INTENSIFICATION OF POWER SYSTEM DYNAMICS USING TCSC BASED HYBRID SERIES CAPACITIVE COMPENSATION

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Abstract : *This paper exemplifies about the proposed Hybrid" series capacitive compensation scheme using Thyristor controlled series capacitor (TCSC) to improve the power system dynamics as it has the dormant of damping power swing as well as the sub synchronous resonance oscillations. The proposed model is explained in a single line and a double line scheme for damping the power system oscillations of three generators and two loads power system to verify the efficiency. In single line scheme, two phases are compensated by fixed series capacitor (Cs) and the third phase is compensated by Thyristor controlled series capacitor (TCSC) with a fixed capacitor (Cc) where as in double line scheme one phase is compensated by fixed series capacitor (Cs) and the other two phases are compensated with a TCSC in series with a fixed capacitor (Cc). The obtained results are proved that the proposed model reduced the fault clearing time in comparison to the without compensation.*

Keywords: ***FACTS devices, Phase imbalance, series compensation, Thyristor Controlled Series Capacitor (TCSC), Phase Locked Loop (PLL).***

I. INTRODUCTION

As we know that today's power system is a complex network because, generation of power does not locate near to the load centers and different generating stations are connected through a grid. The integrated power system results into a low frequency inter-area oscillation [1]. When there is a imbalance between generation and load in each system that results disturbances in transmission lines, those disturbances may cause due to the loss of excitation, loss of prime mover, failure and faults in transmission line and sudden change in the load. Due to that disturbances, some oscillations may occur, which lead to voltage collapse and frequency collapse. In order to overcome these problems Flexible Alternate Current Transmission System (FACTS) devices has been introduced, which play a vital role in controlling the power flow in AC networks that will control both active and reactive power which results in improving the power system transient stability [2]. There are different FACTS devices available in the literature namely, TCSC, SSSC, SVR etc [1]. The FACTS devices can be used to provide the damping in the series sub synchronous capacitance (SSSC) which has been used to intensify power system dynamics [3-5]. The use of phase imbalanced TCSC compensation proves to be effective in improving power system dynamics as it has the dormant of damping the power swing as well as sub synchronous resonance oscillations [6]. In this hybrid capacitive compensation scheme there are two cases, in first case, two phases are compensated by fixed series capacitor (Cs) and the third phase is compensated by fixed capacitor (Cc) in series with TCSC, this type of scheme is called single line compensation. Where as in second case, one phase is compensated with fixed series capacitor (Cs) and another two phases are compensated with TCSC in series with fixed capacitor (Cc), this type of scheme is called double line compensation. The TCSC control is initially set to the equivalent compensations at the power frequency combined with the fixed capacitor yield a resultant compensation equal to the other two phases in single line compensation equal to other phases in double line compensation. Thus, the phase balance is being maintained at the power frequency while at any other frequency, a phase imbalance is created.

The remaining paper is arranged as follows, Section 2 explains about thyristor controlled series capacitor. Section 3 gives information about TCSC in transmission line. Section 4 explains about results and execution. Finally conclusions are given in section 5.

II. THYRISTER CONTROL SERIES CAPACITOR (TCSC)

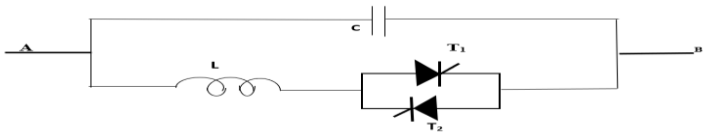

Fig.1 Circuit diagram of TCSC

Fig. 1 explains the block diagram of a thyristor control series capacitor (TCSC) in that an inductor and capacitor are connected in series with the thyristor set. When a fixed capacitor is connected with the thyristor-controlled reactor (TCR), TCSC is formed. This TCSC is connected with a Transmission lines to reduce sub synchronous reactance and improve transmission efficiency. This TCSC can be operated in both inductive mode as well as capacitive mode and it is operated by applying the gate pulses. The impedance is lowest at 90^o firing angle and the operation is done between 49^o-68^o firing angles [1].

