Design And Analysis Of Control Circuit For TCSC FACTS Controller

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Abstract

Power system engineers are currently facing challenges to enhance the power transfer capabilities of existing transmission system. This is where the Flexible AC Transmission Systems (FACTS) technology comes into effect. Thyristor Controlled Series Capacitor (TCSC) is one of the important member of FACTS family, is an impedance compensation which is used in series reactance on an AC transmission system to provide smooth control of series reactance by controlling thyristor firing angle (α) to increase the capability of the reactive power compensation of the transmission line. This paper presents design of control system by MATLAB/PSCAD which is used to implement the performance of the proposed control circuit in case of peak load and half load of the transmission line where the simulation shows a good result where the reactive power is compensated and transmission line capacity is extended.

Key-words: *FACTS, TCSC, Reactive power compensator, static VAR compensator.*

1. Introduction

Present power systems are highly complicated, sometimes made of the thousand buses and hundreds of generators. Basically new power generating stations are primarily determined based on environmental and economic reasons, and are somewhat inexpensive, easy to build and operate. With the lack of new generation and transmission facilities and over exploitation of existing facilities geared by increase in load demand makes system instability. On the other hand new transmission systems are expensive and take considerable amount of time to build. Hence, in order to meet increasing power demands, utilities must rely on power export, important arrangements through existing transmission systems. While the power flows in some of these transmissions line is well below their thermal limits, certain lines are overloaded, which has the effect of fluctuating voltage profiles and decreasing power system stability.

Flexible AC Transmission Systems (FACTS) is a new approach to a more efficient use of existing power system resources based on the utilization of high current high voltage power electronic controllers. Basically this technology is used to enhance the power transfer capability of the existing transmission line while compensating the reactive power. During last decade reactive power control was depend on the mechanically controlled shunt switches controlling a capacitor and reactor which are slow in response for load variation. With the advancement high power semiconductor devices with a combination of digital electronics are being widely used for fast and efficient reactive power compensation. Presently series compensation is used for long transmission lines to compensate the reactive power by the characteristic impedance of the line.

2. Basic Operation of TCSC

A single line diagram of a TCSC is shown in the fig which shows two modules connected in series. There can be one or more modules depending upon the requirement. To reduce the cost, TCSC may be used in conjunction with fixed series capacitors.

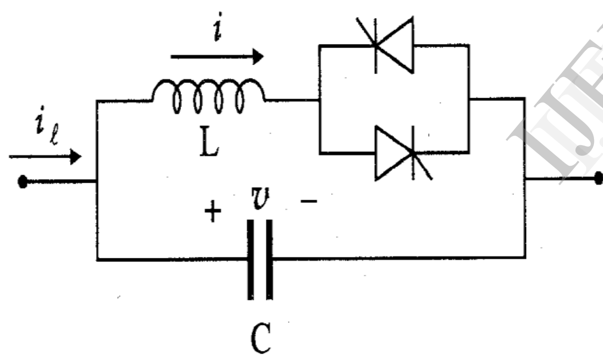

Fig-1: TCSC Circuit Diagram

Each module has three operating modes:

a) By- passed: Here the thyristor valves are gated for 180^o conduction (in each direction) and the current flow in the reactor is continuous and sinusoidal. In this mode, most of the line current flows through the reactor and thyristor valves with some current flows through the capacitor. This terminology is mainly used for protecting the capacitor against over voltages (during transient over currents in the line). The mode is also known as TSR (thyristor switched reactor) mode.

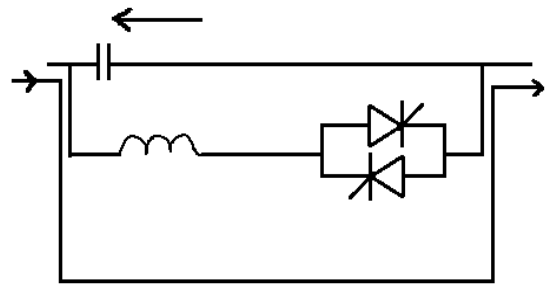

Fig-2: Bypass mode

b) Inserted with thyristor valve blocked: In this mode, due to the blocking of gate pulses no current flows through the valves.
The TCSC reactor is same as that of the fixed capacitor and there is no difference in the performance of TCSC in this mode with that of a fixed capacitor.

