

Thyristor Controlled Series Capacitor with Automatic Control

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ABSTRACT

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 [1], 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.

In this paper a series controller from the Flexible AC Transmission System (FACTS) family called as 'Thyristor Controlled Series Capacitor' (TCSC) is designed using PIC microcontroller. Thyristor controlled series compensator (TCSC), is the first generation of FACTS controller, can govern line impedance through introduction of a thyristor controlled capacitor in series with the transmission line. A grid of transmission lines operating at high voltages is required to transmit power from generating stations to load. In addition to transmission lines that carry power from source to load, modern power systems are highly interconnected for economic reasons. The large interconnected transmission networks occur to faults due to the lightning discharges and reduce insulation strength. Changing loads and atmospheric conditions are unpredictable factors. This may cause overloading of lines due to which voltage collapse takes place. All the above said things are undesirable for secure and economic operation of a line. These problems can be erased by providing sufficient margin of working parameters and power transfer, but it is not possible due to expansion of transmission network. Still the required margin is reduced by introduction of fast dynamic control over reactive and active power by high power electronic controllers.

The TCSC operation which we are simulating in MATLAB (i) To calculate the various resonance points in the impedance characteristics of the TCSC w.r.t. various firing angle.

INTRODUCTION

The TCSC is used as series compensator in transmission system, it can be designed to control the power flow in order to increase the power transfer limits or to improve the transient stability. Power quality is an issue that is nowadays gaining significant interest to both electric utilities and endusers. The term power quality comprises a multitude of aspects, which is not new in essence, but has a growing concern due to the dissemination of sensitive loads (e.g. industrial plants) that use power electronics as a means of modernizing their manufacturing processes. The TCSC controller can provide a very fast action to increase the synchronization power through quick

changing of the equivalent capacitive reactance to the full compensation in first few cycles after a fault, hence subsequent oscillations are damped. Series capacitor compensation is an approach to improve stability limits and increase transfer capabilities. The transmitted power through a line is inversely proportional to the transfer impedance.

POWER SYSTEM STABILITY

Power system stability may be broadly defined as the ability of a power system to remain in a state of operating equilibrium under normal operating conditions and to regain an acceptable state of equilibrium after being subjected to a disturbance.[3] Stability of power system has been a major concern in system operation. The stability of a system determines whether the system can settle down to the original or close to the steady state after the transients disappear. In general, power system stability is the ability to respond to a disturbance from its normal operation by returning to a condition where the operation is again normal. [3] A power system is said to be steady state stable for a particular operating condition if, following any small disturbance, it reaches a steady state operating condition which is identical or close to the predisturbance operating condition.[3] Transient stability is defined as the ability of the power system to maintain synchronism when subjected to a severe transient disturbance. A system is transiently stable if it can survive the initial disturbance but it is transiently unstable if it cannot survive. For the transiently stable system, a large disturbance suddenly occurs, the system angle spread starts to increase but reaches a peak and then starts to decline, making the system transiently stable. The resulting system response involves large excursions of generator rotor angles. Transient stability is sometimes called first swing stability as the instability often occurs during the first angle swing.[3]

To meet rising demand of power, FACTS devices are introduced in the transmission line to enhance its power transfer capability; either in series or in shunt. It is obvious by series compensation technique that power transfer between two stations can be affected by adjusting the net series impedance of line. One such conventional and established method of increasing transmission line capability is to install a series capacitor, which reduces the net series impedance, thus allowing additional power to be transferred. Although this method is well known, slow switching times is the limitation of its use. Thyristor controllers, on the other hand, are able to rapidly and continuously control the line compensation over a continuous range with resulting flexibility. Controller used for series compensation is the Thyristor Controlled Series Compensator (TCSC). TCSC controllers use thyristor-controlled reactor (TCR) in parallel with capacitor segments of series capacitor bank (Figure 1). The combination of TCR and capacitor allow the capacitive reactance to be smoothly controlled over a wide range and switched upon command to a condition where the bidirectional thyristor pairs conduct continuously and insert an inductive reactance into the line. The series compensation is an economic method of improving power transmission capability of the lines.

CONCEPT OF TCSC

Figure 1 is a schematic representation of a TCSC module [2], 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.

