

# A Transient Free Novel Control Technique for Reactive Power Compensation using Thyristor Switched Capacitor

<sup>1</sup>Chaudhari Krunal R, <sup>2</sup>Prof. Rajesh Prasad

<sup>1</sup> PG Student, <sup>2</sup>Assistant Professor,

Electrical Engineering Department, Sarvajani College of Engineering & Technology, Surat, India

<sup>1</sup>[kkrunal2270@yahoo.com](mailto:kkrunal2270@yahoo.com), <sup>2</sup>[rajesh.prasad@scet.ac.in](mailto:rajesh.prasad@scet.ac.in)

**Abstract**— Nowadays the power system is complicated and it's very difficult to fulfill the required demand with good power quality. Power electronics based FACTS device are one of the suitable solution for improving power quality. FACTS devices are divided as Shunt controller and Series controller. Shunt controller called Static Var Compensator (SVC) are used for power factor correction and to improve voltage profile while Series controller are used to control power flow or improve transient stability. Among the various SVCs controller, Thyristor Switched Capacitor (TSC) is proposed in this paper because of their advantages over other SVCs. In this paper, firstly a controller is designed for TSC with simple circuit model is simulated. The modeling and simulation results with improved transient response were obtained in MATLAB software tool. The hardware model with novel control technique of TSC is also discussed with results.

**Index Terms** - FACTS Controller, TSC, SVC, Reactive Power

## I. INTRODUCTION

With increasing demands, our power system network is largely interconnected for economic reason and very complex to meet that demands. During transmitting the power from one to another station, there are many losses which may lead to excessive reactive power in system, poor voltage profile and it is difficult to control the effective player of the system. Due to inadequate reactive power compensation facilities in our power system, there is substantial power loss taking place which results in poor power factor<sup>[1]</sup>.

Reactive power requirement for the system can be fulfilled by connecting a device with transmission line which has ability to inject or absorb reactive power to regain reactive power balance in system. One of the most important reactive power sources is power electronics based FACTS device and it has ability to control the power flow by adjusting system parameters such as line impedance, phase angle and voltage magnitude in power system<sup>[2]</sup>. The FACTS Controller is defined as “a power electronic based system and other static equipment that provide control of one or more AC transmission system parameters.” The advantages of FACTS are:

- Power quality improvement
- Voltage profile improvement
- Power factor correction
- Less active and reactive power loss
- Improvement in efficiency of power system operation

A shunt connected TSC is important building block of thyristor based SVCs and applied by utilities for several purposes<sup>[3]</sup>. The major components of a TSC are switched capacitor employed with two anti-parallel thyristor pair and inductor. TSC is simply controlled by on - off control technique<sup>[4]</sup>. This paper deal with a transient free novel control technique to control the TSC located at midpoint of transmission network, which provides voltage regulation and the reactive power. The effect of TSC to load voltage has been discussed with simple circuit model.

## II. THE THYRISTOR SWITCHED CAPACITOR

TSC is one of shunt connected compensator used to provide rapid and continuous control of reactive power. TSC has advantages: stepwise control, cheaper device, and no generation of harmonics and hence no filtering is required. A TSC defined as “A shunt connected, thyristor switched capacitor whose effective reactance is varied in stepwise manner by full or zero conduction operation of thyristor valve.”<sup>[5]</sup>

Fig 1 shows simplified TSC circuit. As shown in fig 1, the TSC consists of a capacitor, inductor and two anti parallel thyristors supplied from ideal ac voltage source. Fig 2 shows voltage and current waveforms. The capacitor voltage is not equal to the supply voltage when the thyristors are fired. After closing the switch, an infinite magnitude current flows and charges the capacitor for infinitely short time to the supply voltage. The thyristors cannot withstand this stress and it would fail. Hence an inductor must be

connected in series with switched capacitor to avoid inrush current of the capacitor. The capacitor value is chosen based on the desired compensation power [4].

Since each capacitor is connected at zero voltage across the thyristor, resulting is no on-switching transient and disconnection takes place at zero current, resulting in no turn-off transient [6].

