# Implementation of FACTS Device to Improve Power System Stability

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**Abstract-** *The demand for power and non-linear loads is increasing day by day, and thus stability problems arise. A technique that can efficiently afford compensation with growing or reducing load requirement and available transmission network resources are necessary. The FACTS devices are implemented, to increase the power flow capacity in an electric power network. The primary aim is to increase the load capability of the system to maintain stability after a fault occurrence. Here fault is created on system build in MATLAB/Simulink environment and the effect of series FACTS device i.e. TCSC controller is observed.*

***Key Words***: **FACTS devices, Stability, TCSC, MATLAB/Simulink.**

## 1. INTRODUCTION

As transmission systems are getting closer to the limits of their stability and thermal limits whereas the main focus on the power quality delivered has increased significantly. Increased demands on transmission, absence of long-term planning, and the need to provide open access to generating companies and customers, all together have created tendencies toward less security and reduced quality of supply [5]. For both operational reliability and economical profitability, the transmission systems framework's utilization is crucial in a more effective and measured way. The FACTS technology is essential to overcome some of these difficulties by enabling utilities to get the most service from their transmission facilities and enhance grid reliability[4].The ability of FACTS Controllers to control the interrelated parameters that regulate the operation of transmission systems parameter including -series impedance, shunt impedance, current, voltage, phase angle, and the damping of oscillations at various frequencies below the rated frequency.[5] The FACTS technology is not a single high-power Controller, but moreover a collection of Controllers, which can be applied individually or in combination with others to control one or more of the interrelated system parameters[1]. In this paper a study of series FACTS device-TCSC (Thyristor control series compensator) is been carried out and its effect on fault compensation on a considered system is been observed.

### 1.1 Controlling of power system-

In any power system, the generation, transmission, and usage of electrical power can be separated into three areas, which traditionally determined the way in which electric utility companies had been organized.
These are adorned as:

- Generation
- Transmission
- Distribution.

Although power electronic based equipment is prevalent in each of these three areas, such as with static excitation systems for generators and Custom Power equipment in distribution systems. The rapt of this paper is on transmission network i.e. moving the power from where it is generated to where there is the usage.

### 1.2 Power system limitations-

The limitations of the transmission system can take many forms and may involve power transfer between areas or within a single area or region and may include one or more of the following characteristics:

- Steady-State Power Transfer Limit
- Voltage Stability Limit
- Dynamic Voltage Limit
- Transient Stability Limit
- Power System Oscillation Damping Limit
- Inadvertent Loop Flow Limit
- Thermal Limit
- Short-Circuit Current Limit

The cue of solving these problems in the most cost-effective and coordinated manner is by rigorous system's engineering analysis. These limitations can overcome by controlling some system parameters by the implementation of FACTS controllers that are capable to oversee these problems.

## 2. Thyristor Controlled Series Compensators (TCSC)-

Capacitive reactance compensator which consists of a series capacitor bank shunted by a thyristor-controlled reactor (TCR) in order to provide a smoothly variable series capacitive reactance. A TCR is used in parallel with a fixed capacitor to enable continuous control over the series compensation. An actual TCSC system usually comprises a cascaded combination of many such TCSC modules, together with a fixed-series capacitor. This fixed series capacitor is provided primarily to minimize costs.

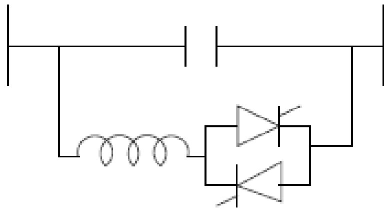

Fig 2.1 Basic TCSC model

The basic principle of variable-series compensation is simply to increase the fundamental-frequency voltage across a fixed capacitor (FC) in a series compensated line through appropriate variation of the firing angle, α. A simple interpretation of TCSC functioning can be obtained by analyzing the behavior of a variable inductor connected in parallel with an FC. The equivalent impedance, *Zeq*, of this *LC* combination is expressed as-

$$Zeq = (j\frac{1}{\omega c})||(j\omega l)$$
$$= -j\frac{1}{\omega c - \frac{1}{\omega l}}$$

### 2.1 Modes of operation of TCSC –

TCSC can operate in different modes because of various operations of thyristor valves. There are three different modes of TCSC operation:

#### Bypassed thyristor mode-

In this bypassed mode, the thyristors are made to fully conduct with a conduction angle of 180°. Gate pulses are applied as soon as the voltage across the thyristors reaches zero and becomes positive, resulting in a continuous sinusoidal flow of current through the thyristor valves. The TCSC module behaves like a parallel capacitor–inductor combination.

