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Static Synchronous Series Compensator Based Power Oscillation Damping Controller

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ABSTRACT

The main aim of this project is to damp out power system oscillations, which has been recognized as one of the major concerns in power system operation. In a Static Synchronous Series Compensator (SSSC), a controllable AC voltage is generated by a voltage-source converter.There are two control channels for controlling the magnitude and phase of the voltage. This project describes the damping of power oscillations by static synchronous series compensator (SSSC) based POD controllers. The advantage of this approach is that it can handle the nonlinearities, at the same time it is faster than other conventional controllers and it improve the reactive power of the system. Simulation studies are carried out in Matlab/Simulink environment to evaluate the effectiveness of the proposed Static synchronous series compensator (SSSC) of multi-area power system. Results show that the proposed SSSC based damping controllers improve the damping performance of the in the event of a major disturbance.

KEYWORDS: *power system oscillations,POD controllers, SSSC*

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I. Introduction

The ability to control power flow in an electric power system without generation rescheduling or topology changes can improve the power system performance using controllable components, the line flows can be changed in such a way that thermal limits are not exceed, losses are minimized, stability margins are increased and contractual requirements are fulfilled without violating the economic generation dispatch. Flexible AC Transmission systems (FACTS) technology is the ultimate tool for getting the most out of existing equipment via faster control action and new capabilities. The most striking feature is the ability to directly control transmission line flows by structurally changing parameters of the grid and to implement high- gain type controllers based on fast switching. The application of FACTS devices to power system security has been an attractive ongoing area of research. In most of the reported studies, attention has been focused on the ability of these devices to improve the power system security by damping system oscillations and minimal attempts have been made to investigate the effect of these devices on power system reliability. The opportunities arise through the ability of FACTS controllers to control the interrelated parameters that governs the operation of transmission systems including series impedance and shunt impedance, current, phase angle and damping of oscillations at various frequencies below the rated frequency. These constraints cannot be overcome otherwise, while maintaining the required system stability, by mechanical means with out lowering the useable transmission capacity. By providing added flexibility, FACTS controller can enable a line to carry power closer to its thermal rating. Mechanical switching needs to be supplemented by rapid-response power electronics. The facts technology can certainly be used to overcome any to the stability limits, in which case the ultimate limits would be thermal and dielectric.

The power supply systems are widely interconnected. This is done for economic reasons to reduce the cost of electricity and improve reliability of power supply and to minimize the total power generation capability and fuel cost .The power demand continues and building of new generating units and transmission circuits is becoming more difficult because of economic reasons and environmental reasons . Therefore power utilities are forced to relay on existing generating units by loading them close to thermal limits, maintaining the stability of the line at all times. In order to operate power system effectively without reduction in system security and quality of power supply, even in the case of contingency conditions such as loss of transmission lines, generating units which occur frequently, new control strategies must be implemented.

The application of power electronic devices to power systems known as flexible ac transmission systems (FACTS) seems to be a good solution .Two main objectives of FACTS are:

1. To increase the power transfer capability of transmission network

2. To provide direct control of power flow over designated transmission lines

The FACTS technology is not a single high power controller but rather a collection of controllers, which can be applied individually or in co-ordination with others to control one or more of the interrelated system parameters mentioned above. A Well-chosen FACTS controller can overcome specific limitations of designated transmission line on a corridor. But all FACTS controller represent applications of some basic technology, their production can eventually take advantage of technologies of scale.

II. Static Synchronous Series Compensator (SSSC)

Static Synchronous Series Compensator (SSSC) is one of the converter based FACTS devices. It is inserted in series with the line to provide compensation. The basic element in the static synchronous series compensator is the voltage sourced converter (VSI). The aim of a voltage sourced converter is to generate a three phase voltage using a DC voltage source. The on-off sequence applied to the VSI generates a three phase voltage with a fundamental frequency of 50Hz.

Immunity to resonance:

The SSSC has a very fast response and effective in the damping of sub synchronous oscillations if the electronic control is structured to provide this function.The behavior of the SSSC in the transmission network is also different from that of the series capacitor at the fundamental frequency. The compensating voltage of the SSSC is set by the control and it is independent of network impedance (and, consequently, line current) changes. This means that the SSSC could not be tuned with any finite line inductance to have a classical series resonance at the fundamental frequency, because the voltage across the line reactance would, in all practical cases, be greater than, and limited by, the voltage of the SSSC.