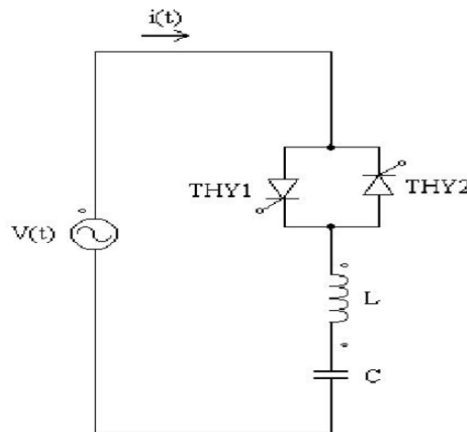


Fig 1 Basic structure of TSC

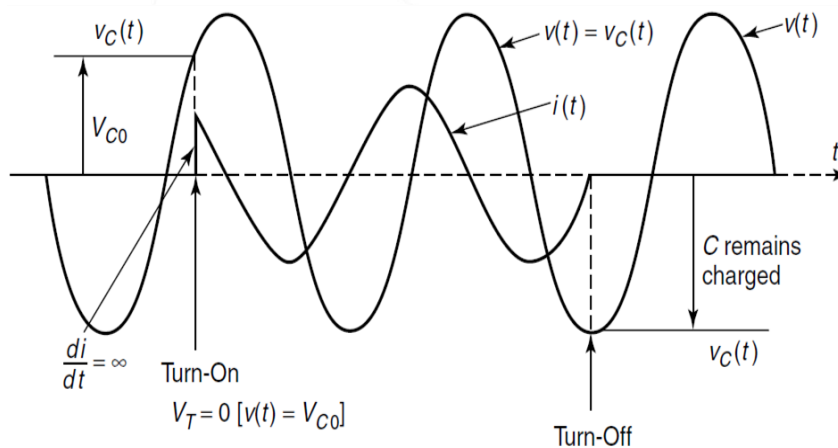


Fig 2 Voltage and current waveforms

**Switching Strategies for Thyristor Switched Capacitor:**

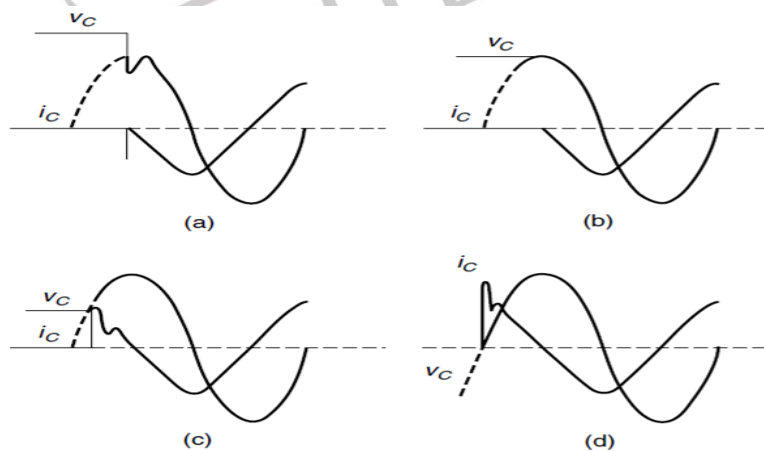


Fig 3 Switching Strategies for TSC

The switching strategies shown here to minimize the transients to acceptable limits and are based on very simple technique to decide when the thyristors should be fired. The capacitors discharge if they are not connected to the system. Therefore, any initial voltage across the capacitor is possible. If capacitor is charged ( $V_{C0} < V$ ) or overcharged ( $V_{C0} > V$ ), at the time of demand for the capacitor, it is switched on, when the voltage across the thyristor valve reaches zero.

This firing strategy uses to limit the current transients. It requires no special capacitor charging strategy and can operate with conventional ac power capacitors. It is widely used in TSC plants for transmission systems. The strategy is presented in fig. 3 in a simplified manner for four cases:

- Firing at the minimum valve voltage,  $V_c > V_s$
- Firing at the zero valve voltage,  $V_c = V_s$
- Firing at the zero valve voltage,  $V_c < V_s$
- Firing at the zero valve voltage,  $V_c = 0$

But at the time of switching, thyristor voltage is not equal to supply voltage, but it is higher than the supply voltage. This increase thyristor rating and reduce the efficiency of system.

