Stability Modeling and Comparative Study of Series Vectorial Compensators using IEEE 14 Bus System. S.H.Pawar(Faculty)

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ABSTRACT : *Power systems are currently operating closer to their static and dynamic stability limits due to an increase in the power transfer demands on existing transmission systems, significant growth of loads and generation, lack of new transmission lines, and competitive electricity market pressures. Stability problems associated with voltage collapse and undamped oscillations are currently the leading causes of major blackouts.To increase stability margins of the system, FACTS controllers are added, modeled and tested to show the effect of these controllers on the different stability margins under both large and small disturbances.Comparative evaluation of Series Vectorial Compensator (SVeC) with respect to controllers used mainly for oscillation control in transmission corridors, namely, thyristor-controlled series capacitors (TCSC) and series static synchronous compensators (SSSC). The IEEE 14-bus benchmark system model is used for illustrative and comparison purposes. The Series Vectorial Compensator has better oscillation damping characteristics than the TCSC and SSSC, hence making these types of controllers a competitive alternative against existing series flexible ac transmission system (FACTS) controllers for dynamic series compensation of transmission lines.*
Keywords - 14 Bus System, Series Vectorial Compensator(SVeC), TCR, TCSC, TSSS.

I. INTRODUCTION

The industrial growth of a nation requires increased consumption of energy, particularly electrical energy. This has lead to increase the generation and transmission facility to meet the increasing demand. For generation, transmission, distribution and utilization of electrical energy, 3 phase AC systems are used universally. It is beneficial to use AC system because of its features like reduction of electrical losses, increasing transmission efficiency and capacity, better voltage regulation, reduction in conducting material, flexibility for growth and possibility of interconnection. FACTS Controller is defined as a power electronic-based system and the other static equipment that provide control of one or more AC transmission system parameters.

1.WHAT IS FACTS

Flexibility of electric power transmission is the ability to accommodate changes in the electrical transmission system or operating conditions while maintaining sufficient steady-state and transient margins.Flexible AC Transmission System (FACTS) is nothing but alternating current transmission systems incorporating power electronic-based and other static controllers to enhance controllability and increase power transfer capability.

1.1 Relative importance of controllable parameters
   A few basic points regarding the possibility of power flow control are,
1. Control of the line impedance X
2. Control of X or the angle substantially provides the control of active power.
3. Control of angle (with a Phase Angle Regulator, for example), which in turn controls the driving voltage

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4. Injecting voltage in series with the line and with any phase angle with respect to the driving voltage can control the magnitude and the phase of the line current.

Combination of the line impedance control with a series Controller can also provide control of active as well as

reactive power.

II. SERIES VECTORIAL COMPENSATOR (SvEc)

Concept of SVeC is to control active power on a transmission line with a simple structure, injecting a series capacitive reactance that is adjusted automatically through a duty cycle control. These controllers are based on thyristors or VSC-based converters. However, more recently, new controllers based on ac-ac vectorial converters are used.
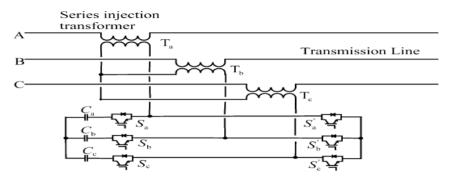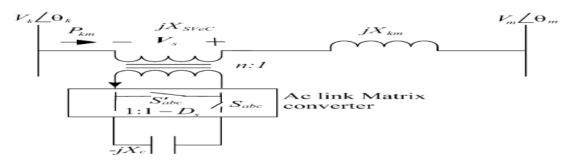

Figure no.1 Transmission line with PWM SVeC.

Ta,Tb,Tc **-** Transformer for phase A, phase B and phase C Sa,Sb,Sc – Switches for phase A, phase B and phase C

Ca,Cb,Cc – Capacitors for phase A, phase B and phase C

The schematics of the SVeC are shown in Fig.1 The series compensator consists of series injection transformers Ta, Tb and Tc; compensation capacitors Ca, Cb and Cc; and PWM controlled switches,Sa, Sb, Sc,and Sa' Sb', Sc'. During the period when the switches Sa, Sb, and Sc, are closed, the compensation capacitors are connected. The switches, Sa' Sb' and Sc' and operate complementarily with respect to Sa, Sb, and Sc, thus avoiding the short-circuiting.

Figure 2. SVeC Single line

Single-line diagram associated with Fig. 2 is depicted; here, the switches , and are represented by and , respectively.

III. Model and Control

Models used are based on complex equations that lead to some convergence problems during the numerical studies. Furthermore, a simple PI controller is used to control the active power through the transmission line, which does not provide adequate damping for all power oscillations triggered by system contingencies. Therefore, a simpler stability model that does not present numerical problems is used here, together with the improved control shown in Fig. 3 for the regulation and oscillation damping of the transmission line's active power.   From Fig. 3, the equivalent impedance between the sending and receiving end of the SVeC- transmission-line system can be defined as
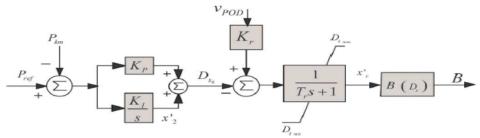
Figure 3: SVeC Power Regulator

IV. Variable Impedance Type Static Var Generators

The performance and operating characteristics of the impedance type var generators are determined by their major thyristor-controlled constituents the thyristor- controlled reactor and the thyristor- switched capacitor.

