Implementation Of Thyristor Switched Capacitor For Reactive Power Compensation At Secondary Of Distribution Level Feeders For Voltage Stability Improvement

Preethi B
Department of Electrical and Electronics Engg
GAT, Bangalore

Dr. B. V. Sumangala
Department of Electrical and Electronics Engg
Dr.AIT, Bangalore

Abstract*: *The analysis of the FACTS device, Thyristor Switched Capacitor (TSC) connected on the secondary terminals of the distribution feeder (transformer) in a power system network for effective voltage stability and reactive power control is presented. The FACTS device is advantageous over the mechanical switch operated capacitors in the aspects of faster control, improved system performance and system voltage stability. The power system network simulations are carried out and the model of the TSC is realised using Simulink in MATLAB. Experimental results also presented which are obtained from a physical Power System Simulator.

Keywords - AC transmission, FACTS, Static VAR Compensator (SVC), Thyristor Switched Capacitor (TSC), Reactive Power Compensation, Volt Ampere Reactive(var)

1. INTRODUCTION

The expansion in power transmission system has taken place not only due to the increase in generation and loads but also due to the extensive interconnection among different power utilities. The major factor for system interconnections is to economise the generation reserves, to minimise generation cost and also to achieve the reliability of supply. The demand for electricity increases proportional to growth in population, creation of special economic zones, urbanization and industrialization. Setting up of a new generation station is not feasible because of economic and environmental considerations. So the challenge of meeting the demand for electrical energy can be achieved by improvising the system performance of existing power system network. This in turn is achieved by minimizing power losses in the transmission and distribution system, effective reactive power control, tapping alternative generation resources and by implementation of energy management systems.

As a commitment by the regulation of the Electricity act, it is required to maintain rated constant voltage, constant frequency power supply to the consumers with system security. The consistency of these parameters mainly depends on the characteristics of the load, majority of which are inductive in nature. This characteristic of inductive loads reflects with dip-in voltage. Also there is reduction in operating power factor which further results in increased power losses. This in turn results in degradation in the power system performance and also the consumer getting penalized for low power factor.

In the conventional systems, load conditions vary throughout the day. There is overvoltage due to lightly loaded condition or overloaded condition during peak hours of load consumption. The increase in load levels is accompanied by higher reactive power consumption. In the night, when the demand is low, there will be excess reactive power i.e. capacitive reactive power available and the voltage magnitude would increase. While during peak hours the excessive loads which are in majority inductive in nature result in large voltage drops and also the inductive reactive power of the lines adds to the reactive power flow. In case of mismatch in the reactive power balance in the system, it results in voltage instability and collapse. The load variations throughout the day results in unbalanced load. The unbalanced load in each phase of the load feeder, results in frequent failure of distribution transformers. These voltage variations also affect the power flow performance of the grid. As per the statistics 25% transformers are getting failed at distribution side either because of unbalanced overloads or due to overvoltage at lightly loaded conditions or also may be due to poor maintenance.

Reactive power flow involves generation of additional reactive power. Reactive power transmission over long distances results in voltage drops and losses. Hence reactive power transmission is not only uneconomical but also ineffective from control point of view. The balance between reactive power generation and demand has to be maintained on a regional basis within the area of operation concerned.

Reactive power demand varies throughout the day. During the lightly loaded conditions, there will be excess reactive power i.e. capacitive reactive power available and it is necessary to connect parallel reactors for consuming the additional capacitive reactive power of the lines or else to change the on-load transformer tap change settings. While during peak load conditions the inductive power which is in excess has to be compensated. Hence additional capacitive reactive power has to be injected into the system to meet additional reactive power requirements. In order to increase the lifespan of the transformer and also to reduce the losses occurring due to the low power factor, effective reactive power management system has to be incorporated.

.

Reactive power is a basic requirement for maintaining system voltage stability. Voltage collapse is associated with reactive power demands not being met because of limitations on the production and transmission of reactive power. During voltage emergencies, reactive resources should activate to boost transmission voltage levels.

Reactive power (var) compensation or control is an essential part in a power system to minimize power transmission losses, to maximize power transmission capability, to stabilize the power system, and to maintain the supply voltage. Reactive power compensation of AC lines using fixed series capacitors can solve some of the problems associated with AC networks. However the slow nature of control using mechanical switches (circuit breakers) and limits on the frequency of switching imply that faster dynamic controls are required to overcome the problems of AC transmission networks.

