APPLICATION OF THYRISTOR CONTROLLED SERIES COMPENSATOR IN POWER SYSTEMS

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Abstract— Today's transmission system is becoming increasingly complex and very difficult in every aspect and is expected to carry large or heavy power in ways it was never designed for or used. The expectation is that transmission requirements will only increase, as power generation sources are continuously evolving. Series Compensation System allows utilities to cost effectively increase the power transfer capabilities of their existing infrastructure and new transmission lines. Series compensation systems are installed in series with High Voltage transmission lines, and consist of an integrated, complex custom-designed system with many power capacitors placed in series and parallel. The most critical equipment is the parallel protective system which prevents damage to the capacitors during power circuit or system faults.

In series compensation we will add a capacitor in series with the transmission line as a compensator. When the compensator is placed at the mid point of the transmission line then there is minimum distortion in the Waveshapes and hence the system is more stable.

Further TCSC, a FACTS device is added in the transmission line which will increase the power transmission, makes the system more stable and more controllable.

TCSC model of transmission line will be observed for different parameters of TCSC. Henceforth different Waveshapes of power, voltages and current will be obtained and power is seen to be more or less for different values of TCSC and transmission line parameters.

1. INTRODUCTION

Series Compensation is the strategy for improving the framework voltage by associating a capacitor in arrangement with the transmission line. As it were, in arrangement remuneration, receptive force is embedded in arrangement with the transmission line for improving the impedance of the framework. It improves the force move ability of the line. It is for the most part utilized in extra and ultra high voltage line.

Favorable circumstances of Series Compensation

- Increase in Power Transfer Capability
- Control of Voltage
- Improvement in System Stability

Location of Series capacitor

The area can vary on the basis technical and economical conditions of the line. It can be placed or located at the sending end, receiving end or at the centre of the transmission line. For the next step the project focuses on the FACTS device.

Flexible Alternating Current Transmission System. It is a system which has static components used for AC transmission of energy. This system is mainly used for better controlling of the system and for more power transfer capability.

There are various sorts of FACTS

- SVC
- TCSC
- STATCOM, etc

In this project we are working on TCSC facts. Thyristor controlled series capacitor is used in power system to control the reactance which results in more power flow and more control over the system with better voltage regulations.

2. TCSC

TCSC is a FACTS device which is associated in the transmission line. It consists of a series capacitor and a TCR i.e. thyristor controlled reactor which is connected in parallel to the series capacitor.

TCSC has various methods of activity depending on the triggering of the thyristor. Different modes of TCSC can be operated depending upon the requirements of the system. TCSC has a separate control system which is used in controlling the compensation. Compensation can be changed by managing the mode of TCSC and by altering the parameters of TCSC.

It also helps in dampening the oscillations which helps in transferring more power and maintaining the system stability and giving more controlled system.

USES OF TCSC

- System losses are reduced
- System stability is improved
- Transmission capability of power is enhanced
- Voltage of the distribution lines improved

ADVANTAGES OF TCSC

- Damping of power oscillations
- System stability is improved
- System losses are reduced
- More controlled system

MODES OF TCSC

As discussed earlier there are different operating modes of TCSC depending on the firing angle.

1. Thyristor blocked mode
2. Thyristor bypassed mode
3. Vernier operating mode

1. **Thyristor blocked mode** - when there is no triggering of the thyristor valve then the TCSC is operated in blocking mode. TCSC behaves like a non variable series capacitor.

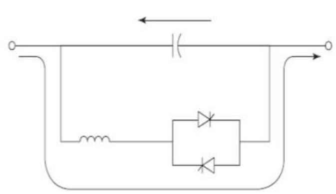

Fig.1 Thyristor Blocked Mode

2. **Thyristor bypassed mode** – in this mode there is continuous triggering of the thyristor valve and it stays conducting all the time which can be seen as the capacitor connected in corresponding with the inductor connected to the thyristor.

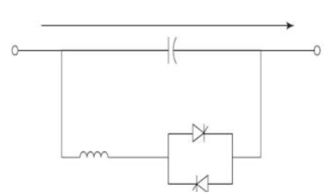

Fig. 2 Thyristor Bypassed Mode

3. **Vernier operating mode** - in this mode the TCSC is being controlled by different values of the terminating edge of the thyristor. The values which are possible for the firing angles can vary from 0° to 90°. This mode is further divided into two modes.

