CHAPTER 9

CONCLUSION
9.1 Opening Remarks:

Electrical energy has become an essential pre-requisite for all industrial, commercial and life activities. Unfortunately a large amount of power generated is getting wasted in the transmission and distribution systems. In particular, electrical distribution systems are incurring large losses as the loads are wide spread, inadequate reactive power compensation facilities and their improper control. Power is distributed through radial feeders extending over wide spread areas in the rural sector due to agricultural loads. The LT consumers are of both three phase and single phase. The consumer end voltages are poor, the power factors are very much lagging, the network losses are high and quality of power supply is poor. On account of these reasons, power system engineers are very much concerned to alleviate these problems in the distribution sector. Voltage control and reactive power compensation have remained the most engaging problems in power system engineering. It is in this perspective. This thesis work is undertaken to develop a Static Var Compensator, most suitable for distribution systems.

9.2 Scope of Thesis Work:

A Static Var Compensator consisting of capacitor bank in five binary sequential steps operated in conjunction with a Thyristor Controlled Reactor of the smallest step size in designed, developed and tested on a practical system. The performance evaluation through analytical and simulation studies using the system data are carried out. A fast acting error adaptive controller is developed suitable both for contactor switched and thyristor switched capacitors. The switching operations achieved are transient free, practically no need to provide inrush current limiting reactors and the TCR size being minimum offer
small percentages of non-triplen harmonics. It also facilitates real time mode of control for stepless variation of reactive power closely matching with load requirement so as to maintain power factor near unity always. A microcontroller developed is elegant, closed loop and have the features of automatic self adjustment in adaptive mode. Logic and control techniques employed are unique, innovative, newly introduced, comprehensive and possesses number of attractive features which can be easily extended to HT system. It is successfully tested for six sample load cases on a distribution transformer of three phase, 50 Hz, Dy11, 11 KV/440 volts, 125 KVA capacity. The functional feasibility of the scheme, its technical soundness and economical justification are proved. Stepless control of Q closely matching with load requirement is achieved for the entire range of operation, transition from one step to another for any load level is timed to be smooth and switching operations are achieved to be practically transient free. Thus, the scheme and associated controller developed are new, technically sound and economical, giving reliable performance. The chapter wise coverage of the work carried out in this Thesis are dealt in brief as below.

9.3 Chapterwise Coverage:

In chapter 1, a typical radial feeder with reactive power compensator is dealt and the performance requirements are brought out. A shunt compensator (SVC) with capacitor bank in steps and TCR is introduced. A literature survey is presented bringing out the limitations of the shunt compensation techniques presently in vogue and the necessity to develop a comprehensive Static Var Compensator with appropriate adaptive controller is discussed.
In chapter 2, the characteristic features of basic elements as required in a typical shunt compensator are given. The important aspect of energizing capacitors, the transients for individual and back to back switching are dealt in detail. Six identical air cored coils are designed and fabricated suitable for the SVC scheme for the work undertaken. The introductory operating principle of TCR is presented.

In chapter 3, the problem associated with reactive power compensation, conventional methods and recently introduced advanced compensators are dealt in brief. The desirable features for shunt compensator are highlighted the four quadrant operation for changes both in P and Q through voltage and magnitude control respectively are dealt. However, this Thesis work has main focus on reactive power compensation, hence the requirements of an advanced compensator suitable for distribution systems are presented.

In chapter 4, the distribution system as available in Walchand College of Engg., Sangli Campus is undertaken as a case study which forms the basis for investigative work. The statistical data pertaining to the pattern of load demand, energy consumption and its growth, the range of variation in power factor and the penalties imposed by MSEDCL for the period from April 2005 to December 2009 is given. How much the college could have saved had the power factor been maintained at near unity by reduction in both the penalties and demand charges is brought out. The graphical portraits of data presented for the five years emphasize the necessity for a technically sound shunt compensator with self regulating facility.

In chapter 5, the design features of microcontroller for SVC as developed are dealt along with the control strategy. The scheme consisting of capacitor bank in five binary sequential steps along with a
TCR is presented. Voltage and current signals are obtained, processed in a controller and signals are generated both for capacitor steps switching and for Q lag level maintenance in the TCR for closely matching with load reactive power during any specified time interval. A systematically developed logic as provided in the microcontroller enables the choice of capacitor steps and the level of TCR at periodical intervals so as to match the reactive power of SVC with load requirement continuously and uninterruptedly.

