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Power System Stability Enhancement using Fact Controller

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Abstract

The article deals with the use of thyristor controlled series capacitor (TCSC) in the power system. Aim of this work is to show the possibilities of using TCSC and its modelling in a simple electrical network from the perspective of power flow control by using MATLAB SimPowerSystem. Given the current pace of increasing electricity transmission and growth requirements for transit is to increase safety, capacity, controllability and flexibility of systems for the transmission of electricity, needed the implementation of certain measures and specialized equipment. Such specialized equipment is also TCSC from group of FACTS devices.

Keywords: TCSC, FACTS, power flow control, power system, modelling of TCSC, SimPowerSystem.

I. INTRODUCTION

At present the demand for electricity is rising phenomenally especially in developing country like India. This persistent demand is leading to operation of the power system at its limit. The need for reliable, stable and quality power is on the rise due to electric power sensitive industries like information technology, communication, electronics etc.

In this scenario, meeting the electric power demand is not the only criteria but also it is the responsibility of the power system engineers to provide a stable and quality power to the consumers. These issues highlight the necessity of understanding the power system stability. In this course we will try to understand how to asses the stability of a power system, how to improve the stability and finally how to prevent system becoming unstable.

1.1 Basic Concepts and Definitions of Power System Stability
Power system stability is the ability of an electric power system, for a given initial operating condition, to regain a state of operating equilibrium after being subjected to a physical disturbance, with most of the system variables bounded so that practically the entire system remains intact” [1], [2].

The disturbances mentioned in the definition could be faults, load changes, generator outages, line outages, voltage collapse or some combination of these. Power system stability can be broadly classified into rotor angle, voltage and frequency stability. Each of these three stabilities can be further classified into large disturbance or small disturbance, short term or long term.

1.2 Rotor angle stability
“It is the ability of the system to remain in synchronism when subjected to a disturbance”. The rotor angle of a generator depends on the balance between the electromagnetic torque due to the generator electrical power output and mechanical torque due to the input mechanical power through a prime mover.

Remaining in synchronism means that all the generators electromagnetic 1.2 torque is exactly equal to the mechanical torque in the opposite direction.

If in a generator the balance between electromagnetic and mechanical torque is disturbed, due to disturbances in the system, then this will lead to oscillations in the rotor angle. Rotor angle stability is further classified into small disturbance angle stability and large disturbance angle stability.

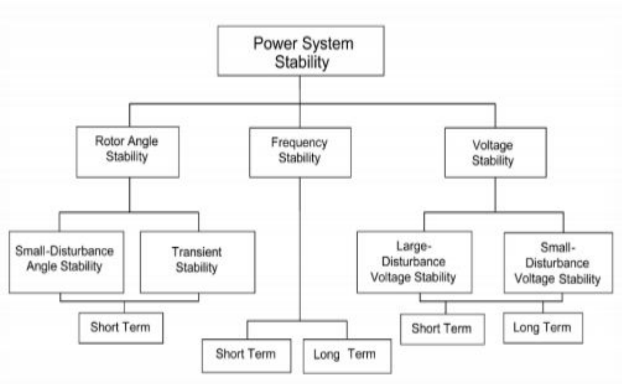

Figure 1.1: Classification of power system stability

1.3 Small-disturbance or small-signal angle stability
"It is the ability of the system to remain in synchronism when subjected to small disturbances". If a disturbance is small enough so that the nonlinear power system can be approximated by a linear system, then the study of rotor angle stability of that particular system is called as small-disturbance angle stability analysis. Small disturbances can be small load changes like switching on or off of small loads, line tripping, small generators tripping etc. Due to small disturbances there can be two types of instability: non-oscillatory instability and oscillatory instability. In non-oscillatory instability the rotor angle of a generator keeps on increasing due to a small disturbance and in case of oscillatory instability the rotor angle oscillates with increasing magnitude.

