

Maintaining voltage profile in a power system using shunt connected FACTS Controllers

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Abstract— For a secure power system operation, voltage stability is of great concern. For any system the main reason for deterioration of the voltage profile and reduced is the reactive load.. Compensators are used to maintain the voltage stability and reduce the voltage drop. The compensation is provided using the switching devices such as circuit breakers or semiconductor devices. The synchronous gate pulse generation models also help in keeping the power system well in control and synchronism. Closed loop control is also shown for Thyristor Switched Capacitor. Stable voltage with dynamic load changes is obtained using FACTS controllers (TSC).

KEYWORDS: Sending end voltage (V_s), Receiving end voltage (V_r), Thyristor Switched Capacitor(TSC); Power Quality; Voltage profile; closed loop control.

INTRODUCTION

As on today, large scale industries are developing across the globe and these industries require a constant source of electrical power. Along with the assurance of continuous supply, industries require that the power quality is good and the power system is flexible in all respects. The abrupt voltage changes should not be there in the power system to maintain a better power quality. The voltage changes occur due to the dynamic load of the large industries that are supplied by the power grid. So to maintain the voltage constant inspite of large load changes, some compensation methods are implemented into the power system so that the power quality is assured. This paper presents such techniques to maintain the voltage constant inspite of load changes. Along with voltage profile maintenance, power factor improvement is also done by using shunt compensation technique and the total transfer capability is also increased. For shunt compensation, circuit breakers are generally used to connect or disconnect the capacitors into the circuit. But here, bulky slow acting circuit breakers are replaced small fast acting thyristors. Thyristors give a very dynamic control and fast response as compared to the circuit breakers. Fig.1 shows the comparison of time taken by a C.B and a thyristor to operate when enable command is given. This gives the added advantage to the system to control the power flow in a very dynamic manner. The technique incorporating thyristors in place of C.B is termed as Flexible AC Transmission Systems (FACTS) [1]. [2]. The FACTS technology provides the advantage of faster control in a closed loop

manner since the thyristor triggering and controlling can be done using microcontrollers and other digital circuits.

Using thyristor at different firing angle in the circuit provides stepless operation which is not possible using circuit breakers [3], [4], [6], [7], [8], [9], [10].

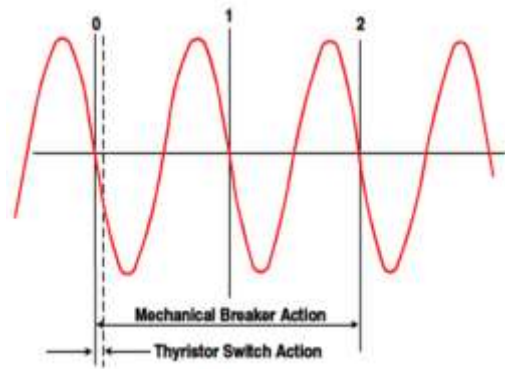


Fig. 1 Comparison of Circuit Breaker and Thyristor operation speed.

SHUNT COMPENSATION

In shunt compensation capacitors are connected in parallel to the load whenever required. The idea of connecting capacitors in parallel is to supply some amount of reactive power required by the load so that the supply is relieved of supplying that much amount of the reactive power. Hence the power factor is improved and the power transferred can be further increased. The reactive power from the capacitors is injected at the center of the transmission line. The capacitors are connected or disconnected as per the requirement. The phasor diagram is shown in Fig. 2. The normal voltage and current are V and I as referred to Fig. 2, after adding a capacitor in parallel to the load, I_c starts flowing and the total current is now the phasor sum of I and I_c . This

sum I' is lesser than the initial current I before connecting the capacitor.

Also the power factor is improved as the angle between V and I' is lesser as compared to the angle between V and I .

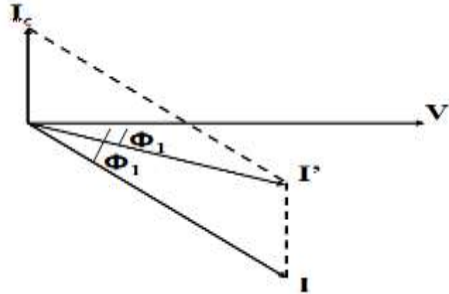


Fig. 2 Phasor Diagram of Shunt Compensation.

