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Power Flow Control in the Electrical Power System using TCSC FACTs Device

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Abstract:

Due to the ever-increasing demand for power and the growth of the transmission network, transmission lines must now be operated under load, posing a danger of power flow control and voltage instability. This study proposes using TCSC and SVC devices to control power flow in a power system network. The TCSC is a series compensated device that lowers transmission line reactance and improves power flow, whereas the SVC is a shunt compensated device that improves voltage profile. This paper describes a method for modelling and simulation with MATLAB/SIMULINK (Simpower System blockset). For power flow management and voltage stability limit, the appropriate position of TCSC and SVC devices is evaluated. The proposed method is implemented on a two-area four-machine 11-bus test system model, and the simulated results are shown to validate the test case system. The performance of the TCSC and SVC devices is evaluated in this study, and the simulated results are compared for better power flow regulation in the power system.

Keywords **— Power Flow Control, Matlab/Simulink, FACTS Device TCSC and SVC..**

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I. INTRODUCTION

The contemporary interconnected electricity grid is extremely complicated. The reliability and stability of the electric power system are two of the most significant requirements during operation. Maintaining the stability of a multi-area interconnected electricity supply has become a difficult undertaking. Flexible AC Transmission System (FACTS) devices have been proposed as a solution to these issues. Flexible ac transmission system (FACTS) technology can aid in the search for a solution. Facts devices regulate power flow in important lines and provide voltage support at critical buses in the system (shunt linked controllers) (with series connected controllers). The demand for power flow controllers that can boost transmission capacity while also managing power flows is growing.

II. INTRODUCTION OF FLEXIBLE AC TRANSMISSION SYSTEM (FACTS)

Series Capacitors are connected in series with a transmission line, which necessitates the installation of all equipment on a fully insulated platform. A TCSC is a significant device from the FACTS group, and it can be used to solve a variety of problems in the power system. Its features can boost the transmission capacity of power lines and control power flow. The TCSC is a FACT device that may be used in an AC line with a voltage of up to 500kV. Figure 1 shows the TCSC model's equivalent circuit as a capacitance in parallel with a variable inductor. The TCSC impedance (ZTCSC) is provided by.

$$Z_{TCSC} = (-jX_c)\,(jX_{TCR}) / j\,(X_{TCR} - X_c) \quad ..(1)$$

$$Z_{TCSC} = (-jX_c) / (1 - X_c / X_{TCR}) \quad ..(2)$$

The current through the TCR (ITCSC) is given by

$$I_{TCSC} = (-jX_c)\, I_L / j\,(X_{TCR} - X_c) \quad ..(3)$$

$$I_{TCSC} = I_L / (1 - X_{TCR} / X_c) \quad ...(4)$$

Since the losses are neglected, the impedance of TCSC is purely reactive [5]. The capacitive reactance of TCSC is obtained from figure 2.

$$X_{TCSC} = X_c / (1 - X_c / X_{TCR}) \quad ..(5)$$

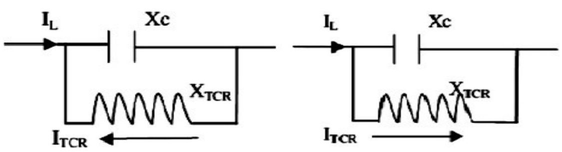


Fig. 1. Equivalent circuit of TCSC.

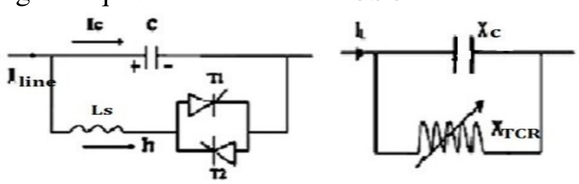


Fig. 2. Capacitive operation and Inductive operation of TCSC

series compensation, from a system perspective, is to increase the fundamental frequency voltage across a fixed capacitor (FC) in a series compensated line by adjusting the firing angle () [6]. The effective value of the series- capacitive reactance changes as a result of the increased voltage [7]. The TCSC can work in either capacitive or inductive mode, however the latter is rarely employed. Since this TCSC's resonance is around 580 degrees firing angle (), When the line impedance is taken into account, the overall system resonance is roughly 670. Because the impedance is lowest at 900, As a result, as the firing angle is reduced, power transfer rises. The impedance values in capacitive mode range from about 120 to 136. [.

