Congestion management in power system using TCSC

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Abstract - ***Due to the increasing demand, transmission line outage, generator outage etc., the power system becomes congested. Congestion is condition of the power system when it reaches at or beyond the transfer capability limit of the transmission line. The transfer capability limit of the transmission lines are voltage limit, thermal limit, stability limit etc. The congestion of the line will cause huge power loss, poor voltage regulation, high temperature rise etc. So relieving congestion is the most important task for the efficient power transfer. For keeping the network out of congestion, the power transfer should be kept within the transfer capability limit of the transmission line. The congestion can be managed by the use of TCSC.***

Key Words: *Power system, Congestion, Congestion management methods, FACTS devices, TCSC.*

1. INTRODUCTION

Power system is the network of electrical components applied to supply, transmit and generate electrical energy. Due to increased demand, transmission line outage etc., the probability of congestion of transmission line gets increased. Congestion is the condition of the power system when the power transfer reaches at or beyond the transfer capability limit. Because of congestion in the network the power transfer through the network became inefficient and the power losses also get increases. So tackling the congestion is main task to maintain an efficient power transfer. Congestion management is the action taken to control the power transfer within the transfer capability limit of the transmission line. Congestion management methods [1],[2] can be divided into two: cost free means and non-cost free means.

Cost free means:

- Out-ageing of congested line
- Operation of transformer taps/phase shifters
- Use of FACTS devices

Non-cost free means:

- Generation re-dispatching: In this method, some generators back down while others increase their output. The effect of re-dispatching is that generator no longer at equal incremental cost.
- Curtailment of loads

As per [3] the congestion management is done using optimal rescheduling of generator. The objective function of generator rescheduling is increasing or decreasing the active power output of the generator. As per [4] the generator for rescheduling is selected according to the generator sensitivity factor. The generator sensitivity factor is defined as the ratio of change of real power flow of the congested line to the change of real power of the generator. But from the above methods the cost free means is feasible than non-cost free means. Among the cost free means FACTS device can reduce transmission congestion effectively and better utilization of transmission line also possible.

2. FACTS Devices

The development of power electronic device introduces FACTS devices in the power system. The FACTS devices are capable of controlling the power flow in a fast manner. The FACTS devices are used in the power system in order to improve the power transfer capability limit of the line. The FACTS devices [5] can control the parameters of the transmission system such as series impedance, shunt admittance, phase angle, current, voltage, and damping of oscillation at various frequencies below rated frequency. FACTS are defined by IEEE as a power electronic based system and other static equipment which has the ability to enhance controllability, increase power transfer capability. The FACTS device can connect either in series or parallel to the power system in order to provide the power compensation. FACTS device such as variable series capacitors, phase shifters and UPFC etc are most commonly used to maintain the power flow. The use of FACTS device in power system results power loss reduction, increased stability margin, increased transfer capability, reactive power compensation, voltage control, power flow control etc,. Due to these advantages the FACTS devices can be used as solution for the congestion management issues in the power system.

2.1. Benefits of FACTS Devices

As per [6],[7],[8] the benefits of FACTS devices can be summarized as follows:

- Increased load ability
- Low system loss
- Improved stability
- Elimination of the need for new transmission lines
- Added flexibility in finding new generation
- Upgrade of transmission lines
- Reduce reactive power flows
- Increase the loading capability of lines to their thermal capabilities
- Loop flow control
- Improve transient stability
- Power oscillation damping and voltage stability control
- Reduced cost of production

2.2. Classification of FACTS Devices

As per [5] the FACTS devices are classified as follows:

