International Journal of Advance Research in Science and Engineering
Volume No.07, Special Issue No.03, February 2018
www.ijarse.com
IJARSE
ISSN: 2319-8354

A Prototype Hardware Model of TSC-TCR Static VAR Compensator With Closed Loop Control For Dynamic Reactive Load

Reshma Mane[1], Puja Gurav[2], Swapnil Patil[3]

[1, 2] Professor, Electrical,
Nanasaheb Mahadik College of Engineering, Peth, Shivaji University, (India)
[3] Professor, Electrical,
Annasaheb Dange College of Engineering, Ashta, Shivaji University, (India)

ABSTRACT

The proposed topology work deals with a firing angle range control and minimization of harmonics in thyristor controlled reactor (TCR) and transient free switching of thyristor switched capacitor (TSC). In recently Static VAR Compensators generally consists of a TSC and a TCR and compensates loads through generation or absorption of reactive power. The operation of TCR at appropriate conduction angles can be used advantageously to meet the phase-wise unbalanced and varying load reactive power demand in a system. However, such as an operation deteriorates the quality of power supply through percolation of harmonic currents generated into the mains. This topology proposes how the delta connected TCR minimizes the harmonic components and transient free switching operation of TSC bank. Harmonics in the SVC can be minimizing by controlling the firing angle within the range of TCR. Also it provides almost step less variation of reactive power.

Keywords : Firing angle, TSC, TCR, Transient Free Switching, Conduction Angle.

I.INTRODUCTION

This is well documented in literature and through public discussions at various levels that a substantial power loss is taking place in our low voltage distribution systems on account of poor power factor, due to inadequate reactive power compensation facilities and their improper control. [1,2] Switched LT capacitors can directly supply the reactive power of loads and improve the operating condition. Government of India has been insisting on shunt capacitor installations in massive way and encouraging the state electricity boards through Rural Electrification Corporation and various other financing bodies. The expansion of rural power distribution systems with new connections and catering to agricultural sector in wide spread remote areas, giving rise to more inductive loads resulting in very low power factors. [3] The voltages at the remote ends are low and the farmer‘s use high HP motors operating at low load levels with low efficiencies. This is giving rise to large losses in the distribution network. [4]

In case of power system there mainly two types of compensating devices, static shunt compensators and static series compensators and one another type i.e. combined compensator. Static series compensators are Gate Turn Off thyristor (GTO), Thyristor Controlled Series Capacitor (GCSC), Thyristor Switched Series Capacitor (TSSC), Thyristor Controlled Series Capacitor (TCSC), Static Synchronous Series Compensator (SSSC), Static shunt compensators are Static Synchronous Compensators (STATCOM) and Static VAR Compensator (SVC) , combined compensators Unified Power Flow Controller (UPFC), Interline Power Flow Controller (IPFC). [5] The SVC is indispensible and based on proven technology for reactive power compensation. Traditionally SVC has been used as shunt device that offers voltage stability and reactive power compensation to the load or at PCC (Point of Common Coupling). Since EPRI‘s (Electric Power Research Institute) release of FACTS strategies in 1987 SVC‘s have grown in popularity and are well established in power industry. The Basin Electric Power Corporation (BEPC) installed the first SVC at Nebraska in 1977. Typical shunt compensator to be employed in a distribution system primarily consists of shunt capacitor and shunt reactors to provide variable inductive reactive power respectively. Reactors are employed in power systems for various purposes both in series and shunt forms in LT and HT systems. There exists number of types designed and manufactured to serve variety of applications

Major Drawbacks which are appeared in Literature Survey:

1. TCR generates harmonics due to controlling of reactor.
2. More I2R losses in TCR due to use of large amount of Cu.
3. Also cost of TCR is more due to use large amount of copper and Filter required to eliminate Harmonics which are generates due to mainly TCR.

These are some major disadvantages appears in literature survey. [6, 7]

In this paper the drawbacks which are appear in literature are overcome in proposed topology in following way:

1. By choosing capacity of TCR bank as same like smallest capacity of TSC bank among all five TSC banks. Because of choosing smallest capacity TCR bank harmonics content are very low and also the required firing angle range is small.
2. Due to smallest capacity of TCR, small amount of copper conductor is used that‘s why less I2R losses.
3. Due to small capacity of TCR, the copper conductor material is used in less amounts and small capacity filter is reactor so that cost of proposed topology is very low.