(1) α for Inductive mode: 0^0-49^0
(2) α for Resonance Region: 49^0-69^0
α for Capacitive mode: 69^0-90^0

III. SVC (STATIC VAR COMPENSATOR)

A shunt-connected static var generator or absorber whose output is modified to interchange capacitive or inductive current in order to maintain or manage specified electrical power system parameters is known as an SVC (typically bus voltage). SVCs are most commonly employed in power systems to manage voltage or improve system stability. This is a generic word for a thyristor-controlled or thyristor-switched reactor, thyristor-switched capacitor, or a combination of the two that is used to absorb and supply reactive power. [10]. To control shunt-connected capacitors and reactors quickly, the SVC employs standard thyristors. Figure depicts the SVC's configuration, which consists primarily of a fixed capacitor (C) and a thyristor-controlled reactor (L). The equivalent shunt admittance presented to the power system is determined by the firing angle control of the thyristor banks.'

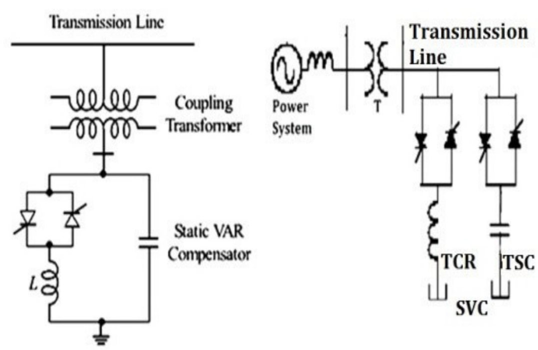
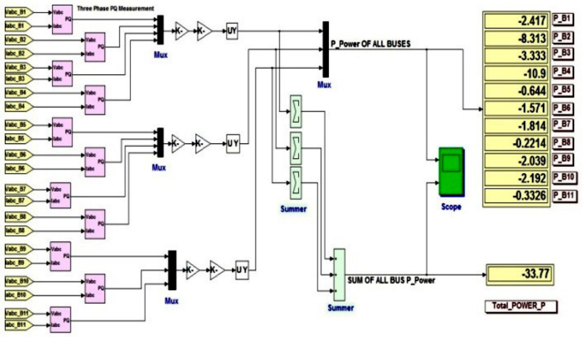


Fig. 3. Different connections of SVC are connected to transmission line.

IV TWO-AREA TEST SYSTEM MODEL WITH SVC FACT DEVICE

To verify the effectiveness of the SVC model established, a multi machine power system with 11 bus two areas test system, Area-1 and Area-2 system is employed. Figure 4 depicts a proposed single line diagram of an 11-bus power system with an installed SVC shunt Fact device.



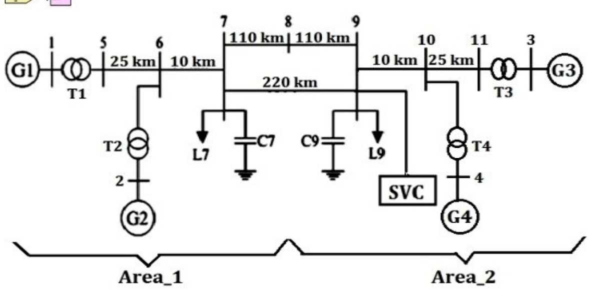


Fig. 4. Two-area Four-machine 11-bus power system with shunt FACT device SVC.

TEST SYSTEM SIMULATION MODEL OF SVC USING MATLAB/SIMULINK

In the Appendix, you'll find all of the relevant parameters. A 290km transmission line connects the 13.8 kV source voltages via three-phase step-up transformers. The system comprises of two transformer output voltages of 500KV equivalents, with 1000MVA and 4200MVA in each location, and is connected by a 290-kilometer transmission line. The 30KW loads in each region are chosen in such a way that real power flows from area 1 to area 2 on the transmission line. Figure 7 shows the SVC utilised for this model, which is a phasor model. The active and reactive power absorbed by the load is a function of the system voltage in this model of a 60KW load centre.

V SIMULATION RESULTS OF SVC

The SVC parameters control block displays the SVC susceptance, voltage actual and measure values, as well as the SVC reactive power measure value. Figure 8 depicts the actual quantities. In this thesis, the SVC is exclusively used for voltage regulation, and all of the data for the SVC is collected in this mode. It's depicted in the following diagrams. Figure 1: SVC Variation and Actual Values of B, V, and Qm

The SVC shunt FACT device is mounted in 11 bus systems to determine the active and reactive power flow in all buses. The power at bus B1, B2, B3, B4, B5, B6, B7, B8, B9, B10, and B11 is calculated, and the variations in total active reactive power are displayed in figure.10, figure 11, figure 12 and figure 13.

