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Analysis of TCSC for Real and Reactive Power Control using MATLAB/SIMULATION

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ABSTRACT

A Thyristor controlled series capacitor (TCSC) belongs to the flexible alternatingcurrent transmission systems (FACTS). It is a variable capacitive and inductive reactance device that can be used to provide series compensation in power transmission lines. One of the significant advantages that a TCSC has over other series compensation devices is that the TCSC's reactance is instantaneously variable. This means that the TCSC can be used not only to provide series compensation but can also be used to enhance the stability of the power system. In this paper, performance of TCSC is analyzed. Initially, Real and reactive power flow through the transmission line have been analyzed for fixed and then after the same parameters are evaluated by inserting controllable capacitor in the same transmission network. The considered topology of TCSC consists of back to back thyristors that controls the reactance of the TCSC. By changing the firing angle of these back to back thyristors it is possible to vary the reactance of the TCSC. As per the TCSC characteristics, in inductive region at the firing angle $0 \leq \alpha \leq \alpha Llim$ the power flow decreasing and in capacitive region at the firing angle $\alpha Clim \leq \alpha \leq 90$ hence the power flow increase. For the simulation 1-phase model degree of compensation and the ratio of XC/XL is so adjusted to increase power transfer capability. The simulation is carried out by using MATLAB /simulink.

Keywords : TCSC, FACTS, Power Flow Control, Power System, Modeling of TCSC

I. INTRODUCTION

In the present days the quality of the electric supply has been reduced due to the improper planning of the power system which is unable to meet the load demands. There is a increase in private industries to meet the requirements which are causing the problems in power system security, voltage deviations, collapse of the system. To overcome these problems we can construct new transmission lines but this task is becoming difficult due to political and environmental challenges. Due to the present terms and conditions the security of the power system could not be improved even though there are techniques like load shedding, generation rescheduling. The better solution to overcome these problems is the usage of FACTS devices. Their installation cost is minimum and moreover they improve the stability and security of the system along with good voltage profile at the buses. They reduce the overloading of the branches by controlling their power flow.

Thyristor controlled series compensator (TCSC) is one of the best FACTS devices. It has a faster response when compared to the other FACTS devices. This is because it has better control over line impedance, by changing its reactance it can reduce the line impedance. This helps in increased power flow in the system. Placing the device would just not be sufficient for achieving the objectives. It must be placed at proper location and with proper sizing for its efficient usage Series Capacitors are installed in series with a transmission line, which means that all the equipment has to be installed on a fully insulated platform. Significant device from the group FACTS is a TCSC, which finds application in solving many problems in the power system. Its properties can increase the power lines transmission capacity and power flow control. It also provides a wide range of other uses to ensure effective, trouble-free and economical operation of power systems. Simulation behaviors of these devices are very important before the real deployment of these devices to the power system. Various computing and simulation programs, which help in understanding the activities and setting appropriate parameters of these devices, have found its application to modeling and simulating these devices.

N. G. Hingorani and L. Gyugyi gives The information about all series type facts controller design and the basic definition, which define that how the series facts controller are differ from the shunt controller for the compensation of reactive power. Mathur R. Mohan and Rajiv K. Varmain described TCSC advantages, modes of operation, controller, Analysis of TCSC, capability characteristics, harmonic performance, losses and modeling of TCSC. The operation, reactance characteristic and resonance condition of TCSC from the paper of resonance behavior, For increasing power transfer capability the better degree of compensation in region between 0.3 to 0.7. The reactive power at the receiving end side is controlled using TCSC at different firing angle to verify the TCSC characteristics curve. The main aim of this paper is to analyze the design of a TCSC controller for stability enhancement, under normal operation and fault conditions at different load power flows.

