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SIMULATION AND ANALYSIS OF STATIC SYNCHRONOUS SERIES COMPENSATOR FOR POWER FLOW CONTROL IN POWER SYSTEM: REVIEW

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ABSTRACT

Electric power supply networks around the world are highly connected. These links are necessary because, in addition to facilitating delivery, the transmission network aims to pool power plants and load centres to reduce total power generation capacity and fuel costs. As loads on the electricity grid have increased, it has been harder to maintain stability and control. This research provides an investigation of SSSC performance and power system power flow control using thyristor driven series compensation. FACTS technology offers new ways to manage power and increase the useful capacity of existing systems, in addition to new and improved lines. The research of SSSCs with capacitive and inductive modes of operation, applications, and benefits of FACTS are covered in this work. Series compensation that is thyristor controlled consists of a capacitor that is switched back and forth between two thyristors. It is feasible to alter the reactance of the SSSC in accordance with SSSC features by adjusting the firing angle of this back-to-back thyristor. The true power flow is improved by this correction, which regulates the transmission line reactance. SSSC power flow changes between growing and decreasing in the capacitive area.

Keywords: SSSC, FACTS Device, power flow control, matlab simulation.

1. INTRODUCTION

Here Since energy is a need for daily living, it must be delivered to consumers in a consistent, high-quality manner. Due to rising increase in consumption and power generation, the transmission of electricity in the connected cooperative electrical system is gradually expanding. Worldwide transmission systems are constantly changing and being reorganised. They are getting weighed down more and more. For the transmission networks to respond to more varied generation and load patterns, they must be adaptable. The three control parameters that regulate the flow of power in the transmission system are voltage magnitudes, phase angles, and line reactance. When two locations are connected by a symmetrical, lossless transmission line (Fig. 1), the power flow P in the line can be stated as follows:

Whereas (s - r) is the phase angle between the two ends and |Vs| & |Vr| are the voltage magnitudes at the transmitting and receiving ends, respectively. Taking into account that resistance and susceptance are insignificant, XTL is referred to as the transmission line's reactance.

Power flow in the transmission line can be successfully managed, allowing for the system to be operated reliably and securely. This can be done by adjusting voltage magnitudes, phase angles, or line reactance. The sending end or receiving end voltage profile (|Vs| & |Vr|) can be improved to improve the real and reactive power flow of the transmission line. The sending-end and receiving-end voltages' absolute magnitudes control the reactive power flow in the transmission line. When Vs > Vr Then, as depicted in Fig. 1, reactive power moves from the sending end to the receiving end side, or from area-1 to area-2. The phase angles difference (s - r) between the sending end and receiving end voltages in the transmission line, on the other hand, controls the real power flow. Real power flow in the transmission line is significant and flows in the direction from area-1 to area-2 as illustrated in Fig. 1 if the difference between the phase angles (s - r) is large and positive. When the phase angle difference is negative, the power flow is the opposite. Moreover, transmission line reactance (XTL) and real power flow in transmission lines are inversely related to one another. Performance can therefore be enhanced by partially correcting for inherent line reactance. These three factors help the transmission line's electricity flow. Equations 1.1 and 1.2's equations for the power (P and Q) at the receiving end bus

$$P=\frac{V^{2\,Sin\,(\delta s-\delta r)}}{XTL} \dots\dots\dots\dots\dots\dots\dots\dots\dots (1.1)$$

$$Q=\frac{V^{2\,Sin\,(1-COS\delta)}}{XTL} \dots\dots\dots\dots\dots\dots\dots (1.2)$$

$$\delta=\delta s-\delta r \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1.3)$$

2. FLEXIBLE AC TRANSMISSION SYSTEM

Use this document as a template and type your material into it to easily adhere to the formatting specifications for conference papers. Adaptable AC The development of transmission system technology creates new possibilities for managing power and increasing the useful capacity of both existing lines and newly constructed or upgraded ones. The FACTS devices are unquestionably an advance over the traditional approaches since they are quick and effectively control these parameters to regulate power flow in transmission systems. These chances are made possible by the FACTS Controllers' capacity to regulate the interconnected parameters that control the operation of transmission systems, such as series impedance, shunt impedance, current, voltage, phase angle, and the damping of oscillations at various frequencies below the rated frequency. In general, FACTs controller may divided into four categories as shown in figure. 2