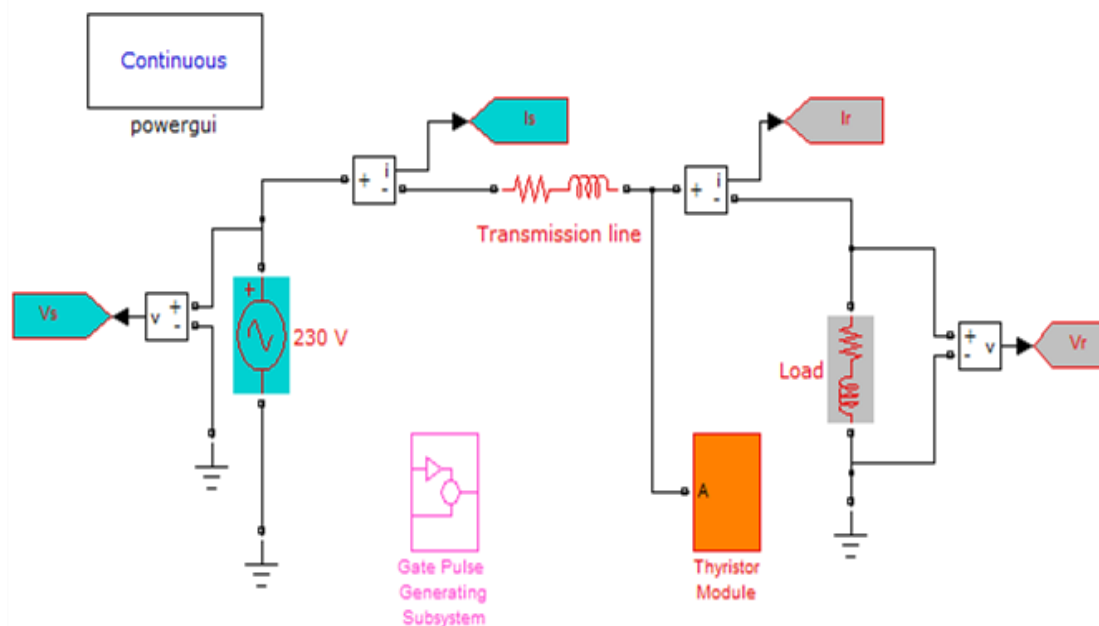
### III. SIMULATION MODEL AND RESULTS

In this paper, firstly a single phase system of lagging power factor load with a short transmission line is modeled and this circuit is used to show the effect of TSC. Table 1 shows parameters:

Fig 4 shows TSC type SVC configuration for above mentioned parameters. In TSC, a capacitor is connected in series with inductor and two anti-parallel thyristors.  $V_s$ ,  $V_r$ ,  $V_c$  and  $V_t$  are supply end voltage, receiving end voltage, capacitor voltage and thyristor voltage respectively.  $I_s$ ,  $I_r$  and  $I_t$  are supply side current, receiving side current and thyristor current respectively which flows through the TSC circuit.

**Table 1: Circuit parameters**

Supply Voltage	230 Volts
Supply Frequency	50 Hz
Transmission line Resistance	2.2 $\Omega$
Transmission line Inductance	2.4 mH
Load	300 watts
Actual Load power factor	0.70 lagging
Desired power factor	0.98 lagging
Capacitor	20 $\mu$ F



**Fig 4 Simulation Model of TSC**

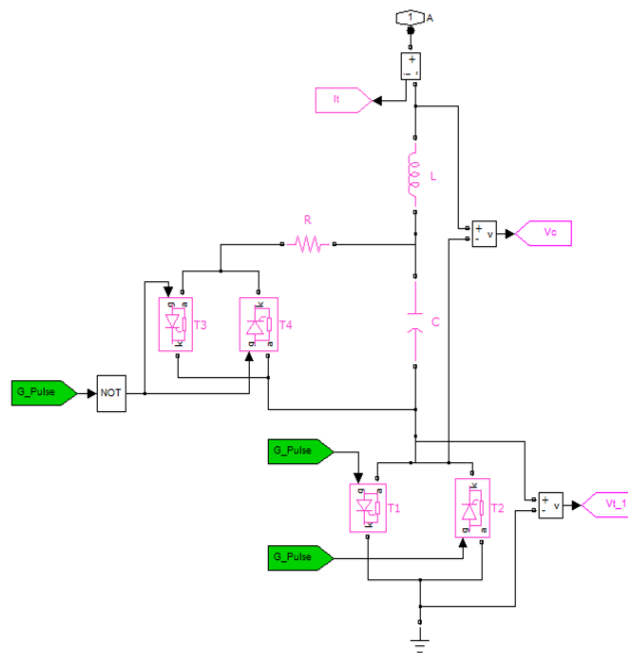


Fig 5 Thyristor Module

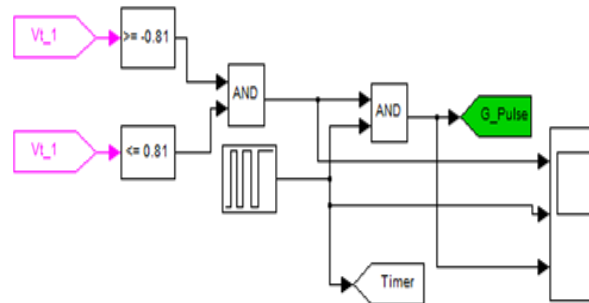


Fig 6 Gate Pulse Generating System

TSC is high speed controlled reactive device and it provides stepped response used for voltage control through its utilization. TSC is simply controlled by ON/OFF control technique and firing takes place when the thyristor voltage has zero crossing. The forward voltage is 0.8 volt. Hence measured thyristor voltage is compared with forward voltage drop of thyristor i.e 0.8 volt to determine the zero voltage across the thyristor valve and it is also compared logically with timer, results no switching transients. Fig 6 shows gate pulse generating system and fig 5 shows the Thyristor Module which connected at midpoint of the system. The new control scheme implemented for TSC works as follows:

- Firstly, the zero voltage across thyristor valve is detected using thyristor forward voltage, comparing with positive and negative forward voltage of two anti-parallel thyristor.
- Thyristor voltage is logically compared with timer which decides the TSC ON/OFF instants.
- In this novel control tech., for every condition of capacitor voltage, the capacitor is discharge when thyristor is on and this discharging time is depend open the value of capacitor and resistor which connected with Thyristor module.

