Testing and Control of TSC-TCR Type Static Var Compensator (SVC) Using Microcontroller

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Abstract

Implemented a small scale laboratory based Thyristor switched capacitor - thyristor controlled reactor (TSC-TCR) type static var compensator (SVC). The automatic control circuit has been implemented using microcontroller and tested with the Single Machine Two Bus Test system (SMTB) without and with SVC. Experimental results are presented and P-V Curves have been drawn for both the cases. Automatic control circuit have been designed and fabricated using LPC 2148 Microcontroller. The same test system was tested with SVC automatic control circuit and experimental results have been presented in this paper. The P-V Curves of the SMTB Test system with and with out SVC have been plotted which shows the effectiveness of SVC on Voltage Stability improvement.

Keywords: *TSC-TCR type SVC, FACTS Controllers, Microcontroller based control of Reactive power, Automatic control of SVC, TCR control, Voltage Stability Enhancement and P-V Curves*

1. Introduction

Thyristor Controlled Reactor (TCR) is one of the most important building blocks of thyristor-based SVCs. Although it can be used alone, it is more often employed in conjunction with fixed or thyristor switched capacitors to provide rapid, continuous control of reactive power over the entire selected lagging-to-leading rang. Traditionally TCR controllers are microcontroller based. Recently, with the development of microelectronics, LPC 2148Chip become more and more widely used in electric apparatus controllers to increase the accuracy and the computation rate of the control algorithms.

A power system is stable if it returns to a steady-state or equilibrium operating condition following a disturbance. This criterion shall hold true for all loading conditions and generation schedules under normal operating conditions; following either the loss of any power plant, or for the most severe network faults. In the planning and operation of a power system it is important to consider the potential emergence of a variety of stability problems. Angle stability mainly involves the dynamics of generators and their associated control systems. Angle stability can be further categorized into transient stability and small signal or steady-state stability. Frequency stability is closely related to angle stability. Voltage stability mainly involves the dynamic characteristics of loads and reactive power. Voltage Collapse is perhaps the most widely recognized form of voltage instability.

This paper deals with the Design, Fabrication and Testing of Microcontroller based 2KVAR (TSC-TCR type) SVC. The laboratory setup of the SMTB test system with and with out SVC have been Developed and Tested. SVC is comprised of a 1-Kvar thyristor controlled reactor in parallel with two thyristor switched 1-Kvar power capacitors. The test results to

inject or absorb VArs into the system for maintaining constant voltage profile have been presented in this paper. This fine tuning is accomplished by varying the firing delay angle (α) of the reactor, thus modifying the TCR VArs absorbed. Experimentally the P-V Curves of the test system without and with SVC have been drawn. Ultimately results show the effectiveness of SVC on Voltage Stability Enhancement.

2. Power System Stability

2.1. Classification of Stability

The stability of an interconnected power system is its ability to return to its normal or stable operation after having been subjected to some form of disturbance. The tendency of synchronous machine to develop forces so as to maintain synchronism and equilibrium is called stability. The stability limit represents the maximum stead state power flow possible when the synchronous machine is operating with stability. There are three forms of stability viz. Steady state stability, Transient stability and Dynamic Stability. Angle stability mainly involves the dynamics of generators and their associated control systems. Angle stability can be further categorized into transient stability and small signal or steady-state stability. Frequency stability is closely related to angle stability. Voltage stability mainly involves the dynamic characteristics of loads and reactive power. Voltage Collapse is perhaps the most widely recognized form of voltage instability.

2.2. Stability Improvement

Various kinds of stability improvement are: 1. Use of double circuit lines and bundle conductors , 2. Fast Acting AVR and ALFC loops 3. HVDC links, 4. Fast Acting C.B's, 5. FACTS Controllers, 6. Load shedding.

2.3. P-V Curve

As the power transfer increases, the voltage at the receiving end decreases. Finally, the critical or nose point is reached. It is the point at which the system reactive power is out of use. The curve between the variation of bus voltages with loading factor is called as P-V curve or 'Nose' curve. PV curves are used to determine the loading margin of the power system. The margin between the voltage collapse point and the operating point is the available voltage stability margin.

