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# Congestion Management by TCPST In IEEE 9 Bus System Using Matlab Simulink

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## Abstract

Increased electric power consumption causes transmission lines to be driven close to or even beyond their transfer capacities resulting in overloaded lines and congestions. Flexible AC Transmission Systems (FACTS) provide an opportunity to resolve congestions by controlling power flows and voltages. Main focus in this paper lies on the Thyristor Controlled Phase Shift Transformer (TCPST). IEEE 9 bus system is considered for congestion management. Parameters for bus system are predefined by IEEE. Voltage and current is measured individually at each bus and in transmission line between any two congested bus, TCPST is installed. The opening and closing time of Thyristors in TCPST are controlled by PID controller. All this system is implemented and analyzed in MATLAB Simulink.

**Keywords**: FACTS, TCPST, IEEE9 bus, PID, MATLAB Simulink.

## Introduction

The electric utility industries are undergoing rapid changes in a global scope due to their restructuring and deregulation. The key idea is to introduce free competition in to power system, thus to achieve more efficiency during the process of system operation. Unfortunately, sometimes such a free trade schedule cannot be arranged into real operation due to the capacity limit of transmission network, which is so called ‘congestion’ [1].Congestion management is one of the important tasks for Independent System Operator (ISO) in the deregulated operation environments. This function guarantees resources scheduled on the basis of maximizing the social benefit and keeps power system operate in a secure state. Generally, it is formulated as an optimal problem with object and system constrains [2].

Depending on market structures and market rules, one or more of these congestion management processes may be applied. Effective congestion management is crucial for the efficient operation of any electricity market where congestion exists. However, it has been recognised that completely eliminating all transmission congestion is neither necessary nor efficient. In other words, congestion management should compromise between the benefits and costs of solutions. In the short term, the objective of congestion management is to maintain the physical and operational reliability and security of the electricity transmission network and facilitate a competitive electricity market. Basically, congestion management has an important impact on spot prices, the degree of competition and the bidding incentives for energy market participants. In the long term, congestion management will impaction the investment decisions of new generators, load, network transmission infrastructure and the opportunities for integration of alternative generation sources (e.g. renewable sources) into electricity transmission networks. The problem of congestion has increased in recent years due to number of reasons:

- First, deregulation of the electricity industry has brought the benefits of possible lower electricity prices and better service quality and large-volume electricity trade can be conducted cross-border in competitive electricity markets. However, such electricity trade may cause large-scale transmission of electric power across regions where the unexpected power flows may push electricity networks towards their physical limits.
- Second, in deregulated environments there is a lack of investment in electricity networks in order to meet demand and generation where there is a lack of transmission capacity. In other words, transmission capacity, relative to peak load, has been declining in many countries. It is anticipated that this trend may continue in deregulated environments.
- Third, with the continuous large-scale integration of wind generation into electricity transmission networks, there are difficulties in

managing congestion due to the fast-changing power flows of electricity networks.

- Fourth, the continuous development of an internal electricity market within the Member States of the EU, with increased cross border electricity trade, is making congestion management an even bigger challenge [3][4][5][6].

In this paper congestion has been controlled by power flow control in transmission lines. Because congestion results in more power flow in some transmission lines and less power goes to other. This power is measured and then optimal location of controlling device determined. I have considered TCPST as the controlling device as its controlling action only depends upon the phase rather than the voltage and current. My system is checked for IEEE 9 bus system.

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## Modeling of TCPST

Thyristor controlled phase shift transformer is a device based on both thyristor and phase shifting transformer technologies. PSTs are transformers with a complex transformation ratio. These transformers as controller of power flow, reduces the transmission losses. With the advancement of power electronics devices, the mechanical tap changers are replaced by thyristors, increased the speed of phase shifters. The phase angle difference between terminals of TCPST is absorbed by series transformer (boosting transformer) with transmission line. The active and reactive power taken to the transmission line by series transformer must be absorbed by a shunt transformer. Figure 1 shows the basic scheme of TCPST. If losses are neglected then TCPST neither absorbs nor produces active and reactive power.