With this novel control technique, it also limits the thyristor voltage and restricted to acceptable limit. For all above cases, thyristor voltage is equal to supply voltage, not the twice of the supply voltage, which reduce the thyristor rating. Thus, improvement of voltage profile and power factor occurs with addition of reactive power to the system.

**Design of CAPACITOR:**

Consider load of 300W, with 0.70 lagging power factor. The desired power factor is 0.98 lagging, and the improvement is done depending on the following calculation.

Assuming 100% efficiency,

Leading kVAR taken by condenser bank,  
 $= P (\tan \phi_1 - \tan \phi_2)$   
 $= 245.16 \text{ VAR}$

Now,  $\text{kVAR/phase} = V_{ph} \times I_{CP}$   
 $= 162.2 \times 50.96 \times 10^3 \times C$

Where,  $I_{CP}$  = Phase current of capacitor

Now, the capacitor value,

$162.2 \times 50.96 \times 10^3 \times C = 245.16 \text{ VAR}$

The value of capacitor connected is **20  $\mu\text{F}$** .

The Simulink model of TSC shown in fig 4 for above mention load with 20  $\mu\text{F}$  capacitor is simulated in MATLAB software tool and results are obtained as follows:

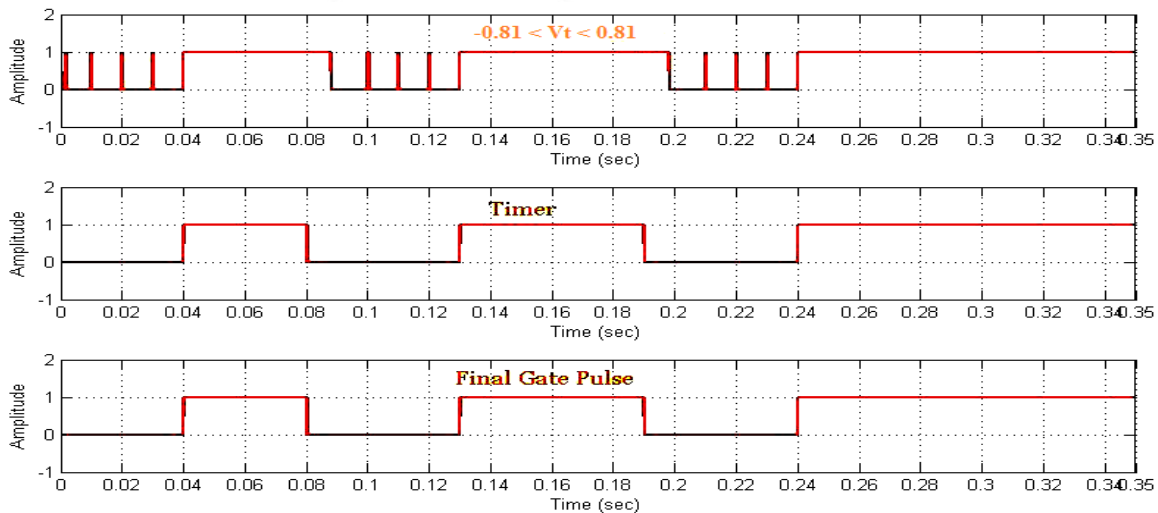


Fig 7 Final Gate pulse

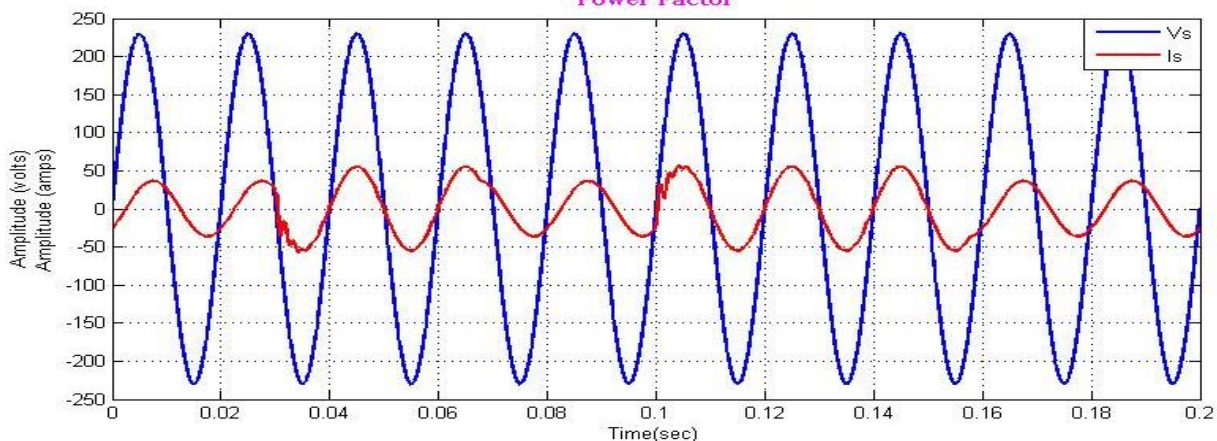


Fig 8 Power Factor with Novel Control Technique



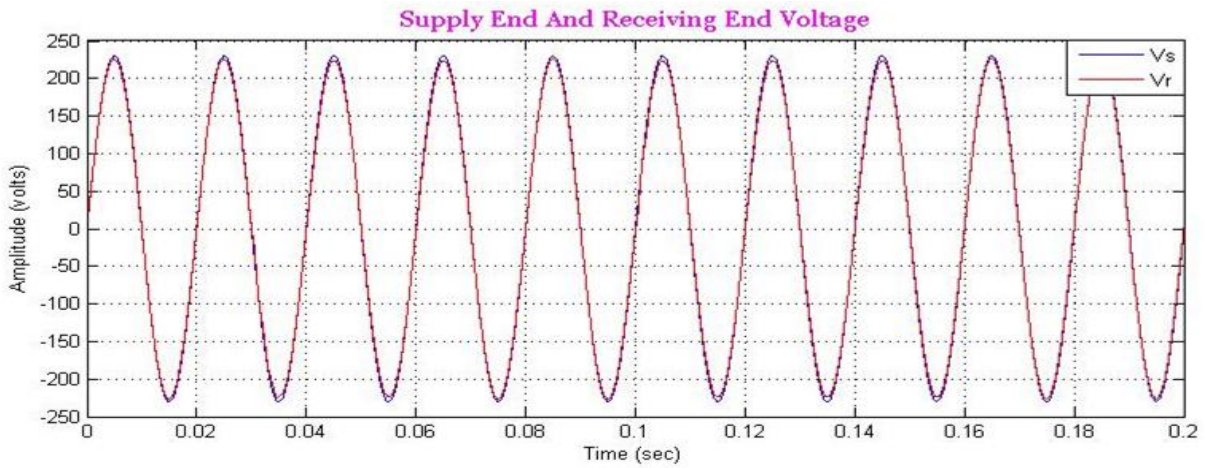


Fig 9 Supply end and Receiving End Voltage with Novel

Fig 7 shows final gate pulse for thyristor pair. It can be seen that TSC is ON at zero crossing of capacitor voltage. Fig 8 shows the simulation results with improved power factor and fig 9 shows the simulation results of supply end and receiving end voltage with applying novel control technique. It can be seen in fig 8, the voltage phase is lags current phase and the transients are eliminated by applying control technique to the TSC. At 0.03 sec and 0.1 sec, phase difference between voltage and current is zero and the power factor is increases.