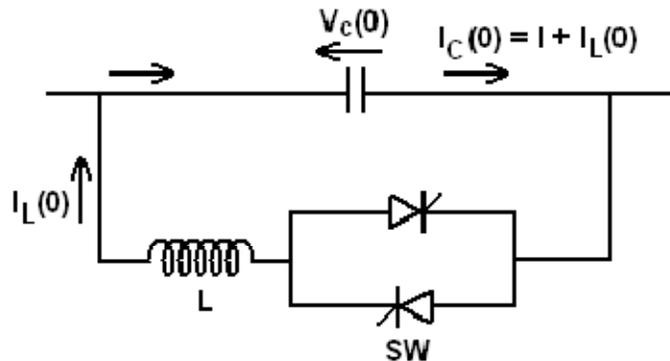


Figure 1. Thyristor Controlled Series Capacitor

A TCSC is a series controlled capacitive reactance that can provide continuous control of power on the ac line over a wide range. The functioning of TCSC can be comprehended by analyzing the behavior of a variable inductor connected in series with a fixed capacitor.

The introduction of thyristor technology brings the concept of series compensation still a large step further. Important added benefits are:

1. Increased dynamic stability of power transmission systems,
2. Improved stability,
3. Improved load sharing between parallel lines,
4. Elimination of line overloads,
5. Reduction of loop flows,
6. Improved voltage regulation and reactive power balance,
7. Elimination of subsynchronous resonance risks (SSR),
8. Damping of active power oscillations,
9. Dynamic power flow control,
10. Minimizing system losses,
11. Reduction of the gap between commercial and physical flows.
12. Optimizing load sharing between parallel circuits,

CLASSIFICATION OF STABILITY

The stability limit represents the maximum steady state power flow possible when the synchronous machine is operating with stability. There are two forms of stability. One is synchronous stability and other is voltage stability. Synchronous stability can be assessed by using P- δ curve and voltage stability can be estimated using P-V curve as explained below.

4. 1 SYNCHRONOUS STABILITY INDEX

P- δ curve

The relation between input power and the load angle is called power angle characteristics. The equation is given by, $P=EV\sin\delta/X$. The steady state stability limit is EV/X and it occurs at 90°

4.2 VOLTAGE STABILITY INDEX

P-V curve

As the power transfer increases, the voltage at the receiving end decreases. Finally, the critical or nose point is reached. It is the point at which the system reactive power is out of use. The curve between the variation of bus voltages with loading factor is called as P-V curve or “Nose” curve. PV curves are used to determine the loading margin of the power system. The margin between the voltage collapse point and the operating point is the available voltage stability margin.

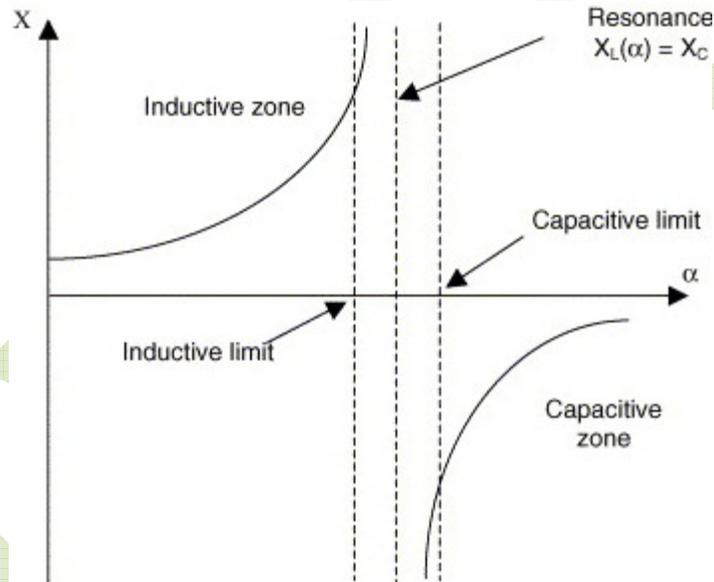


Figure 2 Resonance region of TCSC

As shown in the figure 2, the impedance of TCSC acts like a function of firing angle. According to this diagram we have three regions:

1. Capacitive region
2. Inductive region
3. Resonance region

If we want to decrease the power transfer from sending bus bar to receiving bus bar we have to operate TCSC in inductive region. In such scenario the length of transmission line enlarged. In such mode the TCSC is rarely operated. If we want to decrease the electric length of transmission line that is we want to amplify power transfer from sending bus bar to receiving bus

bar, TCSC should be operated in capacitive region. Due to stability issues TCSC is not operated in Resonance region.

There are three modes of operation of TCSC depending upon the firing angle of the pulses fed to the thyristor.

1. Thyristor blocked mode
2. Thyristor bypassed mode
3. Vernier or Partially Conducting Thyristor operating mode

1. Thyristor blocked Operating Mode:

In Thyristor blocked mode, our firing angle is 180 degree and thyristor are non-conducting. The TCSC's net or effective impedance is merely due to capacitive reactance. In such cases the line current is equal to capacitor current.

