Implementation of Three phase TCSC Controller Design for Power System Stability Improvement

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Abstract: Due to the rapid technological progress, the consumption of electric energy increases continuously. But the transmission systems are not extended to the same extent because building of new lines is difficult for environmental as well as political reasons. Hence, the systems are driven closer to their limits resulting in congestions and critical situations endangering the system security. Power Flow Control devices such as Flexible AC Transmission Systems (FACTS) provide the opportunity to influence power flows and voltages and therefore to enhance system security, e.g. by resolving congestions and improving the voltage profile. Furthermore, shunt capacitors typically must be connected at the line midpoint, whereas no such requirement exists for series capacitors. There are different types of FACTS controllers proposed for the regulation of the power system. They are Series controllers, Shunt Controllers and combination of both. This paper focuses on the series controller Thyristor Controlled Series Compensator (TCSC) which improves the power flow in the system and provides continuous control over the entire operating region.

Key Words—FACTS Controllers, series compensation, thyristor controlled series capacitor.

I. INTRODUCTION

An inherent characteristic of electric energy transmission and distribution by alternating current (AC) is that real power is generally associated with reactive power. AC transmission and distribution associated with relative power. AC transmission and distribution lines are dominantly reactive networks, characterized by their per-mile series inductance and shunt capacitance. Thus, load and load power factor changes alter the voltage profile along the transmission lines and can cause large amplitude variations in the receiving end voltage. Most of loads are not tolerant to voltage variation. Under voltage causes degradation in the performance of loads such as induction motors, light bulbs, etc.; overvoltage causes magnetic saturation and resultant harmonic generation, as well as equipment failure due to insulation breakdown.

Reactive power also increases transmission losses. Power System Stability is the ability of the system to regain its original operating conditions after a disturbance to the system. Power system transient stability analysis is considered with large disturbances like sudden change in load, generation or transmission system configuration due to fault or switching [1]. Dynamic voltage support and reactive power compensation have been identified as a very significant measure to improve the transient stability of the system.

Flexible AC Transmission Systems (FACTS) devices with a suitable control strategy have the potential to increase the system stability margin [2, 3]. Shunt FACTS devices play an important role in reactive power flow in the power network. In large power systems, low frequency electro-mechanical oscillations often follow the electrical disturbances. Generally, power system stabilizers (PSS) are used in conjunction with Automatic Voltage Regulators (AVR) to damp out the oscillations [3]. However, during some operating conditions this device may not produce adequate damping and other effective alterations are needed in addition to PSS [4, 5].

The recently proposed phase imbalanced series capacitive compensation concept has been shown to be effective in enhancing power system dynamics as it has the potential of damping power swing as well as sub synchronous resonance oscillations [6]. In hybrid capacitive compensation scheme, in one case two phases are compensated by fixed series capacitor (Cs) and the third phase is compensated by a TCSC in series with a fixed capacitor (Cc) in singe line scheme. In second case one phase is compensated by fixed series capacitor (Cs) and the other phase are compensated by a TCSC in series with a fixed capacitor (Cc) in double line scheme [7]. The TCSC control is initially set to 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 the other phases in double line compensation. Thus, the phase balance is maintained at the power frequency while at any other frequency, a phase imbalance is created. To further improve power oscillations

damping, the TCSC is operated with a supplementary controller [8-9].
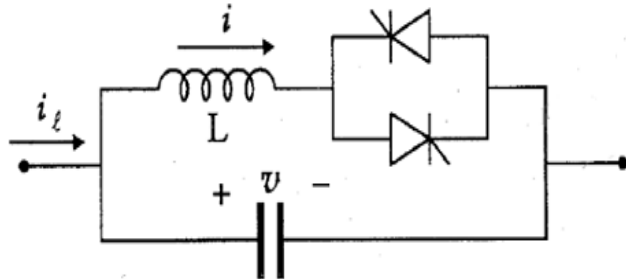
II.OPERATION OF TCSC

Fig 1.Thyristor Controlled Series Compensator

Depending on the varying load conditions, the thyristor firing angles are varied to provide the necessary impedance to the transmission network. Based on the impedance provided by the TCSC, there are three different operating modes.