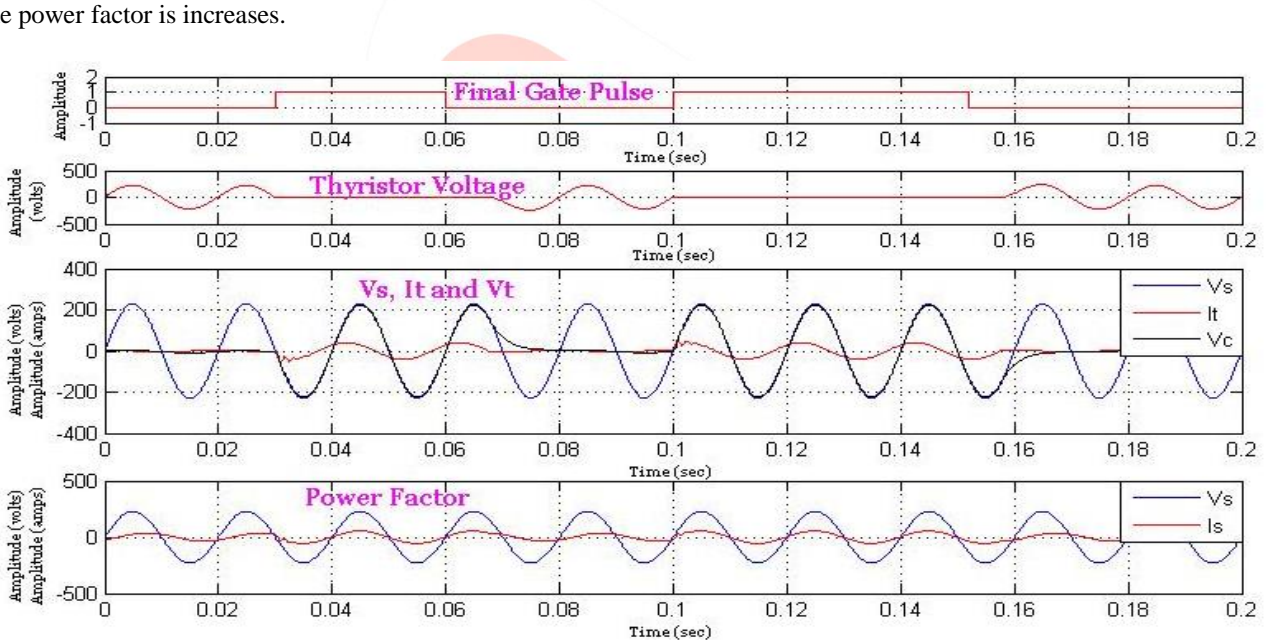


Fig 10 Simulation Results, when  $V_c = 0$

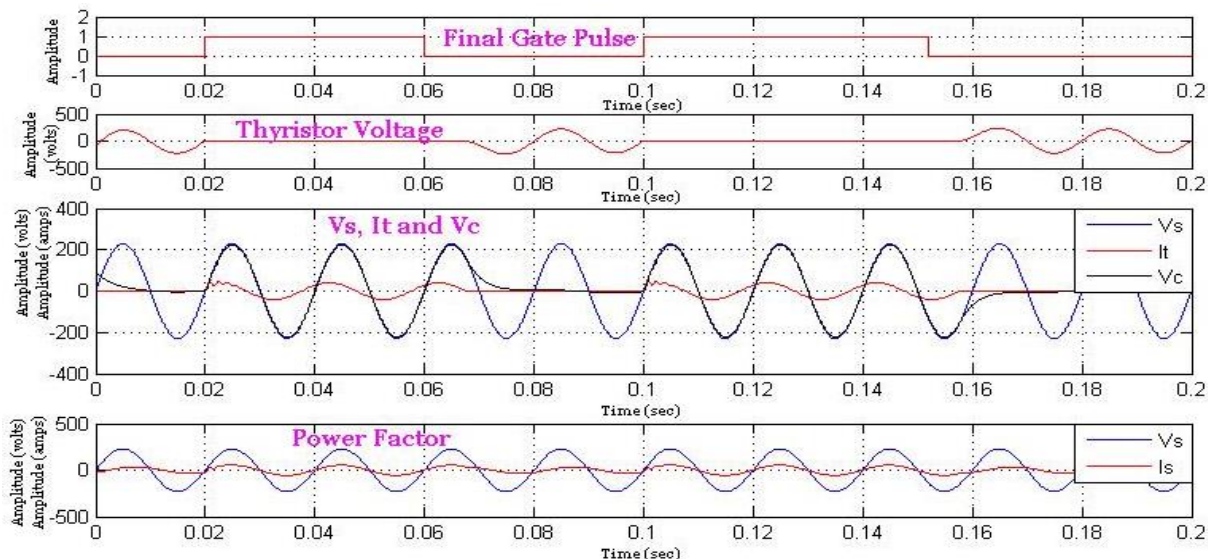


Fig 11 Simulation Results, when  $V_s > V_c$

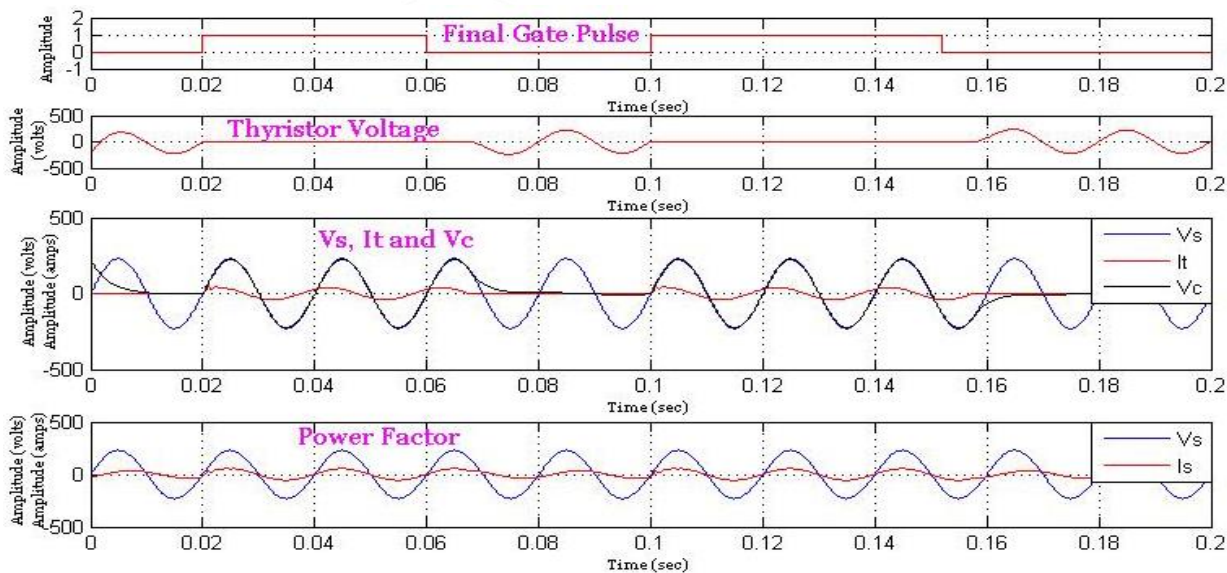


Fig 12 Simulation Results, when  $V_s = V_c$

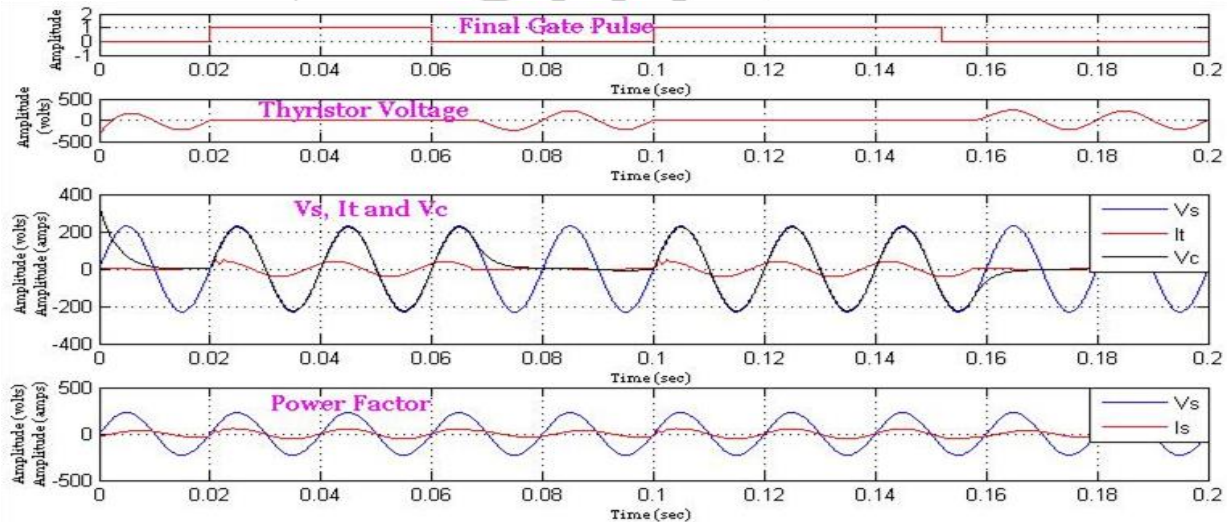


Fig 13 Simulation Results, when  $V_s < V_c$

Fig 10 shows the simulation results when initial capacitor voltage is zero i.e. capacitor is not charge at the time of compensation. Fig 11 and fig 12 shows the simulation results when initial capacitor voltage is less than supply voltage and when

capacitor voltage and supply voltage is equal respectively. With help of transient free novel control technique, turn ON transient is removed and voltage profile is improved after TSC is ON.

Fig 13 shows simulation results when capacitor voltage is higher than supply voltage i.e. capacitor is over charged. For all above mention condition, as shown in simulation results, the TSC has ability to control system voltage and power factor correction. Below table shows the simulation result:

Table 2 Simulation Results with Novel Control Technique