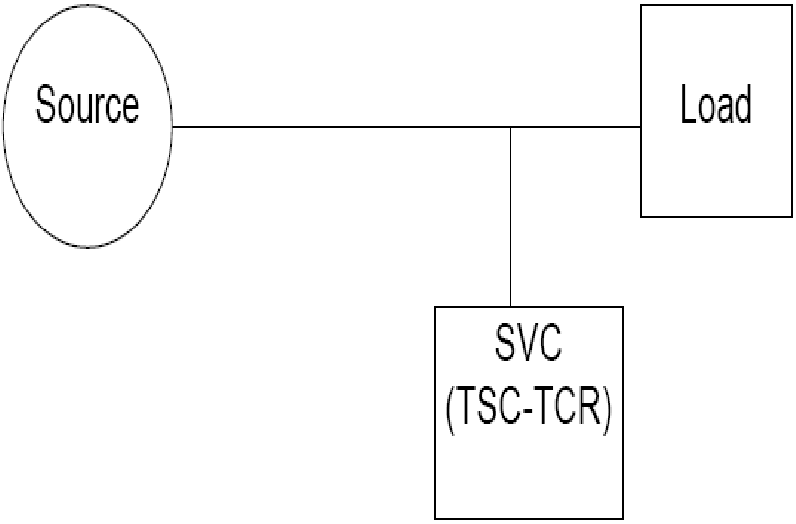

Fig.1 Proposed Topology

II.OBJECTIVES OF PROPOSED TOPOLOGY

1. Maintaining the power factor at unity.
2. Maintaining the power factor at the PCC to any specified value.
3. Transient free switching of capacitors is carried out.
4. Obtain almost step less control of reactive power so that we can operate the system at any desired power factor.
5. Minimum feeder current and loss reduction.
6. Improvement in distribution feeder efficiency.
7. Improvement in the voltage at load end.

III.PROPOSED TOPOLOGY

This paper presents a simple topology, which is shown in Fig.1. The proposed scheme consists of thyristor Switched capacitor (TSC) banks operated in conjunction with thyristor controlled reactor (TCR) of the smallest step size. In proposed scheme the harmonics are eliminated by using suitable firing angle range control of TCR.