FACTS CONTROLLER FOR SHUNT COMPENSATION: THYRISTOR SWITCHED (TSC)

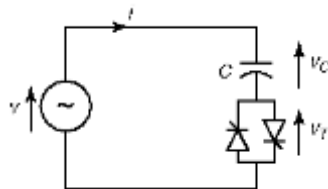


Fig. 3 Conceptual circuit of TSC.

The circuit shown in Fig. 3 consists of a capacitor in series with a bidirectional thyristor switch. It is supplied from an ideal ac voltage source with neither resistance nor reactance present in the circuit. The analysis of the current transients after closing the switch brings forth two cases:

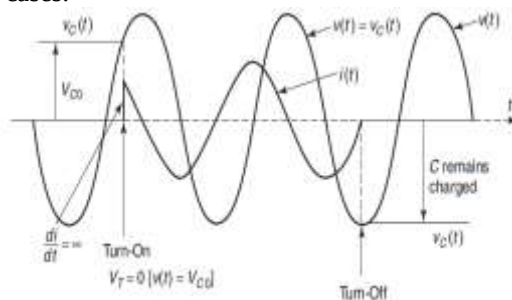


Fig. 4 Waveforms of TSC.

1) The capacitor voltage is not equal to the supply voltage when the thyristors are fired. Immediately after closing the switch, a current of infinite magnitude flows and charges the capacitor to the supply voltage in an infinitely short time. The switch realized by thyristors cannot withstand this stress and would fail.

2) The capacitor voltage is equal to the supply voltage when the thyristors are fired, as illustrated in Fig. 4. The analysis shows that the current will jump immediately to the value of the steady-state current. The steady-state condition is reached in an infinitely short time. Although the magnitude of the current does not exceed the steady-state values, the thyristors have an upper limit of di/dt values that they can withstand

during the firing process. Here, di/dt is infinite, and the thyristor switch will again fail.

The circuit explained in the above explanation is not the practical circuit. In practical case, to limit the di/dt value an inductor is placed in series with the capacitor so the switches are not damaged. The actual circuit is shown in Fig.5.

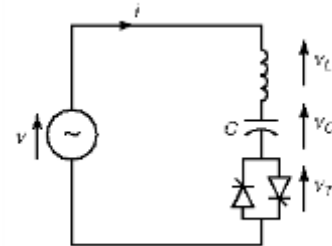


Fig. 5 Practical circuit of TSC.

SIMULATION OF TSC AND RESULTS

Simulation of TSC is done in MATLAB 7.8. For simulation, generator is taken as a constant supply model of MATLAB, transmission line pi-model is prepared and a load of 2.6MW is supplied by the source via the transmission line. The load is increased to double after some time and the response of the system with closed loop is checked. Fig. 6 shows the MATLAB model of TSC developed.

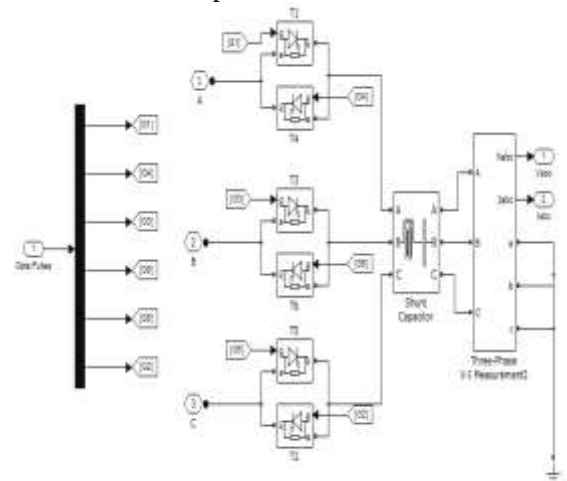


Fig. 6 MATLAB model of TSC.

Fig. 7 shows the gate pulses generated for TSC at different frequency. Synchronized block for gate pulse generation is developed using logic circuit to keep the gate pulses well synchronized with the changes in supply frequency.