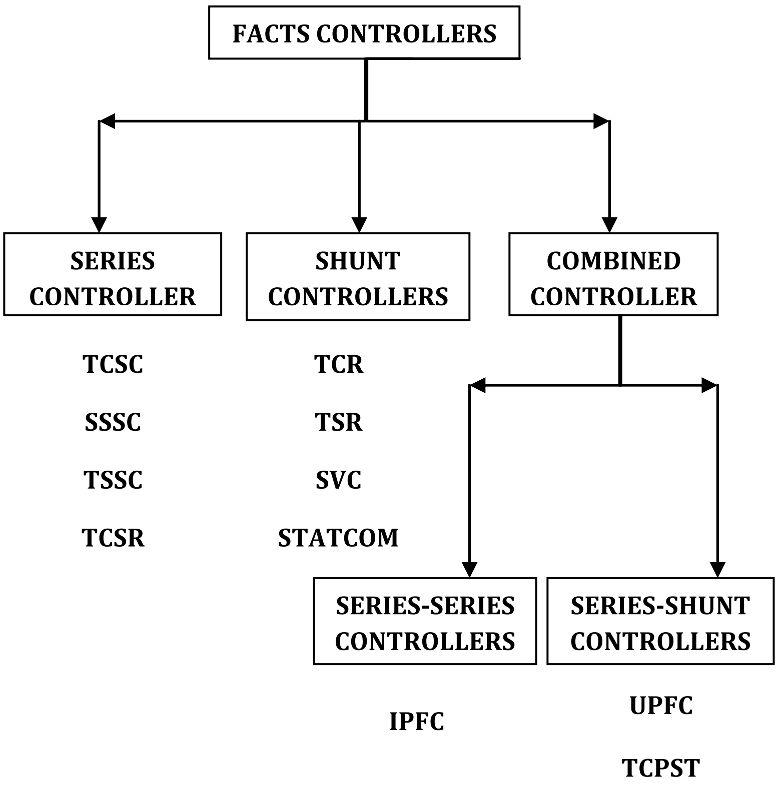

Chart -1: Classification of FACTS devices

- Series controllers: The series controller [5] could be variable impedance, such as capacitor, reactor, etc. The series controllers are injected to the transmission line in order to inject the voltage in series to the transmission line. The injected series voltage in the line can be represented by variable impedance multiplied by the current flow through it. The series controllers supplies or consume reactive power until the voltage is in phase quadrature with the line current. The main series controllers are Thyristor-Controlled Series Capacitor (TCSC), Static Synchronous Series Compensator (SSSC), Thyristor-Switched Series Capacitor (TSSC), Thyristor-Controlled Series Reactor (TCSR), etc. They can be effectively used to control current and power flow in the system.
- Shunt controller: Shunt controllers are used to inject current to the point where they are connected into the system. The variable shunt impedance of the shunt controller will vary the current flow in the respected line by injecting a current into the system. The controller can adjust the reactive power until the current is in quadrature with the line voltage and the controller can adjusts real power if the current is not in quadrature. The shunt controllers are Static Synchronous Generator (SSG), Static Var Compensator (SVC). It can be used for voltage control by supplying or receiving reactive or real power.
- Combined series-series controller: The combined series-series controller has two configurations one is series controllers operating in a coordinated manner in a multi line transmission system and the other configuration provides independent reactive power control and, at the same time, provides real power transfer through the power link. An example of this type of controller is the Interline Power Flow Controller (IPFC), which is capable of balancing both the real and reactive power flows on the lines.
- Combined series-shunt controller: The combined series-shunt controller may have two configurations, one consists two separate series and shunt controllers that can operate in a coordinated manner and the other one being an interconnected series and shunt component. In each configuration, the shunt component injects a current into the system while the series component injects a series voltage. When these two elements are unified, a real power can be exchanged between them via the power link. Examples of such controllers are UPFC and Thyristor-Controlled Phase-Shifting Transformer (TCPST).

Among the above mentioned FACTS classifications the series controllers are better than the shunt controllers. The series compensation directly controls the overall series impedance of transmission line. The power transmitted on the transmission line can be limited by the reactive impedance of that line. And the series controller can boost the voltage to the transmission line voltage drop, therefore reducing series line impedance. In[9] the congestion management for pool market model with SVC and TCSC was done. From the study the TCSC has better performance and less cost than SVC. The series controller is most commonly used for the power flow control because by driving the line voltage the series controller can control the power flow in the transmission line. The series controller injects voltage in series to the line so it will improve voltage profile also. The series controller have the capability of bypassing the short circuit current and it can also handle the over loading of the transmission line. Because of the above mentioned capabilities it is concluded that the series controller is much better than the shunt controller. So it is used for the application of congestion management. For relieving the congestion management TCSC and UPFC are commonly used. But TCSC is largely used for the case of congestion management. Because the cost of UPFC is larger than TCSC. As per [10] the TCSC has the following advantages:

- Rapid control of series reactance of the transmission line
- The interfacing equipments were absent
- Less cost compared to other FACTS controllers
- More economic

2.3. TCSC

TCSC is a device consisting of a fixed series compensating capacitor with impedance $-jX_C$ and shunt connected Thyristor Controlled Reactor (TCR) with a variable inductive impedance $X_L(\alpha)$. Inductive reactance of the TCR can be controlled by controlling the firing angle α. TCSC usually connects in series with line and allows changing to influence power flows. Control is fast, efficient and increase limits of transmitted power. The diagram of TCSC is shown in the following Fig-1 [11].

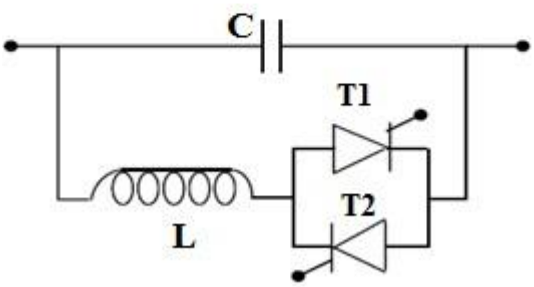

Fig -1: Simple diagram of TCSC

The impedance change of TCSC can be achieved by the thyristor switched reactor connected in parallel to the capacitor. The TCSC is usually connected in series with the line. This allows a rapid change in transmission line reactance and results changes in the power flow also.