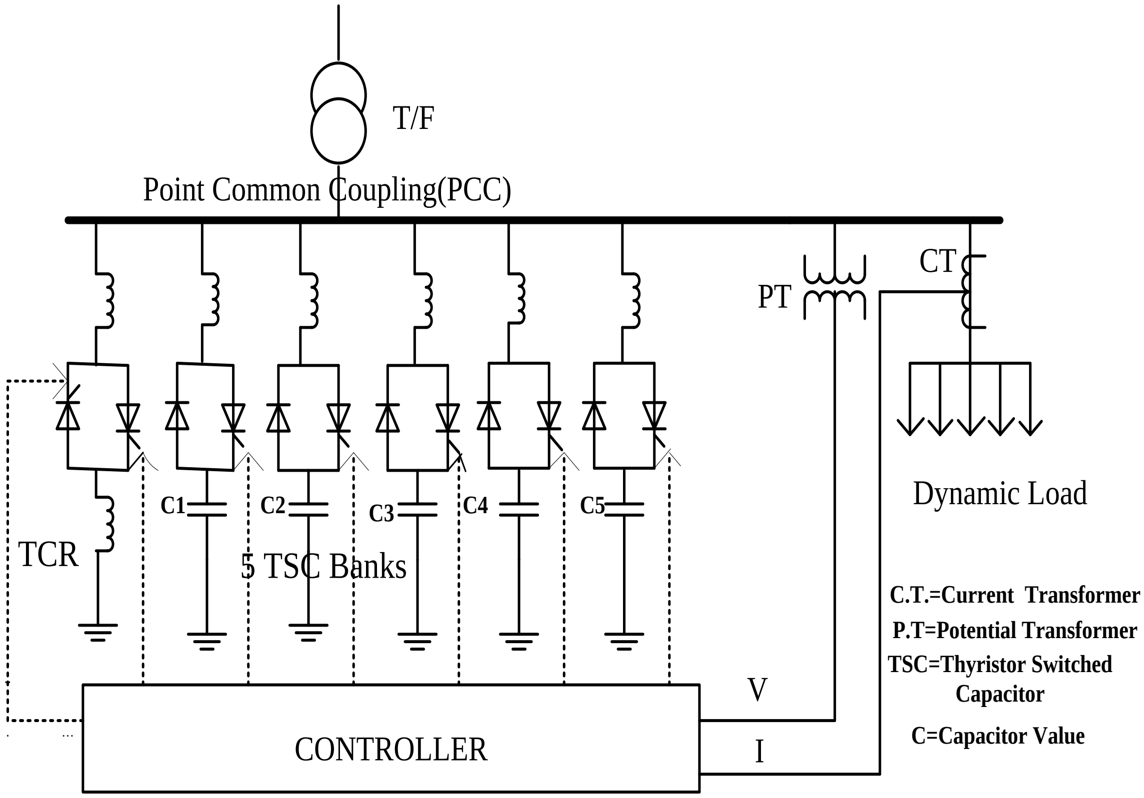

Fig.2 Block diagram of TSC-TCR Compensator

In above proposed topology block diagram Fig. 2 five TSC banks values are 5,5,10,10,20 KVAR. Smallest capacity TSC bank value is 5 KVAR. So TCR bank value chosen is of 5KVAR variable. In case of literature FC-TCR scheme for 50KVAR system reactor is of 50 KVAR used. But in case of TSC-TCR scheme for 50 KVAR system, TCR bank value should be of 5 KVAR having same capacity as like smallest TSC bank. In case of FC-TCR system 10 times greater TCR unit is used as compared to TSC-TCR. So because of using smallest capacity of TCR unit the drawbacks overcome in proposed topology appeared in literature. So system having advantages **Reduced THD, Less Losses, Low cost.**

A. *Firing angle range control for minimizing harmonics in TCR:*

A basic TCR consist of an anti-parallel connected pair of thyristor valves in series with reactor. The anti-parallel connected thyristor pair acts like a bidirectional switch. The TCR acts like a variable susceptance. Variations in the firing angle, alpha changes the susceptance and consequently, the fundamental current component which is shown by equation;

$$I_L(\alpha)=\frac{V}{wL}\left(1-\frac{2}{\pi}\alpha-\frac{1}{\pi}\sin 2\alpha\right)$$

V-Peak value of the supply voltage

w- Angular frequency of supply voltage

α -Firing angle

The controllable range of TCR firing angle ‘α’ extends from 90^{o} to 180^{o} . In case of ideal reactor of L Henry firing angle of 90^{0} results in full conduction with continuous sinusoidal current flow. The relation between firing angle ‘α’ and the current through inductor ‘I_L’ for ideal inductor having resistance tending towards zero.

Thus the TCR acts like a variable admittance. By varying the firing angle ‘α’ admittance changes and consequently fundamental current component which in turn gives rise to variation of reactive power absorbed by reactor, if continuous conduction of current take place. However, if firing angle is increased beyond this, non sinusoidal currents are generated and hence harmonics get occurred. All TSC‘s are arranged in such manner that it results into the reduced TCR capacity. Therefore harmonic distortion as well as cost of overall system gets reduced. TCR of capacity 5 KVAR is used because minimum capacitor bank step size is 5 KVAR.

B. Transient free switching of TSC bank:

TSC consists of an anti-parallel connected thyristor and diode, thyristor as a bidirectional switch. The anti-parallel connected diode and thyristor are in series with a capacitor. Transient free switching of capacitors is obtained by satisfying following two conditions;

a) Firing the thyristors at the negative/positive peak of supply voltage.

b) Pre-charging the Capacitors to the negative/positive peak of supply voltage.