3. Operation of SVC

SVC behaves like a shunt-connected variable reactance, which either generates or absorbs reactive power in order to regulate the PCC voltage magnitude. In its simplest form, the SVC consists of a TCR in parallel with a bank of capacitors as shown in Figure 1 below. The SVC regulates voltage at its terminals by controlling the amount of reactive power injected into or absorbed from the power system. When system voltage is low, the SVC generates reactive power (SVC capacitive). When system voltage is high, it absorbs reactive power (SVC inductive).SVC principle is supplying a varying amount of leading or lagging VAR to the lagging or leading system. By phase angle control of thyristor, the flow of current through the reactor is varied. Hence by varying the firing angle alpha from 90 Deg. to 180 Deg. the conduction interval is reduced from maximum to zero.
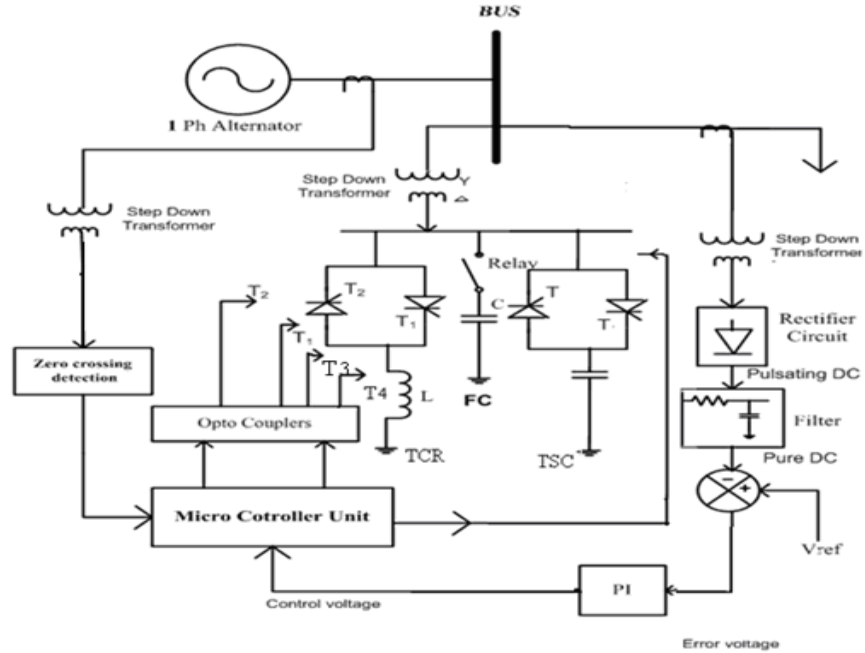
Figure 1. SVC with Control Concept Briefly Illustrated

$$\mathbf{Q}_{svc} = \frac{V^2 \left(X_C [2\pi - \alpha + \sin 2\alpha] - \pi X_L \right])}{\left(\pi X_C X_L \right)} \quad (1)$$

Generally, by changing the firing angle 'α' the fundamental reactance X_L of the reactor is changed. Conventional thyristor controlled compensator, the SVC, presents variable reactive *impedance* to, and thus acts indirectly on, the transmission network. The SVC functions as a controlled shunt reactive admittance that produces the required reactive compensating *current.* Thus, the attainable reactive compensating current is a function of the prevailing line voltage.