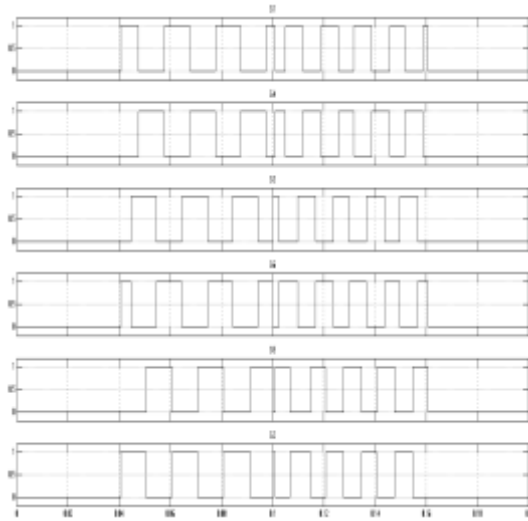


Fig. 7 Gate pulses for TSC with change in frequency from 50Hz to 75Hz.

Fig. 8 shows the complete circuit of the power system developed in MATLAB. The closed loop block takes a feedback from the receiving end voltage continuously. It checks that whether the voltage level is within the limits or not. If the voltage falls below the prescribed limit, then the block will generate a pulse that will enable the gate signals of the TSC module and hence the compensation will be started which will cause a boost in the voltage at the receiving end.

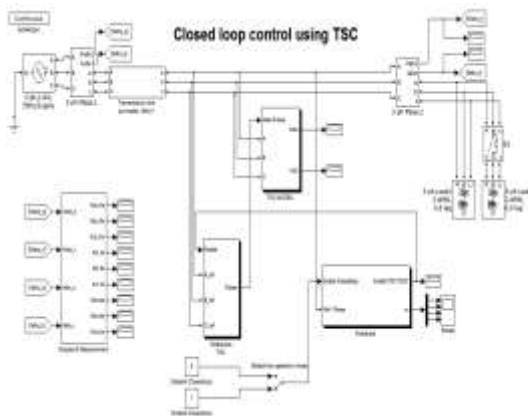


Fig. 8 Simulation circuit for closed loop control of TSC.

Fig. 9 and Fig. 10 show the voltage waveforms at sending and receiving end with closed loop blocked disabled. The load is increased at 0.04 seconds.

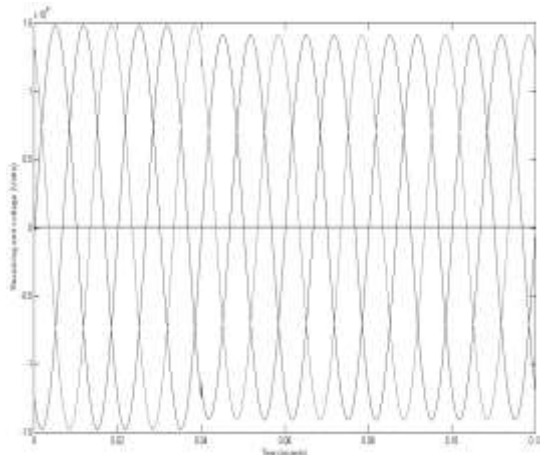


Fig. 9 Receiving end voltage for open loop control.

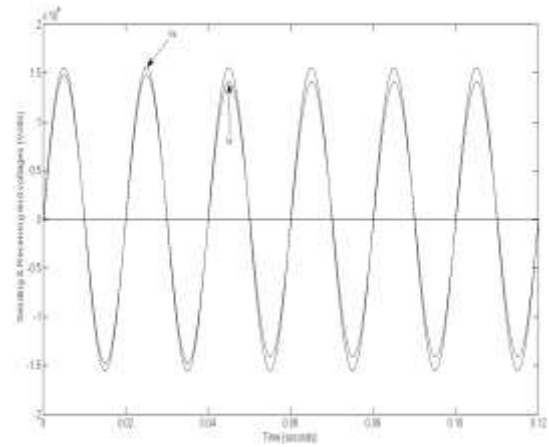


Fig. 10 Comparison of sending and receiving end voltages for open loop control

Fig. 11 and Fig. 12 show the voltage waveforms at sending and receiving end with closed loop blocked enabled. The load is increased at 0.04 seconds.