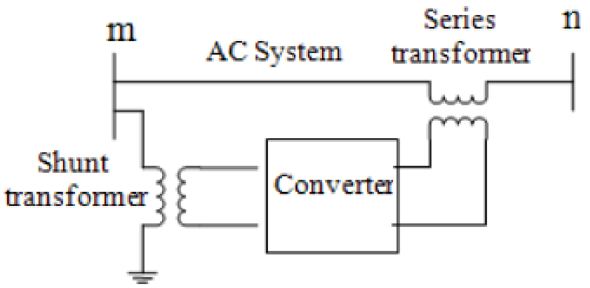


**Figure 1: Basic Scheme of TCPST**

A MATLAB model of TCPST is shown in figure2. In this 4 thyristors are connected in two pairs. In one pair the anode of one thyristor is connected to cathode of another. The series transformer takes the current from the single phase line and shunt transformer takes the three phase voltage.

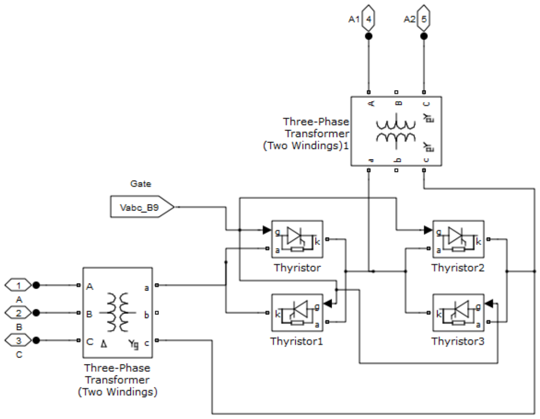


**Figure2: TCPST model in MATLAB**

Changes after applying TCPST in transmission line having two generators at two ends of 350 MW are shown in figure 3.

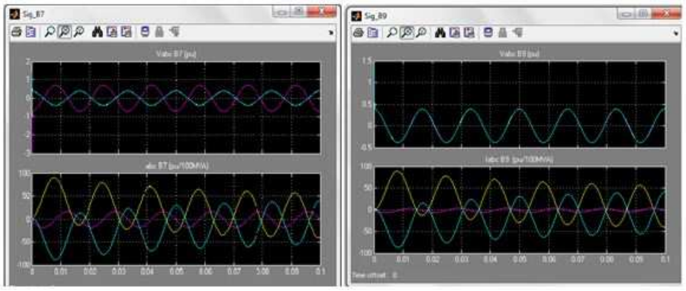


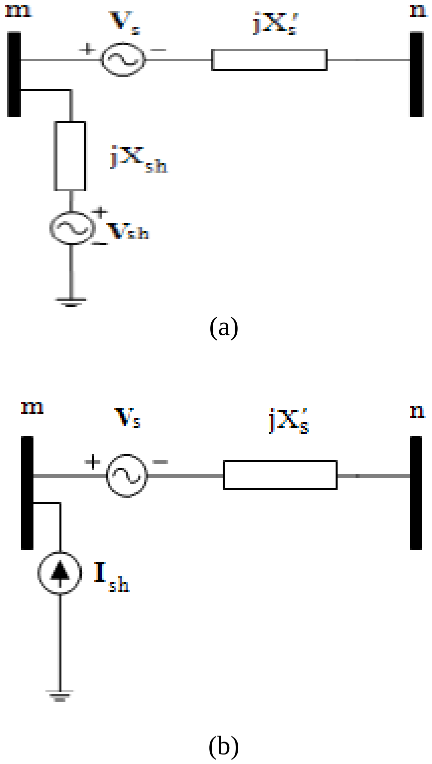
**Figure 3: Voltage and Current before and after applying TCPST in transmission line**

First graph shows the voltage and current before applying TCPST and other shows after applying TCPST. The red phase voltage is changed by TCPST.

## Mathematical Model

Figure 1 shows the schematic diagram of the Thyristor Controlled Phase Shifter (TCPS). The series transformer injects the voltage in series in the system. The active and reactive power injected by the series transformer is taken from the shunt transformer. For sake simplicity of analysis, the insignificant losses from transformer and converter is neglected. Thus the net complex power (real and reactive power) exchange between the TCPS and the system is zero.

The injection of this complex power depends on the injection of a series voltage controlled by a converter. Figure 4 shows the equivalent circuit of Fig. 1. Vs and Vsh are represented by the synchronous voltage sources in series and shunt, respectively. Xsh is the leakage reactance of the shunt transformer. Xs/ is the leakage reactance seen from primary side of series transformer is given by Xs/ = Xs + n2 Xsh where n is the turn ratio number of the shunt transformer and Xs is the leakage reactance of the series transformer [7][8].