4.1 Thyristor-controlled and thyristor-switched reactor(TCR AND TSR)

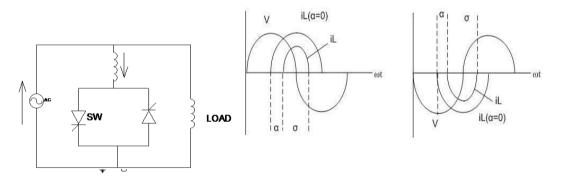An elementary single phase Thyristor-controlled reactor (TCR) is shown in fig. 4

Figure 4. Basic Thyristor-controlled reactor (TCR) firing Delay Angle Control and operating waveform

It consists of a fixed reactor of inductance L, and a bidirectional thyristors valve or a switch sw. The current in the reactor can be controlled from maximum to zero by the method of firing delay angle control. That is, closure of the thyristors valve is delayed with respect to the peak of the applied voltage in each half cycle and thus the duration of the current conduction intervals is controlled.

This methods of current control is illustrated separately for the positive and negative half cycles in fig.4, where the applied voltage v and the rector current $i_L(\alpha)$, at zero delay angle and at arbitrary α delay angle, are shown.
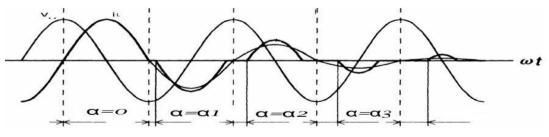

Figure 5. Operating waveform of TCR

V. Matlab simulation of Thyristor Controlled Reactor (TCR)

The construction and principle of TCR have already discussed in the previous chapter, from which it can be

evaluated that TCR acts like a variable reactive admittance. Variation of the firing angle changes the reactive admittance and, consequently, the fundamental current component, which leads to a variation of reactive power absorbed by the reactor because the applied ac voltage is constant. The capacitive load supplied through single phase thyristor controlled reactor, consisting of fixed reactor of inductance L and a bidirectional thyristor valves, is shown in fig.6
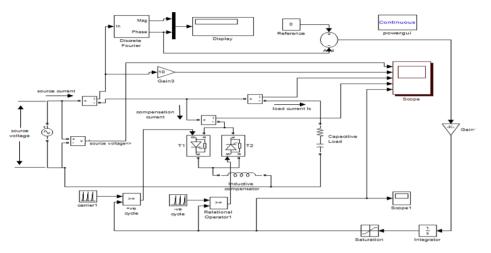

Figure.6 Circuit Configuration of TCR

The controllable range of the TCR firing angles of T1 and T2, are extends from 90° to 180° and 270° to 360° respectively. A firing angle of 90° for T1 and 270° for T2, results in full thyristor conduction with a continuous sinusoidal current flow in the TCR. As the firing angle is varied from 90° to close to 180° and from 270° to close to 360°, the current flows in the form of discontinuous pulses symmetrically located in the positive and negative half-cycles. At 180° and 360° current in the reactor becomes zero. Hence, firing of thyristors T1 and

T2 at 90° and 180° gives full possible compensation whereas at 270° and 360° gives zero compensation. According to load variation, for automatic change in the firing angles, the closed loop control circuit as shown in Fig.6 is used to achieve appropriate compensation.
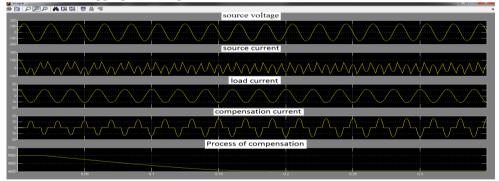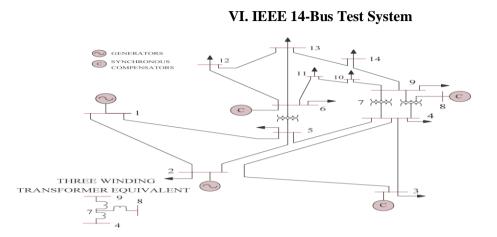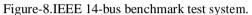

Figure.7 Source voltage, line current, load current, compensation current and process of closed loop compensation of TCR circuit.

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shown in fig.7

VI. IEEE 14-Bus Test System

Figure-8.IEEE 14-bus benchmark test system.

A single-line diagram of the IEEE 14-bus benchmark system described in [6] is shown in Fig. 8. It consists of 5 generators,three of which are synchronous compensators used only for reactive power support, all modeled sing subtransient stabilitymodels and IEEE Type 1 exciters and voltage regulators

VII. CONCLUSION

The FACTS technology gives awareness of shunt and series types of compensation. Shunt compensation injects current in the system whereas series compensator injects voltage in the system and serves their purposes. Thyristor-controlled and thyristor-switched reactor (TCR and TSR), Thyristor-Switched Capacitor (TSC), Thyristor-Switched Capacitor-Thyristor Controlled Reactor Type Var Generator are the various types used in shunt compensation. The performance of particular controller can be obtained by designing its model in MATLAB software. Hence the circuit configurations for TCR with their corresponding responses have been realized in MATLAB software. Series Vectorial compensator (SVeC) is competitive device to the FACTS technology. It can be compare by using IEEE 14 bus system.

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