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Series compensation in 400 KV transmission systems with performance comparison with Thyristor Controlled Series Capacitor

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ABSTRACT

This paper series compensation in 400KV transmission systems with performance comparison with TCSC investigates the effect of series compensation on transmission voltages under different fault conditions. Insertion of series capacitor in transmission line reduces net line reactance and hence improves the power transfer capability of line. This paper also provides recommendations for the operation of series capacitor. The paper also shows comparison with TCSC. A thyristor- controlled series compensator is composed of a series capacitance which has a parallel branch including a thyristor- controlled reactor. It is used in power systems to dynamically control the reactance of line. A 400kV transmission line from Khandwa to Seoni is taken as an example and monitored in this study. The system is simulated in MATLAB software and simulation results are discussed. The information given here would be valuable for grid operators that deal with compensated lines and switch in and out series capacitors.

INTRODUCTION

The increasing use of non- linear loads in the industries based on the power electronic elements introduced serious perturbation problems in the electric power system. In recent years, the highly increasing cost of building new transmission corridors, has led to a search for increasing the transmission line capacity of existing lines. With series compensation, the viable distances of AC power transmission become sufficiently large to eliminate altogether the issue of distance as a limiting factor for AC transmission in most cases. Thus, series compensation is an efficient way to overcome these issues. It should be inserted in series with transmission line.

Series compensation is the method of improving the system voltage by connecting a capacitor in series with the transmission line. In other words, in series compensation, reactive power is inserted in series with the transmission line for improving the impedance of the system. It improves the power transfer capability of the line. It is mostly used in extra and ultra high voltage line.

The advantages of series compensation are-

- Improvement in System Stability
- Increase in power transfer capability

The power transfer (P_1) over a uncompensated line is given by ;

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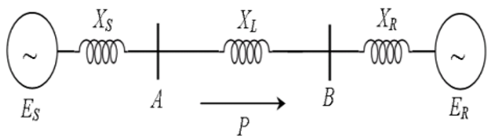

Fig-1 Transmission line without series compensation

$$P_1 = \frac{V_s V_R}{X_L} sin\delta$$

The power (P_2) transmitted through series compensated transmission line is given by;

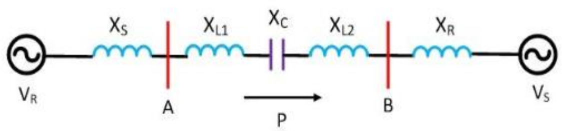

Fig. 2- Transmission line with series compensation

$$P_2 = \frac{V_s V_R}{X_L - X_C} sin\delta$$

$$\frac{P_1}{P_2} = \frac{X_L}{X_L - X_C} = \frac{1}{1 - \frac{X_C}{X_L}} = \frac{1}{1-k}$$

K is degree of compensation which may lie between 0.4 to 0.8. The amount of transmitted power is increased with series compensation.

- Load Division among Parallel Line
- Control of Voltage

The series capacitor may be located at the sending end, receiving end, or at the center of the line. Sometimes they are located at two or more points along the line.

2. Thyristor Controlled Series Capacitor:-

TCSC is a FACT controller. The use of thyristor control to provide variable series compensation makes it attractive to employ series capacitor in long lines. A thyristor controlled series capacitor comprises of a series capacitor bank shunted by thyristor controlled reactor. Fig. 2 shows a linear reactor ‘L’ connected to AC source through two thyristors connected in anti parallel. Parallel combination of switched capacitors and controlled reactors provides a smooth current control rang from capacitive to inductive values by switching the capacitor and controlling the current in the reactor.

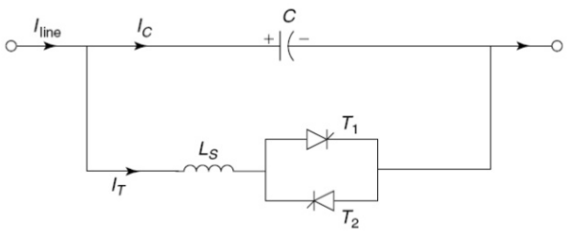

Fig. 3- Thyristor Controlled Series Capacitor

Thyristor controlled series capacitor may be used for current control, stability improvement, damping oscillations, and for limiting fault current.

Advantages of FACTS ;

- It increases the loading capability of the lines to their thermal capability.
- Overcoming their limitations and sharing of power among lines can accomplish this.
- Provides greater flexibility in sitting new generation.
- FACTS devices improve the speed of operation of the overall system.
- It improves the stability of the system and thus makes the system secure.