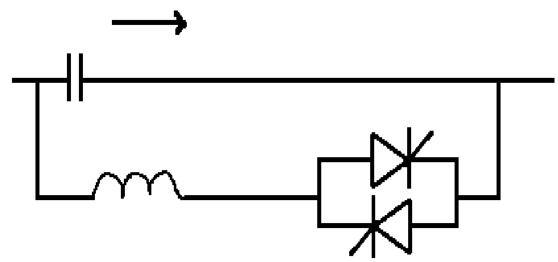

Fig-3: Thyristor blocked

Hence, the mode is generally avoided. This method is also known as waiting mode.

c) Inserted with vernier control: In this operation, the thyristor valves are gated in the region of ($\alpha_{min}<\alpha<90^o$) such that they conduct for the part of a cycle. The valve of TCSC reactance (in the capacitive region) increases as the conduction angle increases from zero.
In the inductive vernier mode, the TCSC (inductive) reactance increases as the conduction angle reduced from 180^o.
Generally this scheme is used only in the capacitive region and not in the inductive region.

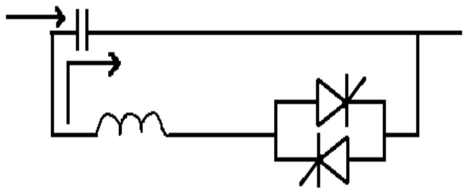

Fig-4: Vernier operations

3. Circuit Analysis of TCSC

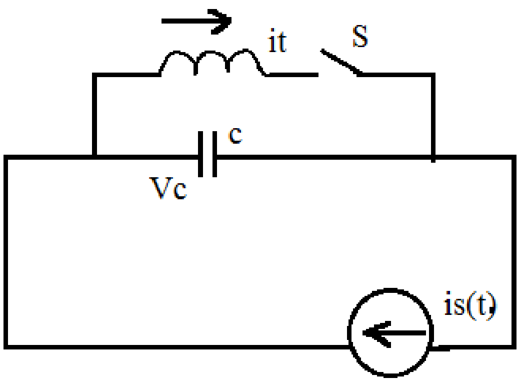

Fig-5: The TCSC Circuit

For simplicity, it is assumed that the line current is specified and can be viewed as a current source.

The equations are:

$C.\frac{dvc}{dt}=i_S(t)-i_T$

$L.\frac{diT}{dt}=V_C u$

Where u=1 when the switch is closed and u=0 when it is open. The current in the thyrister switch and the reactor(i_T) is zero at the instant when the switch is opened.

The line current i_S is given by

$i_S(t)=I_m \cos\omega t$

for convenience, to measure the firing angle (α) from the zero crossing instant of the line current. It can be shown that, the zero crossing of the capacitor voltage (Vc) coincides with the peak value of the line current in steady state.

The range of α is from 0 to 90^o corresponding to the conduction angle varying from 180^o to 0^o.

The angle of advance (β) is defined as

$\beta=90^o-\alpha$.