Flexible Alternating Current Transmission Systems (FACTS) are new devices emanating from recent innovative technologies that are capable of altering voltage, phase angle and/or impedance at particular points in power systems. Their fast response offers a high potential for power system stability enhancement apart from steady state flow control. Flexible AC transmission system (FACTS) involves the application of high power electronic controllers in AC transmission networks which enable fast and reliable control of power flows and voltages. The objectives are:

1. Regulation and enhancement of power flows by reducing transmission losses in prescribed transmission routes
2. Improve stability with fast acting voltage regulation
3. Secure loading of lines nearer their thermal limits
4. Damping of oscillations which can threaten security or limit the usable line capacity
5. Higher transient stability limit

There are several FACTS controllers which have been developed or proposed. These include:

1. Static Var Compensator(SVC)
2. Thyristor controlled Series capacitor(TCSC)
3. Thyristor controlled Phase Angle Regulator(TCPAR)

4. Static Synchronous Compensator(STATCOM) OR Static Condenser(STATCON)
5. Unified Power Flow Controller(UPFC)

2. STATIC VAR COMPENSATOR (SVC)

Static VAR compensators are devices which control the voltage at their point of connection to the power system by adjusting their susceptance to compensate for reactive power deficiencies. SVC provides fast acting dynamic reactive compensation for voltage support during contingency events. SVC also dampens power swings and reduces system losses by optimized reactive power control.

These compensators comprise of either thyristor-switched capacitors (TSCs) and/or thyristor-controlled reactor(TCR) with fixed (permanently connected) power factor correcting capacitors which also provide when combined with appropriate tuning reactors, harmonic filtering. SVC schemes using TCRs in combination of TSCs and fixed capacitive filters on the secondary side of a coupling transformer were devised and successfully applied for the dynamic compensation of power systems to provide voltage support, increase transient stability and improve damping.

Functionally the thyristor controlled SVCs are controllable reactive impedances. Essentially, the thyristor valves control the current drawn by the capacitor and reactor banks and thereby the reactive power they generate for or absorb from the ac system. Thus, an SVC in addition with the necessary coupling transformer requires, fully rated capacitors and reactors to generate or absorb reactive power and an electronic switching circuit(thyristor valves) accounting for a large system.

2.1. SVC: OPERATION AND CHARACTERISTICS:

A shunt connected static var generator or absorber whose output is adjusted to exchange capacitor or inductive current so as to maintain or control specific parameters of the electrical system typically the bus voltage.

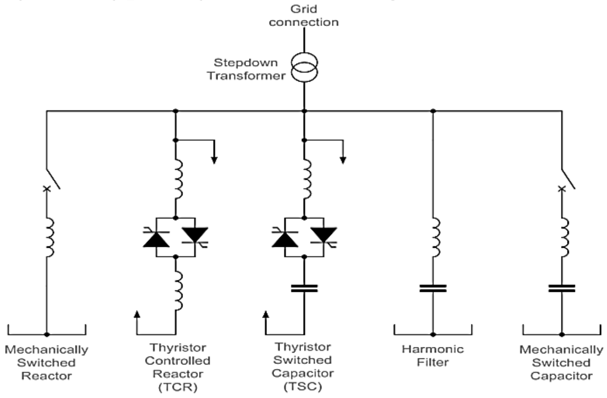


Fig 1. Static var compensator

Conventional Static VAR Generators employ large banks of shunt connected capacitors, thyristor switched capacitors and thyristor phase controlled reactors to provide the needed controlled shunt reactive compensation. In such installations ac capacitors are used as the var source and shunt connected phase controlled reactors are used to absorb vars. The net reactive power is the difference between the two. A conventional SVC employs thyristor switched capacitors with valves rated at two times the peak line voltage seen by the capacitors and phase controlled reactors with valves rated at the peak line voltage for the reactors.