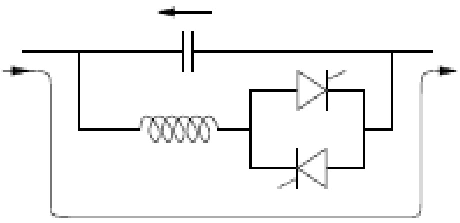

Fig 2.2 Bypassed thyristor mode

#### Blocked thyristor mode-

In this mode, the firing pulses to the thyristor valves are blocked. If the thyristors are conducting and a blocking command is given, the thyristors turn off as soon as the current through them reaches a zero crossing.

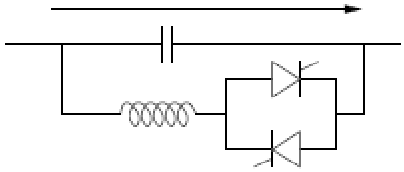

Fig 2.3 Blocked thyristor mode

#### Vernier mode-

In this operating mode, the thyristor valves are gated in the region of ($\alpha_{min} < \alpha < 90°$) such that they conduct for the part of a cycle. The effective value of TCSC reactance (in the capacitive region) increases as the conduction angle increases from zero. $\alpha_{min}$ is above the value of α corresponding to the parallel resonance of TCR and the capacitor (at fundamental frequency). In the inductive vernier mode, the TCSC (inductive) reactance increases as the conduction angle reduced from 180°.

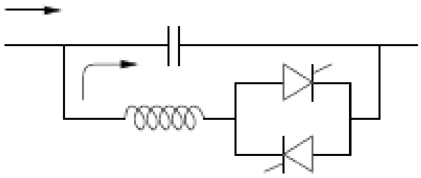

Fig 2.4 vernier mode

### 2.2 Reactance characteristics curve of TCSC-

The reactance characteristics curved of TCSC device drawn with respect to firing angle α. The reactance characteristics are divided into three different regions such as inductive, capacitive and resonance region. Inductive and capacitive region are the working regions and resonance region where TCSC should not be operated. Nearer to resonance region, there is large in reactance for a small change in firing angle.

$90 \le \alpha \le \alpha_{Llim}$ -Inductive region
$\alpha_{Clim} \le \alpha \le 180$ –Capacitive region
$\alpha_{Llim} \le \alpha \le \alpha_{Clim}$ -Resonance region