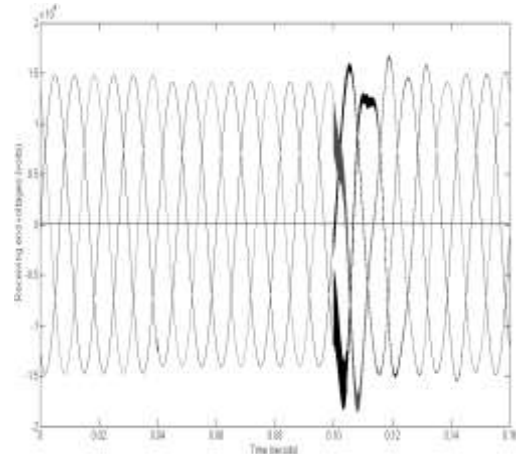


Fig. 11 Receiving end voltage for closed loop control.

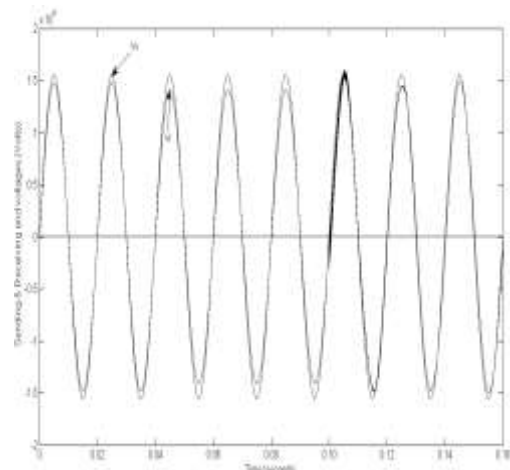


Fig. 12 Comparison of sending and receiving end voltages for closed loop control

I. CONCLUSION

From the simulation of results of Shunt compensation, it can be concluded that shunt compensation proves to be a very rapid acting system to maintain the voltage stable at the receiving end as shown in Fig. 11 and Fig. 12. Also, it helps in power factor improvement of the power system. It does not add to the short circuit capacity as compared to the series

compensation, because shunt compensation does not affect the overall line reactance where as the series compensation decreases the line reactance and hence the fault current increases above the normal value. Among all the shunt compensators Thyristor Switched Capacitor (TSC) is the best one as it does not inject any kind of harmonics into the system. Also the closed loop control of TSC gives the required operation of a reliable power system. The closed loop control makes the power system unaffected by dynamic load changes and maintains the voltage profile better as shown in Fig. 11 and Fig 12 [5], [6], [9].

REFERENCES

- [1] Prabha Kundur, John Paserba, Venkat Ajjarapu, Goran Andersson, Anjan Bose, Claudio Canizares, Nikos Hatziaargyriou, David Hill, Alex Stankovic, Carson Taylor, Thierry Van Cutsem, and Vijay Vittal, "Definition and Classification of Power System Stability", IEEE Transactions on power systems, vol. 19, no. 2, may 2004.
- [2] R. Adapa, M. H. Baker, L. Bohmann, K. Clark, K. Habashi, L. Gyugyi, J. Lemay, A. S. Mehraban, A. K. Myers, J. Reeve, F. Sener, D. R. Torgerson, R. R. Wood, "Proposed Terms and Definitions for Flexible AC Transmission System (FACTS)", IEEE Transactions on Power Delivery, Vol. 12, No. 4, October 1997.
- [3] Brian K. Johnson, "Benchmark Systems for Simulation of TCSC and SVC", IEEE Transaction, 2002.
- [4] M. Moghawemi, and M. O. Faruque, "Effects of FACTS devices on Static Voltage Stability", IEEE Transaction, 2000.
- [5] Jong Su Yoon, Soo Yeol Kim, Byung Hoon Chang, Doo Hyun Baek, "Application of FACTS Technology for Power System Control", Korea Electric Power Research Institute.
- [6] U. Eminoglu, m. H. Hocaoglu, "Effect of svcs on transmission system voltage profile for different static load models".
- [7] John J. Paserba, "How FACTS Controllers Benefit AC Transmission Systems", IEEE 2003.
- [8] H. K. Tyll, "FACTS Technology for Reactive Power ompensation and System Control", 2004 IEEE IPES Transmission & Distribution Conference \& Exposition .
- [9] Shankaralingappa C. B., and Suresh. H. Jangamashetti, "FACTS Controllers to Improve Voltage Profile and Enhancement of Line Loadability in EHV Long Transmission Lines", IEEE Transaction 2008.
- [10] R.M.Mathur, R.k.Verma, "Thyristor-based FACTS controllers for electrical transmission systems", IEEE Press, 2002, pp 277-288.