The characteristics of the SVC is as shown in Fig.2

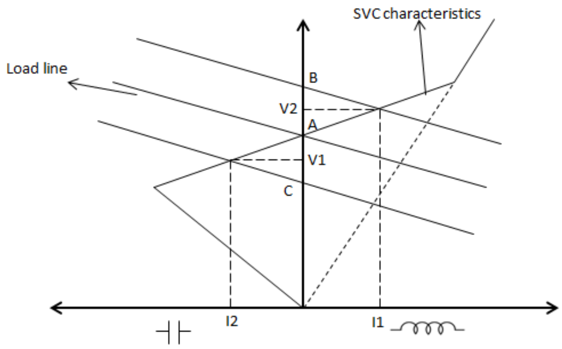


Fig 2.Composite SVC characteristics

The normal characteristics represented by load line A will intersect the SVC characteristics at reference voltage. The load line B intersects the SVC characteristics at a voltage V2. Since voltage V2 is above the reference voltage, it indicates inductive reactive power requirement. The current I1corresponding to voltage V2 hence is in the inductive region and it requires operation of thyristor controlled reactor. The load line C intersects the SVC characteristics at a voltage V1. As it can be observed that the voltage V1 is below the reference voltage and hence capacitive reactive power is required. The current I2 is in the capacitive region of operation.

2.2. Thyristor switched Capacitor

The circuit diagram of Thyristor switched capacitor is as shown in Fig 3.

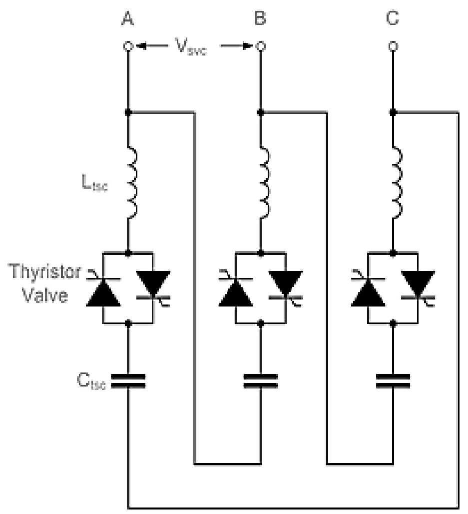


Fig 3. Thyristor switched capacitor

The three thyristor valves are connected in delta in order to eliminate zero sequence triplen harmonics (3rd, 9th….).The harmonics remain trapped inside the delta and thus reduce harmonic injection into the power system. Reactor L is used to limit the surge current when thyristor is ON under abnormal operating condition.

Advantages of TSC over mechanically switched capacitors

1. TSC provide instantaneous response to the changes in the system parameters.
2. Faster control is achieved by the switching of thyristor operated devices.
3. TSCs are more reliable compared to the mechanically switched capacitors.
4. Permanent connection of fixed capacitors in the network draws unnecessary charging current.

3. SIMULATION DETAILS

The system under consideration for simulation is given in fig 4(after References). The simulations are carried out using Simulink of MATLAB software.

With reference to the fig 4, the loads connected at secondary side of distribution transformer represent the illumination, heating, motor and the capacitive load. The capacitive load represents the load compensation provided at the consumer end (for ex. Industrial customers). The results are obtained in the absence of this load compensation which brings out the significance of the proposed TSC controller. The TSC controller connected at the secondary side of the distribution transformer stabilizes the load end terminal voltage at rated value irrespective of the presence of load compensation at consumer end which will be referred as load compensation (existing).
TSC is symbolically represented in simulation as two antiparallel thyristors and a capacitor connected in series in each phase.

3.1 VOLTAGE PROFILE

The P-V curve with TSC shows a significant improvement to the tune of nearly 40% the power handling capability (nose point) of the transmission line. With the incorporation of the TSC, it is shifted further which shows the improvement in the power handling capability.

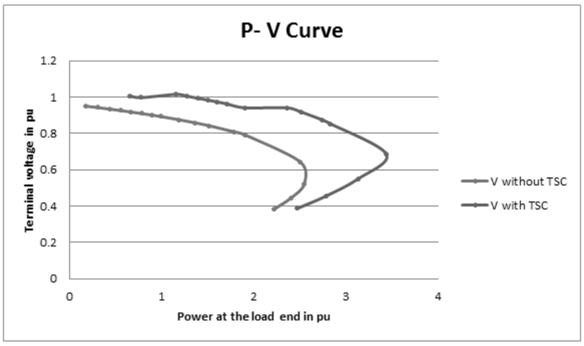


Fig 5. P-V curve

3.2 OPERATION OF TSC CONTROLLER

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 2 Issue 5, May - 2013

Power factor is taken as the reference for improvement in voltage profile. The load end power factor is compared with a reference value (in the simulation taken as 0.98), and the TSCs are switched ON in steps till the load end power factor reaches the desired i.e., the reference value.