C. Controller:

Controller is the heart of compensator. Voltage (V) and current (I) at PCC are sensed by Potential Transformer (P.T.) & Current Transformer (C.T.) respectively and given to controller. Controller determines the value of reactive power required to achieve the desired power factor & then generate the control signals (gate signals) which are given to SVC. By coordinating the control of SVC, it is possible to obtain almost step-less control of reactive power in closed loop by the control signals (gate signals) which are given to SVC

IV.PROTOTYPE HARDWARE IMPLEMENTATION

The below Fig. 3 shows the Block Diagram of prototype hardware model of TSC-TCR SVC Compensator with the various components for reactive power sensing and control, used in the controller. It includes KVAR sensor (CT and PT), ADC converter, zero crossing detectors, I to V convertor and gate pulse generation for TSC bank to ON/OFF bank with the help of microcontroller 89C51.

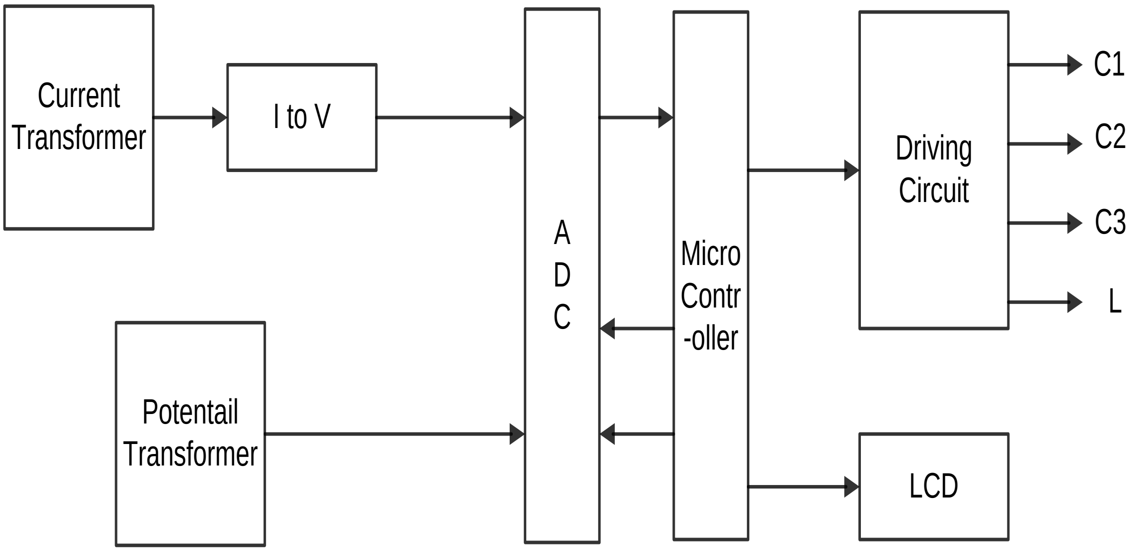

Fig.3 Prototype Hardware model of TSC-TCR SVC compensator

Hardware Result:

- **Experimental Results**

All the above components are fabricated, tested and implemented as a prototype hardware model, at 230 volts, 50Hz, 1phase AC supply. The load was increased from 0 VAR to 1500 VAR. The details of the system performance with and without TSC-TCR Compensator are given in the Table 1 and Table 2 respectively.

TABLE 1 System Performance without TSC-TCR Compensator:

Sr. No.	Voltage (V)	Current (A)	Active Power (KW)	Reactive Power (KVAR)	Apparent Power (KVA)	Power Factor (p.f)
1.	227.7	0.8	0.18	0.01	0.18	1.00
2.	227.9	0.9	0.18	0.10	0.20	0.88
3.	227.8	1.1	0.17	0.17	0.24	0.70
4.	227.7	1.1	0.17	0.18	0.24	0.70

TABLE 2 System Performance with TSC-TCR Compensator:

Sr. No.	**Voltage (V)**	**Current (A)**	**Active Power (KW)**	**Reactive Power (KVAR)**	**Apparent Power (KVA)**	**Power Factor (p.f)**
1.	227.8	1.2	0.24	0.14	0.27	0.88
2.	226.5	1.0	0.23	0.05	0.24	0.99
3.	226.6	1.0	0.23	0.06	0.23	0.98
4.	225.0	1.0	0.22	0.06	0.23	0.98