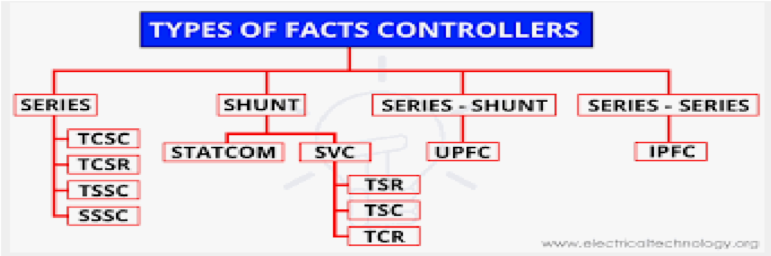

Fig.2. Classification of FACTS controllers.

Each FACTS device can individually or collectively control. The Static VAR Compensator (SVC) and Static Synchronous Compensator (STATCOM) improve the power flow of the transmission line by increasing the voltage profile at the point of connection. The Thyristor Controlled Series Compensator (TCSC) and Static Series Synchronous Compensator (SSSC) is series compensator switch Compensator. The transmission line reactance to improve the real power flow. In addition, SSSC regulates the phase angle of the transmission system. The Unified Power Flow Controller (UPFC) is the only device which can be employed to govern all three parameters of given transmission line, however cost and complexity is an important issue.

High-voltage flexible AC transmission systems are critical to maintaining proper voltage quantities and qualities. Without FACTS, your system may not be properly regulating voltage or changing the power that is either injected into or absorbed via the power system.

FACTS enhance the overall grid capacity and performance. They also increase the reliability and efficiency of your power system. By mitigating power oscillations, FACTS are able to offer you greater control over your energy.

Increased Reliability via Static Var Compensators

Static var compensators are a component of an energy-efficient and dependable power grid system (SVC). By carefully regulating your entire network voltage to maintain it within specified limits, SVCs boost the dynamic character of your high voltage systems. The voltages that are either injected into or absorbed by the system are regulated with the help of these compensators. This is achieved by producing reactive power when the voltage falls below a certain point and absorbing reactive power when the voltage levels rise above average.

The concept of FACTS and static var compensators is the ideal for all high voltage substation and switchyard owners, however, a concept is nothing without implementation. At Beta Engineering, we focus on the overall regulation and management of systems via our civil engineering, electrical engineering and project management teams. Our teams have extensive experience building flexible AC transmission systems that provide our clients with greater reliability. Across the country, we've implemented a number of FACTS projects, including SVCs, series capacitor banks, and reactor yards.

The basic applications and advantages of FACTS devices are:

- Power flow control
- Voltage control
- Reduce system losses
- Reactive power compensation
- Enhance power system stability
- Power quality improvement.

- Flicker mitigation Power conditioning
- Increased system security and reliability
- Rapid, continuous control of the transmission line reactance
- Optimizing load sharing between parallel circuits

Power flow control and SSSC facts Device

Controllers for FACTS are used in power systems. The SSSC, a static synchronous generator operated as a series compensator without the use of an external electric energy source, is a significant device from the FACTS group. The overall reactive voltage drop can change without being influenced by the line current. It has energy-absorbing components that add real power to brief changes in real voltage drop in the transmission line, increasing the dynamic behaviour of the system. SSSC can add voltage that is either ahead of or after the current. This can be used to solve a variety of power system issues. A smoothly changing series capacitive reactance is provided by SSSC. The SSSC controller can be used to regulate the transmission of power, raise the transmission limit, improve network stability, and offer continuous variable and impedance. The SSSSC concept's two basic tenets are as follows: first, by altering the reactance of a particular interconnecting power line, huge electrical networks can be electromechanically dampened. The SSSC's apparent impedance for sub-synchronous frequencies will also alter. so as to prevent a potential sub synchronous resonance. Figures depict a Static Synchonous Series Compensator comparable circuit and a Basic SSSC Setup.