A daily load cycle consisting of residential and commercial load is considered as shown below.

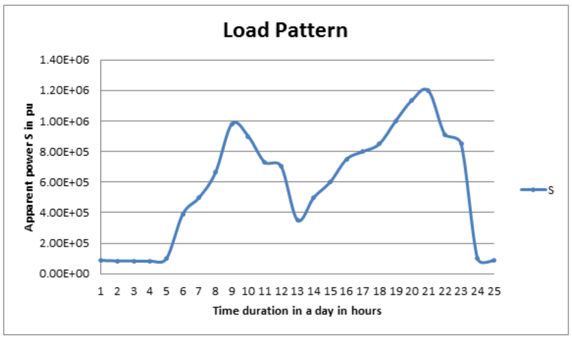


Fig 6. Daily Load Cycle

In the load pattern, the load varies to peak values during the morning and evening as per the practical scenario.

4. RESULTS

The simulation results for power profile and voltage profile without the TSC and with TSC connected along with load compensation are shown. The profile also compares the results where TSC is connected and load compensation is not provided which may be practically possible due to the failure of the compensation provided at consumer end.

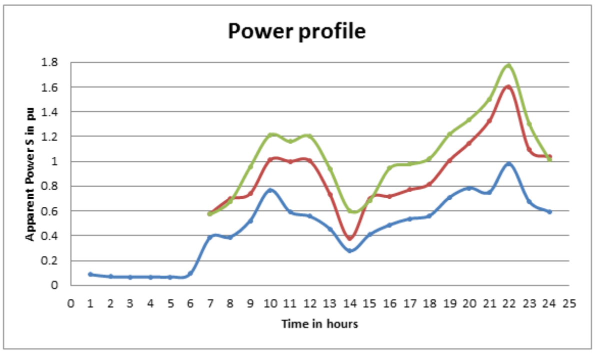
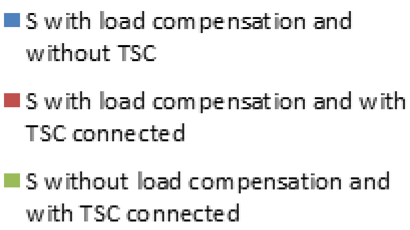


Fig 7. Power profile



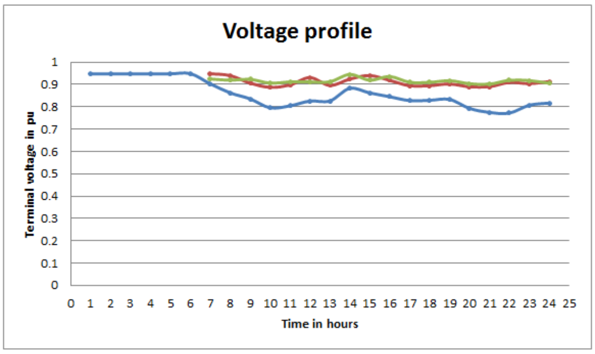
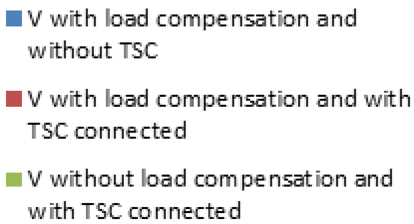


Fig 8. Voltage profile



As per the graph showing the voltage profile, the voltage is maintained nearly at 1 pu as per the system requirements and voltage profile improved by nearly 20%.

From the graph showing the power profile, the spare power available that can be used to deliver additional loads is increased approximately to around 40% with the incorporation of TSCs.

5. PHYSICAL SIMULATOR

The Power System Simulator is a physical simulator in which the power system network shown in fig.4 is realized with reduced scale of the ratings of various components of the system.