- **Experimental setup:**

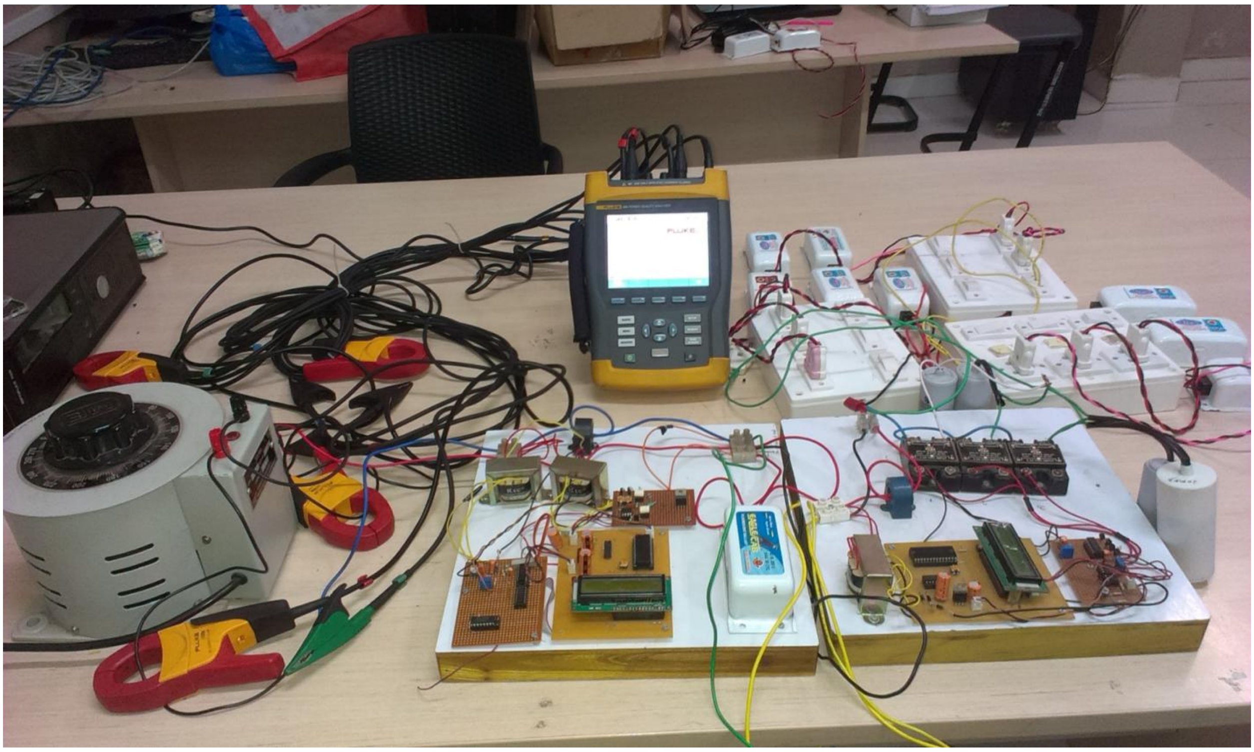

Photo 1. Experimental Set up of TSC-TCR

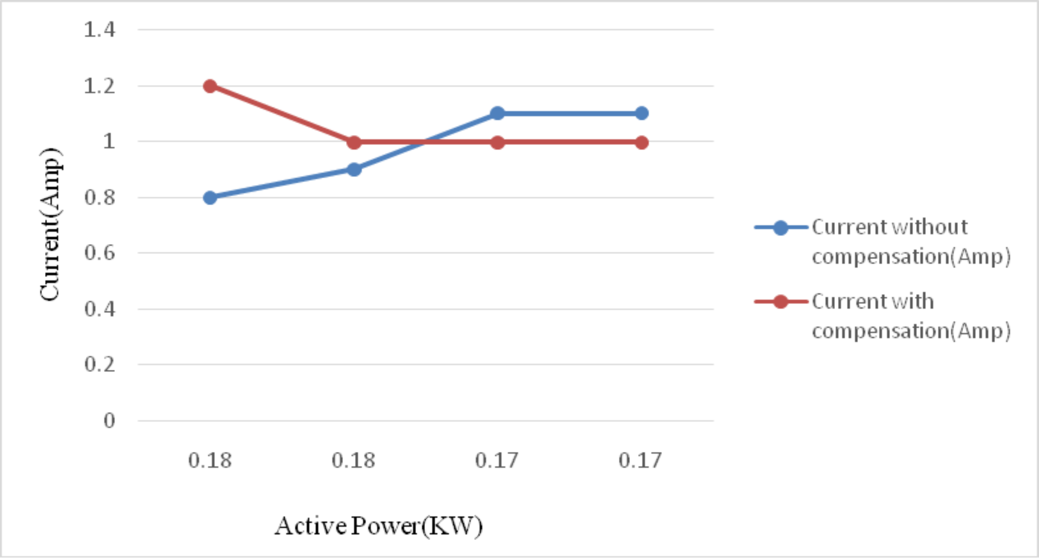

Fig. 4 Reduction in Load Current

As shown in Fig. 4 without compensation current increases with increase in active power. When system is compensated current decreases with increase in active power. It will reduce the losses.

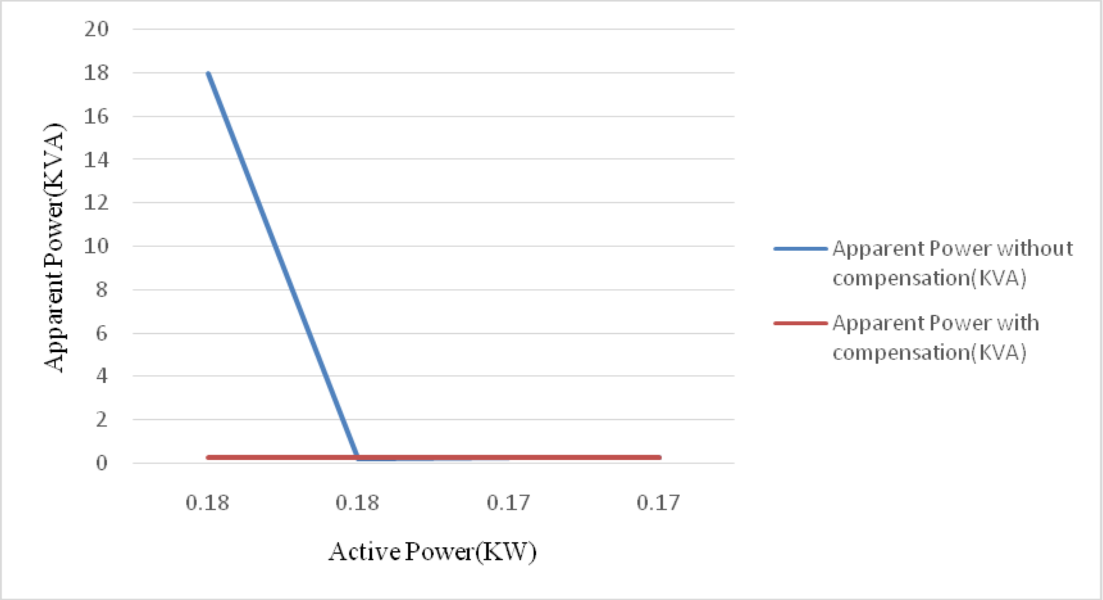

Fig. 5 Reduction in Load Reactive Power

As shown in Fig. 5 in without compensation system, reactive power drawn from the supply increases with active power. When the system is compensated reactive power decreases even if active power increases.

As shown in Fig. 6 in without compensation system, active power increases with small change then apparent power decreases. In compensated system apparent power is constant throughout.