The power system stability enhance by decrease the effective transfer reactance of transmission line at sending end side and receiving end side for that the firing angles of the thyristors are controlled to adjust the TCSC reactance in accordance with a system control strategy, normally in response to some system parameter variations. In this paper the simulation on parallel line with different load and different firing angle to evaluated performance of TCSC characteristics in inductive region and capacitive region for the control the reactive power at the receiving end. The paper is structured as follows: Section II gives the introduction about the basic TCSC scheme and operation of TCSC controller. Section III briefly describes the control scheme of a typical TCSC controller. In Section IV the reactive power control at the receiving end side by using TCSC. In Section V modeling of the TCSC using two parallel line in MATLAB simulation programmed. Simulation & results are showed in Section VI. The conclusion is presented in section VII.

II. METHODS AND MATERIAL

1. TCSC

The Thyristor Controlled Series Capacitor (TCSC) belongs to the Flexible AC Transmission Systems (FACTS) group of power systems devices. The concept of the TCSC has been around since the mid 1980s, with the first known commercial installation being in 1992 in the United States of America. The TCSC controller was developed for the Kanpur-Ballabhgarh 400kV single circuit ac transmission line located in North India. 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 α. This enhanced voltage changes the effective value of the series-capacitive reactance. Essentially a TCSC is a variable reactance device that can be used to provide an adjustable series compensating reactance to a transmission line. Its advantage over other series compensating devices is that its reactance can be instantaneously and precisely controlled. A TCSC consists of a fixed capacitor in parallel with a variable inductive reactance as shown in Fig. 1. This variable inductive reactance is obtained by connecting back to back thyristors in series with a fixed-reactance inductor, and is known as a Thyristor Controlled Reactor or TCR. By controlling the trigger angle of the back to back thyristors, it is possible to vary the effective inductive reactance of the TCR, and hence control the reactance provided by the TCSC. The reactance of the TCSC can be capacitive or inductive, depending on the trigger angle of the back to back thyristors; The capacitive reactance characteristic of the TCSC is a highly non-linear function of the trigger angle of the back to back thyristors, The TCSC consists of the series compensating capacitor shunted by a Thyristor-Controlled Reactor. In a practical TCSC implementation, several such basic compensators maybe connected in series to obtain the desired voltage rating and operating characteristics. The basic idea behind the TCSC scheme is to provide a by continuously variable capacitor by means of partially canceling the effective compensating capacitance the TCR.

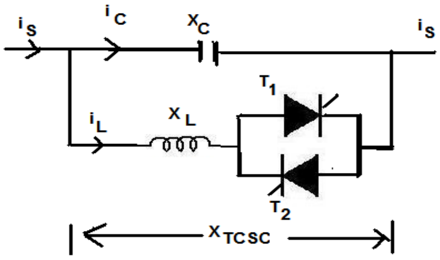


Figure 1. Basic Thyristor-Controlled Series Capacitor scheme

The TCR at the fundamental system frequency is continuously variable reactive impedance, controllable by delay angle α. The steady state impedance of the TCSC is that of a parallel LC circuit, consisting of a fixed capacitive impedance XC.
The variable inductive impedance XL(α):-