In chapter 6, the switching transient phenomenon is thoroughly investigated through simulation studies using SIMULINK model. In all, six loading conditions have been investigated. The magnitude of transient current, its frequency and duration depend on L, C & R values in the circuit. A systematic logic presented for switching actions to be carried out ensures transient free operations. The harmonic spectra for TCR as a function of firing angle $\alpha$ are presented. In addition the harmonic related aspects both for line and phase currents are given in detail.

In chapter 7, the performance evaluation for the six loading cases undertaken is investigated. A MATLAB program is used for calculation purpose. The improvements in the voltage at the receiving end, reduction in voltage regulation, enhancement in feeder efficiency, increase in the current capability of feeder and reduction in KVA demand when SVC is in operation are brought out through the analytical studies.

In chapter 8, the hardware implementation scheme for KVAR control is dealt. The general schematic diagram for the compensator, KVAR sensing, ADC interfacing, zero crossing detection of line voltage and square wave generation are presented. The application of gate signals both for thyristor switched capacitor steps and thyristor controlled reactor is discussed. The switching and control operations are carried out in every
two minutes of periodicity and the algorithmic steps are given for the same. Finally, the economic justification for installation of SVC in college campus is presented.

9.4 Attractive Features of the Scheme:

There are number of reactive power compensators developed and used in power systems at low, medium and high voltages. There are synchronous condensers SRFC, FC-TCR, FC-TCT, TSC, TSC-TCR, MSC-TCR. Of all these schemes TSC-TCR appears to be relatively more attractive, technically sound and economical as compared to all others as dealt in the literature survey. It is possible to apply the scheme developed and tested in this work starting from low voltages in the distribution system as well as at substations/receiving stations of higher voltages. The notable features of TSC-TCR scheme are as follows –

1. The scheme is static with proven elements employed for Q generation and its control.

2. It permits continuous stepless control closely matching with system requirements.

3. The response time is small and hence very fast acting as per the requirements for continuously varying loads.

4. The control capability is very good with respect to voltage maintenance and can even offer individual phase control to mitigate the problems of unbalance.

5. If the TSC is arranged in binary sequential steps, the resolution is small, the TCR rating gets minimized and harmonic levels are low. Thus, there may not be a necessity to employ separate filter for characteristic harmonics and the triplen harmonics are find closed path due to delta connection.
6. The scheme has adequate overload capability and limited over voltage withstand capability.

7. The scheme consists of all static and fast acting elements and has no rotating elements and inertial problems.

8. The scheme is practically insensitive to frequency deviations and does not give rise to any resonance problems.

9. The scheme is advantageous from energy conservation point of view, because of very small losses.

10. The capacitor bank energisation is fast enough with suitable control and has been made practically transient free.

11. In case this scheme has to be implemented in high voltage systems it has to be connected through an appropriate coupling transformer with the same control strategy as developed.

12. The logic employed is new, practically tested on a live system and the operations are very fast and transient free.

13. The practically observed results are closely matching with those obtained from analytical and simulation studies.

14. If necessary at a substation or a receiving station, it is possible to operate in inductive range with large capacity TCR.

The main concentration in the thesis work has been to develop a static VAR compensator with a capability to self adjust based on load requirement. The emphasis was given on development of suitable circuitry for transient free switching operations. As established the transition from one level of loading to another is smooth and operates at periodical intervals. The performance on a practical feeder from theoretical consideration, simulation studies and practical implementation are dealt for six loading cases on the distribution transformer covering its
entire range. The results obtained are quite encouraging, the scheme has been technically sound and economical as established. The scope for further work is dealt below –

**9.5 The Scope for Future Work:**

The static VAR compensator developed and installed on one of the transformer in the college campus is a good demonstrating model for both students and faculty members. It offers in depth knowledge of the SVC scheme, its control for various aspects of reactive power compensation, voltage maintenance, power factor improvement, reduction in maximum demand and effective utilization of transformer and feeder. The harmonic studies on TCR can be carried out and how the harmonic currents and THD can be reduced with firing angle $\alpha$ is quite useful information.

- It is possible to operate SVC with individual phase control to mitigate the unbalanced related problems.
- The working feasibility of the scheme for flicker control similar to dynamic voltage restorer needs to be investigated.
- The application of the developed scheme at a substation making use of the tested circuitry can be undertaken.
- It is also possible to hook up the system developed with SCADA without any difficulty for continuous control in real time mode.
- The same type of the scheme can be installed on the remaining two transformers in the college campus and all of them together can be clubbed with SCADA system for full realization of economic benefits.

It is hoped that the work undertaken and carried out in this thesis inspires both students and faculty, useful in the distribution sectors of the power utilities at large and beneficial to the college in particular.