A. Blocked Thyristor Mode
B. Bypassed Thyristor Mode
C. Partially Conducting or Vernier Mode
i) Inductive Vernier Mode
ii) Capacitive Vernier Mode

A. Blocked Thyristor Mode

This   mode, shown in fig. 2, is also known as waiting mode. In this mode thyristor valves are blocked and the capacitors will conduct continuously. The net TCSC reactance is capacitive.
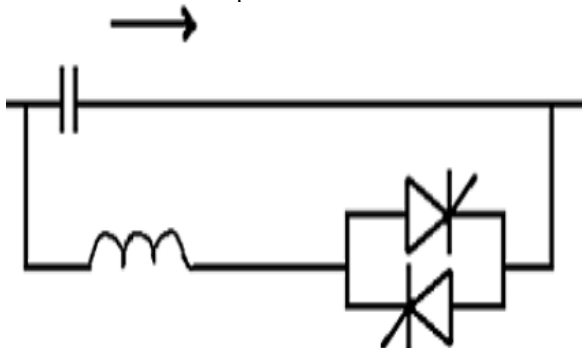
Fig.2 Blocked Thyristor Mode.

B. Bypassed Thyristor Mode

In this mode of operation, thyristors will conduct for the full 180 . The TCSC will behave like a parallel Capacitor–inductor combination. The schematic of this operating mode is shown in fig.3. This mode can be used for control purposes and for protective functions.
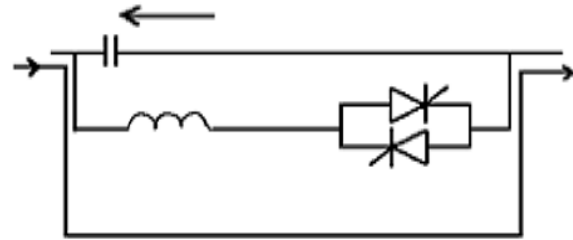

Fig.3 Bypassed Thyristor Mode

C. Partially Conducting or Vernier Mode

This mode, as depicted in fig. 4, allows the TCSC to behave either as a continuously controllable capacitive reactance or as a continuously controllable inductive reactance by varying the thyristor firing angle in the range of αmin≤α≤180. α min is above the value corresponding to the parallel resonance of the TCR and the capacitor (at fundamental frequency). The effective value of TCSC reactance in the capacitive region increases as the conduction angle increases from zero. In the Inductive Vernier mode, the TCSC (inductive) reactance increases as the conduction angle is reduced from 180º.
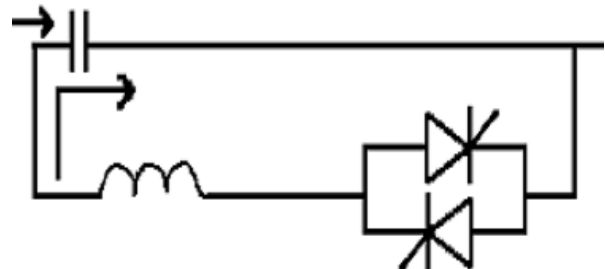

Fig.4 Vernier Mode

III. IMPEDANCE CHARACTERISTICS

Based on the thyristor firing angle and the resultant impedance, different types of operating regions are considered as shown in fig. 5 and expressed in table
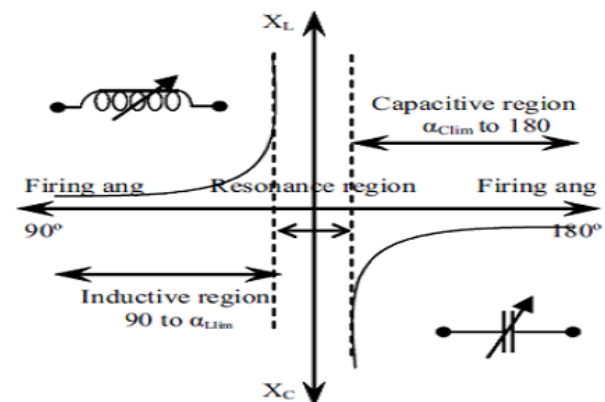

Fig.5 Impedance Characteristics

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p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 03 Issue 11
July 2016