4. Design of SVC

The design of SVC is based on our test system Requirements. For any system find the variation of reactive power with load variations i.e $Q_d = (Q_1, Q_2, .., Q_n)$.Whare Q_d is the Reactive Power Demand and $Q_1, Q_2, ..., Q_n$ are the variations in demand.Set the Reference Voltage it may be set to 1.0 p.u or as closer as possible to it and find corresponding Reactive Power demand. Set reference reactive power Q_{ref} as 1.0 p.u (corresponding to voltage value of 1.0 p.u).The fixed Capacitor (FC) value of the SVC can be obtained as $Q_c = Q_{max} - Q_{ref}$, Where Q_c is the Reactive Power of the FC and Q_{max} is the maximum Reactive Power Demand. Figure 2 shows the TCR-TSC type SVC with control circuit
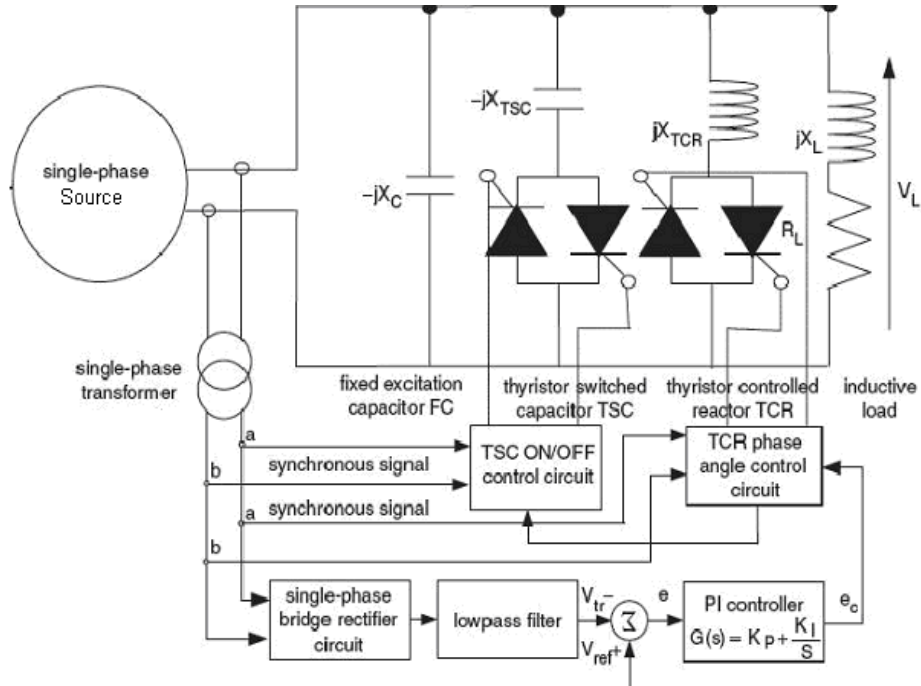
Figure 2. TCR-TSC Type SVC with Control Circuit

$$Q_c = V^2 / X_C \qquad\qquad (2)$$

Therefore $X_C = V^2 / Q_c \qquad\qquad (3)$

$$X_C = 1/2\pi fC$$

$$C = 1/2\pi X_C$$

In SVC circuit X_C is in parallel with X_l

$$Q_{tcr}(\alpha) = Q_{ref} - Q_{min} \qquad\qquad (4)$$

$$X_l = =V^2 / Q_{tcr}(\alpha) \qquad\qquad (5)$$

$$Q_{svc} = Q_c - Q_{tcr}(\alpha) , \qquad\qquad (6)$$

Hence SVC can supply dynamic Reactive power support for maintaining the constant voltage which will enhance the Generator and voltage stability margins tremendously.

5. Implementation of Control Circuit Using Micro Controller

The Power and Control circuits of SVC (TSC-TCR) for the SMTB test system as shown in the Figure 3, Figure 4 and Figure 5 shows the corresponding control and power circuits of SVC. The developed control algorithm using terminal voltage feedback is tested in the laboratory. The assembly program is developed and programmed using LPC-2148 microcontroller which is targeted to keep the terminal voltage as constant irrespective of load variations.

Figure 3. Control Circuit of SVC (TSC-TCR)