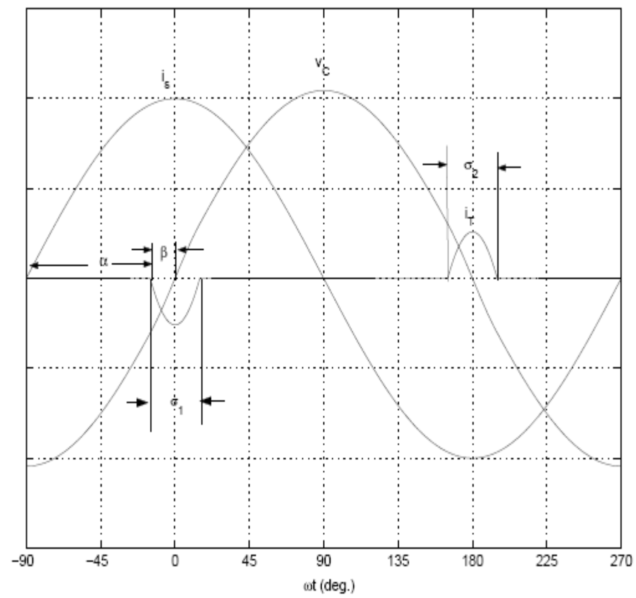

Fig-6: waveform of $i_S(t)$,$i_T(t)$,$V_c(t)$

The switch 'S' is turned on twice in a cycle (of the line current) at the instants (assuming equidistant gating pulses)

$t_1=\beta/\omega$

$t_3=\pi-\beta/\omega$

where $0<\beta<\beta_{max}$

the thyristor switch turn off at the instants t_2 and t_n given by-

$t_2=t_1+\sigma_1/\omega$

$t_n=t_3+\sigma_2/\omega$

where σ_1 and σ_2 are conduction angles in the two values of the cycle. In steady state $\sigma_1=\sigma_2=\sigma$ with half wave system.

4. Power Transfer Capability of Transmission Line:

The power transfer between two ends of uncompensated transmission line is given by

$$P=\frac{Vs\,Vr}{X_l}\sin\partial$$

Where Vs and Vr are sending end and end voltages, respectively , X_l is transmission line reactance (loss is neglected) and is the power angle. The compensating effects results from the voltage drop across the series impedance of TCSC as sown in figure (1). The power transfer through transmission line with series compensated by using TCSC is

$$P = \frac{VsVr}{X_l + X_{TCSC}(\alpha)} \sin \partial$$

5. Control Strategies

There are two types of control (either closed –loop or open-loop) can be used to control over TCSC. Open –loop control is used to generate an output according to a predefined transfer function and no response measuring is required, while closed loop control implies the classical feedback system as shown in figure (7,8). For the proposed study, the second type is employed and both of load current and voltage are traced as feedback, where the ratio of compensator current to the voltage error determines the slope of voltage /current characteristic. The system stability and response are determined by total loop gain and time constants.

Conventionally, reactive power compensator controllers are based on one of the following modes; Constant Current (CC), Constant angle (CA) mode and Constant Power Mode (CP)