III. TCSC IN TRANSMISSION LINES

TCSC is connected in series with the in transmission lines. Here two different cases are considered. In case 1, TCSC is connected to only one phase and the Reactance is measured with respect to other two phases and it is called single line scheme, where as in case 2, TCSC is connected to two phases in series with the line capacitance and these two reactances are measured with respect to another phase. The detailed description of the above two cases is given below.

3.1 TCSC IN SINGLE LINE SCHEME.

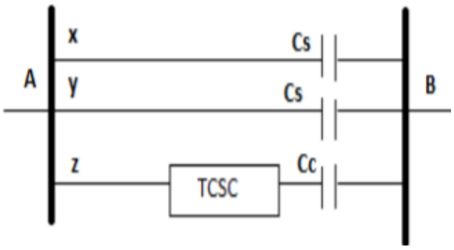

Fig. 2 TCSC for single line scheme

In single line scheme one phase is connected with TCSC in series with fixes capacitor and another two phases are connected with fixed capacitors, as shown in Fig. 2. []

At power frequency, series reactance of two busses A^0 & B^0 in single line scheme in R, Y and B phases are given by

$$X_X = X_Y = \frac{1}{j\omega 0 C_S} \quad (1)$$

$$X_Z = \frac{1}{j\omega 0 Cs} - jX_{TCSCO} \quad (2)$$

Where X_{TCSCO} is reactance offered by TCSC

At other frequencies f_c

$$X_{Z} = \frac{1}{j\omega 0 Cs} - jX_{TCSCO} - j\,\Delta X_{TCSCO} \quad (3)$$

Where ΔX_{TCSCO} change in reactance.

3.2 TCSC IN DOUBLE LINE SCHEME

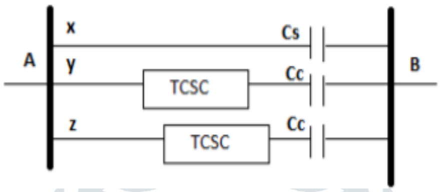

Fig.3 TCSC in double line scheme

In double line scheme one phase has fixed capacitance and other two phases are connected with TCSC in series with fixed capacitance of the line.

At power frequency, series reactance of two busses A^0 & B^0 in double line scheme in R, Y and B phases are given by

$$X_X = \frac{1}{j\omega 0 C_S} \quad (4)$$

$$X_Y = X_Z = \frac{1}{j\omega 0 Cs} - jX_{TCSCO} \quad (5)$$

Where X_{TCSCO} is reactance offered by TCSC

At other frequencies f_c

$$X_{Z} = \frac{1}{j\omega 0 Cs} - jX_{TCSCO} - j\,\Delta X_{TCSCO} \quad (6)$$

Where ΔX_{TCSCO} change in reactance.

In this paper we show performance of power system oscillations for various conditions that is Fault and without Fault using MATLAB simulation.

IV. RESULTS AND DISCUSSION

A single phase TCSC is made by connecting an ideal thyristor pair and RC snubber circuit. A Phase Locked Loop (PLL) is used to get phase information of the fundamental frequency line current which is used to synchronize TCSC operation. The thyristor firing pulses is based on the Synchronous Voltage Reversal (SVR) technique. The impedance of the TCSC is measured in terms of a boost factor kB. This kB is the ratio of apparent reactance of the line to the physical reactance of the TCSC capacitors

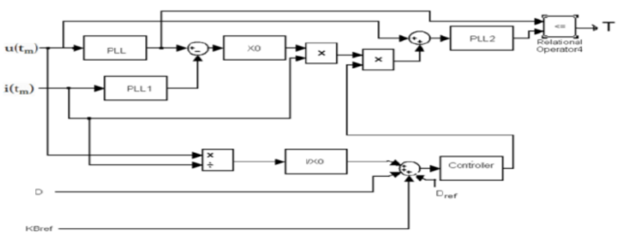

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Fig. 4 Block Diagram of TCSC

The main headings or the first level headings should be D(t) is a supplemental signal generated from m-stage lead-lag Compensation based controller. As the real power flow in lines is inversely proportional to the line reactance. Power swing damping can be achieved by properly modulating the apparent TCSC reactance through this controller.