   I. Capacitive boost mode
   II. Inductive boost mode

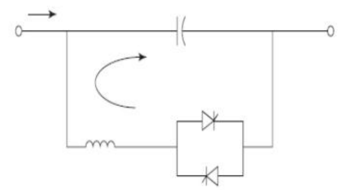

Fig. 3 Vernier Operating Mode

I. **Capacitive Boost mode –** this mode is viewed as typical method of TCSC. In capacitive lift mode an activating heartbeat is provided to the thyristor having forward voltage thus a capacitor current will circle in the equal inductive branch in the circuit, this present includes the line current through the capacitor which causes a capacitor voltage, this capacitor voltage adds to the voltage which is brought about by the line current, bringing about the expansion in capacitive voltage which from now on increment the crucial voltage. There by making this mode a typical mode for TCSC.

II. **Inductive Boost mode –** in this mode the current in the thyristor branch is greater than the current flowing in the line. Which results in the poor capacitive voltage Waveshape making it less usable mode for TCSC.

APPLICATIONS OF TCSC

- Improvement of the System – Stability
- Regulation of Power flow is more accurate
- Damping of power oscillation

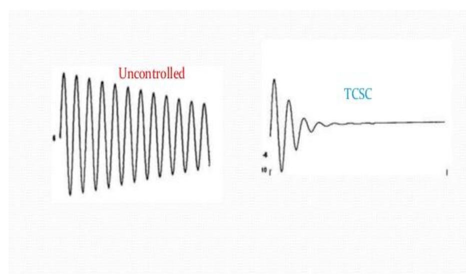

Fig. 4 Damping of Power Oscillation

3. Compensation at 75%

A 500 kv transmission line has a TCSC circuit for 75% compensation, control system and firing unit. There is a CB connected to the TCSC which is initially closed.

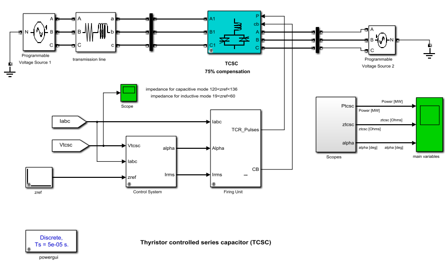

Fig 5 Simulink model of TCSC at compensation at 75%

PARAMETERS

For transmission line

- Total inductance of the line = 0.4176H.
- Total line reactance of the line XTL = 131.1929 Ω.

For TCSC

- For 75% compensation
  Xc = 0.75 XTL
  Xc = 98.3946 Ω
  C = 32.3503 μF
- Xr/Xc should be in range of 0.1 to 0.3, hence Xr/Xc = 0.25 so Xr = 24.598 Ω
- Thus reactor Ltcr = 0.07829H