2. Thyristor Bypassed mode:

Thyristor bypassed mode is obtained if the valves of thyristor are fully conducted and capacitor is bypassed. Our firing angle in this case is 90 degrees. A small of current flows through the capacitor.

3. Vernier Operation mode:

Practically the mode operation used of TCSC is vernier operation. We can divide this mode of operation into two branches:

3.1. Capacitive Boost mode:

In capacitive boost mode a trigger pulse is supplied to the thyristor having forward voltage just before the capacitor voltage crosses the zero line, so a capacitor discharge current pulse will circulate through the parallel inductive branch. The discharge current pulse adds to the line current through the capacitor and causes a capacitor voltage that adds to the voltage caused by the line current. The capacitor peak voltage thus will be increased in proportion to the charge that passes through the thyristor branch. The fundamental voltage also increases almost proportionally to the charge. From the system point of view, this mode inserts capacitors to the line up to nearly three times the fixed capacitor. This is the normal operating mode of TCSC [4] [6].

3.2. Inductive Boost Mode:

In inductive boost mode the circulating current in the TCSC thyristor branch is bigger than the line current. In this mode, large thyristor currents result and further the capacitor voltage waveform is very much distorted from its sinusoidal shape. The peak voltage appears close to the turn on. The poor waveform and the high valve stress make the inductive boost mode less attractive for steady state operation [8].

Automatic Control Circuit for TCSC

Voltage regulation is provided by means of a closed-loop controller. TCSC control circuit consists following blocks, such as step down/up transformer, rectifier bridge circuit, active power filter, voltage regulator, PI controller, gate pulse generating unit (i.e. firing unit). Figure3 illustrates a TCSC including the operational concept.

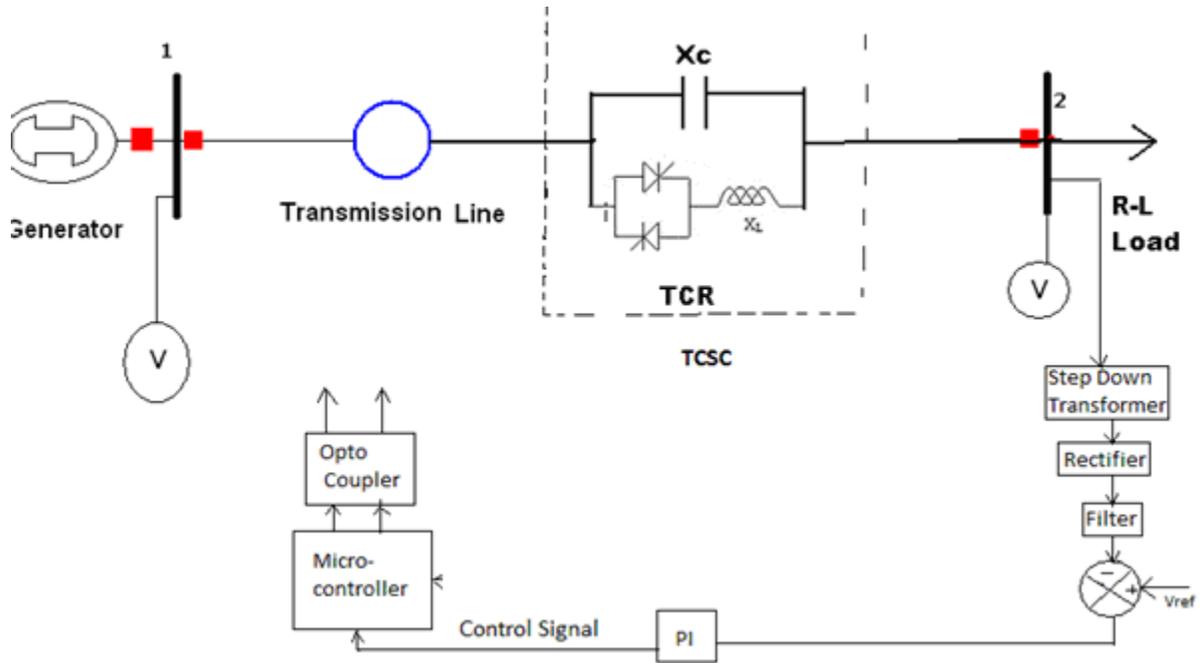


Figure 3. Automatic control of TCSC

P-V and P- δ Curves:

This case is considered when the generator is feeding the load through a line. To estimate the stability of the system, the P-V curves have been drawn for without and with TCSC.