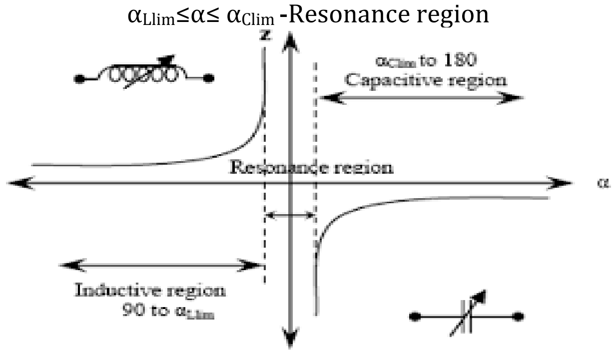


Fig 2.5 Reactance characteristics curve of TCSC

### 2.3 Controls circuit of TCSC-

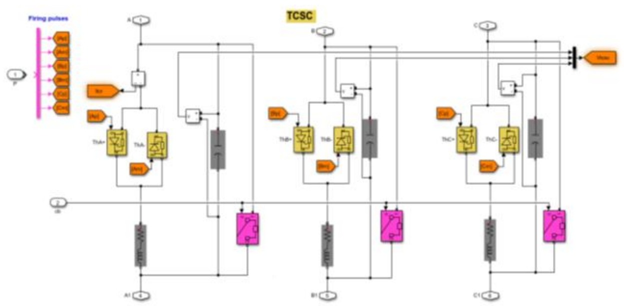

Fig 2.6 Internal circuit of TCSC

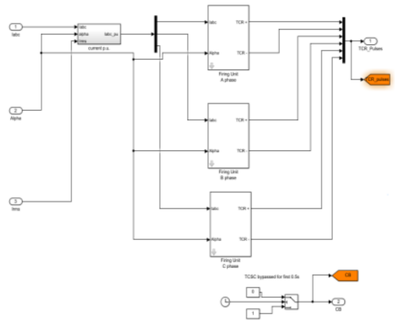

Fig 2.7 Firing unit of TCSC

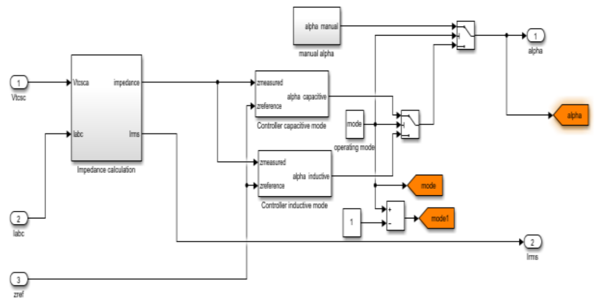

Fig 2.8 control unit of TCSC

The firing unit measures the Line voltage and Line current and is continuously analyzed, when the fault occurs on the system the firing unit measures it and drop in the voltage is sensed due to which the firing unit gives trigger to the control scheme because of which the triggering occurs and by which the TCSC operates in capacitive mode and oscillation damping is done and voltage drop occurred in the system is stabilized by reactive power compensation. Effectively enhancing the equivalent-capacitive reactance and the series-compensation level for the same value of line current. By varying the thyristor-pair firing angle in an appropriate range.

## 3. MATLAB/Simulink-

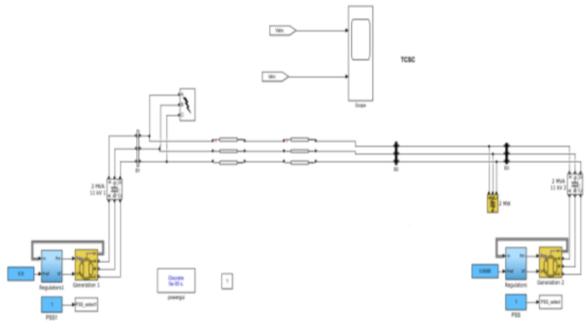

Fig 3.1 MATLAB simulation of Network for transient stability without using TCSC

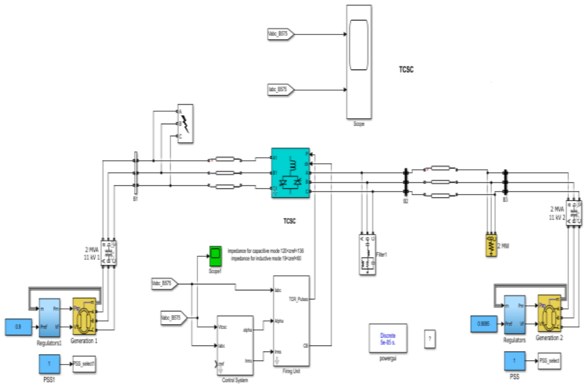

Fig 3.2 MATLAB simulation of Network for transient stability using TCSC

When fault is occurred at 5sec the TCSC gets fired and compensation takes place in capacitive mode, by which the oscillations which were produced in the system are damped out in 0.5sec, after 5.5sec voltage is enhanced by the effective value of the series-capacitive reactance and system again gets in stable operation.

The parameters used for Simulink given in tables below-

| Parameter | Value |
|---|---|
| Generator 1 and 2 | 2 MVA, 11KV salient pole 3ph synchronous generator |
| Transformer 1 and 2 | 2 MVA Δ/Y grounded |
| Line parameter | 50KM, 11kV |
| Load | Ph A,B,C 2MW, Resistive load |
| Line frequency (Hz) | 50 |
| TCSC compensation (%) | 80 |

## 4. Results-

In this paper, fault is created on the system and the analysis, without application of TCSC and with compensation of TCSC is been carried out. By drawing the equivalent

MATLAB/Simulink model and applying fault the stability of the system is studied. The results of Simulink have been discussed below:

### 4.1 Simulation results of LLLG fault on system:

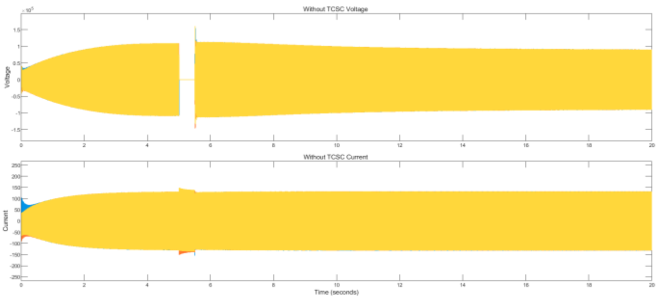

Fig 4.1 Effect of LLLG Fault without TCSC

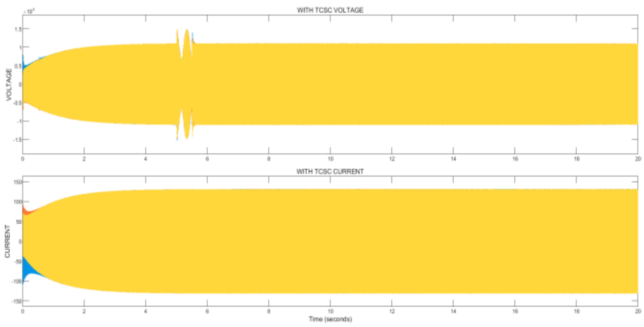

Fig 4.2 Effect of LLLG Fault with TCSC

In above graphs, the run time of system is 20sec, as we can see that as the fault occurs on the system at 5sec without TCSC the line voltage becomes zero and current is increased. But when the fault occurs on the system with TCSC it compensates the fault and prevents the line voltage from becoming zero and with that it also makes sure that the current in the system does not shoot up during fault.