Control range VA rating:

SSSC can provide capacitive or inductive compensating voltage independent of the line current up to its specified current rating as shown in fig.3.5(b) The VA rating of the SSSC is simply the product of the maximum line current and the maximum series compensating voltage. In many practical applications, only capacitive series line compensation is required., the SSSC may be combined cost effectively with a fixed capacitor, where an SSSC of 1/2 p.u. VA rating is combined with a fixed capacitor of ½ p.u VAC rating to form a continuously controllable overall series compensator with a maximum compensating range of zero to 1 p.u. capacitive.

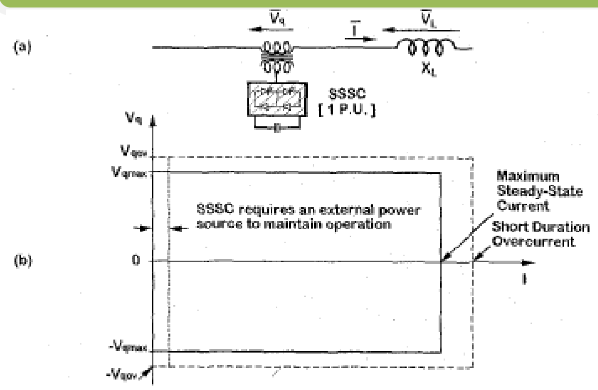


Fig 3.5(a) Static synchronous series compensator and (b) the corresponding Attainable range of series compensating voltage versus line current

Capacitor produces a compensating voltage that is proportional to the line current, the controllable compensating voltage range of the overall compensator also becomes, to some degree, as a function of line current as illustrated in Fig3.6(b)

The comparison of compensation range versus line current characteristics and the corresponding VA requirements of the above SSSC schemes to those pertinent to the conventional thyristor switched and thyristor-controlled series compensators require the basic implementation of the TSSC is shown in Fig.3.7(a) in this approach a string of n capacitor banks, each shunted by a bidirectional thyristor bypass switch (usually via a small

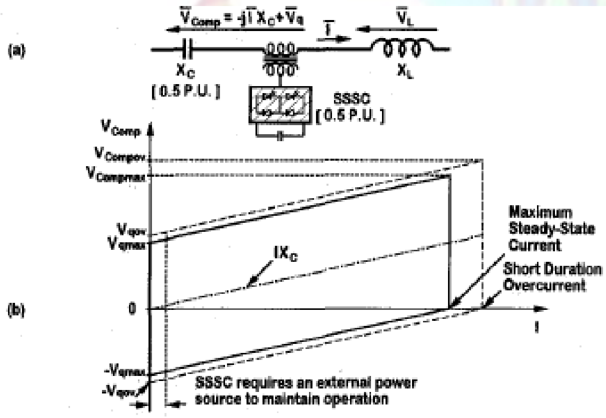


Fig: 3.6. (a) A hybrid compensator scheme consisting of a fixed capacitor and an SSSC (b)The corresponding attainable range of series compensating voltage versus line current

III. Advantages and Applications of SSSC

The SSSC is typically applied to correct the voltage during a fault in the power system. However, it also has several advantages during normal conditions:

- Power factor correction through continuous voltage injection and in combination with a properly structured controller.
- Load balancing in interconnected distribution networks.
- It can also help to cover the capacitive and reactive power demand.
- Power flow control.
- Reduces harmonic distortion by active filtering.