II. VOLTAGE STABILITY

"It is the ability of the system to maintain steady state voltages at all the system buses when subjected to a disturbance. If the disturbance is large then it is called as large-disturbance voltage stability and if the disturbance is small it is called as small-disturbance voltage stability". Unlike angle stability, voltage stability can also be a long term phenomenon. In case voltage fluctuations occur due to fast acting devices like induction motors, power electronic drive, HVDC etc then the time frame for understanding the stability is in the range of 10-20 s and hence can be treated as short term phenomenon. On the other hand if voltage variations are due to slow change in load, over loading of lines, generators hitting reactive power limits, tap changing transformers etc then time frame for voltage stability can stretch from 1 minute to several minutes. The main difference between voltage stability and angle stability is that voltage stability depends on the balance of reactive power demand and generation in the system where as the angle stability mainly depends on the balance between real power generation and demand.

III. PROPOSED METHODOLOGY

The basic Thyristor Controlled Series Capacitor scheme was proposed in 1986 by Vithayathil with others as a method of "rapid adjustment of network impedance". A TCSC can be defined as 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. In a practical TCSC implementation, several such basic compensators may be connected in series to obtain the desired voltage rating and operating characteristics. 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 basic conceptual TCSC module comprises a series capacitor, C, in parallel with a thyristor controlled reactor.

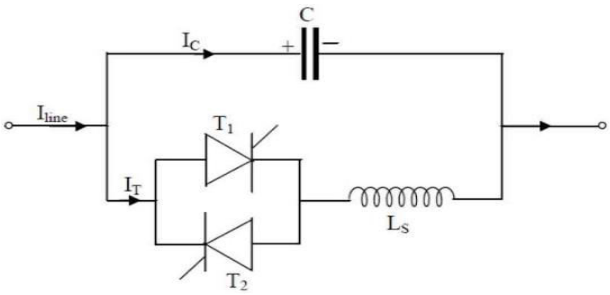

Figure 3.1: Structure of TCSC.

A TCSC is a series-controlled capacitive reactance that can provide continuous control of power on the ac line over a wide range. From the system viewpoint, the 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. This enhanced voltage changes the effective value of the series capacitive reactance. A simple understanding of TCSC functioning can be obtained by analyzing the behavior of a variable inductor connected in parallel with an FC. The maximum voltage and current limits are design values for which the thyristor valve, the reactor and capacitor banks are rated to meet specific application requirements.

IV. CHARACTERISTICS OF TCSC

Below shows the characteristics of TCSC. α is the delay angle measured from the crest of the capacitor voltage or equivalently, the zero crossing of the line current. Therefore, with the usual TCSC arrangement in which the impedance of the TCR reactor XL is smaller than that of the capacitor, XC, the TCSC has two operating ranges around its internal circuit resonance.

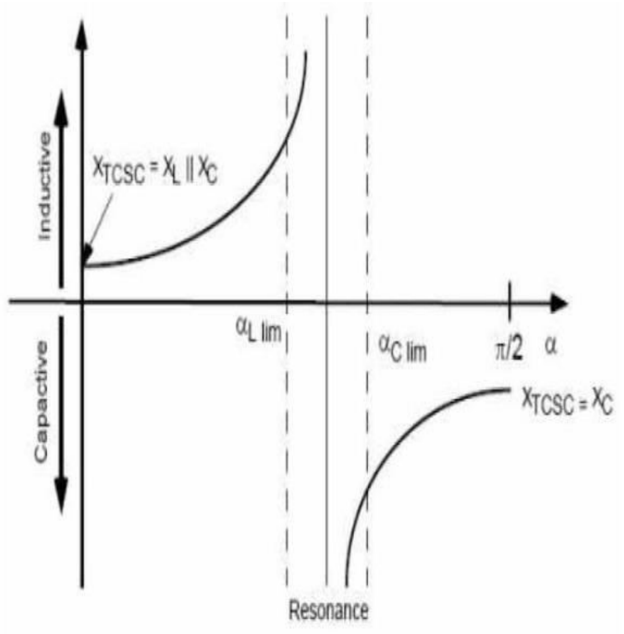

Figure 4.1: Characteristics of TCSC.