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3. MATLAB Simulation and Results :-

The 400 KV three phase transmission systems is simulated in MATLAB using Simulink. The model consist of 400 KV generation system, Step-Up Transformer, Transmission line pi- section of 300 km length, Series capacitors or TCSC. The transmission systems employs three phase R-L Load and connected through circuit breaker. On load side a three phase fault is simulated. Supply system voltage, current is measured. Practical PGCIL Data has been used to obtain simulation results.

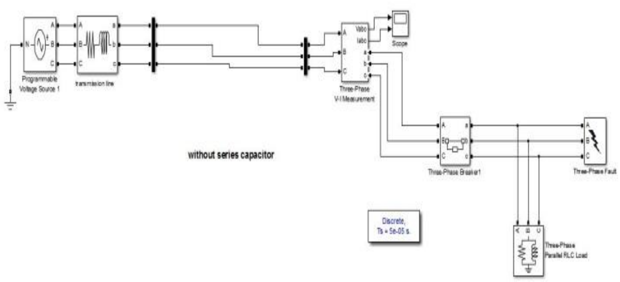

Fig. 4- simulink model of system without series capacitor

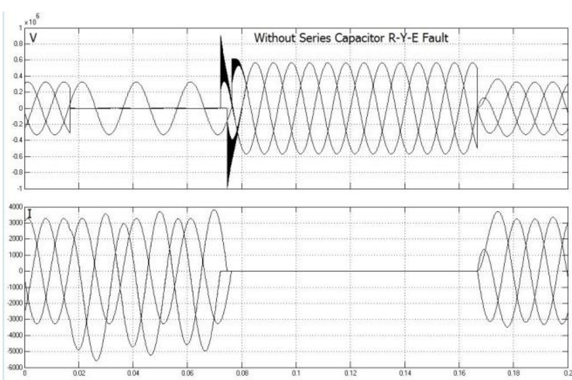

Fig.7-Waveform of V &I without series capacitor

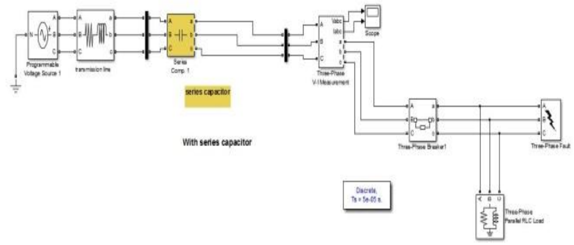

Fig. 5- Simulink model of system with series capacitor

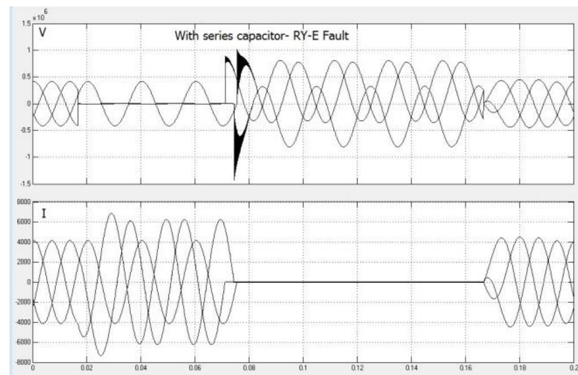

Fig.8-Waveform of V & I with series capacitor

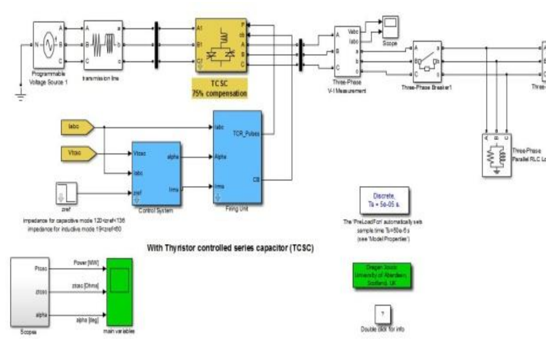

Fig. 6- simulink model of TCSC controller

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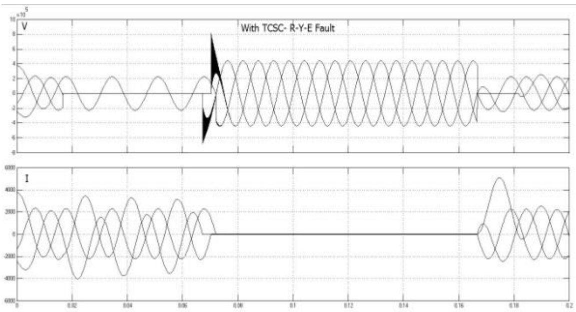