Fig. 5.1 Block represent Active power (P) of all buses and the sum of total power at buses (with SVC Connected at Bus 9)

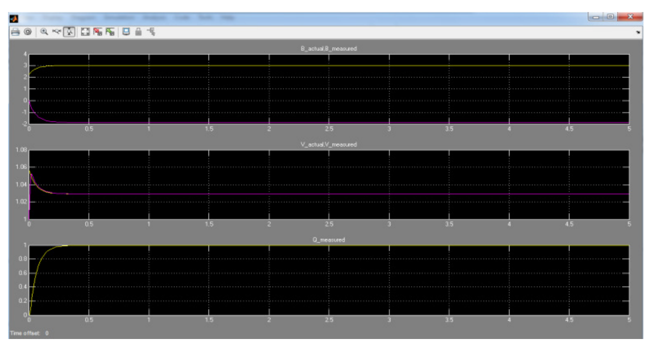


Fig. 5.2 Variation of SVC measure and Actual value of susceptance (B), voltage (V) and reactive power (Qm).

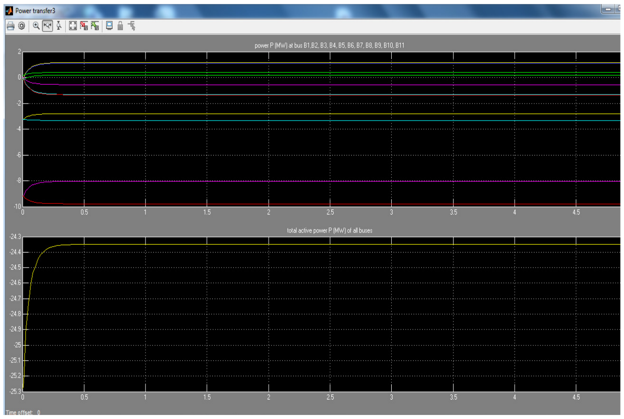


Fig. 5.3 Active power of all buses and sum of total active power at the buses with SVC connected at bus 9.

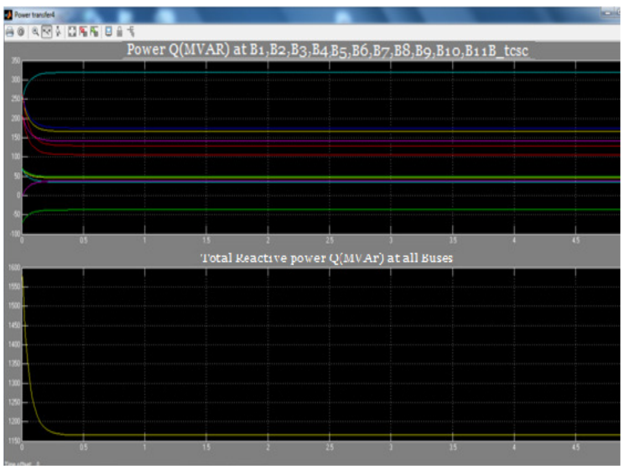


Fig. 5.4 Reactive power of all buses if SVC Connected at Bus 9.

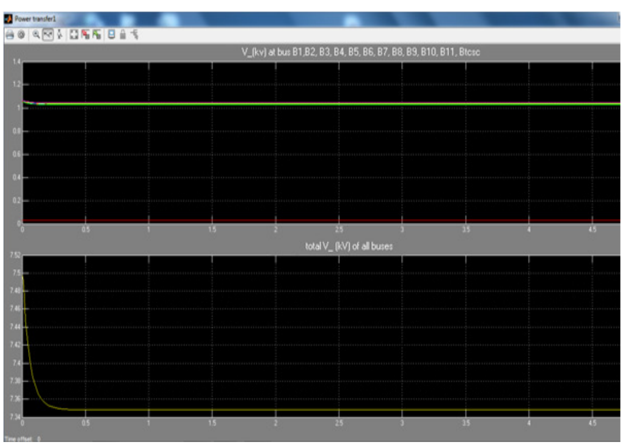


Fig. 5.5 Bus voltage control by SVC controller at different buses and sum of total voltage.

