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# Transient Stability Study by Using Thyristor Controlled Series Compensator Controller for Single Machine Infinite Bus (SMIB) System

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**Abstract:** Power system engineers are currently facing challenges to increase the power transfer capabilities of existing transmission system. This is where the Flexible AC Transmission Systems (FACTS) technology comes into effect. With relatively low investment, compared to new transmission or generation facilities, the FACTS technology allows the industries to better utilize the existing transmission and generation reserves, while enhancing the power system performance. Moreover, the current trend of deregulated electricity market also favors the FACTS controller in many ways. FACTS controllers in the deregulated electricity market allow the system to be used in more flexible way with increase in various stability margins. FACTS controllers are products of FACTS technology; a group of power electronics controllers expected to revolutionize the power transmission and distribution system in many ways. The FACTS controllers clearly enhance power system performance, improve quality of supply and also provide an optimal utilization of the existing resources. Thyristor Controlled Series Compensator (TCSC) is a key FACTS controller and is widely recognized as an effective and economical means to enhance power system stability. In this paper an overview of the general types of FACTS controllers is given along with the simulation of TCSC FACTS controller using SIMULINK. Analysis of the simulated TCSC shows similar functions as a physical one. The simulated TCSC shows that the oscillations are damped out on increasing the damping coefficient. Change in value of reactance of the TCSC also affects the stability of the system.

**Keywords:** FACTS, Power system, Stability, Transient stability, Transient stability limit, Voltage stability, Thermal rating, Power system flexibility, Synchronism.

## I. INTRODUCTION

An increasingly competitive market where economic and environmental pressures limit their scope to expand transmission facilities. The optimization of transmission corridors for power transfer has become a great importance. In this scenario, the FACTS technology is an attractive option for increasing system operation flexibility, New developments in high-current, high-power electronics are making it possible to control electronically the power flows on the high voltage side of the network during both steady state and transient operation. One important FACTS component is the TCSC which allows rapid and continuous changes of the transmission line impedance. Active power flows along the compensated transmission line can be maintained at a specified value under a range of operating conditions. Fig. 1 is a schematic representation of a TCSC module, which consists of a series capacitor bank in parallel with a Thyristor Controlled Reactor (TCR). The controlling element is the thyristor controller, shown as a bidirectional thyristor valve.

Thyristor Controlled Series Capacitor (TCSC) is the series FACTS devices. It consists of the capacitor bank reactor bank and thyristor. The thyristors control the reactance that dictate the power flow through a line. The TCSC can be applied for improving transient stability of power system. The evaluation of Critical Clearing Time (CCT) of power system is one of the most important research areas for power engineers because it indicates the robustness of the faulted power system. The rotor angle of the synchronous generator determines the stability of power system. Although the stability of the synchronous machine is used to represent the stability of the power system, all of the power system components such as transmission line and transformer affect the stability of the power system. This study will investigate the capability of the TCSC on transient stability of the SMIB system with the exact short transmission line model. The concept of two-port network is applied to simplify the mathematical model of the power system. The sample system consist the practical short transmission line is used to investigate in this study. The proposed method is tested on various cases.



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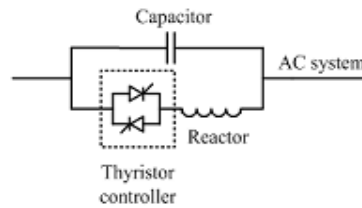


Fig 1 Schematic Diagram of TCSC

Voltage collapse problem has been one of the major problems facing the electric power utilities in many countries. The problem is also a main concern in power system operation and planning. It can be characterized by a continuous decrease of the system voltage. In the initial stage the decrease of the system voltage starts gradually and then decreases rapidly. The following can be considered the main contributing factors to the problem

- Stressed power system; i.e. high active power loading in the system.
- Inadequate reactive power resources.
- Load characteristics at low voltage magnitudes and their difference from those traditionally used in stability studies.
- Transformers tap changer responding to decreasing voltage magnitudes at the load buses.
- Unexpected and or unwanted relay operation may occur during conditions with decreased voltage magnitudes.