TABLE 1

IMPEDANCE CHARACTERISTICS

RANGE OF FIRING ANGLE	OPERATING REGION
$90° \supset \alpha \leq \alpha_{L\lim}$	Inductive region
$\alpha_{L\lim} \leq \alpha \leq \alpha_{C\lim}$	Resonance region
$\alpha_{C\lim} \leq \alpha \leq 180°$	Capacitive region

IV. FUNDAMENTAL REACTANCE OF TCSC

The resultant TCSC impedance is obtained using the formulae (1) and (3) given below. Equation (1) assumes that the capacitor voltage is free from harmonics and considers only the TCR current harmonics. Equation (3) gives more accurate form of TCSC impedance including the capacitor voltage harmonics and the TCR current harmonics.

$$X_{1TCSC} = \left[\frac{X_{tcr} . X_C}{(X_{tcr} + X_C)} \right] \tag{1}$$

$$X_{TCR} = \omega L \left[\frac{\pi}{\sigma - \sin(\sigma)} \right] \tag{2}$$

$$X_{2TCSC} = -j.X_c[1 + \frac{2}{\pi}.\frac{\cos^2\frac{\sigma}{2}}{\lambda^2-1} \left\{ \begin{array}{c} \lambda.\tan(\lambda\frac{\sigma}{2}) - \tan(\frac{\sigma}{2}) \\ -(\frac{\sigma}{2}) - \frac{\sin(\sigma)}{2} \end{array} \right\}] \tag{3}$$

Where

$$\beta = \pi - \alpha \; ; \; \sigma = 2\beta \; ; \; \lambda = \frac{\omega_o}{\omega_N} \; ; \; \omega_o = \frac{1}{\sqrt{LC}}$$
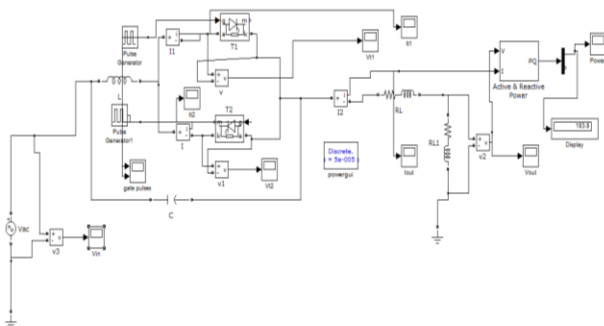
V. SIMULATION RESULTS

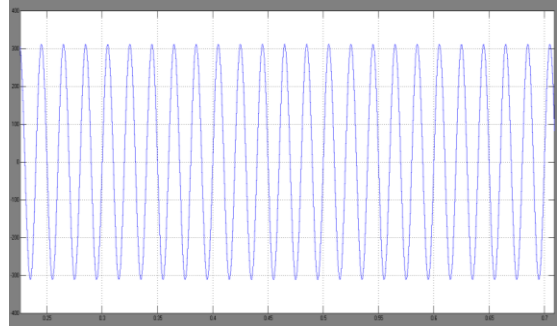Fig.6. Matlab/simulink model of conventional method.
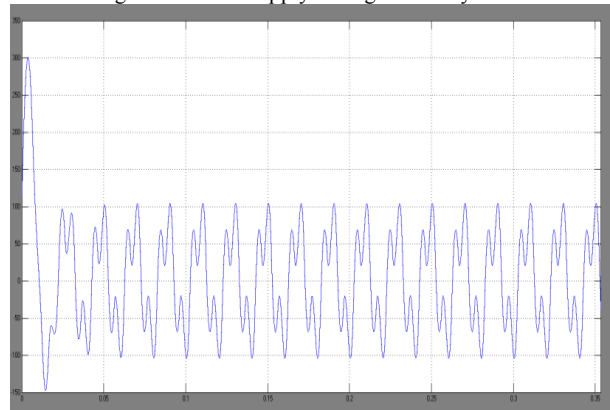

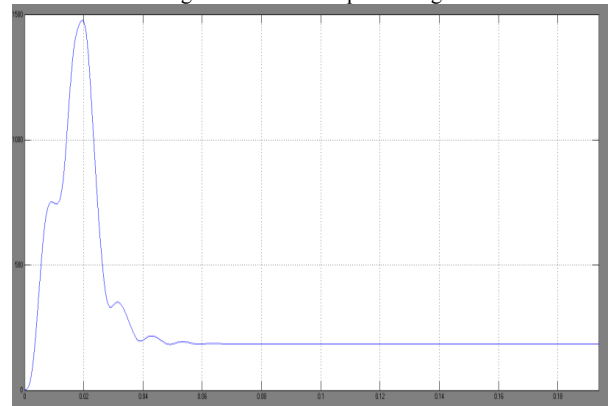Fig.7. shows the supply voltage of the system.