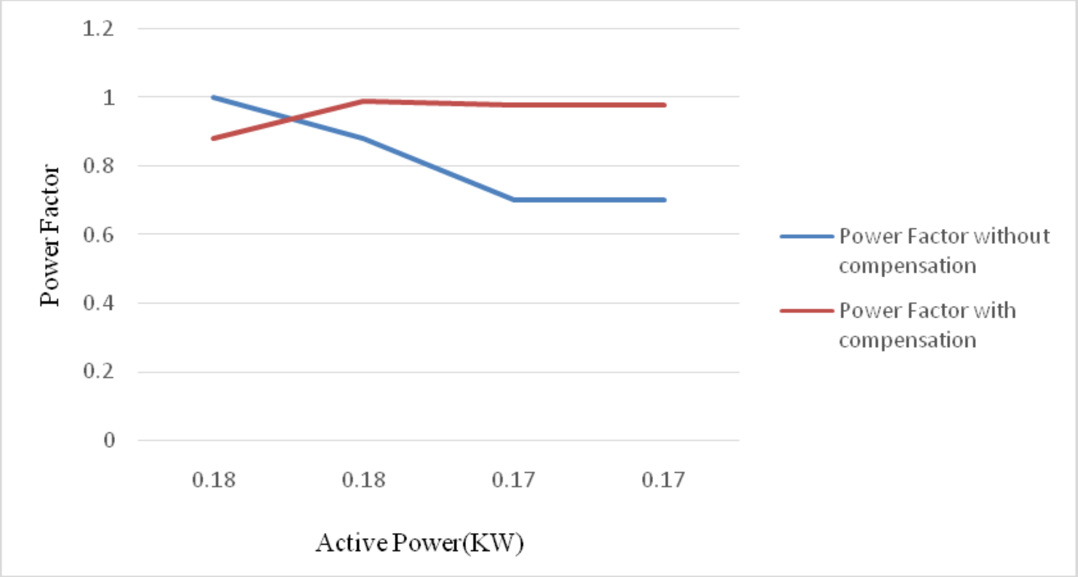

Fig 6 Reduction in Apparent Power

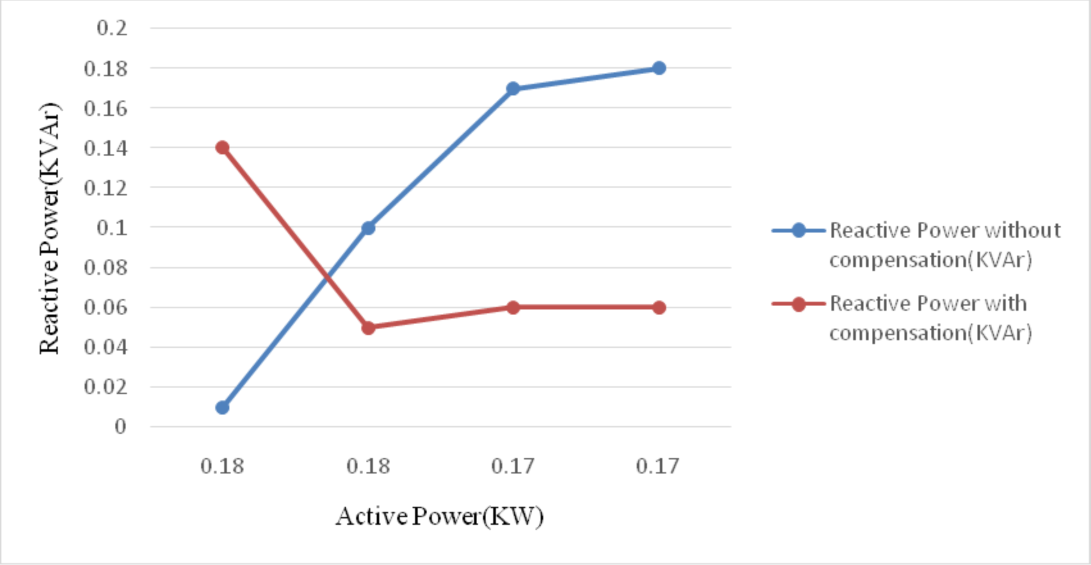

Fig.7 Improvement in Load Power Factor

As shown in Fig.7 in without compensation system, power factor is low. It will affect the system adversely but in compensated system it is maintained at unity.

V. CONCLUSION

Reactive power compensation using combination of TSC-TCR SVC has been presented. The TSC banks values are chosen in such manner that it weights to make the resolution small and to reduce the capacity of TCR. It helps to reduce losses, Harmonics and Cost of TCR. The current flowing through TSC bank is transient free. Almost Step less control of reactive power can be obtained by coordinating the control between TSC-TCR. The proposed scheme can be implemented where there are fast variations in reactive power such as arc furnaces, welding equipments etc.

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