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Enhancement of Transient Stability and Dynamic Power Flow Control Using Thyristor Controlled Series Capacitor

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Abstract-- Now a day's Power plays a vital role in our day to day life and, the expansion of power generation and transmission is limited due to the inadequate resources and environmental factors. And also some transmission lines are heavily loaded and the system stability becomes a power transfer-limiting factor .Hence, voltage stability enhancement and power flow analysis are of paramount essential for a secure power system operation. This paper deals with the use of Thyristor Controlled Series Capacitor (TCSC) in power systems. To improve power stability, Series capacitors are widely used in long distance transmission lines. Thus TCSC provides an addition benefits in transmission line when compared to fixed series capacitor. The design and analysis of TCSC is performed in MATLAB software, to damping system oscillation that occur in the transmission line and enhance the transient stability.
Keywords-- Flexible AC Transmission System (FACTS), Active and Reactive powers, control system, Voltage Stabilization, MATLAB/Simulink.

I. INTRODUCTION

Modern power systems are at dangers of voltage instability problems due to highly stressed operating conditions caused by increased load demand and environmental constraints in the transmission line. This effect will adversely affects the power transmitted and cause instability in transmission system, (i.e) the system is unable to regain synchronism after its normal operating condition is distorted.Loss of synchronism or system instability can be caused by a number of factors. For instance, increase in demand may make the transmission system become more stressed, which in turn, may lead the system to voltage instability. The scope of application of this device has been extended widely in recent years, as these devices provide much better transient responses, compare, With their mechanical, electrical and electromechanical characteristics. The use of these device can increase the level of power that can be transferred over a transmission corridor without endangering the system stability. Thyristor-controlled series capacitors (TCSC) is one of series compensator type, that provide many benefits for a power system including mitigating sub synchronous resonance, controlling power flow in the line and damping power oscillations. Shunt compensation is effective in controlling the actual transmitted power as given by

$$P = \frac{V_s * V_r * \sin\delta}{z_s}$$

Where Zs=Series Line Impedance, δ = Angle between the end voltages, P=Actual transmitted power, Vs= Sending end voltage, Vr= Receiving end Voltage. The primary uses of TCSC is to enhance the power system angle stability and to mitigate the sub-synchronous resonance by regulating real power and maximizing transient synchronizing torque between the interconnected power systems. However, the inserted series capacitor also affects the reactive power distribution in the interconnected power systems. Thus this, Paper specifies that TCSC be used to enhance the voltage stability.

II. THYRISTOR CONTROLLED SERIES CAPACITOR

Thyristor Controlled Series Capacitor(TCSC) is a power electronic-based device that provides a fast and controllable series compensation of transmission line reactance. It has great application potential in accurately regulating power flow a transmission line by increasing transfer power capability ,damping inter-area power oscillation, mitigation subsynchronous resonance(SSR) and improving transient stability.

III. FUNCTIONING OF THYRISTOR CONTROLLED SERIES CAPACITOR

TCSC controllers use thyristor-controlled reactor (TCR) in parallel with capacitor segments of series capacitor bank (fig.1).

ISSN: 2321-9653
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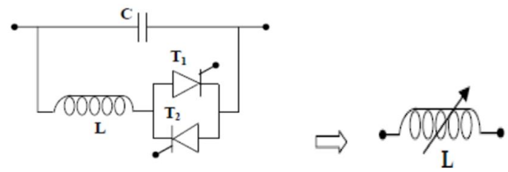

Fig.1 TCSC

The combination of capacitor and TCR allow the capacitive reactance to be smoothly controlled over a wide range and switched to a certain condition required.Where the bi-directional thyristor pairs conduct continuously and insert an inductive reactance into the line. TCSC is more Economical and effiective means of solving problems of , steady state stability ,dynamic stability, transient stability, and voltage stability in long transmission lines.

$$X_{TCSC}(\alpha) = \frac{X_C \, . X_{TCR}(\alpha)}{X_{TCR}\,(\alpha)\, . X_C}$$

$$X_{TCR} = X_L$$

TCSC, the first generation of FACTS, can control the line impedance through the introduction of a thyristor controlled capacitor in series with the transmission line.It 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 analysed by the behaviour of a variable inductor connected in series with a fixed capacitor.

