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Application of SVC in Power System Sability Assessment: A Review

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Abstract — Power system is a very vulnerable entity. It comprises of numerous complex structure and devices. For the proper stable operation of the system, it is very important that system must operates in synchronism after any mishappening events like faults. This paper presents the importance of power system stability and the devices which helps in maintaining it. A brief overview on Static Var Compensator (SVC) with its circuit topology, system configurations and components with its voltage and current waveforms is presented. The performance analysis and its effectiveness in maintaining PSS is overviewed with brief literature survey.

Keywords: Contingency Analysis, Flexible AC Transmission System (FACTS), Power System Stabilizer (PSS), Static Var Compensator (SVC), Voltage Stability

I. Introduction

Modern Power Systems (MPS) are becoming more vulnerable to operating limit violation and voltage instability problems due to large transmission networks, deregulation of the electricity industry and utilization of various renewable energy sources as well as different load patterns. As power systems have evolved through continuing growth in interconnections, use of new technologies and controls, and the increased operation in highly stressed conditions, different forms of system instability have emerged [1, 2].

Power system stability is defined as the condition of normal operation of all the MPS elements with stable equilibrium even though it is subjected to the contingency [3]. Contingency is a common term given to all type of abnormal operating condition of MPS like; faults, sudden load variations, switching in off high power devices, integration of high rating power converters, high penetration of renewable resources, etc. all these events have different operating states and may lead to various stability issues which are presented in figure 1 [4]. Hence, to retain stability firstly contingency analysis is carried out to identify the issue and then methods to improve stability are used. Stability of the system in case of transmission, is improved either by static compensator like fixed inductor, capacitor or by the methods of enhancing transmission line capacities for the duration of contingencies. Else it is improved by dynamic controllers like FACTS controller [5].

Thyristor-based solid-state devices for power compensators were developed in the 1970s which was later commonly termed as FACTS controller [6-9]. These controller were either thyristor switched capacitors or thyristor controlled reactor (TCRs) or the combination of both with the passive filtering unit which eliminates. These are basically a VAR impedance-type controllers, commonly known as static VAR compensator (SVC), whose susceptance is controlled by varying the firing angle of the thyristors connected. This paper presents the literature survey and overview of various SVC topologies available in literature for power conditioning in transmission system [10].

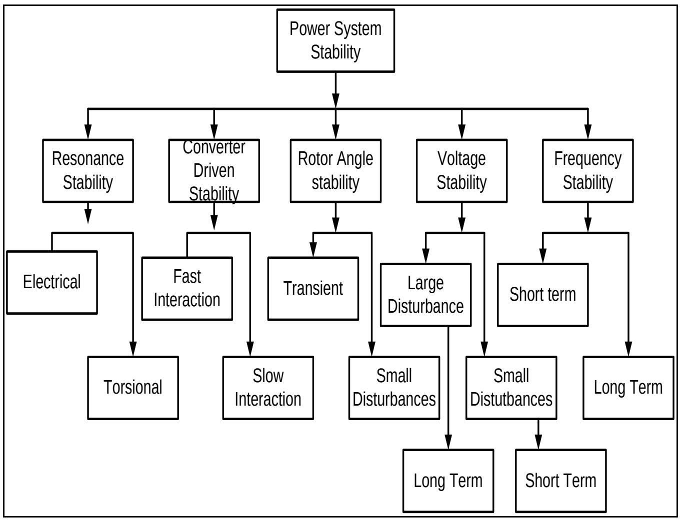

Fig. 1: Classification of Stability in MPS

II. Static VAR Ompensator (SVC)

Static VAR Compensator can be defined as "A FACTS device which is basically connected in shunt and its inductive and capacitive current in output can be controlled respective of an AC voltage" [11]. The major difference is that thyristor valves used in Static VAR Compensator are rated for lower voltages as the SVC is connected to an EHV line through a step-down transformer. [12-14] The application of SVC was initially for load compensation of dynamically changing loads such as arc furnaces and frequency converter transformers. The wide application for transmission line compensators were commenced in the 1970's. The main objective so Static VAR Compensator are:

- Improve the power system stability with dynamic voltage regulation
- Damping of low frequency oscillations due to rotor swing modes
- Controlling of dynamic overvoltage in the system
- Damping of sub synchronous oscillations due to torsional modes
- Improving the power transfer capability in long transmission lines

The Static VAR Compensator (SVC) is one of the device of the Flexible AC Transmission Systems (FACTS) family which contains power electronics devices to control power flow on power grids. The SVC regulates voltage by controlling the amount of reactive power injected into when deficient or reactive power absorb when surplus in the power system [15]. A Static VAR compensator is a parallel combination of controlled reactor and fixed shunt capacitor. A schematic representation of the structure of an SVC is shown in Figure 2, where it is a shunt connected device comprises of several modules built of a fixed capacitance in parallel with a thyristor-circuits.