Fig 9. Power System Simulator

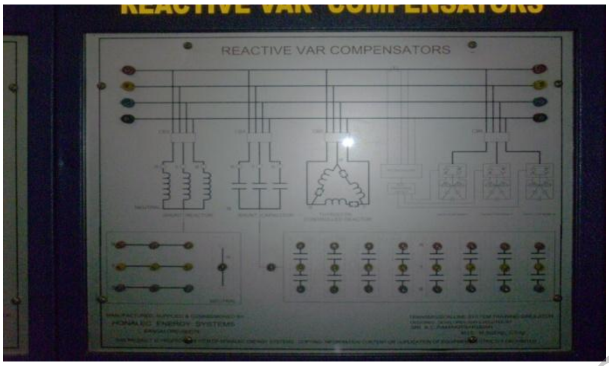


Fig 10. Reactive VAR Compensators Panel

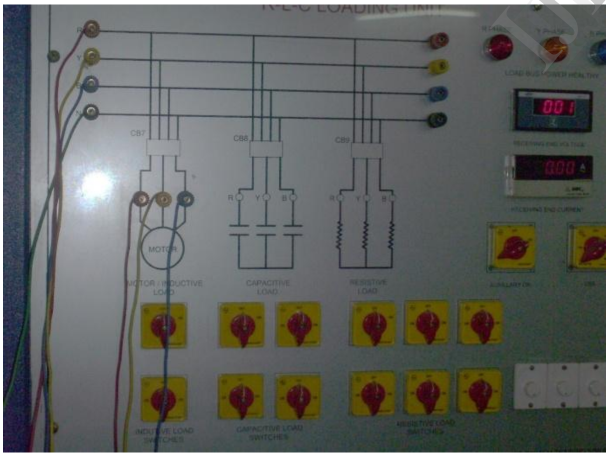


Fig 11. RLC Loading Unit Panel

The Power System Simulator readings for an interval of 5 minutes for 2 hours duration are equated to 24 hour cycle load pattern. The Power profile and the Voltage profile for experimental results obtained from the Power System Simulator are as shown in fig.12 and fig.13.

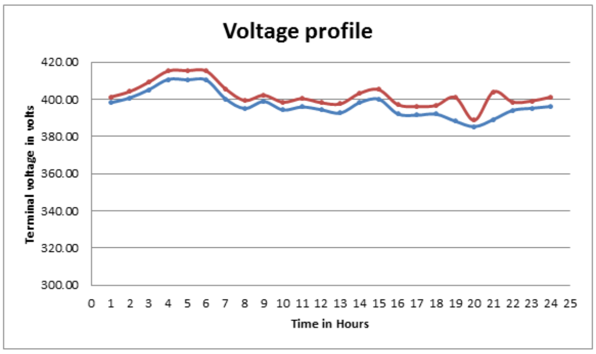


Fig 12. Voltage profile for physical simulator results

V without TSC Connected

V with TSC connected

The voltage is nearly maintained at a rated level of 415V with the incorporation of TSC.

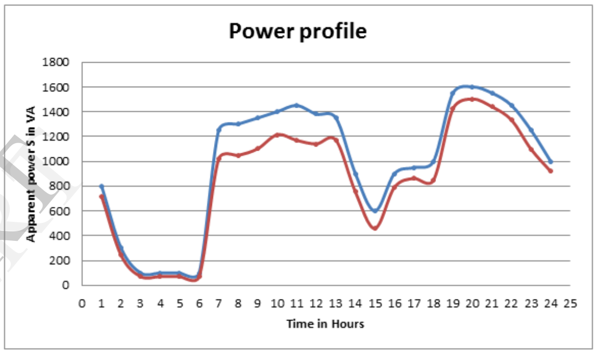


Fig 13. Power profile for physical simulator results

S with TSC not connected

S with TSC connected

The graph shows that for particular load the apparent power drawn by the distribution transformer is decreased by around 20%. Thus the transformer can supply additional load. Hence the transformer's lifespan is increased.

6. CONCLUSION

A real 220kV system simulated using MATLAB – Simulink. Also the results from physical Power System Simulator are obtained. With the incorporation of TSC at the distribution transformer end, the following are the conclusions:

1. The voltage is maintained at constant rated value - almost 1pu, thus achieving voltage stability with a variation of ± 2%.

2. At a particular load considered, the apparent power delivered by the distribution transformer is reduced by 10 to 40%.
3. With the improvement in power factor, power losses are reduced in turn improving the system's efficiency.
4. The loading on the distribution transformer is reduced and hence its lifespan is increased.
5. With the incorporation of TSCs, faster and automatic control is achieved.