IV. OPERATING REGIONS OF THYRISTOR CONTROLLED SERIES CAPACITOR

TCSC module has series capacitor shunted by a thyristor controlled reactor as shown in (fig:1). Usually to obtain a desired voltage more than one TCSC is installed in line. The element controlled by TCSC is the impedance of the line. The varying firing angle of thyristor controlled reactor is used to control impedance of TCSC.
Firing characteristics of TCSC .As shown in the figure above the impedance of TCSC acts like a function of firing angle. According to this diagram we have three regions:

A. Capacitive region
B. Inductive region
C. Resonance region

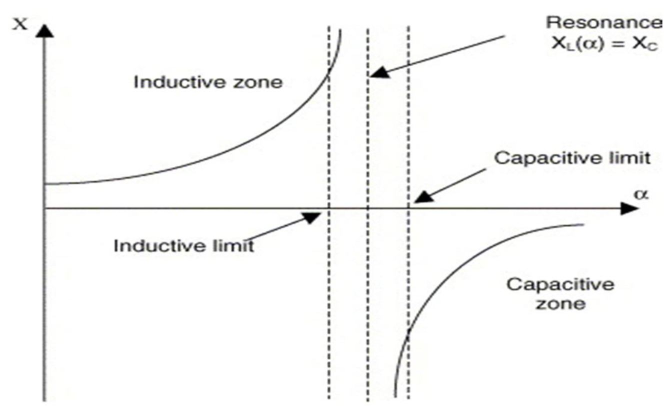

Fig.2 Schematic diagram of TCSC

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.

ISSN: 2321-9653
International Journal for Research in Applied Science & Engineering Technology (IJRASET)

V. 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. Traditionally, the stability problem has been one of maintaining all synchronous machines in synchronism. This aspect of stability is influenced by the dynamics of generator rotor angles. 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 states 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.

A power system is said to be steady state stable for a particular operating condition, it reaches a steady state operating condition which is identical or close to the pre-disturbance operating condition. 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.

VI. DAMPING OF POWER OSCILLATIONS

Oscillations of active power in power transmission systems may arise in corridors between generating areas as a result of poor damping of the interconnection, particularly during heavy power transfer. Such oscillations can be excited by a number of reasons such as line faults or a sudden change of generator output. The presence of active power oscillations acts to limit the power transmission capacity of interconnections between areas or regions or even countries. It is often possible to find remedy by building additional lines or upgrading existing lines, but this costs a lot of money and takes a lot of time, if not rendered impossible altogether by lack of the necessary permits.