Fig.8. shows the output voltage.

Fig.9. shows the output power.

Case: 2

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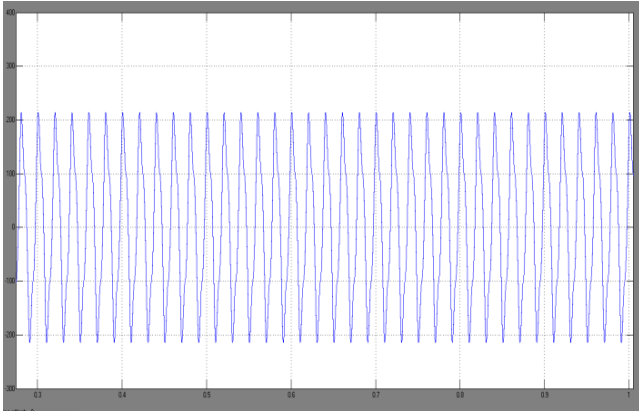
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p-ISSN: 2348-6848
e-ISSN: 2348-795X
Volume 03 Issue 11
July 2016

Fig.10. shows the output voltage.

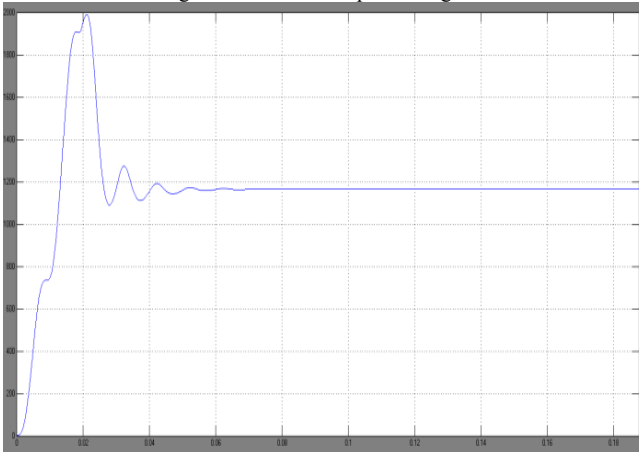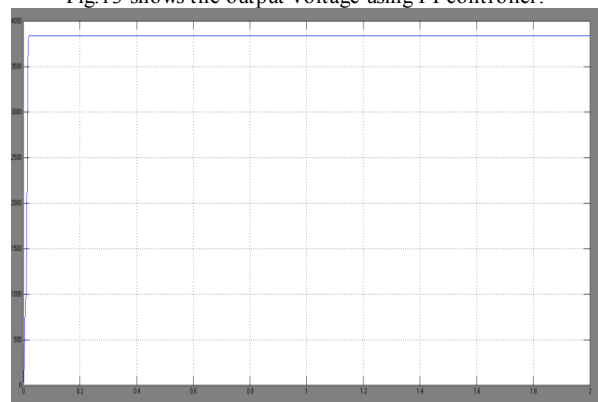Fig.11. shows the output power.

Case3: with PI controller

Fig.12. Matlab/simulink model using PI controller.
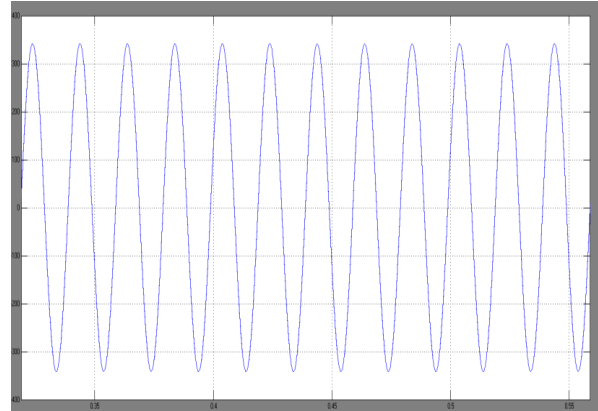
Fig.13 shows the output voltage using PI controller.