2.3.1. Operation of TCSC

TCSC is a series controlled capacitive reactance and it can provide a continuous control of power transmitted over transmission line. The equivalent diagram of TCSC representing the operation of TCSC as shown in the Fig-3. The variable series compensation achieved by the variation of the firing angle α and it results an increase in the fundamental frequency voltage across the fixed capacitor. The impedance characteristics of TCSC are shown in the Fig-3 [12]:

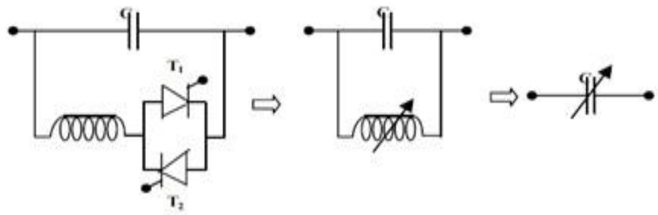

Fig -2: Impedance Vs Firing angle characteristic curve

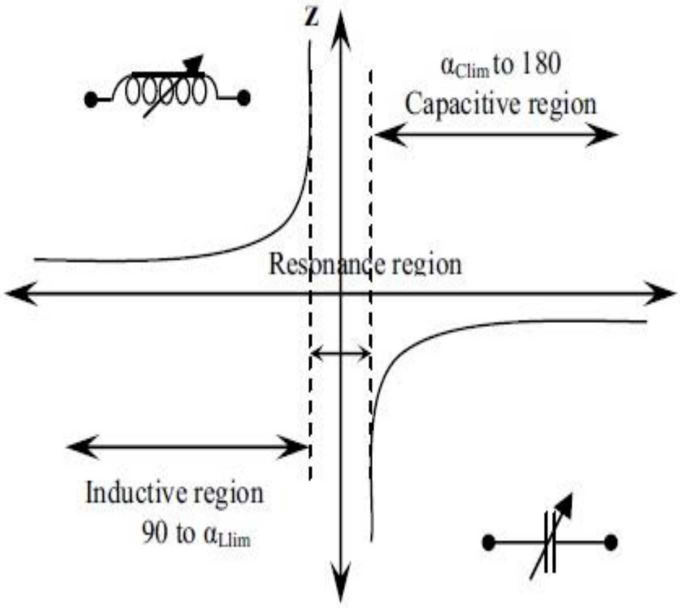

Fig -3: Impedance Vs Firing angle characteristic curve

The net reactance of TCR is varied from minimum value X_L to the maximum value. Likewise effective reactance of TCSC starts increasing from X_L value to till occurrence of parallel resonance condition $X_L(\alpha)= X_C$, theoretically X_{TCSC} is infinity. This region is inductive region. Further increasing of $X_L(\alpha)$ gives capacitive region, Starts decreasing from infinity point to minimum value of capacitive reactance X_L. The series reactance is adjusted automatically, within limits to satisfy a specified amount of active power flows through it.

Thus impedance characteristics of TCSC shows, both the capacitive and inductive region are possible though varying firing angle (α).

- From $90< \alpha< \alpha_{Llim}$, Inductive region
- From $\alpha_{Clm}< \alpha<180$, Capacitive region
- From $\alpha_{Llim}< \alpha< \alpha_{Clim,}$, Resonance region

While selecting inductance X_L should be sufficiently smaller than that of the capacitor X_C. Since to get both effective inductive and capacitive reactance across the

device. Also X_L should not be equal to X_C value or else a resonance develops that result in infinite impedance is an unacceptable condition. Note that while varying $X_L(\alpha)$, a condition should not allow to occur $X_L(\alpha)= X_C$.
In [14] the quantitative analysis of the effect of TCSC on congestion and spot price in deregulated power market was discussed. In [15] the method is determined the optimal location of TCSC for the effective congestion management was discussed. As per [15] there were two methods used, those are real power performance index method and total system VAR power losses.

3. CONCLUSIONS

Power system constitutes the process of generation, transmission and distribution of electrical energy. Due to the increase in electrical demand, transmission line outage etc. there is a chance for occurring congestion. So congestion management is essential for stable and reliable power system. The FACTS controllers are most widely used for congestion management. The FACTS devices are classified into shunt and series controller. Among these two, the series controller is much better than the shunt controller because of its reduced MVA size. The TCSC and UPFC are the commonly used series controllers. But the cost of UPFC is much larger than the TCSC so it is selected for the power system free from congestion.

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BIOGRAPHIES

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