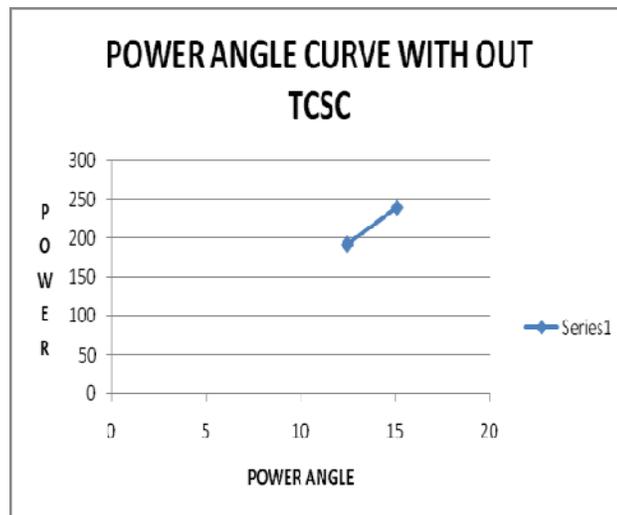


Figure4 P- δ Curve without TCSC

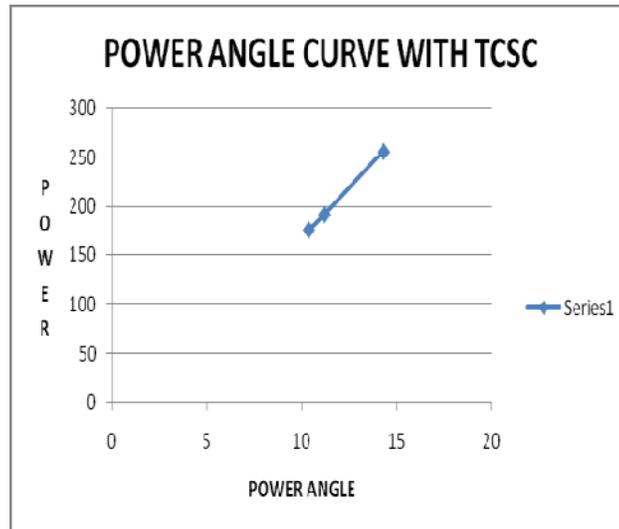


Figure5 P- δ Curve with TCSC

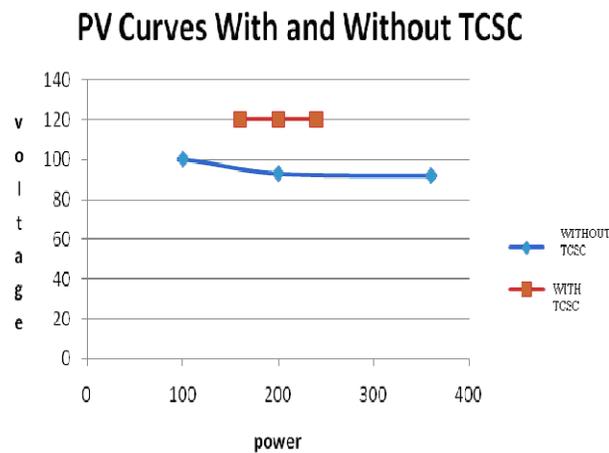


Figure6 P-V Curves with and without TCSC

Series capacitive compensation is thus used to reduce the series reactive impedance to minimize receiving end voltage variation and the possibility of voltage collapse. It is also observed that the compensation by using this technique i.e TCSC is faster when compared to other compensating techniques such as mechanical switching and synchronous condensers. PV curves have been drawn for both the cases. The system stability has been assessed with PV curves.

CONCLUSIONS

Thyristor Control Series Capacitors (TCSC) is maintain the system stability that means if any error occurs during the transmission of electric power, this device is solve the error and work continuously. The function of this device is the ability to change impedance transmission lines and thus increase the transmission capacity and power flow control. TCSC with his composition and capabilities allows widely using in power system. It can be used also for damping of active

power oscillations, improve dynamic and voltage stability, eliminating SSR and other. Before the installation of TCSC is important to determine the parameters of TCSC, prepare power analysis and analysis of the behavior of TCSC at various cases. Thus the subject of analysis was on a simple model of electrical network with two parallel lines simulate the behaviour of TCSC in terms of use in power flow control through the lines. The TCSC has also wide usage, it just makes it suitable for deployment of the electricity system to ensure better operational parameters and safe power transmission.

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