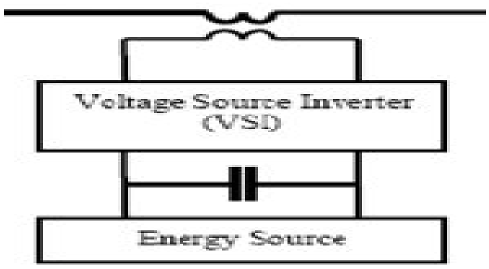

Fig. 3: Basic SSSC Configuration

Fig. 3 depicts the SSSC's fundamental layout. The compensator has an energy source that aids in controlling the flow of reactive power as well as delivering or absorbing active power to or from the transmission line. The SSSC is a series compensator, as the name suggests. It is connected to the transmission line in series. The power system and the compensator are connected in series using three phase series transformers. In order to enable both active and reactive power exchanges with the ac system, the dc capacitor in Fig. 3 has been replaced with an energy storage system, such as a high energy battery installation. The SSSC's output voltage and phase angle can be varied in a controlled manner to influence power flows in a transmission line. The phase displacement of the inserted voltage Vpq with respect to the transmission line current line I , determines the exchange of real and reactive power with the ac system

Operating Mode of SSSC FACTS device

Sstatic synchronous series compensator (SSSC) may be controlled by several ways. The most common control modes of the SSSC are:

- Constant voltage mode,
- Constant impedance emulation mode, and
- Constant power control mode.

Moreover, to improve the dynamic performance of the system, a SSSC may be equipped with supplementary controllers, such as damping controls. Therefore, this paper investigates the impacts of different SSSC control modes on small-signal and transient stability of a power system. The performance of different input signals to the power oscillation damping (POD) controller is also assessed. The stability analysis and the design of the SSSC controllers are based on modal analysis, non-linear simulations, pole placement technique, and time and frequency response techniques. The results obtained allow to conclude that the usage of the SSSC in the constant impedance emulation mode is the most beneficial strategy to improve both the small-signal and transient stability. Due to the almost ideal voltage source characteristic of the VSC, the SSSC can provide capacitive or inductive compensating voltage independent of the line current, up to its specified voltage rating. Thus, the SSSC can maintain the rated maximum capacitive or inductive compensating voltage in the face of changing line current,

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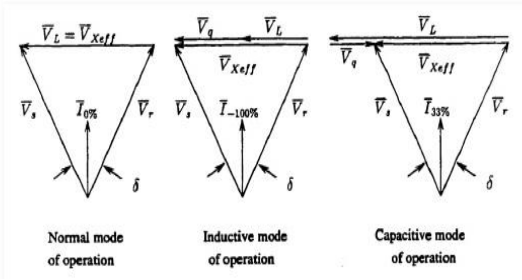

Fig. 4: Operating Mode of SSSC

Theoretically in the total operating range of 0 to Imax. The practical minimum is the line current value at which the SSSC is still able to absorb enough power to replenish its operating losses [2].

The SSSC has two operating modes:

- Control of voltage compensation, where the SSSC operates so as to maintain the capacitive or inductive compensation voltage at a maximal value, regardless of the current variations in the transmission line between 0 and Imax.
- Control of reactance compensation, where the SSSC operates so as to maintain the capacitive or inductive compensation reactance at a maximal value, when the current in the line varies between 0 and Imax

In principle, an SSSC is able to exchange active power and reactive power with the transmission grid. If considering only reactive power compensation, then the size of the power source can be relatively small. In this case, it will only control the magnitude of the voltage phasor, which is kept perpendicular on the line current phasor, leading or lagging it by 90◦. This means that, in the case of the SSSC, the magnitude of the compensating voltage, at fixed +90◦ or –90◦ angle, can be controlled continuously in the operating domain of the VSC.