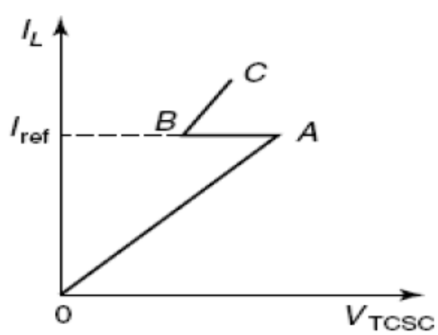

Fig-7: constant current mode

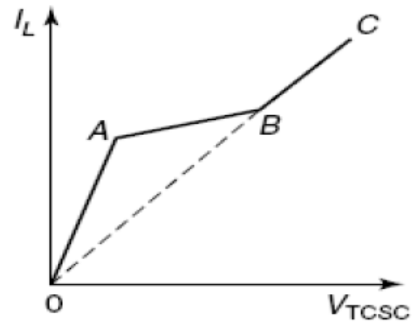

Fig-8: Constant angle mode

6. Simulink Block for TCSC Control

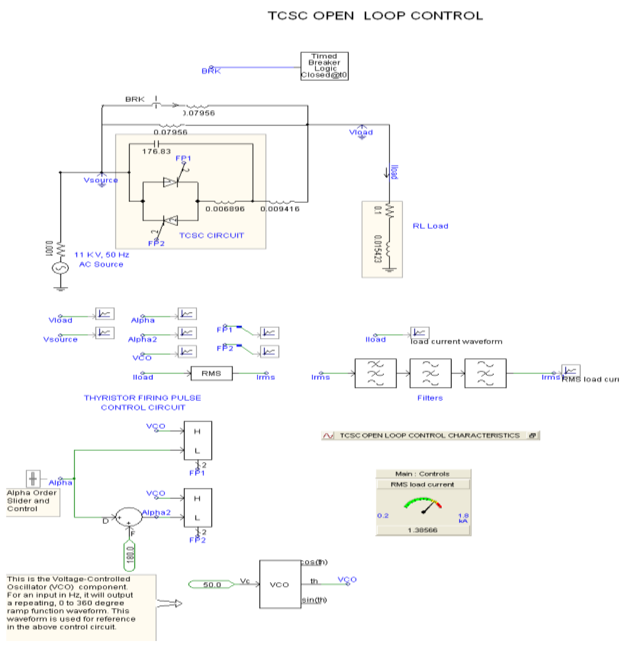

Fig-9: TCSC Open Loop Control

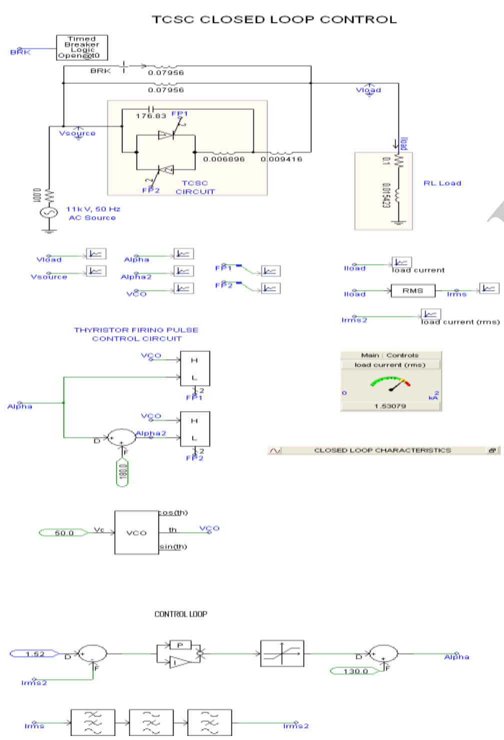

Fig-10: TCSC Closed Loop Control

7. Simulation Result

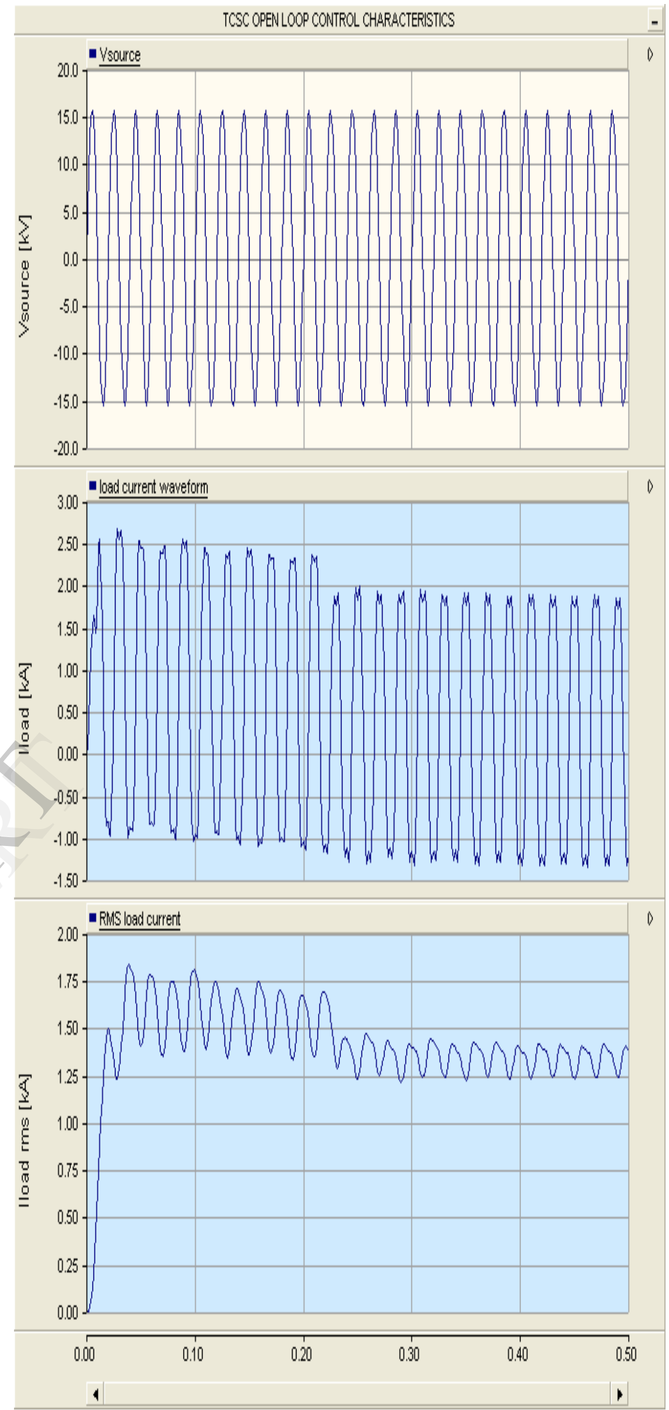

Fig-11: Simulation result of TCSC Open Loop Control

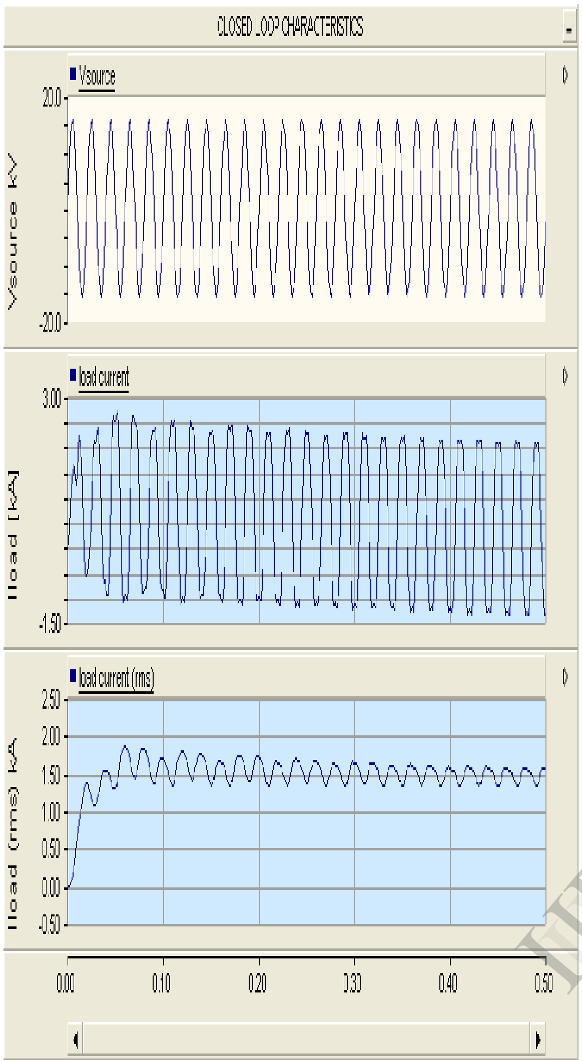

Fig-12: Simulation result of TCSC Closed Loop Control

8. Conclusions

As seen from the simulation results it is cleared that in case of open loop control_the rms load current is decreased from 1.528 kA (steady state value) to 1.385 kA (when breaker opens at t = 0.2 sec). Graphical result also shows the same as I_{load} rms value decreases at t = 0.2 sec. While in case of closed loop control it is cleared that the load current I_{load} (rms) which is decreased to 1.385 kA in the open loop control arrangement is automatically regain to its steady state value (1.53 kA). Thus TCSC provides required series compensation to regain the decreased current to steady state value though one of the parallel inductor is in open condition.

From the above analysis it is evident that while analyzing the TCSC controller circuit its response to the time varying curve shows that TCSC is a good current controller. Thus the TCSC can be utilized as active power controller which enhances the system power to meet the consumers demand.

9. References

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