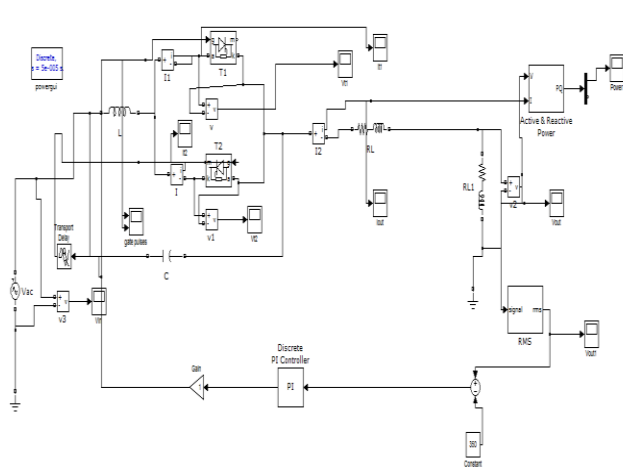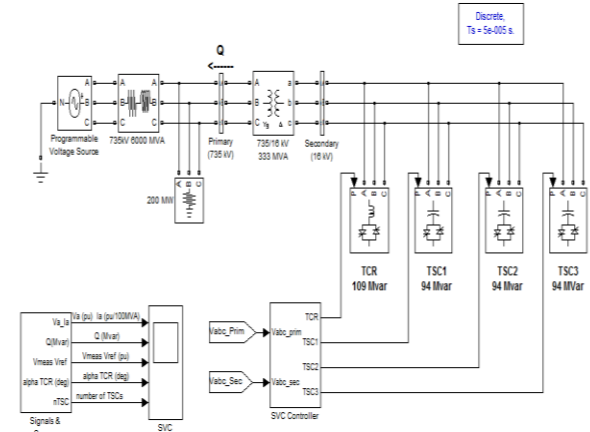Fig.14 shows the output power using PI controller.

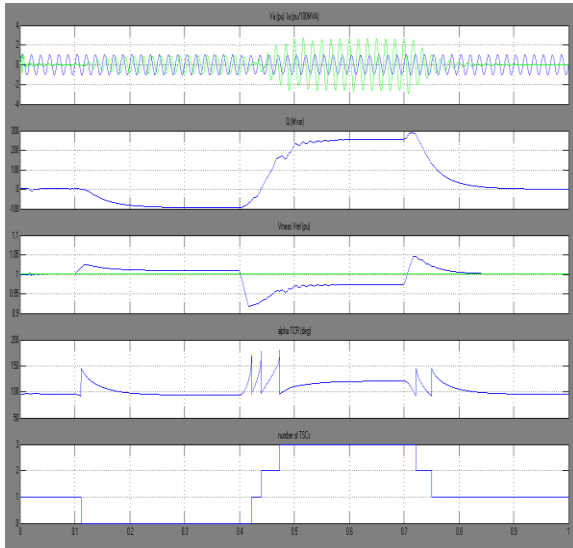Fig.15 Matlab/Simulink Model of three phase TCSC.

Fig.16. Simulation wave form of the voltage and current, reactive power, ref voltage, alpha in TCR, number of TCSC

VI. CONCLUSION

In this paper the power system stability enhancement of test network with FACTS devices TCSC, STATCOM and UPFC is presented and discussed under three phase short circuit fault. It is clear that the system regains its stability under any one of the FACTS device is involved. It is shown that the power flow through the line can be increased and the given system can be made to operate in the rated voltage during varying load conditions using TCSC. From the transient stability analysis, we can conclude that the transient stability can be enhanced when the TCSC is implemented in the system. A detailed analysis of TCSC control performance for improving system stability with different input signals is presented for a hierarchical TCSC control structure, illustrating the need for proper input signal selection and coordination of the different control levels. In particular, a study of the influence of set point values over controller performance is presented, proposing two different control strategies to avoid adverse interactions between the different hierarchical control loops of the TCSC.

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