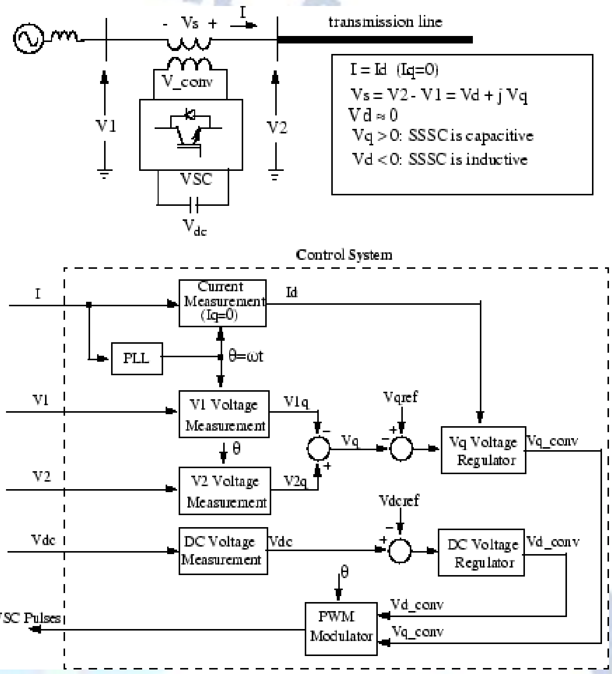
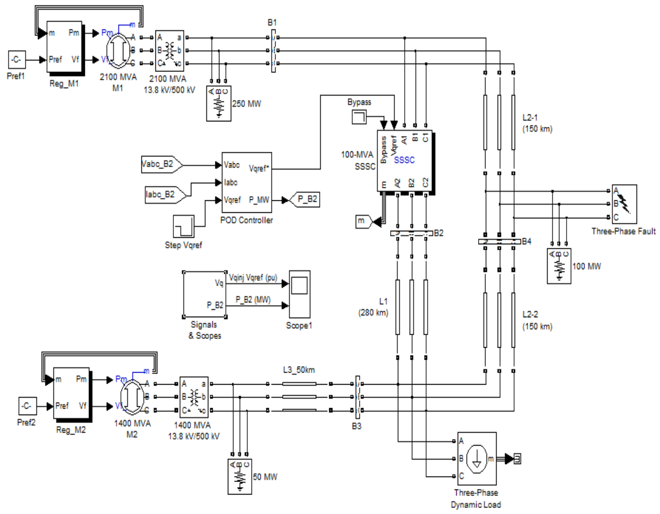


Fig. Single-line Diagram of a SSSC and Its Control

As the SSSC does not use any active power source, the injected voltage must stay in quadrature with line current. By varying the magnitude Vq of the injected voltage in quadrature with current, the SSSC performs the function of a variable reactance compensator, either capacitive or inductive.

The variation of injected voltage is performed by means of a Voltage-Sourced Converter (VSC) connected on the secondary side of a coupling transformer. The VSC uses forced- commutated power electronic devices (GTOs, IGBTs or IGCTs) to synthesize a voltage V_conv from a DC voltage source.

Block diagram of SSSC in Matlab Simulation



IV. Circuit Description

The Static Synchronous Series Compensator (SSSC), one of the key FACTS devices, consists of a voltage-sourced converter and a transformer connected in series with a transmission line. The SSSC injects a voltage of variable magnitude in quadrature with the line current, thereby emulating an inductive or capacitive reactance. This emulated variable reactance in series with the line can then influence the transmitted electric power. In our demo, the SSSC is usedto damp power oscillation on a power grid following a three-phase fault.

The power grid consists of two power generation substations and one major load center at bus B3. The first power generation substation (M1) has a rating of 2100 MVA, representing 6 machines of 350 MVA and the other one (M2) has a rating of 1400 MVA, representing 4 machines of 350 MVA. The load center of approximately 2200 MW is modeled using a dynamic load model where the active & reactive power absorbed by the load is a function of the system voltage.The generation substation M1 is connected to this load by two transmission lines L1 and L2. L1 is 280-km long and L2 is split in two segments of 150 km in order to simulate a three- phase fault (using a fault breaker) at the midpoint of the line. The generation substation M2 is also connected to the load bya 50-km line (L3). When the SSSC is bypass, the power flow towards this major load is as follows: 664 MW flow on L1 (measured at bus B2), 563 MW flow on L2 (measured at B4) and 990 MW flow on L3 (measured at B3)

The SSSC, located at bus B1, is in series with line L1. It has a rating of 100MVA and is capable of injecting up to 10% of the nominal system voltage. This SSSC is a phasor model of a typical three-level PWM SSSC. If you open the SSSC dialog box and select "Display Power data", you will see that our model represents a SSSC having a DC link nominal voltage of 40 kV with an equivalent capacitance of 375 uF. On the AC side, its total equivalent impedance is 0.16 pu on 100 MVA. This impedance represents the transformer leakage reactance and the phase reactor of the IGBT bridge of an actual PWM SSSC.The SSSC injected voltage reference is normally set by a POD (Power Oscillation Damping) controller whose output is connected to the Vqref input of the SSSC. The POD controller consists of an active power measurement system, a general gain, a low-pass filter, a washout high-pass filter, a lead compensator, and an output limiter. The inputs to the POD controller are the bus voltage at B2 and the current flowing in L1.

V. SIMULATION RESULTS

The real power variation has been observed by varying the dc reference voltage .The corresponding variation of real power and dc voltage across capacitor, firing angle has been shown in simulation results shown below.