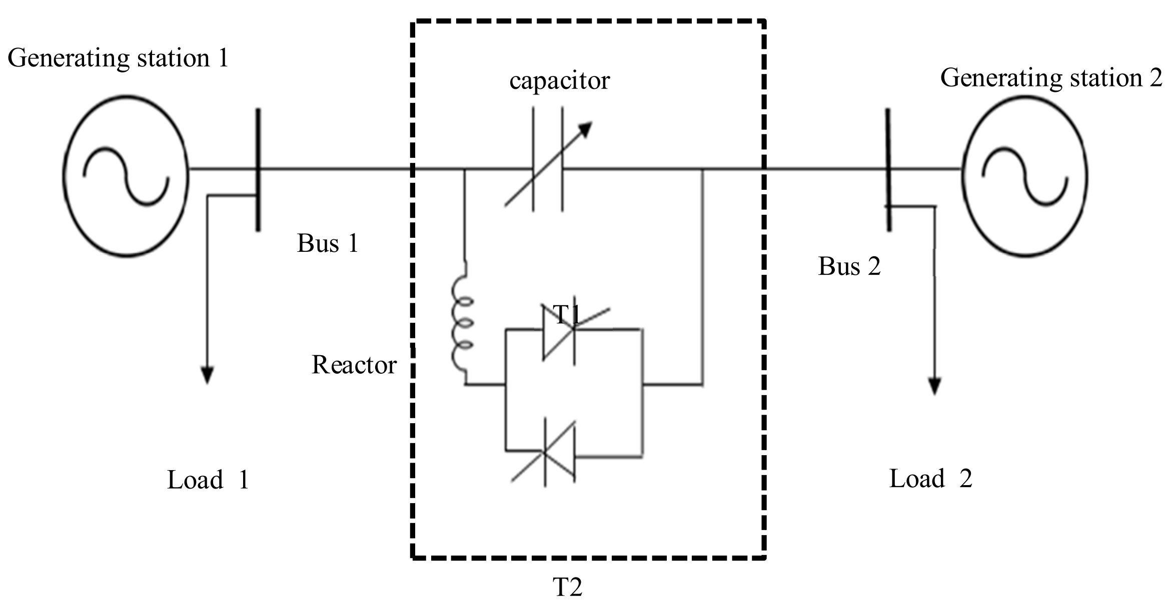

Fig.3 singleline diagram of TCSC

In some cases, it may also be possible to introduce power system stabilizers (PSS) on generators, but this will not always work, particularly not for inter-area power oscillations which tend to be of a low frequency (typically 0,2 Hz to 0,7 Hz).In either case, TCSC will be an attractive alternative to consider. It offers a cost-effective, robust power oscillation damper, insensitive to its location in the system and non-interacting with local oscillation modes. In a number of cases, it will turn out to be the best practicable solution. Power transmission P over a series compensated line is governed by the expression,

ISSN: 2321-9653
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$$P = \frac{U1.U2.\sin\delta}{X_L - X_c}$$

By proper control of the TCSC, the overall transfer reactance is modulated in time in such a way that the power oscillations are damped out. An important benefit of TCSC is its ability for quick boosting of its degree of compensation, making it very useful as a tool for improving the post contingency behaviour of networks. By means of this quality of the TCSC, the degree of compensation of a series capacitor can be increased temporarily following upon a network contingency. Thereby adding to the dynamic stability of the network (voltage and angle) precisely when it is needed. When the system is subjected to a severe disturbance, the stability control loop must provide maximum compensation level during the immediate post-fault period, so that the synchronizing torque is increased to improve the first-swing stability response of the system, as well as provide proper modulation to damp the subsequent power oscillations. In this paper, a linear controller is proposed for stability enhancement, since, with a proper selection of control parameters and input signals, this control can meet the aforementioned control requirements .By this means, the series capacitor can be lower rated for steady-state conditions, thereby keeping transmission losses smaller. For instance, in many applications it is desirable to enable an underlying transmission system to carry a higher amount of power under contingency conditions where a circuit is tripped in higher voltage transmission paths. Series compensation is not needed during normal operation as it would only influence overall system losses in an unfavourable way. In order to meet both objectives, i.e. safeguarding power transmission capability during contingencies and at the same time keeping transmission losses as low as possible during normal operating conditions, controlled series capacitors can be advantageously utilized.

VII. INPUT PARAMETERS DATA USED FOR SIMULATION

A. Power supplied to machine =1000MVA
B. Three phase transformer is supplied with,
C. Nominal power T1 =1000MVA
D. Nominal power T2=5000MVA
E. Phase 1 winding =13.8kV
F. Phase2 winding=500kV