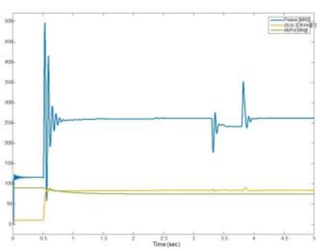

Fig. 6 Waveshape at 75° Firing Angle

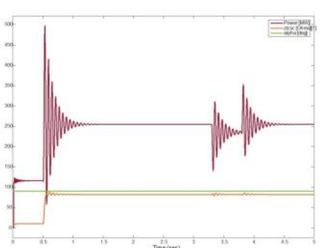

Fig. 7 Waveshape at 90° Firing Angle

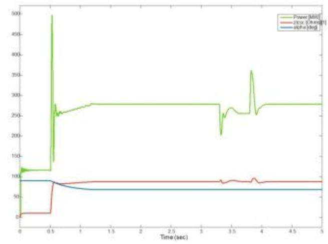

Fig 8 Waveshape at 65° Firing Angle

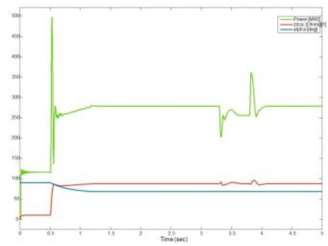

Fig 9 Waveshape at 70° Firing Angle

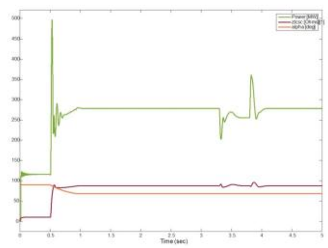

Fig 10 Waveshape at 60° Firing Angle

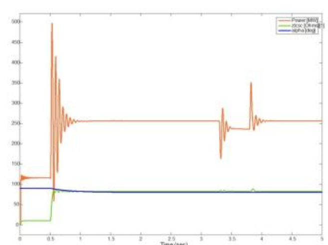

Fig 11 Waveshape at 80° Firing Angle

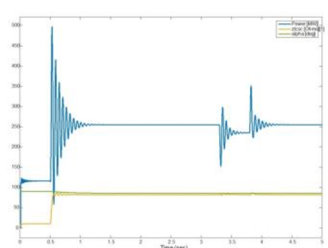

Fig 12 Waveshape at 85 ° Firing Angle

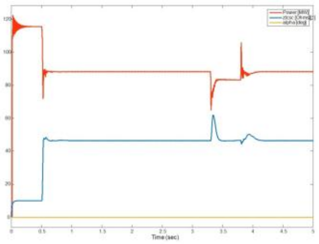

Fig 13 Waveshape at 0° Firing Angle

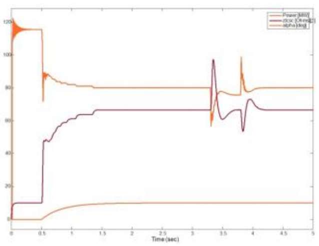

Fig 14 Waveshape at 10° Firing Angle

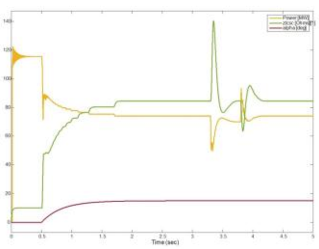

Fig 15 Waveshape at For 15° Firing Angle

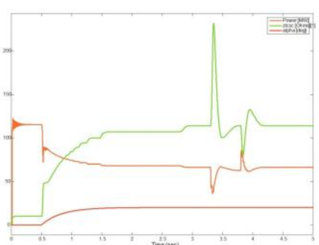

Fig 16 Waveshape at 20° Firing Angle

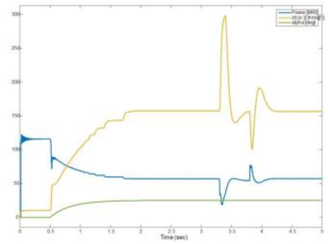

Fig 17 Waveshape at 25° Firing Angle

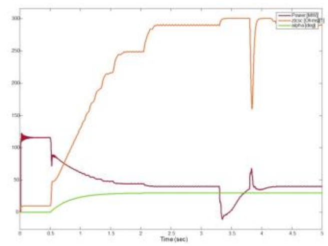

Fig 18 Waveshape at 30° Firing Angle

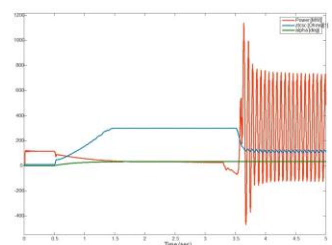

Fig 19 Waveshape at 33° Firing Angle

CAPACITIVE REGION

Firing Angles	Ztcsc (ohms)	Power (MW)
60°	88.7	296.5
65°	85.3	292
70°	82	288
75°	80	270
80°	79	260
85°	79	250.7
90°	78	248

INDUCTIVE REGION

Firing Angles	Ztcsc (ohms)	Power (MW)
0°	47	90
10°	65	83
15°	80	77
20°	101	66
25°	151	58
30°	280	49
33°	300	30

4. Compensation at 60%

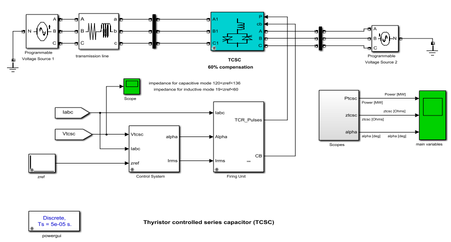

Fig.20 Circuit Diagram of TCSC at Compensation 60%

PARAMETERS

- For 60% Compensation
  Xc = 0.60 XTL
  Xc = 78.2 ohms
  C = 3.37 E-5 F
- Xr = 19.5 ohms
- Ltcr = 0.06210 H