$$XL(\alpha)=Xl\,\frac{\pi}{\pi-2\alpha-Sin\alpha},\ Xl < Xl(\alpha) < \alpha$$

The impedance of TCSC:-

$$Xtcsc(\alpha)=\frac{Xc\,.\,Xl(\alpha)}{Xl(\alpha)-Xc}$$

The effective reactance of TCSC operates in three region:-

1. Inductive region:- 0 ≤ α ≤ αLlim.
2. Capacitive region:- αClim ≤ α ≤ 90.
3. Resonance region:- αLlim ≤ α ≤ αClim.

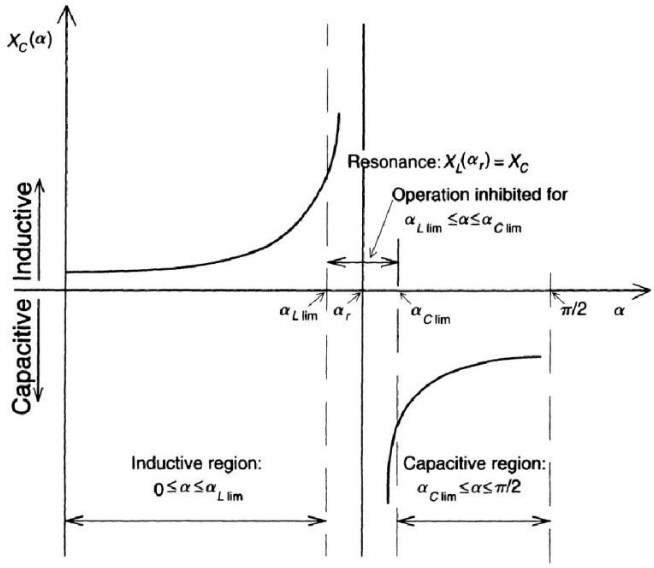


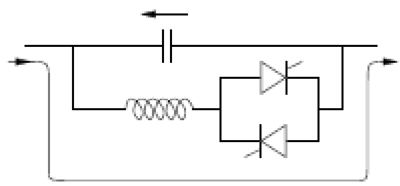
Figure 2. Reactance Vs firing angle characteristic curve.

2. TCSC CONTOLLER

The main principles of the TCSC concept are two; firstly, to provide electromechanical damping between large electrical systems by changing the reactance of a specific interconnecting power line. Secondly, the TCSC shall change its apparent impedance for sub-synchronous frequencies, such that a prospective subsynchronous resonance is avoided.

There are essentially three modes of TCSC operation:-
1. Bypassed-Thyristor mode:-
2. Blocked-Thyristor Mode:-
3. Partially Conducting Thyristor, or Vernier, Mode:-

(1) Bypassed

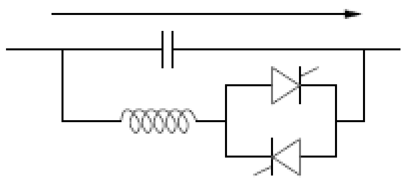


(a) Bypassed

Here the thyristor valves are gated for 180± conduction (in each direction) and the current flow in the reactor is continuous and sinusoidal. The net reactance of the module is slightly inductive as the susceptance of the reactor is larger than that of the capacitor. During this mode, most of the line current is flowing through the reactor and thyristor valves with some current Flowing through the capacitor. This mode is used mainly for protecting the capacitor against over voltages (during transient overcurrents in the line).This mode is also termed as TSR (Thyristor Switched Reactor) mode.

(2) Inserted with Thyristor Valve Blocked

In this operating mode no current flows through the valves with the blocking of gate pulses. Here, the TCSC reactance is same as that of the fixed capacitor and there is no difference in performance of TCSC in this mode with that of fixed capacitor.

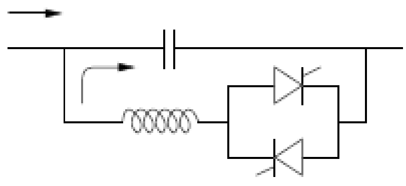


(b)Thyristor blocked

Hence this operating mode is generally avoided.

(3) Inserted with Vernier Control

In this operating mode, the thyristor valves are gated in the region of (αmin <α< 90±) such that they conduct for the part of a cycle. The e®ective value of TCSC reactance (in the capacitive region) increases as the conductionangle increases from zero. αmin is above the value of α corresponding to theparallel resonance of TCR and the capacitor (at fundamental frequency). Inthe inductive vernier mode, the TCSC (inductive) reactance increases as theconduction angle reduced from 180±.Generally, vernier control is used only in the capacitive region andnot in the inductive region.