VIII. SIMULATION MODEL WITHOUT TCSC IN TWO BUS SYSTEM

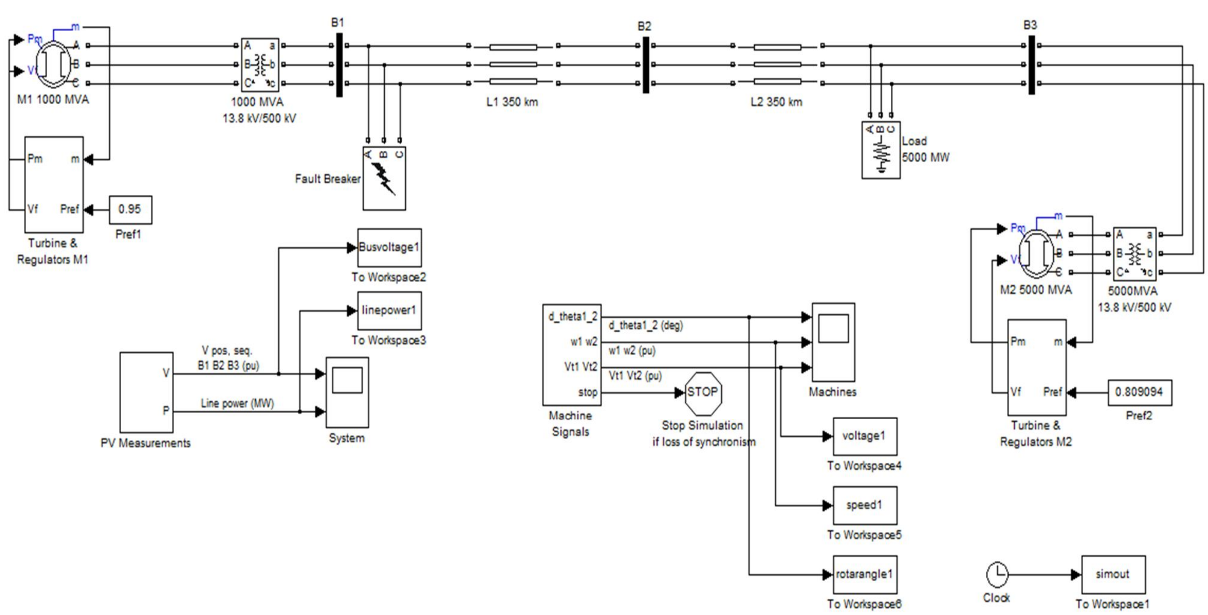

Fig.4 Simulation in MATLAB for without TCSC control

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

IX. SIMULATION MODEL WITH TCSC IN TWO BUS SYSTEM

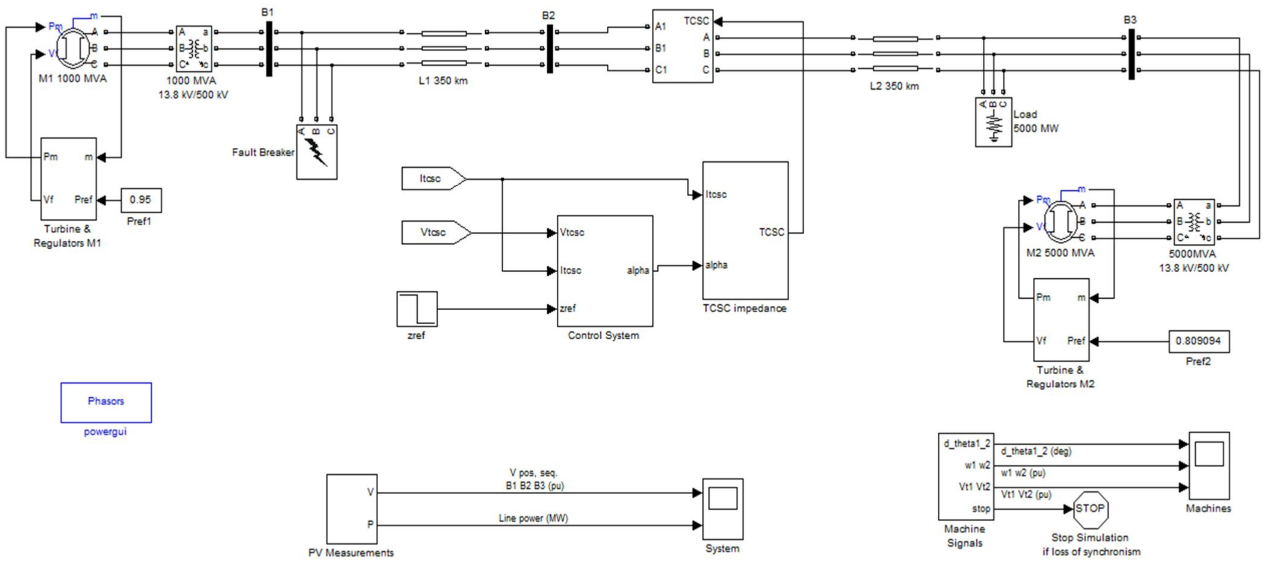