V. OPERATION OF TCSC

Basic Principle

- A TCSC is a series-controlled capacitive reactance that can provide continuous
- Control of power on the ac line over a wide range.
- The principle of variable-series compensation is simply to increase the fundamental-frequency voltage across an fixed capacitor (FC) in a series compensated line through appropriate variation of the firing angle.
- This enhanced voltage changes the effective value of the series-capacitive reactance. A simple understanding of TCSC functioning can be obtained by analyzing the behavior of a variable inductor connected in parallel with an FC, as shown in Figure.

The equivalent impedance, Zeq, of this LC combination is expressed as

$$Z_{eq} = \left(j\,\frac{1}{\omega c}\right) \Big\| \,(j\omega L) = -j\,\frac{1}{\omega C - \dfrac{1}{\omega L}}$$

- The impedance of the FC alone, however, is given by −j(1/ ωC).
- If ωC−(1/ ωL) > 0 or, in other words, ωL > (1/ ωC), the reactance of the FC is less than that of the parallel-connected variable reactor and that this combination provides a variable-capacitive reactance are both implied. Moreover, this inductor increases the equivalent-capacitive reactance of the LC combination above that of the FC.
- If ωC − (1/ ωL) c 0, a resonance develops that results in an infinite-capacitive impedance is obviously unacceptable condition.
- If, however, ωC − (1/ ωL) < 0, the LC combination provides inductance above the value of the fixed inductor. This situation corresponds to the inductive-vernier mode of the TCSC operation.
- In the variable-capacitance mode of the TCSC, as the inductive reactance of the variable inductor is increased, the equivalent-capacitive eactance is gradually decreased.
- The minimum equivalent-capacitive reactance is obtained for extremely large inductive reactance or when the variable inductor is open-circuited, in which the value is equal to the reactance of the FC itself.
- The behavior of the TCSC is similar to that of the parallel LC combination.
- The difference is that the LC-combination analysis is based on the presence of pure sinusoidal voltage and current in the circuit, whereas in the TCSC, because of the voltage and current in the FC and thyristor-controlled reactor (TCR) are not sinusoidal because of thyristor switchings.

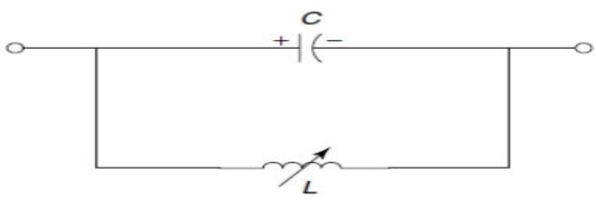

Figure 5.1 A variable inductor connected in shunt with an FC

VI. SIMULATION & RESULT ANALYSIS

6.1 Introduction:-

Simulation is power way to reduce development time and insure the proper fulfillment of critical steps. In this project, simulation work performs which allowed the study of it behavior under different operation condition and permitted the tuning of some controller parameters together with optimization of the active filter component values. MATLAB/SIMULINK and the power system block set were used as simulation tools in this development, as it offered and integrated environment between designing control algorithm and the electrical network models.

