.
- If voltage on the system is not high enough, active power cannot be supplied.
- Reactive power is used to provide the voltage levels necessary for active power to do useful work.
- Reactive power is essential to move active power through the transmission and distribution system to the customer .Reactive power is required to maintain the voltage to deliver active power (watts) through transmission lines.
- Motor loads and other loads require reactive power to convert the flow of electrons into useful work.

– When there is not enough reactive power, the voltage sags down and it is not possible to push the power demanded by loads through the lines.”

II. CONTROL CONCEPT OF SSSC

A. SSSC

The SSSC implants a voltage with changing magnitude in quadrature with the line current, hence mirroring an inductive or capacitive reactance. This mirrored changeable reactance in serial with the line hence has leveragence on transmitted electric power. Therefore SSSC control wide range of power through transmission line.

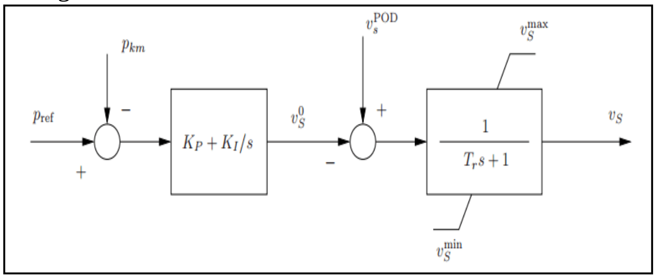

Fig. 4: Control block diagram of SSSC

The SSSC implants a voltage in serial with the line regardless of the line current. The SSSC can yield inductive and capacitive compensating voltage regardless of the power line current equal to the rated current of the line. In voltage compensation zone, the SSSC can keep the rated capacitive and inductive compensating voltage irrespective of the varying line current.

B. POD

POD gives supplementary input signal to AVT for damping the network oscillations. Generally bus voltage, line current, real and reactive power from the bus is the enforced input signals [7]. For maintaining the damping, there is necessary for POD to give electrical torque component which is in phase to speed of rotor diversion (dw_r).

POD subsist of distinct blocks, gain block finds the magnitude of power oscillations confer to its gain value. Washout block shows high pass filter and assure at normal state outcome of POD is zero. Phase compensating block gives the adequate phase lead properties for compensating the phase lag betwixt the input of exciter and torque of alternator. Time constant block manage the proper time lag for controllers. POD block diagram is shown in Fig.**5.**

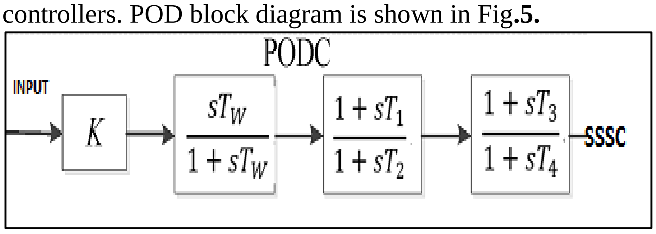

Fig. 5: Block diagram of POD

III. SIMULATION MODEL OF SSSC

The model consist of two substations (M1 &M2)and one main load center at bus3.M1 substation is rated as 2100MVA it shows six machine of each rating of 350MVA and M2 is rated as 1400MVA exhibiting four machine each rating 350MVA .load center near about 2200MW. The SSSC connected in series with line L1 and input to the POD controller from bus voltage (B2) and line current (L1). .The SSSC is rated as 100 MVA is placed at bus B1 in series with line L1 and it is able to implant up to 10% of the nominal network voltage. The reference implanting voltage is intent by power oscillation damping (POD) controller whose outcome is linked with reference input voltage of SSSC. The voltage at bus B2 and current through a line L1 are the inputs of POD controller.

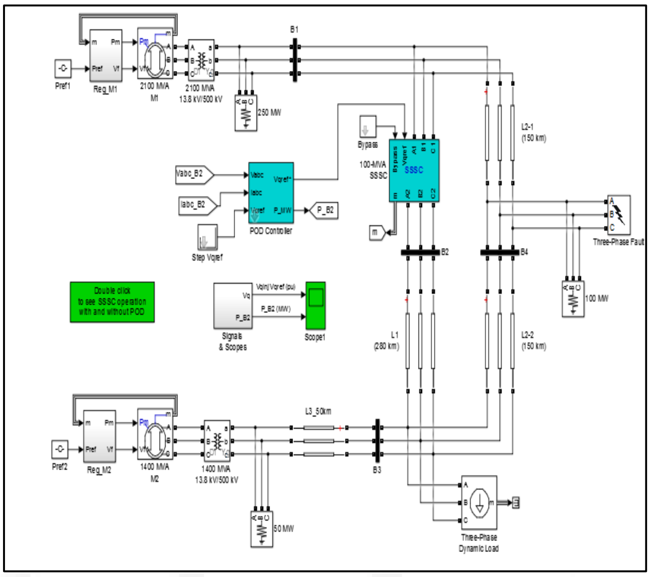

Fig. 6: Model of SSSC with POD

IV. SIMULATION RESULT

Fig.7 shows result with power oscillation damper OFF. The first graph display between V_{qref} signal and measured injected voltage by the SSSC. And the second graph display active power flow on line L1 measured at bus2 (B2).for ground fault

