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Voltage Sag and Swell Control in Distribution Power Systems Using Thyristor Controlled Series Capacitor (*TCSC*)

[1]Vinod Joshi, [2]Ashok Jhala, [3]Manish Prajapati

[1,2,3] Department of Electrical and Electronics

Abstract: **Performance of Installed TCSC Projects". This paper presents brief investigations on performance of Installed Thyristor Controlled Series Compensator (TCSC) projects world around. The main and basic objective of TCSC's in power system is to enhance power flow and improve system stability. The deployment of TCSC in transmission line also improves SSR mitigation, Power Oscillation Damping (POD) and Transient Stability (TS). The paper intends to discuss some important TCSC projects installed world around and highlights the benefits derived in terms of enhancing power networks. In the case of a TCSC such a scheme should consider the different control levels acting on the same control variable, which in this paper is assumed to be the fundamental frequency equivalent impedance, as this is the control variable most commonly studied in the literature. In this kind of hierarchical control design is difficult connections between the different control levels may be expected when not properly coordinated. The main aim is to analyze the design of a hierarchical TCSC controller for stability enhancement, taking into account interactions among the different control levels.**

Keywords: **FACTS, TCSC, Harmonics, voltages sag and voltage swell.**

I. INTRODUCTION

A linear dynamic compensator with various input signals for damping power oscillations is proposed and studied based on a typical stability model of the TCSC. Now in the past few years, the electric power industry suffers a huge increment in power consumption hence to meet the load incremental demand we needs to improve the power transmission capabilities and maintain the voltage stability during abnormal conditions. In generation it is used to improve the power oscillation damping, in transmission to increase the power transfer capability and compensate voltage sag. In distribution SVC is used to improve reactive power compensation and reduce harmonics. In this paper SVC is simulated with fixed capacitor thyristor controlled reactor. The receiving end voltage is observed for various loads in under loading, overloading and considering line to ground faults. To provide constant voltage at receiving end shunt inductor and capacitor is added for various loading conditions. FC-TCR is placed at receiving end and it can be controlled by varying the firing angle of thyristor so that to maintain sending end voltage equal to receiving end voltage. Electrical energy plays an important role in the present industrial society and has immense importance to nation's welfare and development. Hydro, thermal and nuclear power plants account for almost all of the energy generated. A lot of this energy is used for industrial, commercial, home, space and military applications with the application of power electronics.

II. THYRISTOR CONTROLLED SERIES CAPACITOR (TCSC)

The basic Thyristor-Controlled Series Capacitor scheme, proposed with others as a method of "rapid adjustment of network impedance," is shown in Fig. 1.7 It consists of the series compensating capacitor shunted by a Thyristor-Controlled Reactor. In a practical TCSC implementation, several such basic compensators may be connected in series to obtain the desired voltage rating and operating characteristics. [1] A capacitive reactance compensator which consists of a series capacitor bank shunted by a thyristor-controlled reactor in order to provide a smoothly variable series capacitive reactance Specific dynamical issues in transmission systems are addressed by Thyristor Controlled Series Capacitors (TCSC). In case of large interconnected electrical systems it increases damping. It also overcomes the problem of sub-synchronous resonance (SSR). Sub-synchronous resonance is a phenomenon that involves an interaction between large thermal generating units and series compensated transmission systems. The high speed switching capability of TCSC provides a mechanism for controlling line power flow. This permits increased loading of existing transmission lines, and also allows for rapid readjustment of line power flow in response to various contingencies. Regulation of steady-state power flow within its rating limits can be done by the TCSC. The TCSC resembles the conventional series capacitor from a basic technology point of view. All the power equipment is located on an isolated steel platform, including the Thyristor valve which is used for controlling the behavior of the main capacitor bank. Similarly the control and protection is located on ground potential along with other auxiliary systems. This arrangement is similar in structure to the TSSC and, if the impedance of the reactor "X_L" is sufficiently smaller than that of the capacitor "X_C" it can be operated in an on and off manner like the TSSC. However, the basic idea behind the TCSC scheme is to provide a continuously variable capacitor by means of partially canceling the effective compensating capacitance by the TCR. The TCR at the fundamental system frequency is continuously variable reactive impedance controllable by delay angle α. The steady-state impedance of the TCSC is that of a parallel LC circuit, consisting of a fixed capacitive impedance X_C and variable inductive impedance "X_L (α)" that is and α is the delay angle measured from the crest of the capacitor voltage or equivalently the zero crossing of the line current.