This problem is a dynamic phenomenon and transient stability simulation may be used. However, such simulations do not readily provide sensitivity information or the degree of stability. They are also time consuming in terms of computers and engineering effort required for analysis of results. The problem regularly requires inspection of a wide range of system conditions and a large number of contingencies. For such application, the steady state analysis approach is much more suitable and can provide much insight into the voltage and reactive power loads problem. So, there is a requirement to have an analytical method, which can predict the voltage collapse problem in a power system. As a result, considerable attention has been given to this problem by many power system researchers. The problem of reactive power and voltage control is well known and is considered by many researchers. It is known that to maintain an acceptable system voltage profile, a sufficient reactive support at appropriate locations must be found. Nevertheless, maintaining a good voltage profile does not automatically guarantee voltage stability. On the other hand, low voltage although frequently associated with voltage instability is not necessarily its cause.

## II. METHODS OF VOLTAGE STABILITY ANALYSIS

Many algorithms have been proposed in the literature for voltage stability analysis. Most of the utilities have a tendency to depend regularly on conventional load flows for such analysis. Some of the proposed methods are concerned with voltage instability analysis under small perturbations in system load parameters. The analysis of voltage stability, for planning and operation of a power system, involves the examination of two main aspects:

1. How close the system is to voltage instability (i.e. Proximity).
2. When voltage instability occurs, the key contributing factors such as the weak buses, area involved in collapse and generators and lines participating in the collapse are of interest (i.e. Mechanism of voltage collapse). Proximity can provide information regarding voltage security while the mechanism gives useful information for operating plans and system modifications that can be implemented to avoid the voltage collapse. Many techniques have been proposed in the literature for evaluating and predicting voltage stability using steady state analysis methods. Some of these techniques are P- curves, Q-V curves, modal analysis, minimum singular value, sensitivity analysis, reactive power optimization, artificial neural networks, neuro-fuzzy networks, reduced Jacobian determinant, Energy function methods and Thevenin's and load impedance indicator and loading margin by multiple power flow solutions. Some of these methods will be discussed briefly as follow.

## III. OPERATION OF TCSC

When the TCR firing angle is 180 degree the reactor becomes non-conducting and the series capacitor now has the normal impedance. As the firing angle approaches from 180 degree to less than 180 degree, the

capacitor impedance increases. On the other hand, when the TCR firing angle is 90 degree, the reactor becomes fully conducting, and the total impedance becomes inductive, because the reactor impedance is designed to be much lower than the series capacitor impedance with 90 degree firing angle, the TCSC helps in limiting fault current. The TCSC may be a single large unit, or may consist of several equal or different sized smaller capacitors in order to achieve a superior performance.

Thus the TCSC can vary the impedance continuously to levels below and above to the lines' natural impedance. On the other hand adding a TCSC means of adding a variable positive impedance to a value above the lines' natural positive impedance. Once installed, either it will respond to rapidly to control signals to increase or decrease the capacitance or inductance thereby damping those dominant oscillation frequencies that would otherwise breed instabilities or unacceptable dynamic conditions during or after disturbance.

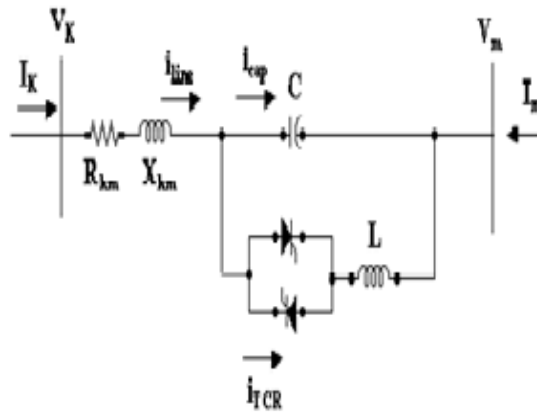


Fig 2 TCSC model

#### IV. RESULTS

This is useful for transient stability study as the power system configuration differ before fault and after fault. The SIMULINK model of SMIB with TCSC controller is analyzed for different conditions of damping constant. Figure 3 shows the rotor angle variation for SMIB with TCSC controller for a damping constant k value 10.