(c)Vernier operation

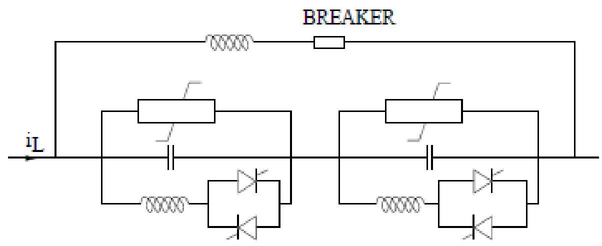


Figure 3. TCSC Module

In the Fig. 3 shows that A metal-oxide varistor (MOV), essentially a nonlinear resistor, is connected across the series capacitor to prevent the occurrence of high-capacitor over voltages. Not only does the MOV limit the voltage across the capacitor, but it allows the capacitor to remain in circuit even during fault conditions and helps improve the transient stability. The circuit breaker (CB) is installed across the capacitor for controlling its insertion in the line. In addition, the CB bypasses the capacitor if severe fault or equipment-malfunction events occur. A current-limiting inductor (LD) is incorporated in the circuit to restrict both the magnitude and the frequency of the capacitor current during the capacitor-bypass operation If the TCSC valves are required to operate in the fully ―on‖ mode for prolonged durations, the conduction losses are minimized by installing an ultra–high-speed contact (UHSC) across the valve. This metallic contact offers a virtually lossless feature similar to that of circuit breakers and is capable of handling many switching operations. The metallic contact is closed shortly after the thyristor valve is turned on, and it is opened shortly before the valve is turned off. During a sudden overload of the valve, and also during fault conditions, the metallic contact is closed to alleviate the stress on the valve.

3. REACTIVE POWER COMPENSATION BY TCSC

TCSC is an important device in the FACTS family. It can have various roles in the operation and control of power systems, such as scheduling power flow; decreasing unsymmetrical components; reducing net loss; providing voltage support; limiting short-circuit currents; mitigating sub synchronous resonance (SSR); damping the power oscillation; and enhancing transient stability. TCSC is one of the most important and best known series FACTS controllers. It has been in use for many years to increase line power transfer as well as to enhance system stability. The firing angles of the thyristors are controlled to adjust the TCSC reactance in accordance with a system analogy, normally in response to some system parameter variations. According to the of the thyristor firing angle (α) or conduction angle (σ), this process can be modeled as a fast switch between corresponding reactance offered to the power system. The total current passing through the TCSC is sinusoidal; the equivalent reactance at the fundamental frequency can be represented as a variable reactance XTCSC. There exists a steady-state relationship between α and reactance XTCSC. In power transmission applications, the degree of compensation is usually chosen in the range $0.3 \leq k \leq 0.7$.

4. 3PHASE COMPENSATION BY CONVENTIONAL METHOD

In Fig.4 show simulation modeled in MATLAB/SIMULINK without TCSC controlled. SIMULINK is used to model, analyze and simulate dynamic systems using block diagrams. Further, it provides a graphical user interface for constructing block diagram of a system and hence is easy to use. Sim Power Systems libraries of SIMULINK contain models of typical power equipment such as transformers, lines, machines, and power electronics. These models are provide and their validity is based on the experience of the Power Systems the active and reactive power flow in line is same at the sending end side and receiving end side. The voltage at the load drops due to loss of voltage on lines. This simulation model work at P=300MW and Q=150MVAR.

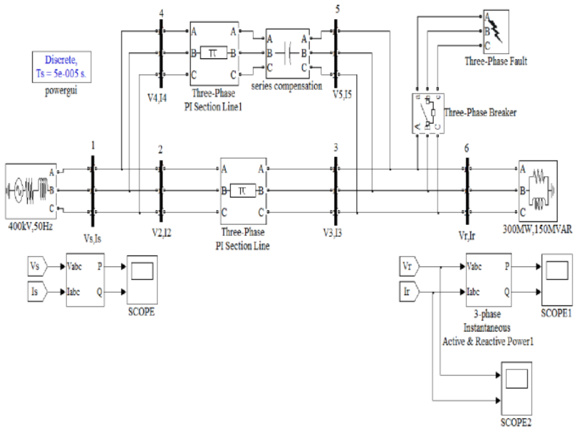


Figure 4. 3-phase Series compensation by conventional method

III. RESULTS AND DISCUSSION

1. MODELLING OF TCSC USING MATLAB SIMULATION

TCSC is the most commonly used series FACTS controller which enhances the power transfer capacity of transmission line and there by improving stability. The whole system has been represented in terms of SIMULINK block set present in Sim power System (SPS). It is considered in the present study for all simulations and TCSC based damping controller design. SPS is a modern design tool which helps to easily build and simulate power system model. The phasor solution model is generally used to study the electro mechanical oscillation resulting in large interconnected power systems. The TCSC can operate in capacitive or inductive mode, although the latter is rarely used in practice