If the power source has real power control capability, then the injected voltage could be controlled both in magnitude and phase. The behavior of an SSSC is the same as that of a series capacitor and a series reactor, both controllable. The main difference is that the voltage generated by the SSSC can be controlled independently of the line current because it does not depend on it. Consequently, an SSSC can operate both in the cases of increased and decreased line loads.

Since the SSSC emulates the line compensation of the series capacitor by the direct injection of the required compensating voltage at the fundamental system frequency, without reproducing the impedance versus frequency characteristic of a physical capacitor, it is, in contrast to the series capacitor, unable to form a classical series resonant circuit with the inductive line impedance to initiate subsynchronous oscillations.

In other words, independent of whether the SSSC is operated in the capacitive or inductive compensation domain, it is seen by the system as a (zero-impedance) voltage source in series with a small inductive impedance (the leakage impedance of the coupling transformer). Because of its fast response, the SSSC could theoretically provide effective damping of subsynchronous oscillation by suitable control, should the condition for subsynchronous oscillation be established by (existing) series capacitors.

The SSSC is a series connected synchronous voltage source that can vary the effective impedance of the transmission line by injecting a voltage containing an appropriate phase angle in relation to the line current. It has tha capability of exchanging both activa and reactive power with tha transmision system. The SSSC Comprises a multi phase VSC with a dc energy storage controller and functional representation of active reactive power flow. Here the Controller is connected in series with the SSSC are illustrated in figure

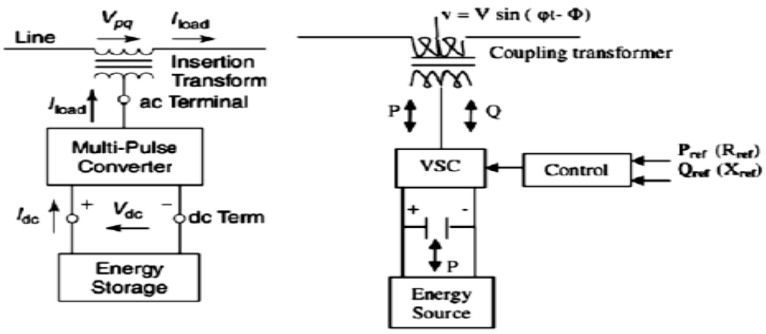

Fig. 5. Series connected synchronous voltage employing multi pulse converter with an energy storage device.

The basic operating principle of the SSSC is to inject the voltage Vinj in quadrature (i.e., at ±90◦) with respect to the transmission line current as illustrated in Figure in below. Therefore, the SSSC exchanges only reactive power with the transmission line. The SSSC has the effect of changing the equivalent line impedance and therefore only the magnitude of the line current. As shown in Figure 6 a, with Vinj = 0,

The magnitude of the line current is unchanged; with capacitive Vinj the line current magnitude is increased (as shown in Figure 6 b), and with inductive Vinj the line current magnitude is decreased

The control of the magnitude of the line current, in effect, controls the real power flow P (MW) in the transmission line. That is, the real power flow can be increased or decreased from the nominal (uncompensated) line power flow by the polarity of the injected voltage. In fact, the real power flow in the line can be reversed depending on the achievable change in the line current magnitude (or the rating of the SSSC) with respect to the nominal (uncompensated) line power flow value.

The SSSC is implemented with a VSC connected in series with the transmission line. The basic operation of the VSC is essentially to convert the DC voltage at their

DC terminals into an AC voltage output, in accordance with a vector reference that defines:

- The ratio between the DC-side and AC-side fundamental voltage;
- The phase angle of the AC output voltage.

3. CONCLUSION

In this paper, the application of SSSC to manage power flow between two transmission line ends in order to maintain voltage magnitude, phase angle, and line impedance. The research of a series compensation SSSC device to regulate the transmission line's power flow by altering the system's actual reactance. The two operating modes for the SSSC are typically inductive and capacitive. The different FACTS controllers, each with its own classification. The benefits of FACTS devices in the power system and several TCSC operating modes are described. This research report can be expanded in the future to include SSSC modelling and simulation with a variety of bus systems for power flow regulation.

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