6.2 Simulation and Results using Indirect Current Control Theory:-

6.2.1 Parameters of the Simulated System:-

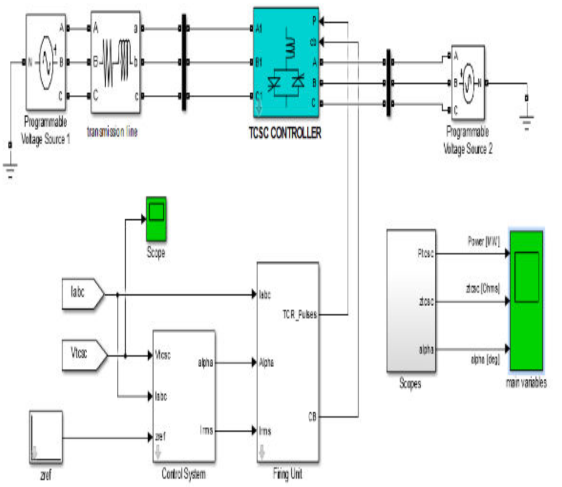

Figure 6.1: TCTC with fact based modelling.

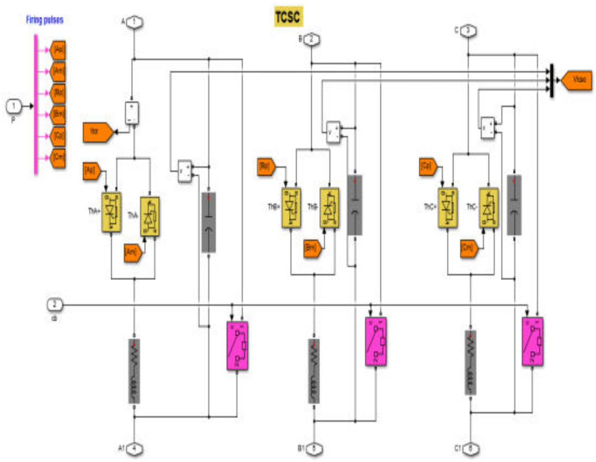

Figure 6.2: Proposed TCSC.

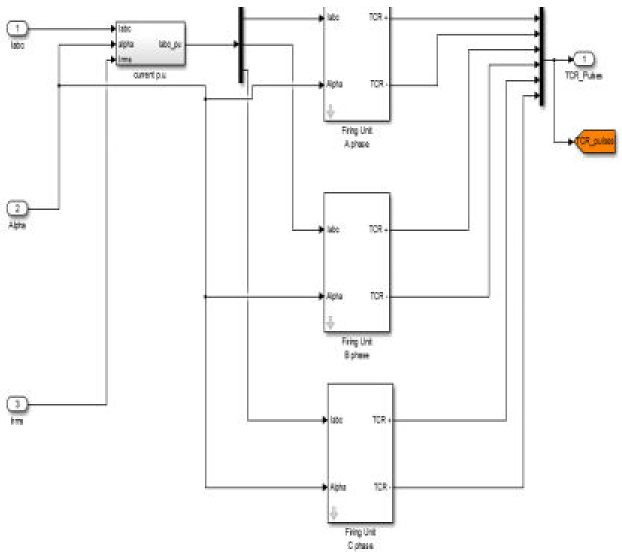

Figure 6.3: Firing Unit.

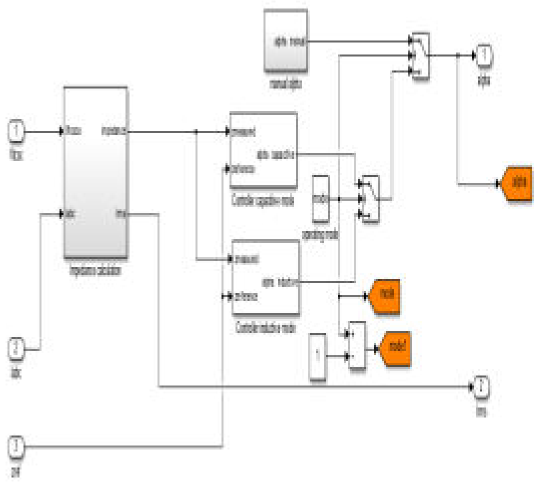

Figure 6.4: Control Unit.