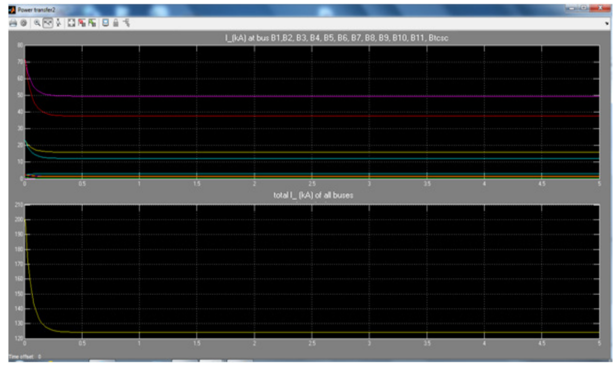


Fig. 5.6 Bus current at different buses and sum of total bus curren if SVC connect.

VI SIMULATION RESULTS OF TCSC

Figure 22 depicts the TCSC parameter blocks and curves with respect to time, including TCSC voltage, TCSC current, Active, Reactive power, TCSC impedance, and firing angle. The TCSC is bypassed for the first 0.5 seconds; after that, the TCSC begins to control the impedance to 128 ohms, increasing power transfer; the TCSC starts with alpha at 900 ohms to ensure the least amount of switching disruption on the line. The TCSC in this study only operates in capacitive mode, regulating the firing angle 900 from 0 to 0.5 sec, then decreasing to 75.60 from 0.56sec to 2.5sec. The capacitive mode begins at 2.5 to 5 seconds, and the firing angle remains constant at 86.310. At this value, the TCSC impedance is 120.5Ω along the reference value 120.8^0 is shown in figure 22.

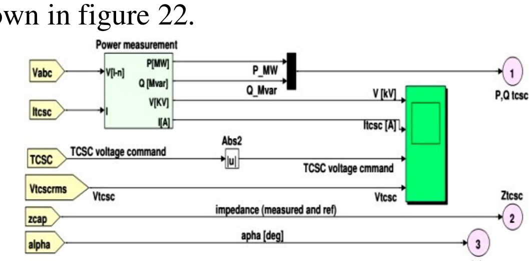


Fig. 6. TCSC parameter blocks.

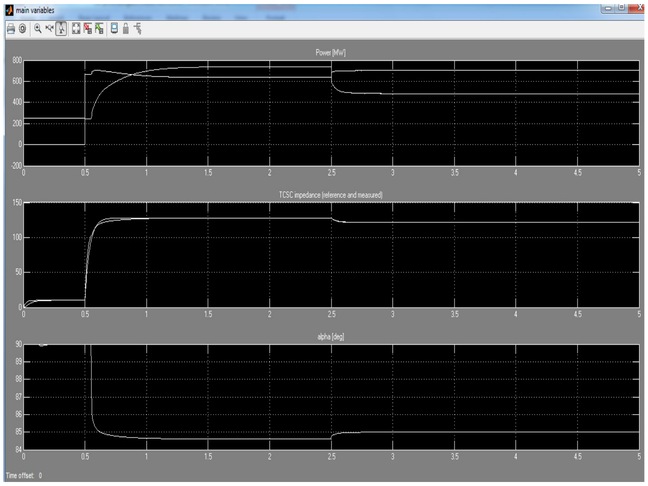


Fig. 6.1. TCSC injected Active, Reactive Power and TCSC regulates the impedance with respect to firing angle.

The TCSC fact device installed in 11 bus system to find out the active power flow in all the buses, the power at bus B1,B2, B3, B4, B5, B6, B7, B8, B9, B10, B11, Btcsc is calculated and total power will be improved by TCSC is 1730 MW is shown in figure 23 and figure 24.

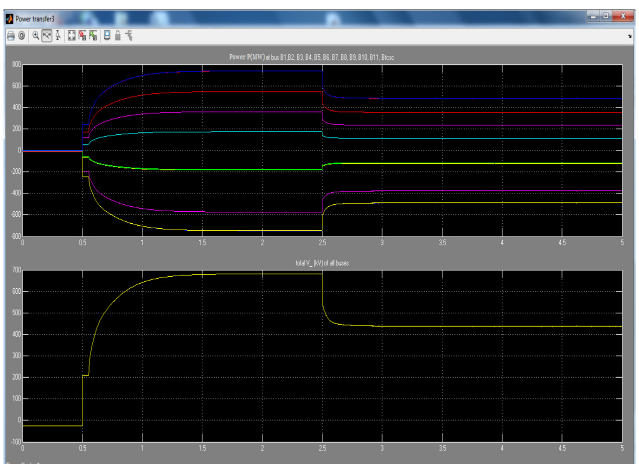


Fig. 6.2 Active power (P) of all buses and sum of total active power at the buses.