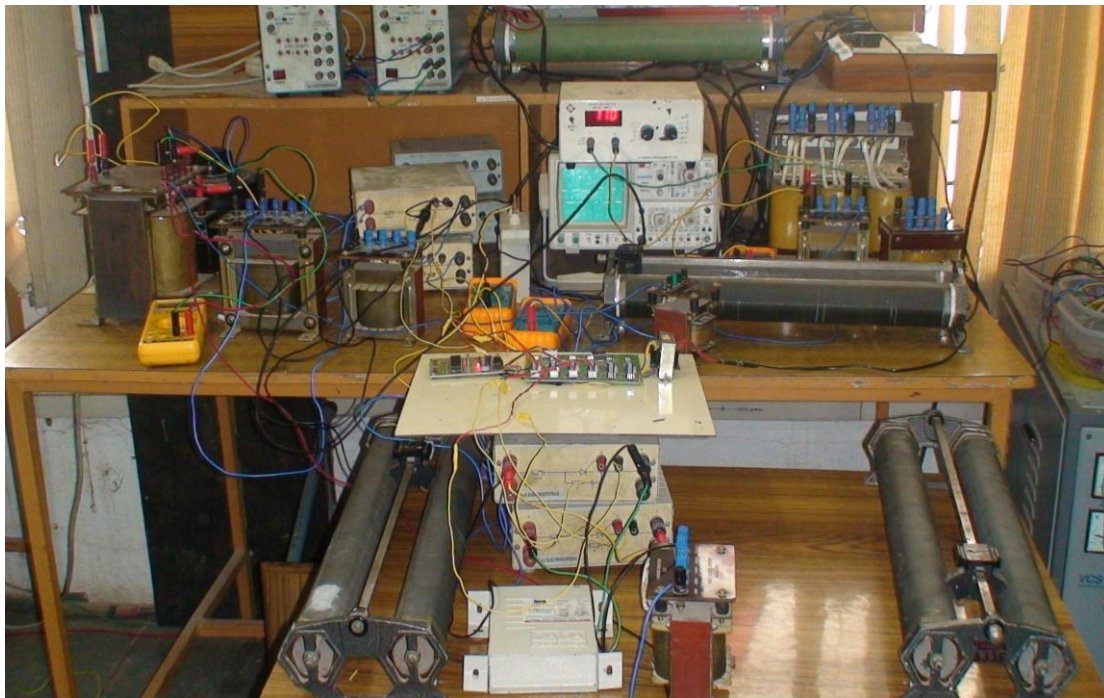**Figure 4. Laboratory Setup of SMTB Test System with SVC**

Figure 5. Laboratory Setup of SMTB Test System with Power and Control Circuits of SVC (TSC-TCR)

5.1. Data Acquisition System

According to the previous section, the overall arrangement data acquisition for single phase system is shown in the Figure 6 below.
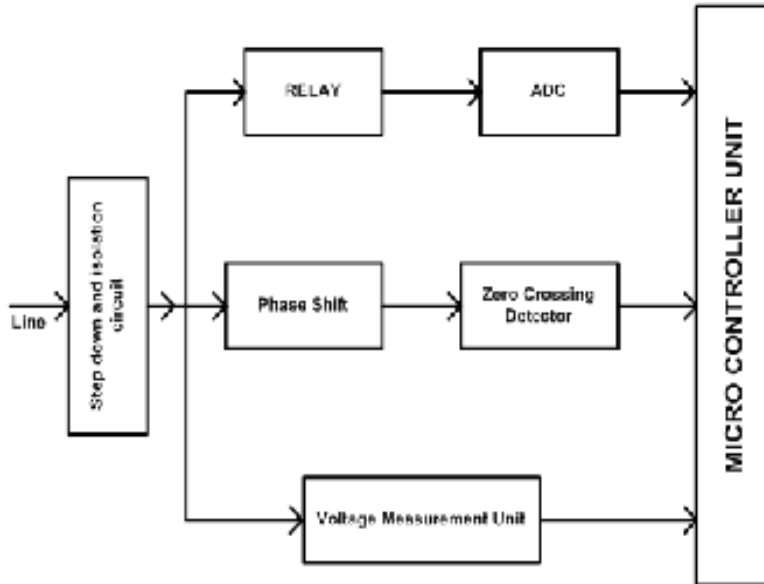

Figure 6. Block Diagram of the Data Acquisition System

The fundamental requirement is that the voltage to be measured must be stepped down by factors that would not render the measured values inaccurate and hence unreliable. An analog to digital converter is added in order to facilitate an instantaneous reading of the phase voltages by the microcontroller. The zero crossing detector permits the detection of negative and positive half-waves and hence reading the peak of the corresponding half wave.