$$X_{TCSC} = \frac{X_c X_L(\alpha)}{X_L(\alpha) - X_C} \qquad 1.1$$

$$X_L(\alpha) = X_L \frac{\pi}{\pi - 2\alpha - \sin\alpha} \quad ,$$

$$X_L \leq X_L(\alpha) \leq \infty \qquad 1.2$$

$$X_L = \omega L$$

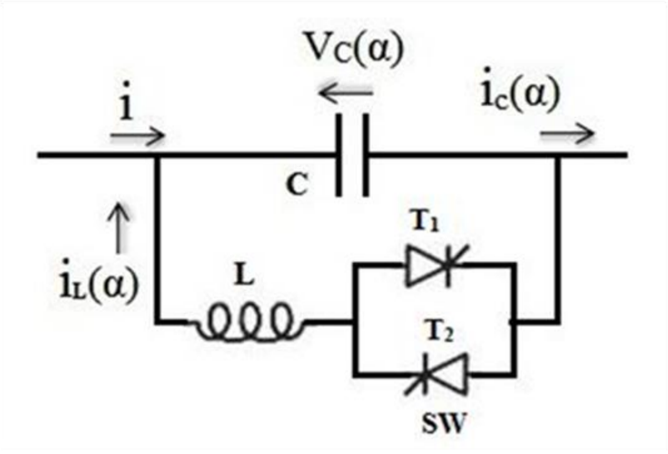

Fig.1.1: Basic Thyristor Controlled Series Capacitor

The TCSC thus presents a tunable parallel LC circuit to the line current that is substantially a constant alternating current source. As the impedance of the controlled reactor, $X_L(\alpha)$, is varied from its maximum (infinity) toward its minimum (ωL) the TCSC increases its minimum capacitive impedance $X_{TCSC.min} = X_C = 1/\omega C$ (and thereby the degree of series capacitive compensation) until parallel resonance at $X_C = X_L(\alpha)$ is established and X_{TCSC}.max theoretically becomes infinite. Decreasing $X_L(\alpha)$ further, the impedance of the TCSC $X_{TCSC}(\alpha)$ becomes inductive reaching its minimum value of $X_L X_C / (X_L - X_C)$ at α = 0 where the capacitor is in effect bypassed by the TCR. Therefore, with the usual TCSC arrangement in which the impedance of the TCR reactor "X_L" is smaller than that of the capacitor "X_C" the TCSC has two operating ranges around its internal circuit resonance: one is the $\alpha_{Clim} \leq \alpha \leq \pi/2$ where $X_{TCSC}(\alpha)$ is capacitive and the other is the $0 \leq \alpha \leq \alpha_{Clim} \leq \pi/2$ where $X_{TCSC}(\alpha)$ is inductive as illustrated in Fig. 1.7. [1]

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Redistribution of Magnetic Field Energy in Transmission Line:

The 100 km long segment of a transmission line that is contains three phase conductors running in parallel but separated from each other by only some tens of meters. Yet no bridges exist between the phase conductors where field energy bound to one phase may pass and bind to another phase. Thus no redistribution between the phases of magnetic field energy is possible within the considered segment. Accordingly, in order to perform the redistribution of the field energy between the phases, the whole field energy must be transported along the transmission line to a location, where such bridges are available. It may appear that bridges only exist at the line terminal through the feeding source beloved Fig. Illustrates this situation.[36]