Simulation Results for FACTS Controller (Thyristor Switched Capacitor)	Voltage		Power Factor	Capacitor
	Supply Side (Volt)	Load Side (Volt)		
without Compensation (TSC is OFF)	162.7	159.8	0.70	-
with Compensation (TSC is ON)	162.7	160.7	0.98	20 $\mu$ F

IV. DESIGN AND IMPLEMENTATION

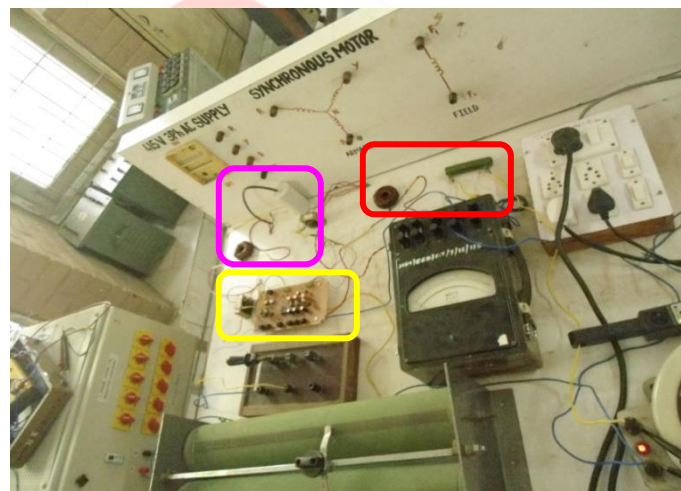


Fig 14 Laboratory Setup TSC with Transient Free Novel Control Technique

Above fig 14 shows the laboratory setup of TSC with a RL load through a transmission line and tested with and without novel control technique. The parameters are listed in table – 1. As shown in fig 14, red block indicate transmission line consists of power resistor and inductor, pink block indicate shunt capacitor with damping inductor and yellow block indicate thyristor module with gate pulse generating circuit. Fig 15 shows voltage (blue) lags current (red) without control technique. Fig 16 shows the power factor with fix capacitor and fig 17 shows the power factor with novel control technique. As seen from below results the transients are minimized with novel control technique and it is used in TSC plant for transmission system.