(a)

(b)

**Figure 4: TCPST; (a) a series and shunt synchronous voltage source equivalent; (b) a series injected voltage source and a shunt injected current source**

The TCPST consists of two transformers; a shunt transformer or magnetizing transformer connected in parallel and a series transformer or booster transformer in series to the line (Fig.1***).*** The current through the magnetizing transformer induces a voltage on the primary side of the booster transformer. The turn ratio of the shunt transformer is 1: n, and the turn ratio of the series transformer is 1:1. Compared to conventional phase shifting transformers, the mechanical tap changer is replaced by a thyristor controlled equivalent. The purpose of the TCPST is to control the power flow by shifting the transmission angle. In general, phase shifting is obtained by adding a perpendicular voltage vector in series with a phase. This vector is derived from the other two phases via shunt connected transformers. The perpendicular series voltage is made variable with a variety of power electronics topologies [9]. A circuit concept that can handle voltage reversal can provide phase shift in either direction. This Controller is also referred to as Thyristor-Controlled Phase Angle Regulator (TCPAR). A phase shifter model can be represented by an equivalent circuit, which is shown in Fig 5. It consists of admittance in series with an ideal transformer having a complex turns ratio.

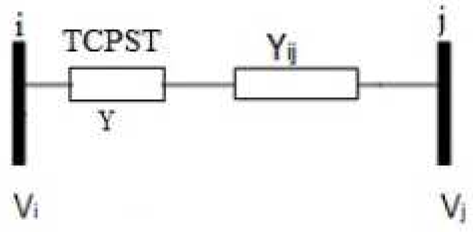


**Figure 5: Admittance diagram of a system containing TCPST**

The mathematical model of TCPST can be derived from Fig5.

$$\begin{vmatrix} I_i \\ I_j \end{vmatrix} = \begin{vmatrix} Y_{ij}+Y & -Y_{ij} \\ -Y_{ij} & Y_{ij}+Y \end{vmatrix} \begin{vmatrix} V_i \\ V_j \end{vmatrix}$$

Where Yij is the admittance of the line and Y is the admittance of the TCPST. The admittance of the TCPST is equal to the reciprocal of the reactance of the TCPST.

## MATLAB Modelling of IEEE 9 bus system with TCPST

The parameters of IEEE 9 bus system is predefined by IEEE. The IEEE 9 bus system is shown in figure 6.

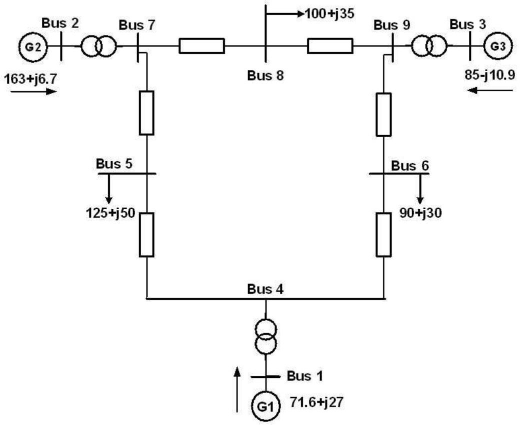
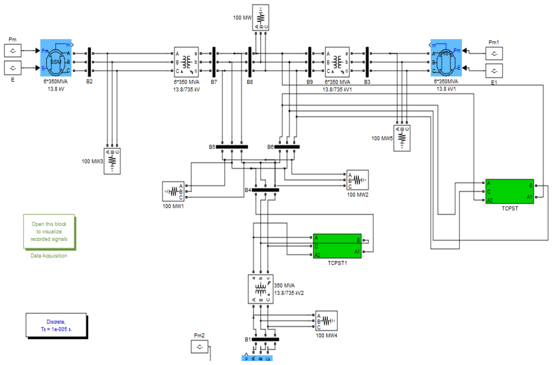


**Figure 6: IEEE 9 bus system.**

MATLAB model of IEEE9 bus system along with TCPST is shown in figure 7 below.



A PID controller is used in TCPST to control the gate voltage. The input voltage to gate is the voltage of the bus at which voltage is higher i.e. congestion is occurring at that bus. Below figures show waveforms at all buses before applying TCPST and after applying TCPST. The boosting transformer is attached to phase A line. It measures current from that. Results can be checked by connecting it to phase b and phase c. but here only results for phase A has been shown in this paper. After studying voltage and current waveforms at all buses it has been found that transmission line connecting bus 9 and bus 6 is congested more. The graph below shows the results befor and after TCPST.

