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Reactive Power Compensation: A Review

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Abstract-This paper is to develop a program to determine the required reactive power compensation method on an EHV long transmission line to improve the voltage stability. Different types of compensation method has been studied. The static VAR compensator (SVC) is the shunt compensation method which is used to compensate the reactive power. The SVC uses Thyristor Controlled Reactor (TCR) /Thyristor Switched Capacitor (TSC) control method by the help of which reactive power is either absorbed or generated. To control the SVC a triggering alpha is used. This paper will commence with an overview of the problems encountered with an EHV transmission line, this is followed up by the literature review that covers the research of useful background theories. The results from the performed studies and simulations will also be discussed in details

Index Terms- Compensation, Reactive and Real Power, Voltage Stability, Transmission line.

1. INTROUCTION

Reactive power compensation is commonly addressed as a constrained single-objective optimization problem [1-3]. Traditionally, it basically consists in determining an adequate location and size of shunt and/or series capacitor and reactor banks. In this context, the objective function is a linear combination of several factors, such as: investment in reactive power devices, Transmission losses and voltage security [4]. Aims of reactive power compensation include increasing the system power factor to balance the real power drawn from an ac supply, eliminating harmonic current components produced by fluctuating nonlinear industrial loads, reducing voltage fluctuation in transmission line terminals, and increasing the maximum active power that can be transmitted in ac power systems. In addition, reactive power compensation can improve high voltage dc conversion terminal performance, increase transmission efficiency, control steady-state and temporary over voltages, and avoid disastrous power blackouts.

In the past, rotating synchronous condensers and fixed or mechanically switched inductors or capacitors have been used for reactive power compensation. Today, static Var generators employ thyristor-switched capacitors and thyristor-controlled reactors to provide reactive power compensation. Static Var generators can also be used to adjust shunt impedance, current, voltage, phase angle, and oscillation damping in power transmission systems.

There are different technologies for reactive power compensation, these includes; Capacitor Bank, Series Compensator, Shunt Reactor, Static Var Compensator (SVC), Static Synchronous Compensator (STATCOM), and Synchronous Condenser. But for the purpose of this paper, three different reactive power technologies are reviewed as possible sources for reactive power compensation. The technologies investigated includes; Synchronous Condenser, Static Var Compensator (SVC) and Static Synchronous Compensator (STATCOM). The most promising technology is recommended for reactive power compensation in electrical power networks.

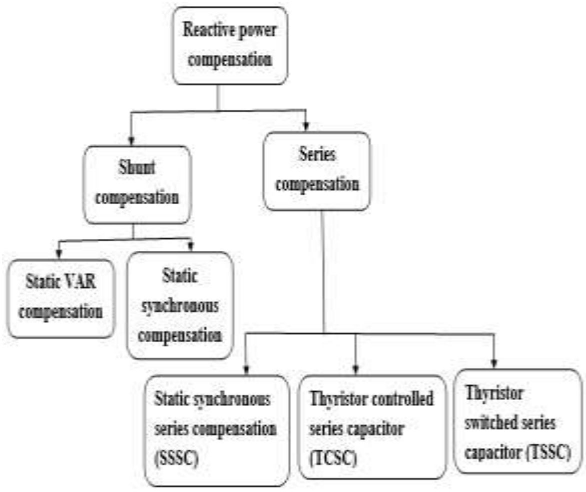

Fig. 1 Classification of Reactive Power Compensator

2. LITERATURE REVIEW

Many surveys and literatures have been conducted on performance evaluating the reactive power compensation methods in EHV transmission line. Some of the authors and the related works are: S.V.N Jithin Sundar et.al[5] proposed and presented his research on the controlled shunt reactor for bus voltage management in EHV system. As the permanent connection of the shunt reactors leads to reduced voltage levels and decreased transmission capacity of the lines during full load conditions. Thus, the paper introduces the solution of continuous voltage drop by introducing the Controlled Shunt Reactor which is a thyristor controlled equipment offers fast response time to take care of dynamic conditions. In his research, the main equipment is RT (Reactor Transformer) is designed as single three phase unit or as three single phase unit. The simulation response shows the transients response improves using controlled shunt reactor. Pasi Vuorenpaa et.,al[15] proposed his research dynamic modeling of Thyristor Controlled Series Capacitor in PSCAD and RTDS . In his research, the main target is to develop new modeling techniques for Thyristor Controlled Series Capacitor (TCSC) and to investigate the interaction phenomena between TCSC and surrounding network, is presented and the effect of control system structure and surrounding network on operational characteristics of TCSC. Salem Rahmani et.,al[12] presented his work on the combined system of a thyristor-controlled reactor (TCR) and a shunt hybrid power filter (SHPF) to suppress current harmonic and reactive power compensation from the load. He established a nonlinear control scheme of a SHPF-TCR compensator which is being simulated and implemented and hence the work shows the fast dynamic response and good performance in both steady-state and transient operations. Rajiv K. Varma et.,al[16] presents the potential occurrence and mitigation of Sub synchronous Resonance (SSR) caused by an induction-generator (IG) effect as well as torsional interactions, in a series-compensated wind farm. The research has done on SVC to effectively damp SSR when equipped with an SSR damping controller. While both FACTS controllers—the SVC and TCSC—can effectively mitigate SSR, the performance of TCSC is shown to be superior. P.Suman Pramod Kumar et.,al[17] proposed the work on static synchronous series compensator(SSSC). The paper discuss about the basic operating and performance characteristics of the SSSC, and compares them to those characterizing and more conventional compensators based on thyristor switched or controlled series capacitors and the simulation of various aspects of Static Synchronous Series Compensator (SSSC), such as power oscillation damping, improving transient stability has been done. Tamal Roy et.,al[18] has presented his paper on simulation of DSTATCOM on PSCAD for voltage sag improvement. He uses generalized sinusoidal pulse width modulation (SPWM) technique as the controller for fast control action of the DSTATCOM.