Case 1: Line to Ground Fault without POD:

For analyzing the effect of unsymmetrical fault, a single line to ground fault is applied on 1.33 sec. which clears after 10 cycles on 1.5 sec. The performance of SSSC and such condition is shown in figures given below.

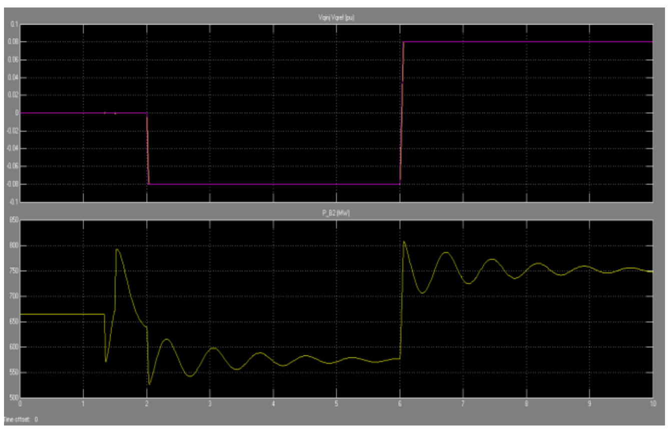


Fig 1: injected voltage and active power

In this condition POD is kept 'off'. Under this condition the effect on power flow at bus no. 2 is shown in fig 1. The fault clears at 1.5 sec as shown in fig1. initially Vqref is set to zero. At 2 sec. it is set to -0.08pu which makes SSSC to operate in inductive mode. At 6 sec. Vqref is set to 0.08 pu which operates SSSC in capacitive mode. A line to ground fault is applied at Bus no. 4 at 1.33 sec. which lasts for 10 cycles. Figure 1 shows the power oscillations observed at bus no.2 . The inductive and capacitive mode of operation can be observed easily.

Case 2: Line to Ground Fault With POD 'ON':
In this case POD is kept on. Figure 2 shows the faults level. It is clearly observable that the SSSC damp out the power oscillation damping very quickly in condition of a unsymmetrical single line fault.

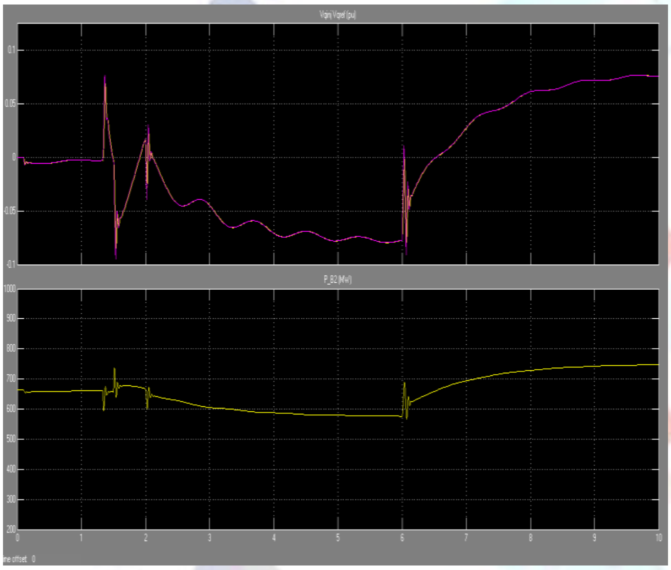


Fig 2 injected voltage and active power

The output results illustrate that the power system oscillations are damped out very rapidly with the help of SSSC based damping controllers in few seconds for a single line to ground fault.

VI. CONCLUSION

This paper presents a nonlinear adaptive controller for damping the inter-area power oscillation and enhancing transient stability in power systems. In this thesis the working of a three level fundamental switching frequency GTO based SSSC has been presented. The SSSC studies is modeled with three level diode clamped multi level inverter based SSSC. A phase angle controller is designed for real power flow control. The voltage balance controller, for obtaining the voltage balance across dc link capacitors is developed. The result of the time domain analysis with the use of MATLAB SIMULATION shows that with balanced voltage across dc link capacitors improves a tensional damping.

SSSC with its superior characteristics like immunity to sub synchronous resonance, power oscillation damping, quick response time, wider control range, and lower maintenance cost can be used effectively for series compensation of the Transmission line. Thus due to above superior characteristics SSSC is going to replace all the conventional series compensators.

FUTURE SCOPE

This future work can be extended in SSSC modelling by replacing the POD Controller with some other controllers for providing voltage stability and respective power in the power systems and a comparative study can be performed.

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