To explain the accurate of these schemes in power system oscillations damping, Fig. 5 & Fig. 6 are taken as the test systems. It has three large generating units (G_1, G_2, G_3) supplying two load centers (L_1 & L_2). The two transmission lines are compensated with hybrid series capacitive compensation in single line and double line. The total capacity and peak load of the systems are 4500 MVA and 3833 MVA respectively. The loads L_1 = 1500+ j300 MVA and L_2 = 2500+ j300 MVA.

Simulation is done on MATLAB 2009a. System requirements are i3 processor 2.3GHz, 4GB RAM,500GB hard disk, windows7.

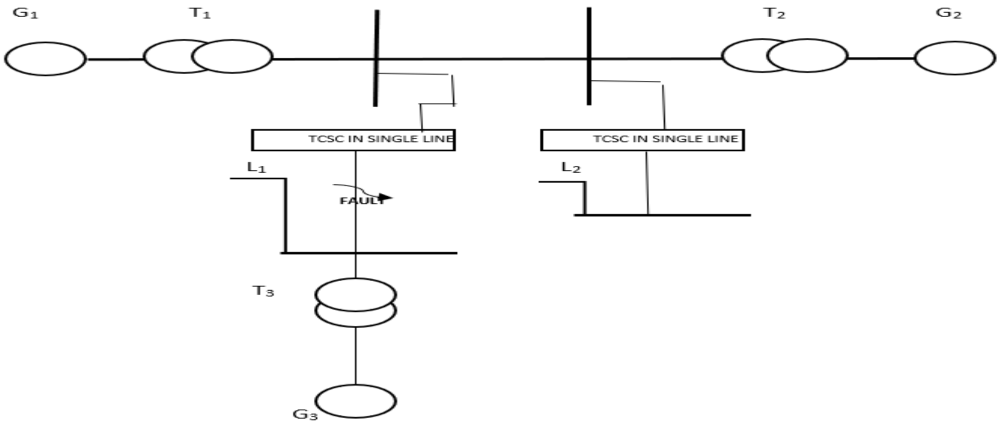


Fig. 5 Schematic diagram of hybrid series compensation scheme in single line

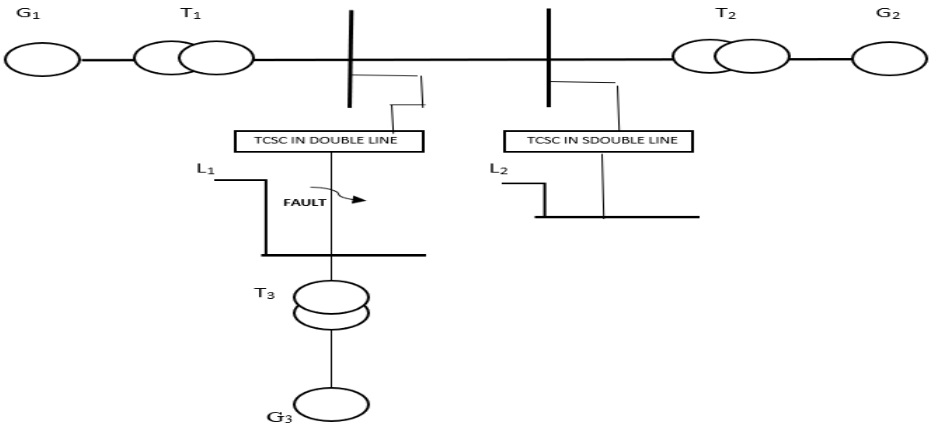


Fig. 6 schematic diagram of hybrid series compensation scheme in double line

4.1 SIMULATION RESULTS

The proposed work has been done on i3 processor 2.3GHz, 4GB RAM, with MATLAB 2009a. Here three different cases are considered which are explained below.