Firing angles	Ztcsc (ohms)	Power (MW)
0°	33	95
20°	65	80
65°	85	280
75°	80	250

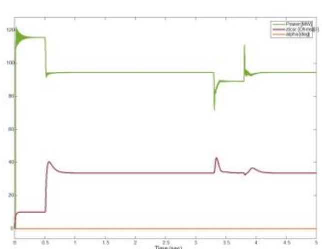

Fig. 21 Waveshape at 0° Firing Angle

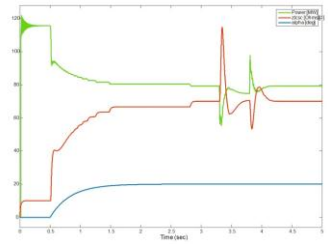

Fig 22 Waveshape at 20° Firing Angle

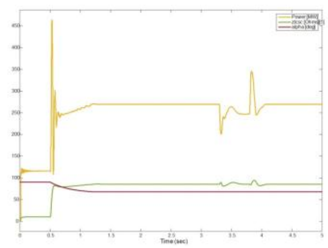

Fig. 23 Waveshape at 65° Firing Angle

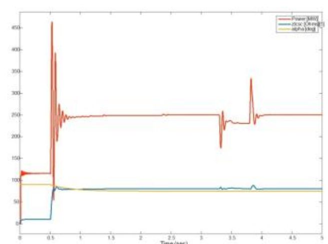

Fig. 24 Waveshape at 75° Firing Angle

5. Compensation at 90%

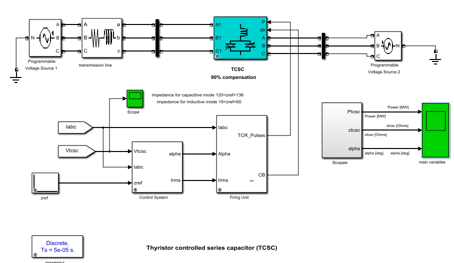

Fig. 25 Circuit Diagram of TCSC at Compensation 90%

PARAMETERS

- For 90% Compensation
  Xc = 0.90 XTL

Xc = 118.0736 ohms
C = 2.69722 E-5 F

- Xr = 29.5184 ohms
- Ltcr = 0.09400 H

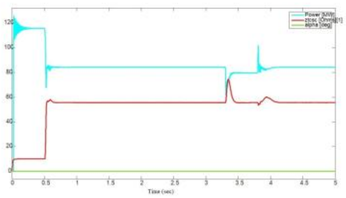

Fig. 26 Waveshape at 0° Firing Angle

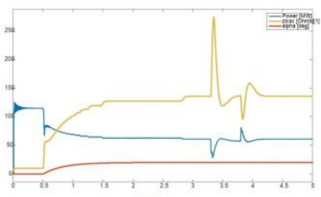

Fig. 27 Waveshape at 20° Firing Angle

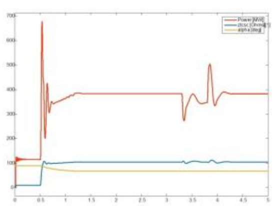

Fig. 28 Waveshape at 65° Firing Angle

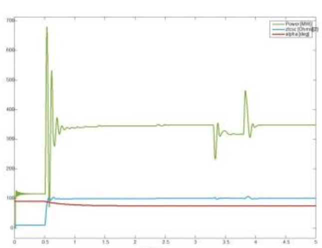

Fig. 29 Waveshape at 75° Firing Angle

Firing Angles	Ztcsc (ohms)	Power (MW)
0°	58	80
20°	125	70
65°	106	398
75°	100	380

6. Conclusion

It is clearly visible from the Waveshapes obtained that in Capacitive region (firing angle 60° to 90) as the value of terminating edge is increased , value of power is decreased. As the value of terminating edge in Capacitive region is increased the value of Impedence also decreases. In inductive region (firing angle 0° to 33°) as the value of terminating edge increases , value of power decreases. In Inductive Region as the value of terminating edge is increased , value of Impedence increases. By changing compensation percentage it is concluded that in capacitive region when the compensation percentage was increased keeping the firing angle constant, the power also increases. In Inductive Region however there was no pattern concluded and the Waveshapes were more distorted. Hence this is why TCSC's normal mode is considered to be Capacitive Mode.

7. Appendix

Parameters

- Control System
  Initial Input – 0(Deg),60Hz
- Firing Unit
  Total Delay – 0
  Initial Phase – 0(deg)
  Frequency of input – 60Hz
- 3 Phase Programmable Voltage Source
  Amplitude values – [1.0 0.96 1.0]
  Time values – [0 3.3 3.8]
- Quality Factor – 500
- Thyristor Snubber – 5000 ohm , 50e-9 F
- Thyristor Data – 1e-2 ohm , 0 V

8. References

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