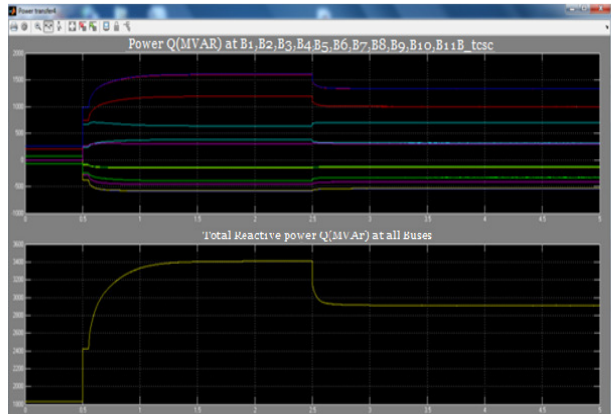


Fig. 6.3 Reactive power (Q) of all buses and sum of total reactive power at the buses.

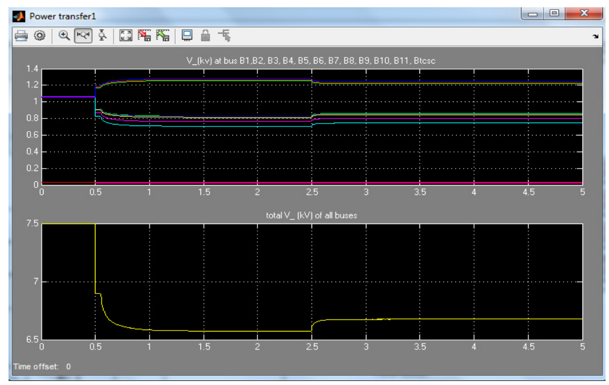


Fig. 6.4 Graphical representation of bus voltage control by TCSC controller at different buses and sum of total voltage.

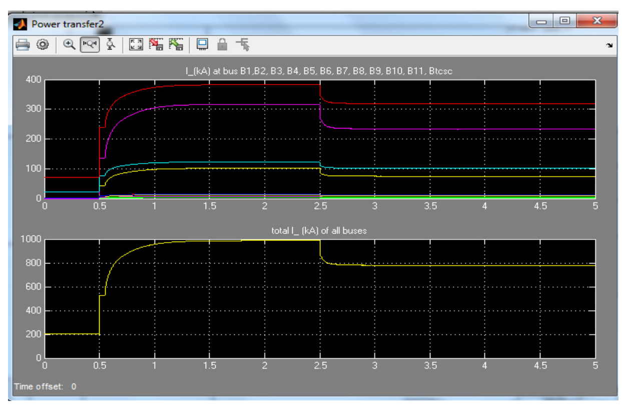


Fig. 6.5 Graphically represents the bus current at different buses and sum of all bus current.

SUMMARY OF SIMULATED RESULTS

The suggested model's performance is studied and compared. According to the results, TCSC can better boost the power flow in transmission lines with active and reactive power of 437.3 MW and 2911 MVA as opposed to SVC's -24.35 MW and 1165 MVA. In addition, as compared to the SVC device, the TCSC boosted the transmission line voltage to 7.919 kv. The TCSC data are all collected in capacitive mode, while the SVC data are only obtained in voltage regulation mode. According to the findings, the TCSC controller is more effective in power flow and voltage regulation in power system networks than the SVC controller.

VII CONCLUSION

A comparison of the TCSC and SVC FACTs devices is shown and explored in this work. Thus, series capacitive compensation is used to reduce the series reactive impedance in order to reduce receiving end voltage variation and the risk of voltage collapse, as well as to increase the line's power flow capabilities. The ideal location and sizing of TCSC devices for improving and managing power flows in the network has been proposed in this research, which can help to boost power flows in severely loaded lines. The effectiveness of the TCSC controller in controlling active and reactive power along the transmission line is demonstrated by a simulation result of a MATLAB/SIMULINK model of a two-area four-machine 11-bus power system with a TCSC controller. As a result, it can be inferred that the outcomes were positive. Based on simulation results obtained using TCSC and SVC devices, a suggested model of TCSC device is suited for active, reactive power flow regulation, and transmission line voltage control is superior than SVC device.

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