5.2. Control System Elements

The microcontroller, which is used as part of the control system in voltage balancer, must be able to respond to the analog electrical quantities. The analog electrical quantities (i.e. Voltage) is to be converted into digital values suitable for the microcontroller by using an ADC converter. The block diagram of the completed control system is shown in Figure 6.
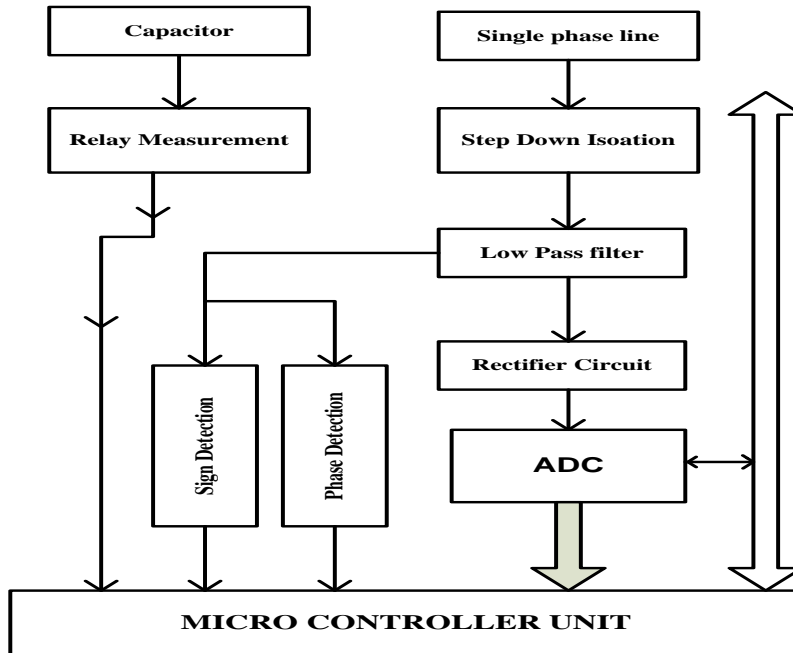
Figure 7. Control System Architecture

6. Development of Algorithm: Results

The LPC2148 microcontroller is used in order to perform the control function. The software developed coordinates the role of the various hardware components, measures the electrical quantities, processes and generates the firing pulses to the thyristors to connect in or out either the capacitors or the inductors. A flowchart of the program is shown in Figure 7, it should be noted that the flowchart illustrate the developed algorithm. For convenience, subroutines have been used whenever possible, since they had to be used more than once in most cases and data is processed every half cycle and an SVC can only be fired once per half cycle. The developed flowchart of control algorithm is as shown in the Appendix Figure 8.The test results have shown in Figure 8, which shows the effectiveness of control algorithm.
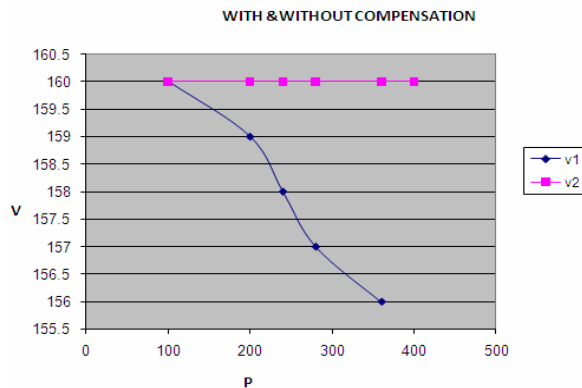

Figure 8. P- V Curves without and with SVC

7. Conclusions

In this paper, TSC-TCR type SVC is designed, fabricated, tested manually and controlled automatically to get constant voltage by supplying variable reactive power to the system. The hardware and software of this SVC control system is developed based on Microcontroller LPC 2148 chip, the most modern industrial controller. The power circuit of single phase 2KVAR TSC-TCR type SVC have been design and tested experimentally using a test system.

The automatic control circuit of SVC has been developed using LPC2148 Microcontroller and also tested with the test system. P-V curves have been drawn with and with SVC. Results demonstrate the effectiveness of the developed control algorithm of the compensator on voltage control and thereby the improvement in voltage stability margin.