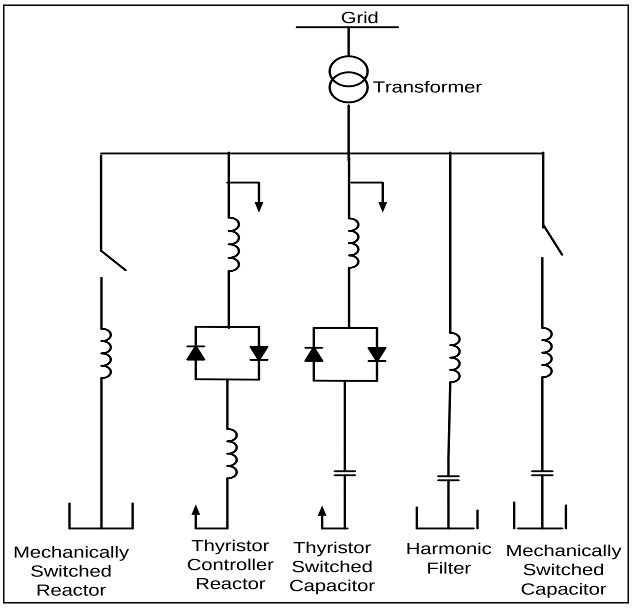

Fig. 2 Schematic of SVC

III. TOPOLOGIES OF SVC

SVC falls under the umbrella of FACTS devices of the variable impedance kind. To control the voltage at a specific bus, SVC either injects or absorbs reactive power. Voltage regulation and VAR control mode are the two modes of operation for SVC [16]. While the SVC susceptance is maintained constant in VAR control mode, the voltage at the supply side of the SVC is regulated in voltage control mode [17]. A reactor whose operation is managed by a thyristor (TCR) is connected in parallel as part of the SVC. (ii) Thyristor switched capacitors (TSC) in three different quantities. With TSC, there are just two possible states for the switch: ON and OFF. When using TCR, the pulse generators' firing angles can be changed to regulate the impedance [18].

The block diagram of SVC is seen in Figure 3. In [19], a system is taken into account for analysis both with and without compensation using shunt and series compensators (TCSC) and SVC, respectively. For SVC and TCSC compensated cases, load flow results are produced, and apparent impedances of the uncompensated case with 100 and 200% loading are compared. Advanced static compensator and SVC are proposed in [20], and optimisation techniques are used to determine the best inductor, capacitor, proportional, and integral gain values.

In [21], IEEE 14 and 30 bus systems are taken into account along with variations in voltage swell. Distribution static VAR compensator (D-SVC) during internal, peak load, and power losses profile is used in [6] to better and efficiently operate the grid while taking into account the impacts of total harmonic distortion (THD) on load profile. [22] models and simulates the IEEE 14 bus system using various forms of load changes and measures of active power, reactive power, and voltage magnitude. Voltage measurement, voltage regulator, distribution unit, and firing unit are the four fundamental parts of an SVC controller and are sequentially coupled. The controller of SVC has input signals as measured voltage and current and firing angle for the thyristors connected are obtained as the output.

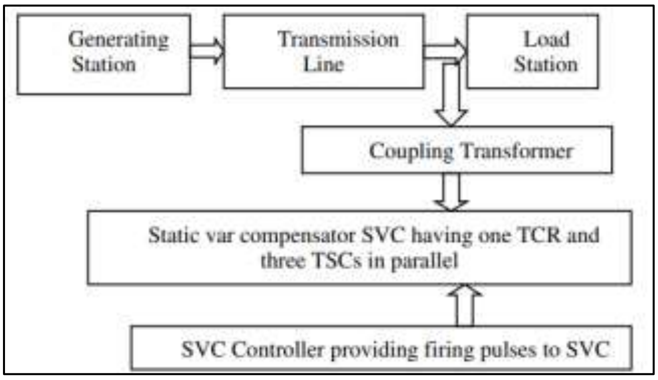

Fig. 3: Block diagram showing interconnection of generators and load through a transmission line along with SVC

IV. WIND POWER GENERATION

The Static VAR Compensator (SVC) device is characterized by fast response of wide operational range and high reliability. From the many possible approaches to generate and control reactive power, presently thyristor valves are used almost in configuration SVC. The Static VAR Compensator (SVC) can be operated in two component compositions: -

Thyristor-controlled reactor (TCR), which is a continuously controlled inductance, between L=0 (where thyristors are blocked) and L=max (where thyristors are in full conduction). Thyristor-switched capacitors (TSC), which are turned on and off by static devices. A continuous control domain of the SVC between the maximum inductive and maximum capacitive is obtained by properly controlling the TCR. This combination enables the SVC to absorb/produce the precise amount of reactive power required; - Fixed filters provided by the TCR specifically for low-order harmonics filtering. Reactive power is also produced by the capacitors included into the filters.

TCR; An elementary thyristor-controlled reactor consists of a fixed reactor of inductance L and a bidirectional thyristor valve (Figure 4).