Case 1: Fixed compensation

Fig.7 shows the simulation diagram of fixed compensation which consists of three generating units and two load centers the below fig.7 &fig.8 shows the simulation result for generator load angle D_{yx} and D_{zx} during fault and after fault with fixed compensation.

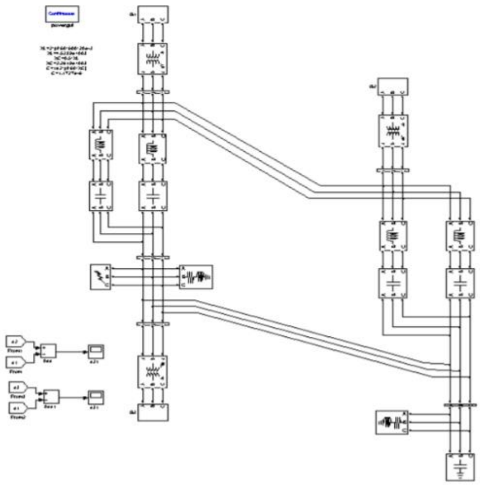
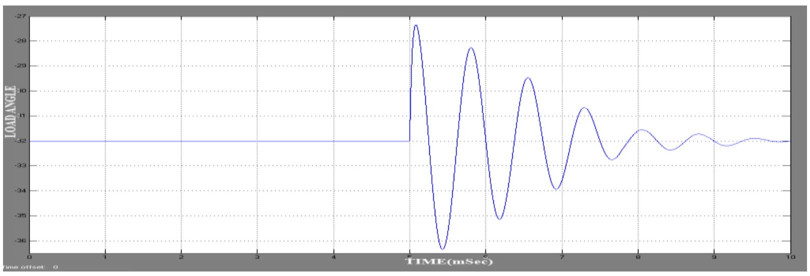


Fig.7 simulation circuit diagram of Fixed Compensation



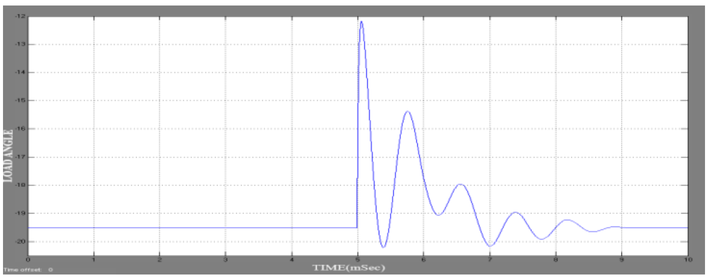


Fig. 8 Generator load angle D_{YX},during fault and after fault with

Fig.9 Generator load angle D_{ZX}, during and after fault with fixed compensation fixed compensation

Case 2: Single line scheme

Fig.10 shows the simulation diagram of hybrid series compensation in single line diagram. In this scheme as the system is compensating with single line TCSC, that fault clearing time is less when compared to the fixed compensation. fig.11 & fig.12 shows the simulation graph of generating load angle D_{YX} & D_{ZX} during fault and after fault using single line scheme.

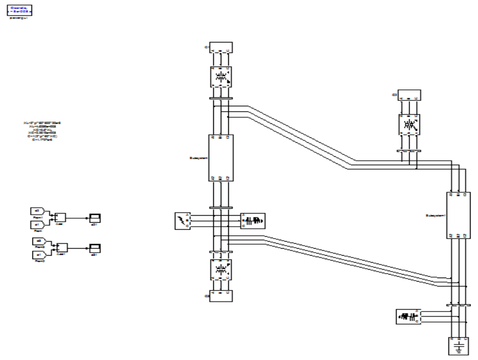


Fig. 10 Simulation diagram of Hybrid Series compensation in single line scheme

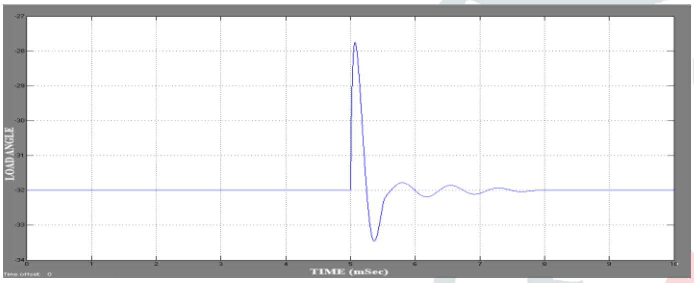


Fig.11 Generator load angle D_{YX}, during fault and after fault by using single line scheme