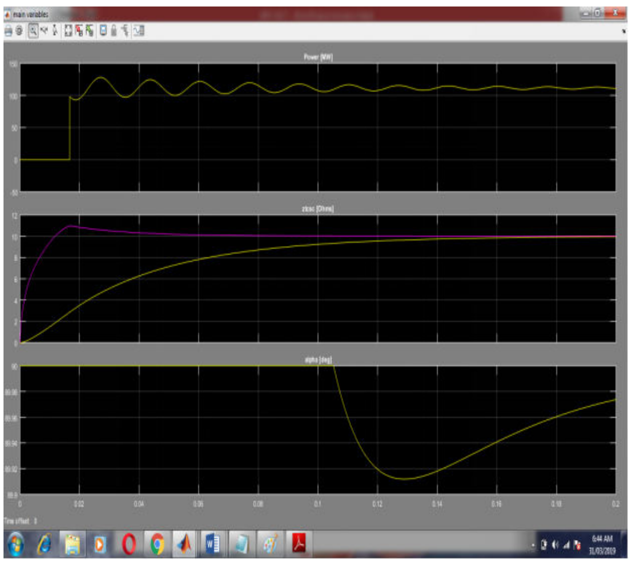

Figure 6.5: P(MW), Z(TCTC), Alpha variation.

Base paper Result:

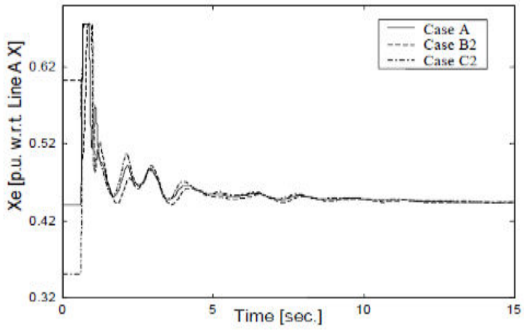

Figure. **6.6.**TCSC equivalent reactance variations, variable post-contingency set Point.

Our Model Result:

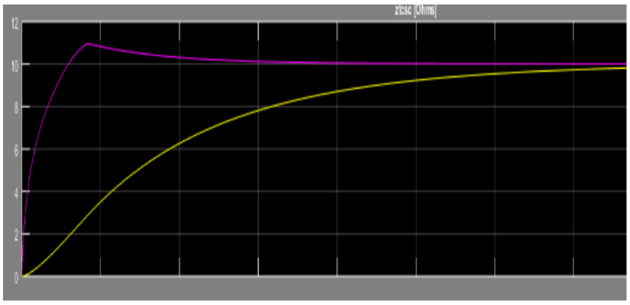

Figure. 6.8: Our proposed Output TCSC equivalent reactance variations, variable post-contingency set Point.

Difference Between and our proposed model:

S.N	PARAMETERS	Our Result(s)	TIME(Base paper)(s)
1.	Xe (Impedence)	4	10
2.	Power(MW)	5	10

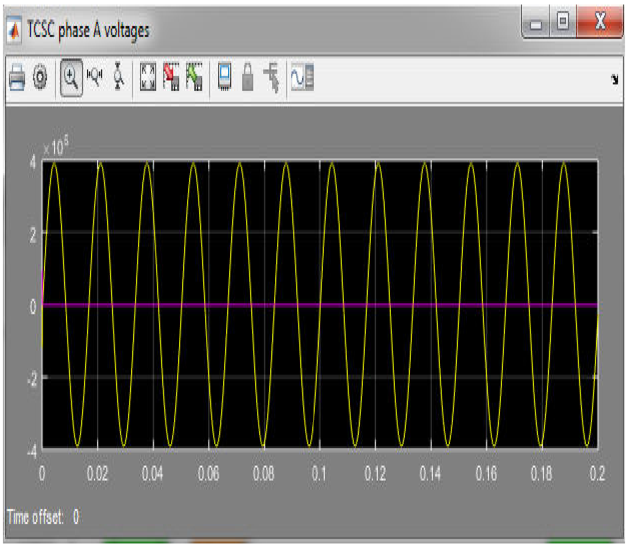

Figure. 6.9: TCSC phase A voltages.