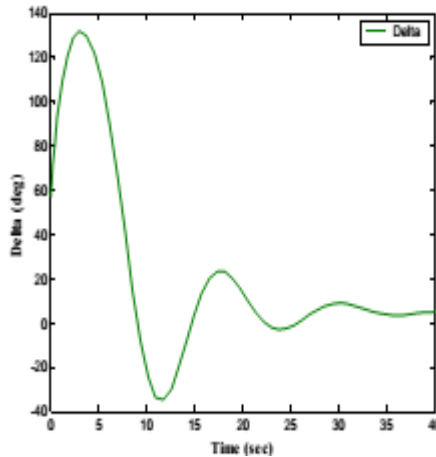


Fig 3 .Rotor angle variation with time for k =10

Figure 3 shows that the rotor angle (delta) with its initial value at  $t = 0$ , increases to its maximum peak and oscillates to attain its steady state within 35-40sec. At this point the System attains stability. The variation of rotor angle for  $k= 30$  is given in Figure 4 and shows that the time to attain stability is decreased to 15 sec. The effect of varying the damping constant on the power system stability and the value of firing angle (alpha) is shown in Table 1. At  $t = 0$ , initially the rotor angle value is very high and at this point the TCSC controller injects the voltage into the line. The analysis shows that if compensation is provided through TCSC controller then the system attains stability at a faster rate.



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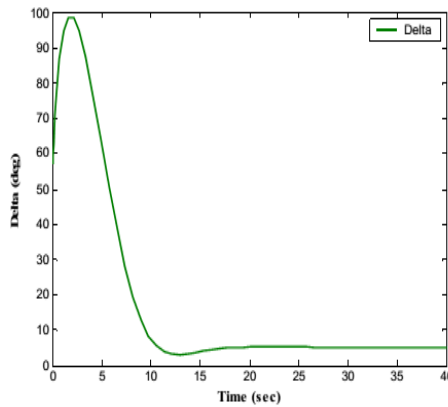


Fig 4. Rotor angle variation with time for  $k = 30$

Now the behavior of the system is again analyzed by increasing the value of TCSC capacitor. Figure 5 shows the variation of rotor angle when the value of the capacitor of the TCSC ( $X_c$ ) is varied. When  $X_c$  is 0.01, the stability is achieved in 35 – 40 sec. Figure 6 shows the variation for  $X_c = 3$  which clearly shows that system finally loses its stability.

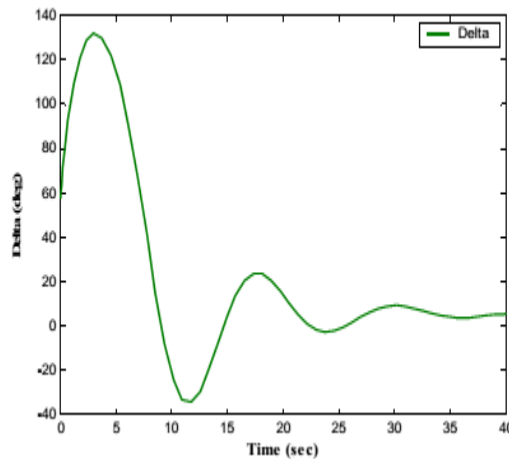


Fig 5. Rotor angle variation with time for  $X_c = 0.01$

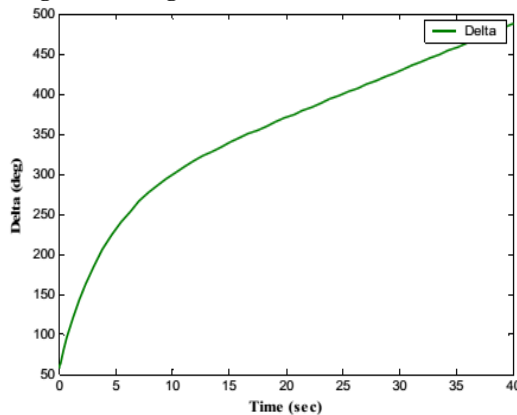


Fig 6. Rotor angle variation with time for  $X_c = 3$

## V. CONCLUSION

The analysis shows that the state of the system indicating whether the system is stable or unstable depends upon the reactance of the TCSC controller whose value changes with the change in conduction angle of thyristor in TCSC controller which in turn is governed by the rotor angle. If the value of damping constant ( $k$ ) is increased keeping the controller gain, it is observed that the time taken for the system to get into a stable state reduces



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significantly. The analysis also shows that if the value of reactance of the fixed capacitor of the TCSC is decreased, the time taken for the suppression of the first highest swing in rotor angle is also increased.

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