### 4.3 Mechanical parameters of Generator 1 for LLLG Fault-

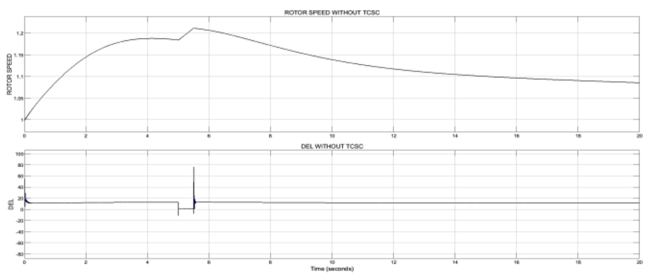

Fig 4.3 Effect on of Generator 1 without TCSC

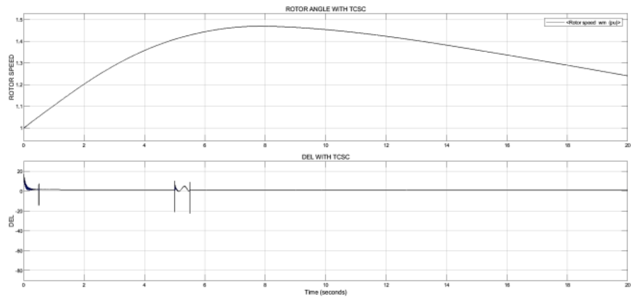

Fig 4.4 Effect on Generator 1 with TCSC

As in the system, the fault is occurred near the Generator 1, without TCSC. Here the Rotor speed and Del is increased during fault but regain its original value after the fault. But in other case, when the fault is occurred near the Generator 1, with TCSC. Here the Rotor angle and Del does not increase much due to compensation done by TCSC.

### 4.5 Mechanical parameters of Generator 2 for LLLG Fault-

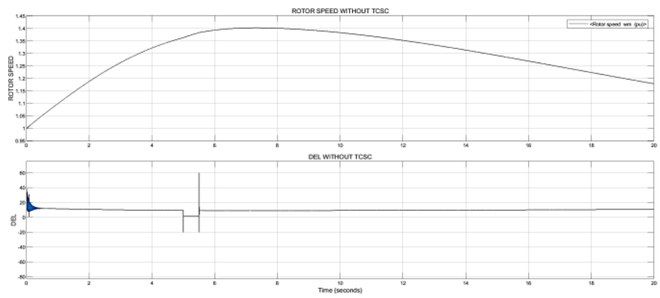

Fig 4.5 Effect on Generator 2 without TCSC

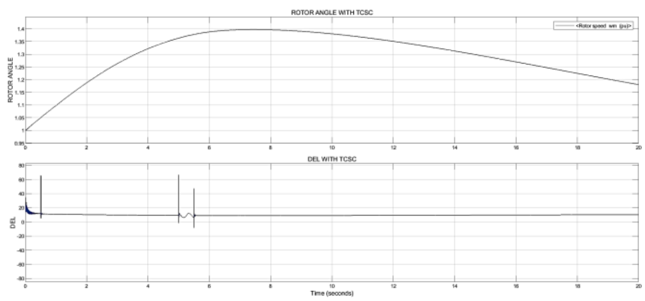

Fig 4.6 Effect on Generator 2 with TCSC.

As in the system, the fault is occurred away from the Generator 2, without TCSC. The effect of fault on Generator 2 is less than that on generator 1. Here the Rotor speed and Del is increased during fault but regain its original value after the fault. But in other case, when the fault is occurred, the effect on Generator 2 with TCSC. Here the Rotor angle and Del does not increase much due to compensation by TCSC.

## 5. CONCLUSION:

In this paper, software based study of FACTS Device TCSC controller has been carried out From the Simulink in MATLAB system analysis. The power angle (Del) and rotor speed has extracted form system simulation model for generator stability analysis. The line voltage (Vabc) and line current (Iabc) has also been extracted from model for transmission line stability analysis. The result shows that the stability of the power network and Generator has eminently afflicted by TCSC (capacitive mode). Here LLLG fault is been applied on the considered system, faults other than LLLG can also be applied and studied for power system stability analysis with the compensation technique of TCSC controller.

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