Fig.5 Simulation in MATLAB for TCSC control

X. SIMULATION OUTPUT

LOAD FLOW ANALYSIS WITHOUT TCSC AT 1ph FAULT

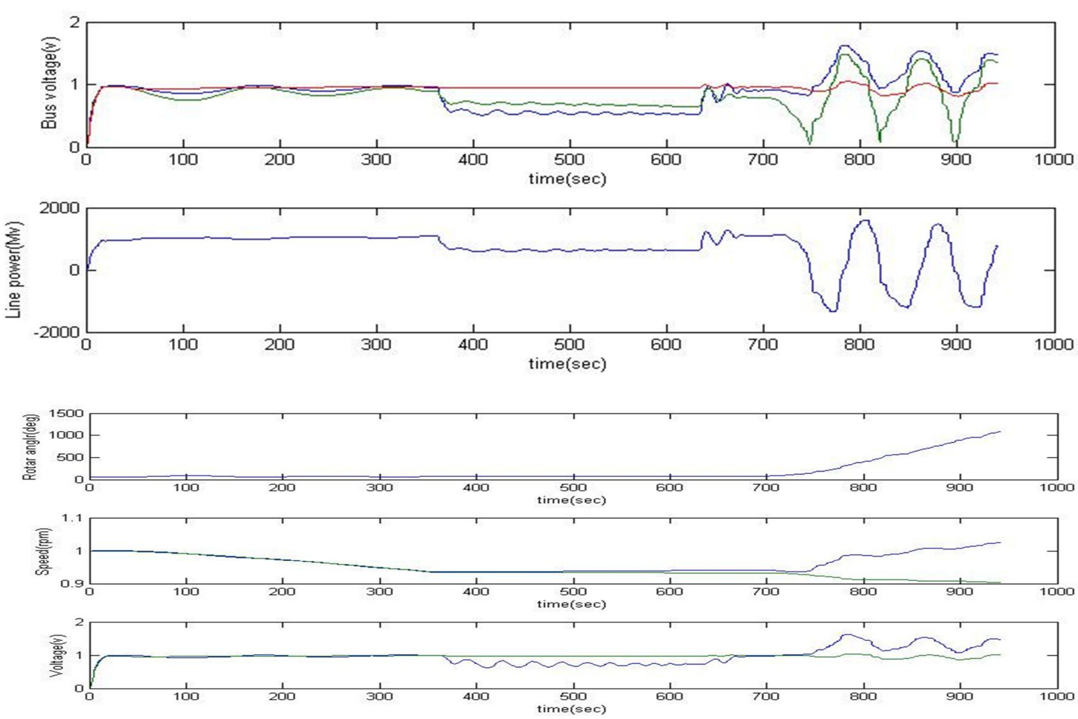

Fig.6 Load at 6000MW becomes Unstable

International Journal for Research in Applied Science & Engineering Technology (IJRASET)