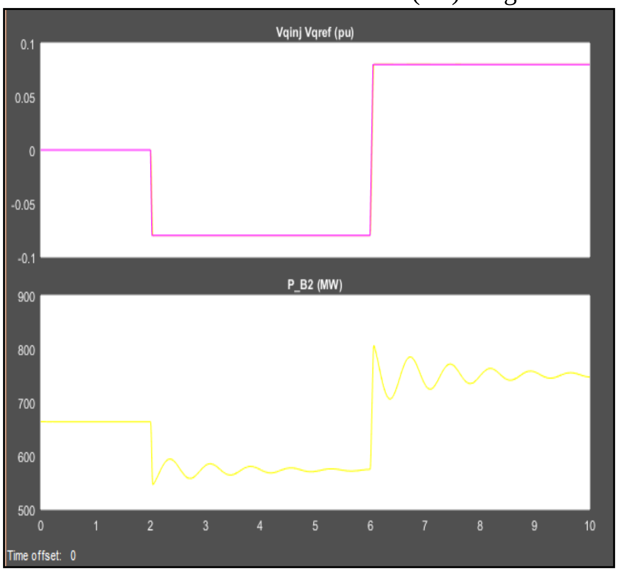

Fig. 7: SSSC inductive and capacitive mode POD OFF

Fig. 8 shows the result with power oscillation damper ON for ground fault. We can see that the SSSC with a POD controller is a very effective tool to damp power oscillation

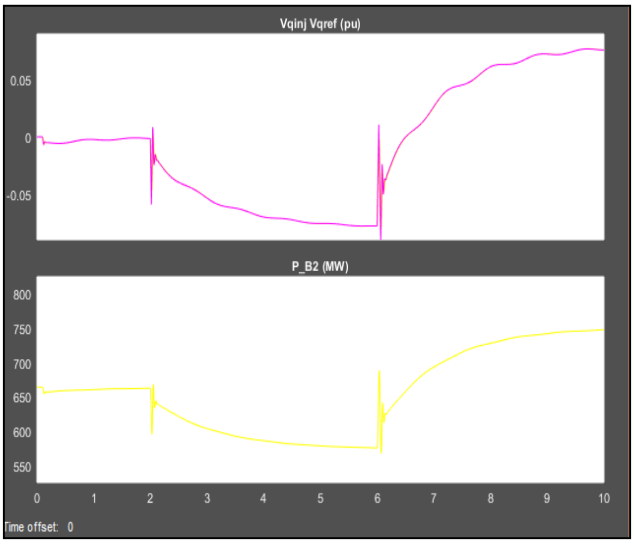

Fig. 8: SSSC inductive and capacitive mode POD ON

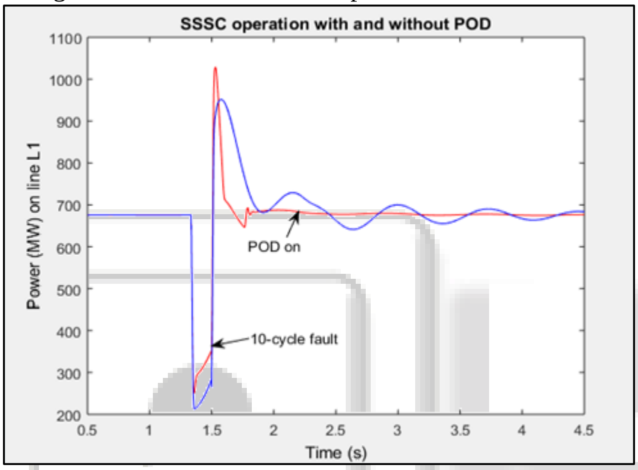

Fig. 9: fault analysis with and without SSSC-POD

From fig.9 it is seen that, three phase fault occurred at 1.33 sec. the fault duration is 10 cycle. It can see that with OPD ON oscillation are damp in less than a second but without POD ON the oscillation are continue and settling time is greater than 5 second.

V. Conclusion

- 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.
- It is found that SSSC is capable of minimizing the harmonics and reactive power compensation.
- 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. Only one PI controller is required to regulate terminal voltage and thus reduces computation effort.
- The control algorithm of the SSSC is flexible and has been tested for power quality improvement for linear as well as nonlinear and Induction motor loads.
- D-SSSC is able to reduce harmonics in voltage at PCC and supply currents to less than 5% IEEE 519 standards. SSSC reduces harmonics in load current to a large extent and provides quality power.

A. Future Implications:

The simulation has been carried out in MATLAB/SIMULINK environment and power factor is unity for supply voltage and current.

- To analyze the effect of non-linear loads, linear loads and Motor loads on Distribution system when feeding a generation with wind and solar.
- Modelling of reactive power theory and compare results with ICCT.
- To Study and Simulation of Fuzzy and ANN based controller on behalf of PI controller.
- In a future work, the obtained simulation results will be compared with experimental results, to be measured in a developed D-SSSC prototype.

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