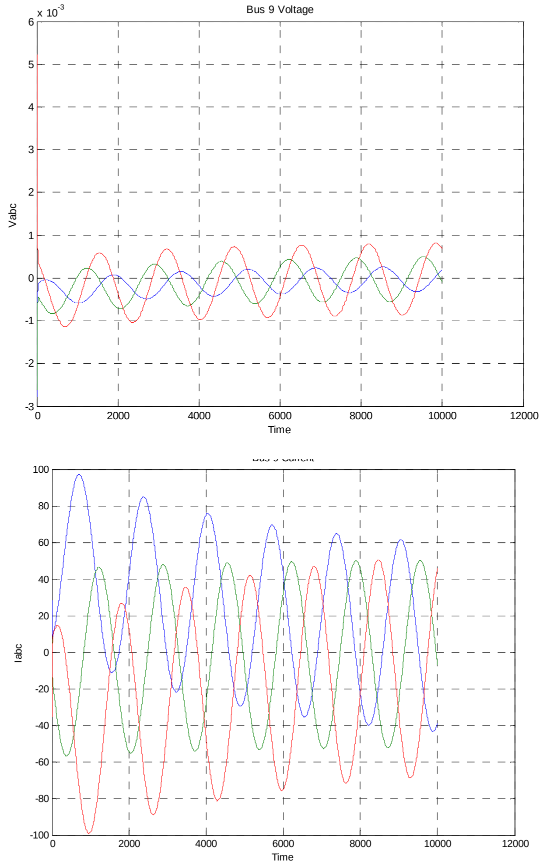


**Figure: Bus 9 Voltage and Current before TCPST**

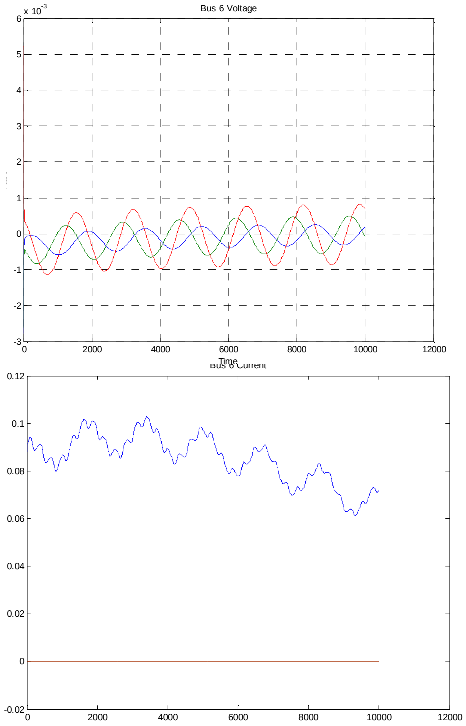


**Figure: Bus 6 Voltage and Current after TCPST connected in phase**

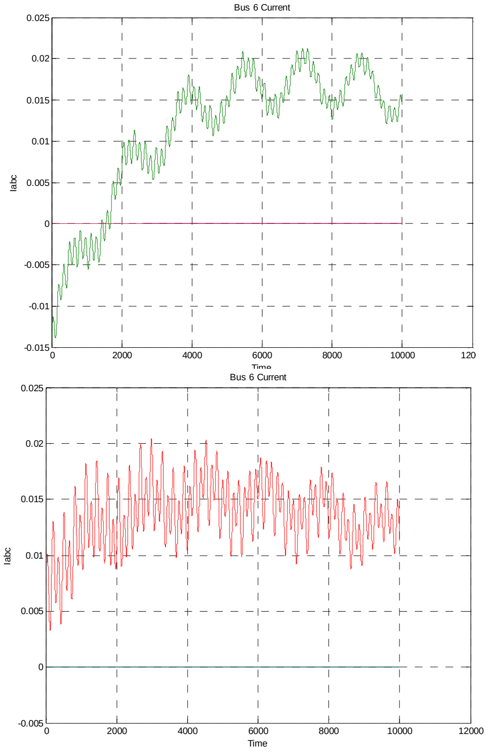


**Figure: Bus 6 Current, TCPST connected in Phase B and phase C**

## Conclusion

Form the above graphs it is clear that the current at bus 9 was more than at bus 6 while voltage remains same. By this way total power is controlled. The TCPST is connected in phase A, then in phase B and then in phase C. Graphs of current shows that in phase A and phase C, TCPST works well as current is decreasing while in phase B current is increasing. Injected voltage remains constant in every case. My work proves that TCPST efficiently controlled the power flow in IEEE 9 bus system. This can be extended by considering the cost factor in congestion management. For that approach should be to minimize the cost of transmission.

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