Fig.9- Waveform of V & I with TCSC

4. Measurement Results :

WITHOUT CAPACITOR		
1:	'UA: Three-Phase V-I Measurement'	231760.89 Vrms -51.64°
2:	'UB Three-Phase V-I Measurement'	231760.89 Vrms -171.64°
3:	'U C: Three-Phase V-I Measurement'	231760.89 Vrms 68.36°
4:	'U A:)1 '	231760.89 Vrms -51.64°
5:	'U B:)1 '	231760.89 Vrms -171.64°
6:	'U C:)1 '	231760.89 Vrms 68.36°
7:	'U A:) '	231760.89 Vrms -51.64°
8:	'U B:) '	231760.89 Vrms -171.64°
9:	'U C:) '	231760.89 Vrms 68.36°
10:	'I A:) '	2317.93 Arms -52.21°
11:	'I A:)1 '	2317.93 Arms -52.21°
12:	'I A: Three-Phase V-I Measurement'	2317.93 Arms -52.21°
13:	'I B: Three-Phase V-I Measurement'	2317.93 Arms -172.21°
14:	'I C: Three-Phase V-I Measurement'	2317.93 Arms 67.79°
15:	'I B:)1 '	2317.93 Arms -172.21°
16:	'I C:)1 '	2317.93 Arms 67.79°
17:	'I B:) '	2317.93 Arms -172.21°
18:	'I C:) ' 2317.93 Arms 67.79°	

WITH TCSC		
•1:	'U A: Three-Phase V-I Measurement'	377091.39 Vrms 4.55°
•2:	'U B: Three-Phase V-I Measurement'	377091.39 Vrms -115.45°
•3:	'U C: Three-Phase V-I Measurement'	377091.39 Vrms 124.55°
•4:	'U A:)1 '	377091.39 Vrms 4.55°
•5:	'U B:)1 '	377091.39 Vrms -115.45°
•6:	'U C:)1 '	377091.39 Vrms 124.55°
•7:	'U A:) '	658791.14 Vrms -51.08°
•8:	'U B:) '	658791.14 Vrms -171.08 °

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•9:	'U C:) '	658791.14 Vrms 68.92°
•10:	'U_TCR/Voltage Measurement '	543786.80 Vrms 94.00°
•11:	'U_TCR/Voltage Measurement1 '	543786.80 Vrms -26.00°
•12:	'U_TCR/Voltage Measurement2 '	543786.80 Vrms -146.00°
•13:	'I A:) '	3771.44 Arms 3.97°
•14:	'I A:)1 '	3771.44 Arms 3.97°
•15:	'I A: Three-Phase V-I Measurement'	3771.44 Arms 3.97°
•16:	'I B: Three-Phase V-I Measurement'	3771.44 Arms -116.03°
•17:	'I C: Three-Phase V-I Measurement'	3771.44 Arms 123.97°
•18:	'I B:)1 '	3771.44 Arms -116.03°
•19:	'I C:)1 '	3771.44 Arms 123.97°
•20:	'I B:) '	3771.44 Arms -116.03 °
•21:	'I C:) '	3771.44 Arms 123.97 °
•22:	'I_TCR/Current Measurement '	17.04 Arms 179.51°

5. Conclusion :

Comparison of these above waveforms clearly shows a substantial increase in the transient stability margin in the system with TCSC. Controlled series compensation can be applied effectively to damp power system oscillations. For power oscillation damping it is necessary to vary the applied compensation so as to counteract the acceleration and decelerating swings on the disturbed machines. That is, when the rotationally oscillating generator accelerates and angle δ increases, the electric power transmitted must be increased to compensate for the excess mechanical input power. Conversely, when the generator decelerates and the angle, the electric power must be decreased to balance the insufficient mechanical input power. Fixed series compensation is self-adaptive to load change and has a compensation effect to heavy load line, but light load line with high load fluctuation may cause abnormal voltage rise in front the compensation point, that needs setting reasonable rules to switch series capacitor.

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