6. REFERENCES

[1] Yongchun Su, Shijie Cheng, Jinyu Wen, "Reactive power generation management for the improvement of power system voltage stability margin", IEEE 2006, 1-4244-0332-4/06.

[2] Pravin Chopade, Dr. Marwan Bikdash, Dr.Ibraheem Kateeb, Dr.Ajit D. Kelkar, "Reactive Power Management and Voltage Control of large Transmission system using SVC (Static VAR Compensator)", IEEE 2011 978-1-61284-738-2/11,

[3] Grzegorz Blajszezak, "Reactive power control in transmission network as a tool for reliable supply", 9th International conference, Electrical Power Quality and Utilisation, Barcelona,9-11 October 2007

[4] Ranjana Singh, Amarjit Singh, " Causes of failure of distribution transformers in India", IEEE 2010 978-1-4244-5370-2/10

[5] N Mithulananthan, M M A Salama, C A Canizares, J Reeve, "Distribution system voltage regulation and var compensation for different static load models", International Journal of Electrical Engineering Education, ISSN-0020-7209 volume 37 Issue 4 oct2000, pp 384-395

[6] Irwin D Lazar, "Electrical Systems Analysis and Design for Industrial Plants", McGraw-Hill, 1980

[7] Prabha Kundur, "Power system stability and control", Tata McGraw-Hill, 2008

[8] M.J.Katira, K.B.Porate, "Computer simulation of 132/11KV Distribution substation using Static Var Compensator (SVC) for voltage enhancement – A case study", IEEE 2009 978-0-7695-3884-6/09

[9] K.R.Padiyar, "FACTS controllers in power transmission and distribution", New Age International Publication, 1st edition, June 2007

[10] Narain G Hingorani, Laszlo Gyugyi, "Understanding FACTS: Concepts and technology of Flexible AC Transmission Systems", IEEE Press 2000

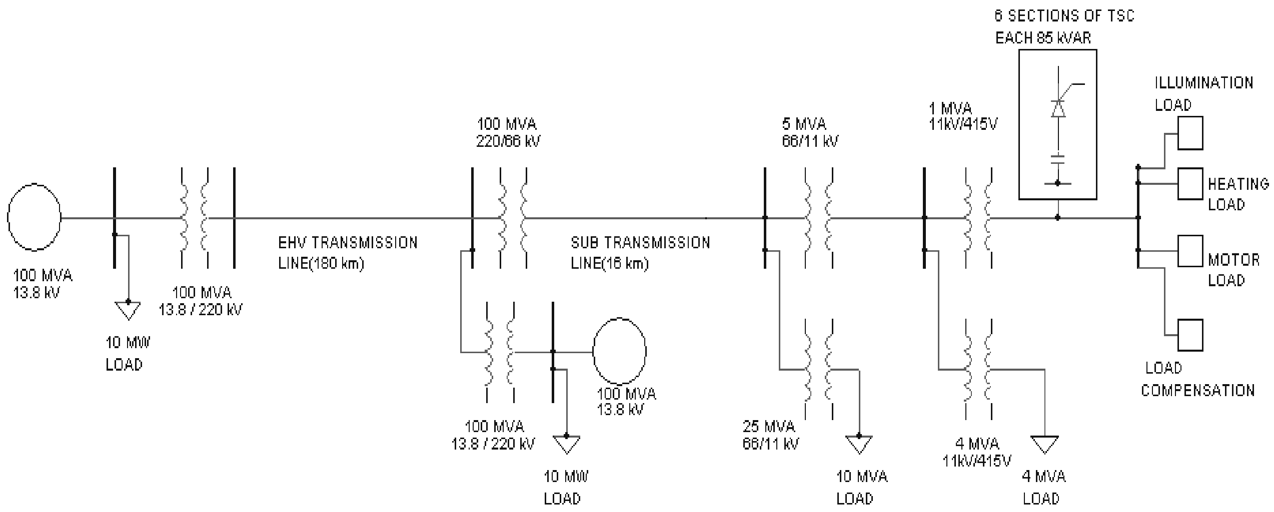


Fig 4. Radial transmission line power system network