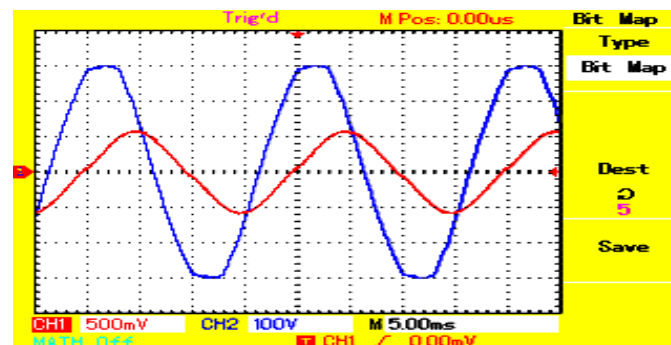


Fig 15 Power factor without Compensation



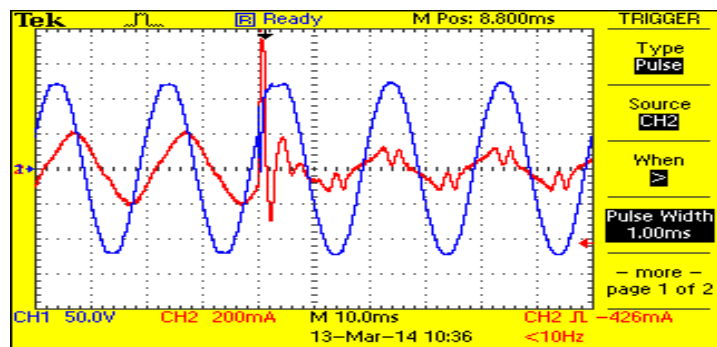


Fig 16 Power factor with Fix Capacitor

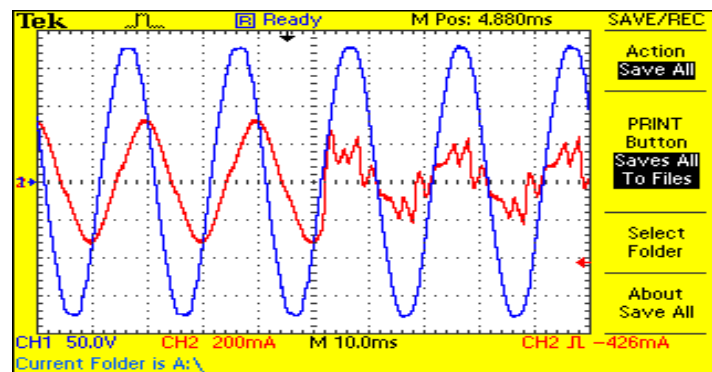


Fig 17 Power factor with Transient Free Novel Control Technique

## V. CONCLUSION

This paper presents analysis of the effect of the TSC on voltage profile and power factor of system. FACTS devices are used to control the power flow by adjusting system parameters such as line impedance, phase angle and voltage magnitude and it has opened new world in power system control. TSC is used as FACTS stabilizer. The proposed transient free novel control technique shows that TSCs are not only improve power factor, but they can also prevent voltage and current transients. The response time is relatively low and also restricts the thyristor voltage to supply voltage. It is also observed that TSCs will effectively regulate the voltage of the power system.

## ACKNOWLEDGMENT

The authors sincerely thank to Electrical Engineering Department, SCET, Surat for providing continuously guidance and other facility to carryout this work.

## REFERENCES

- [1] JBV Subrahmanyam, S. RadhaKrishna Reddy, P. K. Sahoo, C. Sashidhar and N. Madhuka Reddy, "A novel method for Improvement of Power Factor using Thyristor Switched Capacitor in Wind Mill Power Station", International Journal of Emerging Technology & Advances Engineering, ISSN: 2250 – 2459, Volume – 2 Issue - 2, February – 2012.
- [2] Samina Akter, Anulekha Saha, Prof. Priyanath Das, "Modeling, Simulation and Coparison of various FACTS Devices in Power System", International Journal of Advances in Engineering & Technology, ISSN: 2278 – 0181, Volume - 1 Issue - 8, October – 2012.
- [3] Venu Yarlagadda, K. R. M. Rao and B. V. Sankar Ram, "Hardware Circuit Implementation of Automatic Control of SVC using Microcontroller", International Journal of Instrumentation, Control and Automation (IJICA), ISSN: 2231 – 1890 Volume – 1, Issue – 2, 2011.
- [4] Ayetul Gelen (Student Member) and Tankut Yalcinoz (Senior Member), "The Behavior of Thyristor Switched Capacitor Installed in An Infinite Bus System", IEEE 2009.
- [5] R. M. Mathur, R. K. Verma, "Thyristor Based FACTS Controllers for Electrical Transmission Systems", IEEE Press, 2002, pp 277-288.
- [6] Zebardast and H. Mokhtari, "Effect of Low Voltage Thyristor Switched Capacitor Banks on Electrical Energy Consumption", IEEE 2006.
- [7] Alisha Banga and S.S. Kaushik, "Modeling and Simulation of SVC Controller for Enhancement of Power System Stability", International Journal of Advances in Engineering & Technology, ISSN: 2231 – 1963, July 2011.