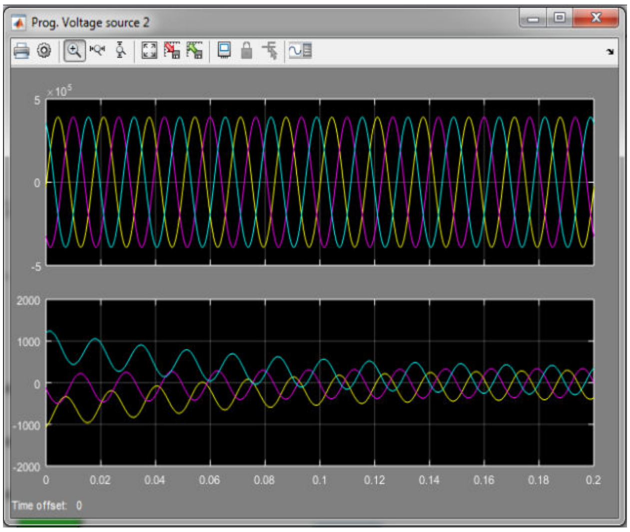

Figure. 6.10: TCSC Vabc and Iabc voltages.

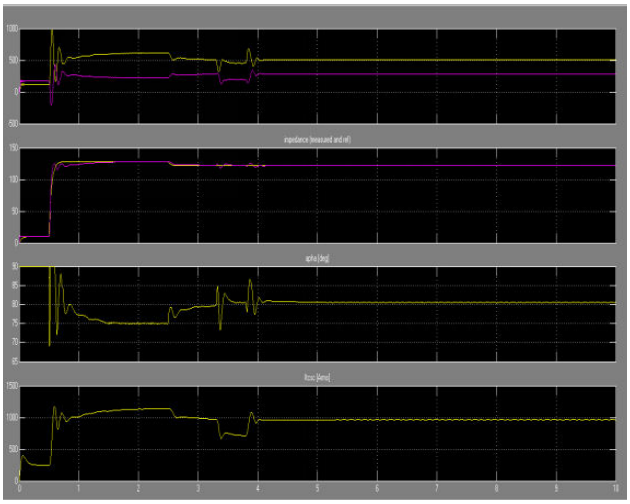

Figure .6.11: TCSC Outputs.

VII. CONCLUSION

In this study, A MATLAB program has executed to incorporate the steady-state mathematical model of long distance transmission in the conventional NR power flow algorithm. The steady state effect of long distance transmission has shown in different system. It is shown that when long distance transmission is incorporated in between two buses in the system, for different value of 'r' and ' ' the active and reactive power loses are reduced. It is also shown that not only the power losses are reduced, the voltage profile of the every buses also improved after incorporate long distance transmission.

1. A model of TCSC has been developed in MATLAB environment using Power System Block-set. The performance of the developed

model is tested under a wide variety of loading conditions.
2. It is found that TCSC is capable of minimizing the harmonics and reactive power compensation.
3. Indirect current control technique has been applied over the sensed and reference supply currents for TCSC and it has been found to be a simple technique. Only one PI controller is required to regulate terminal voltage and thus reduces computation effort.
4. The control algorithm of the TCSC is flexible and has been tested for power quality improvement for linear as well as nonlinear loads.
5. The simulation has been carried out in MATLAB/SIMULINK environment and power factor is unity for supply voltage and current.

VIII. FUTURE SCOPE

Various optimization methods can be used to get the optimal location of the TCSC-UPFC in the system. In this project the switching losses of the two converters is not considered. This research can be done with considering the losses of TCSC. The research can be extended for applying the similar techniques to the transmission line having other FACTS devices which are not included in the proposed study.

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