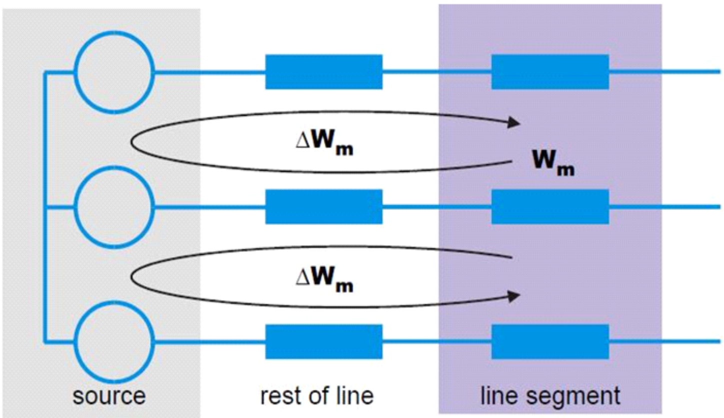

Fig.1.2: Redistribution of Magnetic Field Energy

III. IMPACT OF SERIES COMPENSATION ON VOLTAGE STABILITY

Some buses in the transmission system may lack reactive power support, i.e. there is no nearby generator that controls the voltage in the bus. The voltage in such a point depends very much on the actual power transfer on the line. In Fig. 4.7 it is assumed that only active power only is transported along a transmission line from the generating area *A* to the load area B. The voltage characteristic in *B* versus the power transfer is depicted in Fig. 4.7. For obvious reasons such curve is called a "nose-curve". It indicates that at a certain maximum loading of the transmission line a voltage collapse situation occurs. No power can pass through a node with zero voltage.

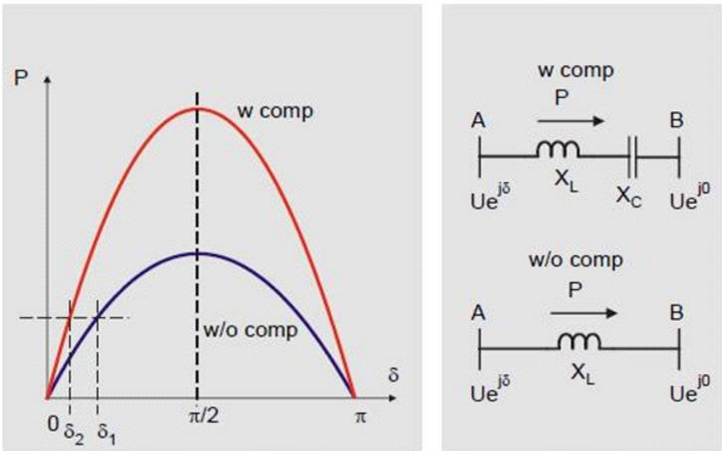

Fig.1.3: Line with Rated Voltage Amplitude in Both Ends

A situation, where one node voltage drops a lot or even collapses, may endanger the power transfer in the whole transmission system.

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IV. SIMULATION MODAL

Model -1 shown in Fig. 4.10 is a traditional transmission power system which comprised of three phase generator, load and circuit breaker for switching purpose. The transmission line has three different voltage levels i.e. 11 kV, 33 kV and 66 kV with different load and length. If the switching operation arise voltage sag, swell and harmonics will be generated in the transmission line. Model- 2 shown in Fig.4.10 has the same configuration with model-1. In addition to the discrete pulse width modulation triggered thyristor controlled switch capacitor (TCSC) is connected in series with transmission line to compensate the voltage sag, swell and harmonics. Model-3 shown in Fig.4.11 has the same component with model-2. Firing angle controlled TCSC is connected in series with transmission line to compensate the losses