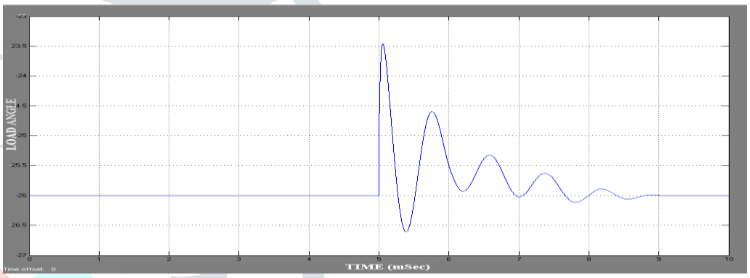


Fig.12 Generator load angle D_{ZX}, during and after fault by using single line scheme

Case 3: Double line scheme

Fig.13 shows the simulation diagram of hybrid series compensation in double line scheme. Here, the outputs Load angle (in degrees) is taken on Y-axis and Time (in mS) is taken on X-axis. D_{YX} is Y-phase with respect to X-phase and D_{ZX} is Z-phase with respect to X-phase. fig.14 & fig 15 shows the simulation graphs for generator load angle D_{YX} & D_{ZX} during fault and after fault using double line scheme.

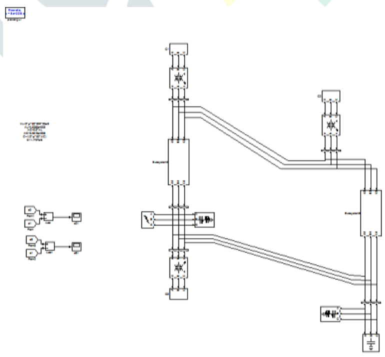


Fig. 13 Simulation diagram of Hybrid Series Compensation in Double Line Scheme

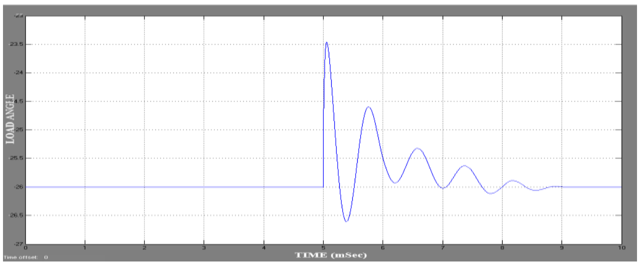


Fig.14 Generator load angle D_{YX}, during and after fault by using double line scheme

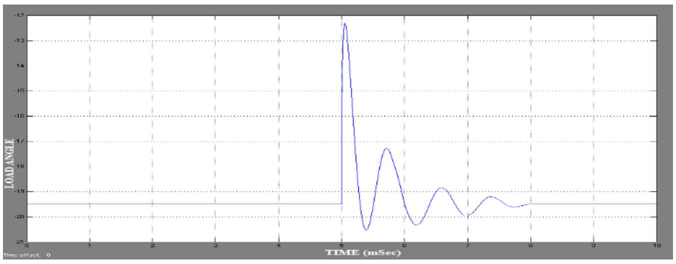


Fig.15 Generator load angle D_{ZX}, during and after fault by using double line scheme

From the figures it observed that the fault clearing time is very less in double line scheme as compared to fixed compensation and single line compensation scheme.

V. CONCLUSIONS

In this paper, TCSC based hybrid series capacitive compensation in single line and double line is considered. In order to verify the effectiveness of a power system with three generators and two loads is considered. The obtained results proved that the fault clearing time is very less in double line scheme in comparison to the single line and without compensation as well as the presented hybrid series capacitive compensation scheme improve the transient stability and sub synchronous resonance.

VI. REFERENCES

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