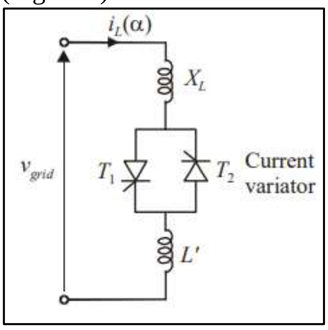

Fig. 4: Thyristor-controlled reactor

Large thyristors that are currently on the market may block voltages of up to 4 to 9 kV and carry currents of up to 3 to 6 kA. Because of this, the valve used in practical applications is made up of a number of thyristors connected in series to achieve the necessary blocking voltage levels for a certain power rating. By controlling the firing delay angle, the current in the reactor can be constantly changed from maximum conduction to zero. By altering the thyristors' instant of ignition and subsequently the conduction period for each half-cycle, the reactor current iL() can be changed. The complete thyristor conduction time and hence the maximum current in the reactor are reached if conduction is started at the maximum input voltage.

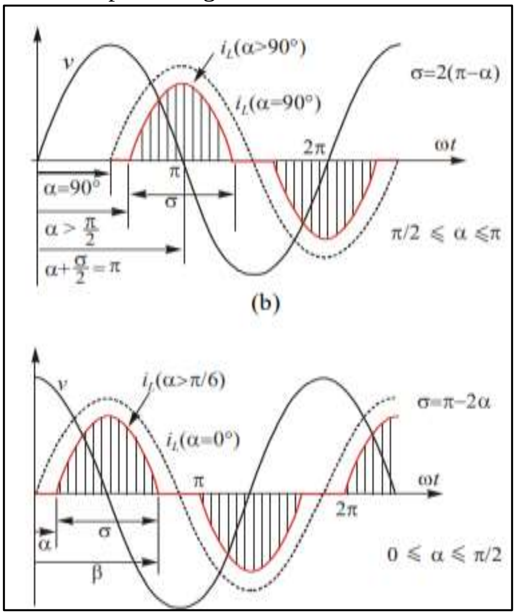

Fig. 5: voltage and current waveforms in the reactor

TSC; A capacitor, a bi-directional thyristor valve, and a small reactor L' make up the single-phase thyristor switched capacitor (TSC) depicted in Figure 6. The reactor L' serves primarily to control the surge current in the thyristor valve (during the commutation process) and to prevent resonance with the AC system at particular frequencies. An RC series that is linked in parallel with each thyristor bank completes the circuit by balancing the voltage levels on the thyristor banks and limiting potentially harmful surge currents that may emerge at thyristor blockings. A control and command device is used to operate the two anti-parallel linked thyristor modules. The control and command device connects fewer or more devices depending on the bus voltage.

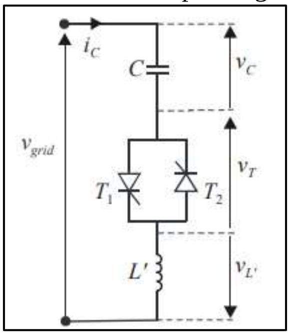

Fig. 6: Circuit diagram of TSC

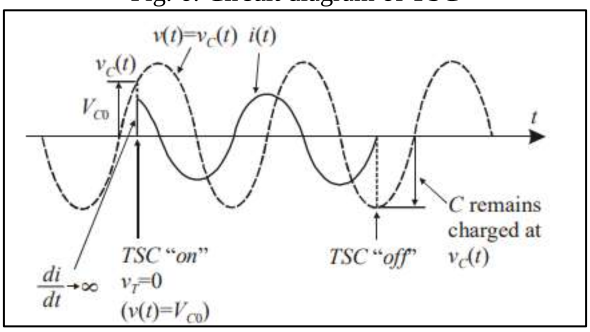

Fig. 7: Associated current and voltage waveforms of TSC

V. CONCLUSION

Seeing to the severity of instability in power system, numerous devices are been foresighted in literature to retain the stability under dynamic operating conditions. Earlier static compensators like synchronous generators, capacitors or reactors were used depending upon the type of instability conditions. These static compensators are either mechanically switched or are of fixed type which not solve the problem efficiently or even they can worsen if they are of fixed type under normal operations. Then the era of power converters or automatically switched controller with thyristors or semiconductor-based devices came into existence which can be connected automatically as per the system conditions. The more advanced form of these types of converters which are widely adopted in MPS transmission side is FACTS controllers. Flexible Alternating Current Transmission System (FACTS) have been discovered that are used in the transmission system to improve the power quality and to compensate the reactive power.

This paper presents the performance overview and literature survey on one such FACTS controller named SVC. SVC stands for Static Var Compensator which is semiconductor based used to restore the condition of transient stability when subjected to large system disturbances. In this work condition of power system faults both single and three phase faults are analysed as the contingency condition and the stability analysis is carried out with and without SVC. One more tool named as Power System Stabilizer is also used to retain stability.

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