Acknowledgements

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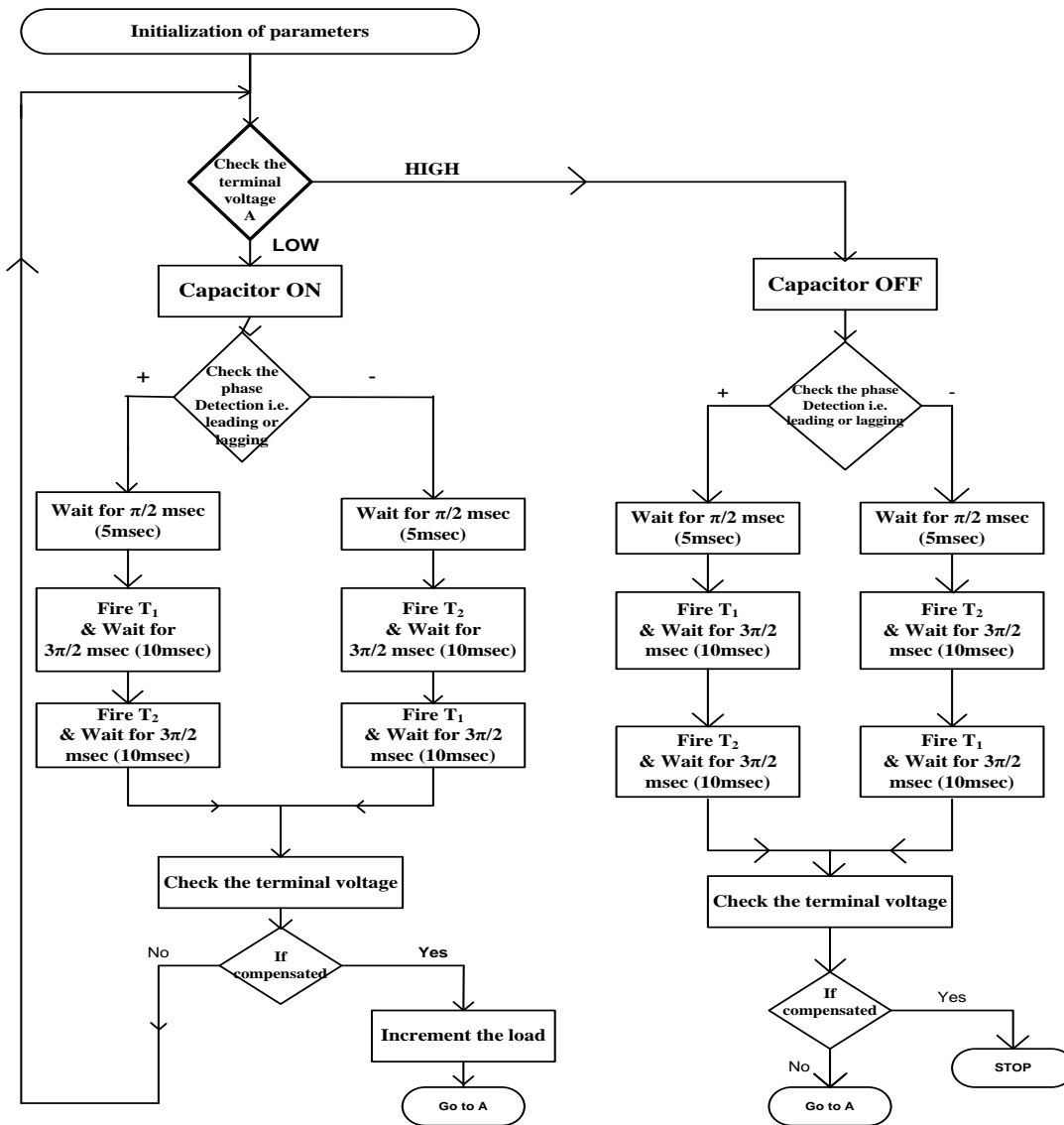
Appendix

Figure 9. Flowchart Describing Control Algorithm of SVC