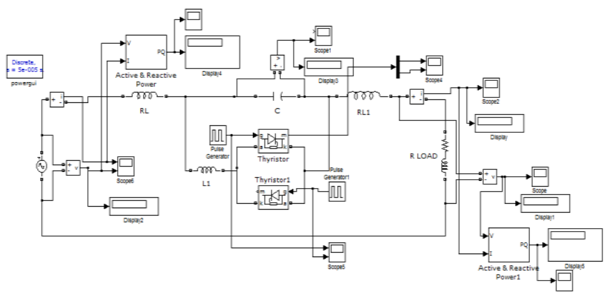


Figure 5. Simulated Diagram

The model of simple electrical network consists of a voltage source, load, two parallel lines and units for measuring and displaying measured electric variables.

Hence by changing the value of firing angle α the reactive can be controlled and also the reactance of the line can be controlled.

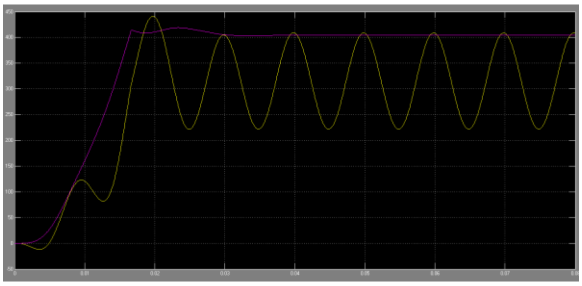


Figure 6. Waveforms of Active & Reactive Power

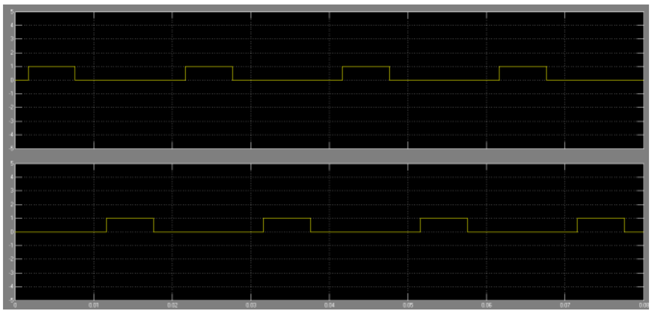


Figure 7. Waveform of triggering of Thyristor.

In Fig. 6 is showed situation in the simulated electrical network at adjusted angle α = 90°. Impedance of TCSC is inductive and therefore there is a change in power flow on lines. Hence the value of the angle of switching leads to decrease power flow on line, whose value has reduce from the original value of P = 407.1 to Q =376.4 (measured at the load).

TABLE.1

Firing Angle α in deg	Power in (V)			
	Source Side		Load side	
	P	Q	P	Q
90	408.66	401.84	407.1	376.4
130	406.12	390.15	394.5	361.55
150	401.25	362.4	382.6	326.1
180	388.56	386.5	381.74	355.45

IV. CONCLUSION

This research paper focused on behavior of TCSC intransmission line. Simulink model of TCSC with transmission line is presented and associated waveforms are analyzed. An open loop MATLAB/simulation modelof TCSC device on transmission line also analyzed with waveform.

V. FUTURE WORK

The analysis of TCSC with the help of simulink / simpower system has been studied in this paper. The behavior TCSC, in which a series connected variable impedance type FACTS is focused here. Further analyzes of TSCS along with SSSC (static synchronous series compensator) can be investigated in transmission line.

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