LOAD FLOW ANALYSIS WITH TCSC AT 1ph FAULT

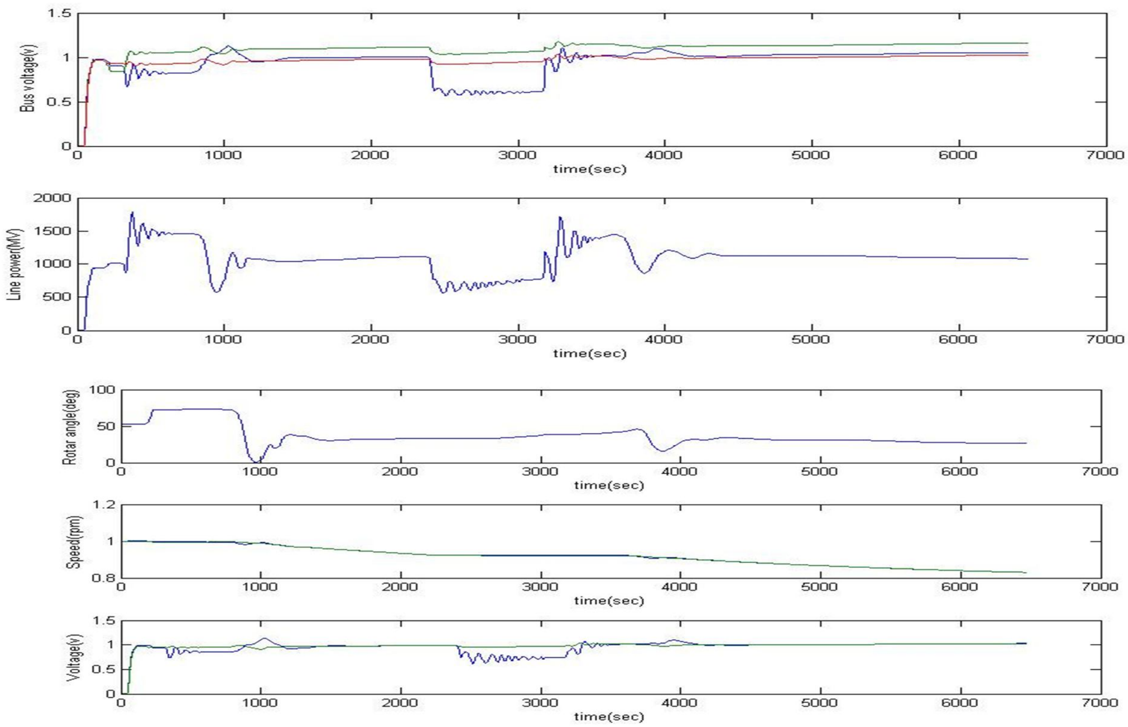

Fig.7 Load at 6000MW maintain stability due to reactive power injection by TCSC

XI. TABULATION

TABLE I SINGLE PHASE FAULT

LOAD (MW)	WITHOUT TCSC		WITH TCSC	
	δ	STABILITY	δ	STABILITY
5000	54	STABLE	29	STABLE
5600	60	STABLE	30	STABLE
5800	50	STABLE	31	STABLE
6000	-	UNSTABLE	32	STABLE
7000	-	UNSTABLE	34	STABLE
8000	-	UNSTABLE	-	UNSTABLE

TABLE II DOUBLE PHASE FAULT

LOAD (MW)	WITHOUT TCSC		WITH TCSC	
	δ	STABILITY	Δ	STABILITY
5000	53	STABLE	27	STABLE
5050	55	STABLE	27.8	STABLE
5100	57	STABLE	28	STABLE
5200	-	UNSTABLE	29	STABLE
6000	-	UNSTABLE	30	STABLE
7000	-	UNSTABLE	40	STABLE
8000	-	UNSTABLE	-	UNSTABLE

TABLE III THREE PHASE FAULT

LOAD (MW)	WITHOUT TCSC		WITH TCSC	
	δ	STABILITY	δ	STABILITY
4000	41	STABLE	25	STABLE
5000	-	STABLE	29	STABLE
6000	-		31	STABLE
7000	-		-	UNSTABLE

XII. DISCUSSION ON OUTPUT

Benefits of TCSC are not subject only to newly built TCSC installation but they can also be achieved by upgrading existing series compensation on the thyristor controlled series compensation or only its part. TCSC is implemented in-between a two bus system to find its enhancement of voltage stability and rotor angle improvement. The load value is varied from 5000MW until the system becomes unstable, when TCSC is not implemented the system becomes unstable at 6000MW. But when TCSC is implemented the system voltage stability gets improved and it becomes unstable only at 8000MW, the rotor angle value also increases linearly.Figure:6 shows that in an two bus system without TCSC the system becomes unstable at 6000MW and after the implementation of TCSC the system maintain stable condition even at 6000MW due to injection of reactive power in the two bus system.

XIII. CONCLUSION

The article deals with the issue of using TCSC in the power system. 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 behaviour of TCSC at various cases. Thus the subject of

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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. Based on simulations we can state the ability of TCSC to change power flows on lines. Since 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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