3. CONTROLLERS

A. Series Controllers

If the line voltage is in phase quadrature with the line current, the series controller absorbs or produces reactive power, if it is not, the controllers absorbs or produces real and reactive power. Examples of such controllers are Static Synchronous Series Compensator (SSSC), Thyristor-Switched Series Capacitor (TSSC), Thyristor-Controlled Series Reactor (TCSR), to cite a few. They can be effectively used to control current and power flow in the system and to damp system's oscillations. Among these Static Synchronous Series Compensator (SSSC) is one of the important series FACTS devices. SSSC is a solid-state voltage source inverter, injects an almost sinusoidal voltage, of variable magnitude in series with the transmission line. The injected voltage is almost in quadrature with the line current. A small part of the injected voltage, which is in phase with the line current, provides the losses in the inverter.

B. Shunt Controllers

Shunt controllers are similar to the series controllers with the difference being that they inject current into the system at the point where they are connected. Variable shunt impedance connected to a line causes a variable current flow by injecting a current into the system. If the injected current is in phase quadrature with the line voltage, the controller adjusts reactive power while if the current is not in phase quadrature, the controller adjusts real power. Examples of such systems are Static Synchronous Generator (SSG), Static Var Compensator (SVC). They can be used as a good way to control the voltage in and around the point of connection by injecting active or reactive current into the system.

C. Combined Series- Series Controllers

A combined series-series controller may have two configurations. One configuration consists of series controllers operating in a coordinated manner in a multiline transmission system. The other configuration provides independent reactive power control for each line of a multiline transmission system and, at the same time, facilitates real power transfer through the power link. An example of this type of controller is the Interline Power Flow Controller (IPFC), which helps in balancing both the real and reactive power flows on the lines.

D. Combined Series- Shunt Controllers

A combined series-shunt controller may have two configurations, one being two separate series and shunt controllers that operate in a coordinated manner and the other one being interconnected series and shunt components. In each configuration, the shunt component injects a current into the system while the series component injects a series voltage. When these two elements are unified, a real power can be exchanged between them via the power link. Examples of such controllers are UPFC (Unified Power Flow Controller) and Thyristor-Controlled Phase-Shifting Transformer (TCPST). These make use of the advantages of both series and shunt controllers and, hence, facilitate effective and independent power/current flow and line voltage control.[19]

4. SVC

The Static Var Compensator (SVC), a first generation FACTS controller is a variable impedance device where the current through a reactor is controlled using back to back connected thyristor valves. The application of thyristor valve technology to SVC is an offshoot of the developments in HVDC technology. The major difference is that thyristor valves used in SVC are rated for lower voltages as the SVC is connected to an EHV line through a step down transformer or connected to the tertiary winding of a power transformer. Typical TSC-TCR type SVC Configuration is shown in fig 2

The application of SVC was initially for load compensation of fast changing loads such as steel mills and arc furnaces. Here the objective is to provide dynamic power factor improvement and also balance the currents on the source side whenever required. The application for transmission line compensators commenced in the late seventies. Here the objectives are:

- Increase power transfer in long lines
- Improve stability with fast acting voltage regulation
- Damp low frequency oscillations due to swing (rotor) modes
- Damp sub synchronous frequency oscillations due to torsional modes

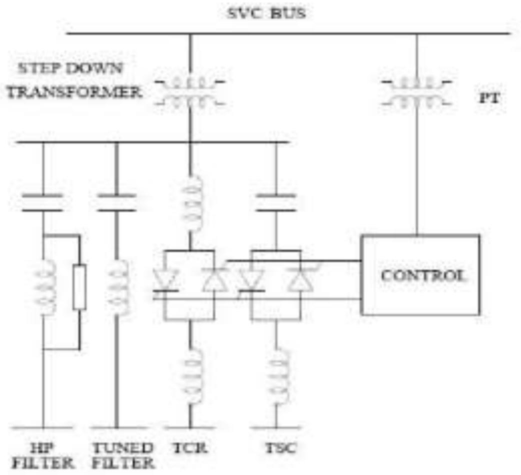

Fig. 2 SVC configuration

5. CONCLUSION

In this study, various techniques of reactive power compensation methods are viewed. Different paper are followed up and finally came into conclusion with one method i.e Static VAR Compensator (SVC) for the voltage stability and to compensate the reactive power is better. By using the SVC in transmission line increases the real power transfer capacity of EHV transmission line increases.

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