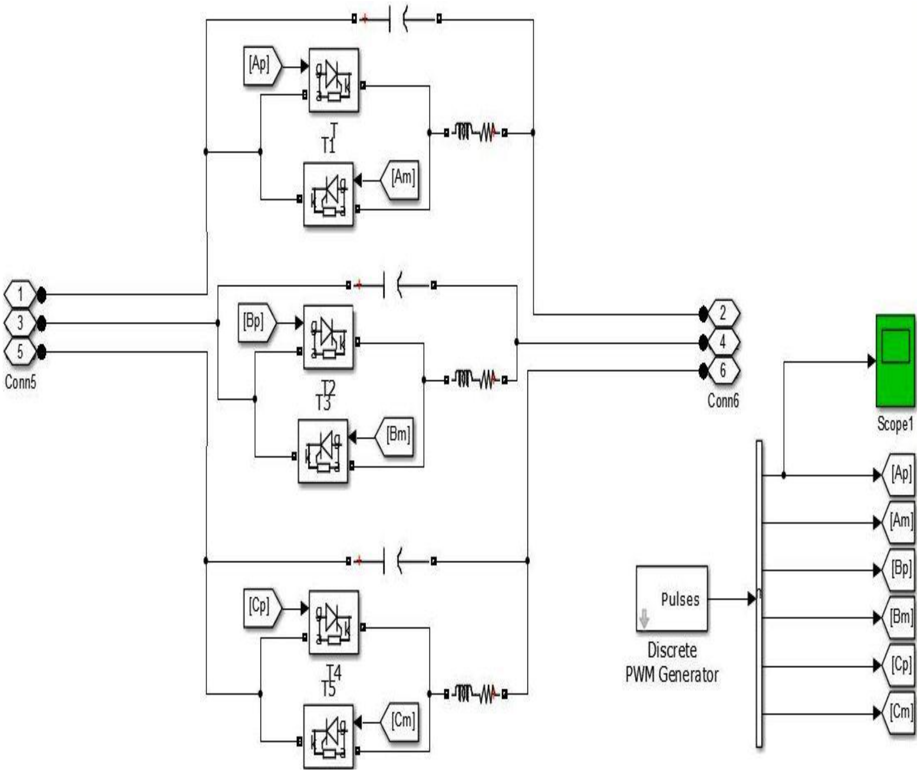

Fig.1.4: Substation with Firing Pulse Controlled TCSC Simulation

V. RRESULT AND DISSCATION

The harmonics presented in Modal-1 The 11kV transmission line 13.95% harmonics present and 33 kV transmissions line 14.2% harmonics present similarly 66 kV transmission line 12.84% harmonics present The harmonics presented in compensated signal voltage of Modal-2. The 11kV transmission line 13.95% harmonics present its compensated 2.66% and 33 kV transmissions line 14.2% harmonics present show in fig 5.8 its compensated 8.59% similarly 66 kV transmission line 12.84% harmonics present its compensated 6.28% The harmonics presented in compensated voltage of Modal-3. The 11kV transmission line 13.95% harmonics present its compensated 5.27% and 33 kV transmissions line 14.2% harmonics present show in fig 5.8 its compensated 9.31% similarly 66 kV transmission line 12.84% harmonics present its compensated 6.84%

S.No.	Sending End Voltage (KV)	Harmonics % Without TCSC	Harmonics % With TCSC	
			Model-2	Model-3
1	11	13.95	2.66	5.27
2	33	14.2	8.59	9.31
3	66	12.84	6.29	6.85

VI. CONCLUSION

From the above expected result we concluded that the use of TCSC compensating device with the Pulse control is effective and it is a simplest way of controlling the reactive power of transmission line. It is observed that TCSC device was able to compensate both over and under voltages, TCSC controller is more efficient than conventional method. The use of TCSC has facilitated the closed loop control of system, which decides the Pulse controlled given to thyristor to attain the required voltage. MATLAB simulation is observed that thyristor switched series capacitor provides an effective reactive power control irrespective of load variation and also provide voltage stability during fault conditions. The FACTS technology is not a single high-power Controller, but rather a collection of Controllers, which can be applied individually or in coordination with others to control one or more of the interrelated system parameters mentioned above.

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