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Simulation Study of 1O Fc-Tcr using ANN Method

D. Pugazhendi[1],M. Mahendran[2]
[1]PG Scholar, Department of EEE Engg., SCSVMV University, Tamil Nadu, India
[2]Asst.Professor, Department of EEE Engg., SCSVMV University, Tamil Nadu, India

ABSTRACT

In simple power system, source and load are connected by the wires or line conductors. Overhead transmission lines are introduced to transmit huge amount of power with high voltage (HV) /extra high voltage level (EHV) of power frequency. The load end voltage is less than the source end voltage magnitude mostly, except no load and lightly loaded conditions. Consequence of that a device needed at the load end/receiving end to retain the voltage constant. Synchronous condensers are used followed by static VAr compensators. Mechanical switches are replaced by power electronics switches. FACTS devices are developed to improve the efficiency of power transmission either series or shunt or series and shunt combination successfully. However fixed capacitor thyristor controlled reactor is a more popular for VAr compensation either Transmission or distribution system or individual load. A single phase FC-TCR type VAr compensator suggested, designed and implemented in a simple distribution system. Characteristics behaviour of FC-TCR are studied using the derived model. MATLab/Simulink Model constructed and tested with the derived analytical model. Artificial neural network based controller implemented to generate the gating signal of the FC-TCR.

Keywords: FC-TCR, ANN, MATLab simulation

I. INTRODUCTION

Over the last two decades, voltage instability problem in power system has become one of the most important concerns in the power industry. The ability to transfer reactive power from generating station to the load centre during steady-state operating conditions is a major problem of voltage stability. A system mainly enters a state of voltage instability when a disturbance, increase in load demand, or change in system condition causes a progressive and uncontrollable decline in voltage. Voltage instability and the problem of voltage collapse can cause the major blackout in the power system.

Higher reactive load causes for high transmission and distribution losses. The presence of highly inductive loads is detrimental to the power system and an increase of such loads leads to increase in reactive power demand thus decreasing power factor of the system resulting in higher losses.The presence of capacitive loads causes supply of reactive power, resulting in increase in voltage and losses.

Placing FACTS devices like SVC, in a suitable location will help to maintain bus voltages at a desired level and also to improve the voltage stability margins [5]. The SVC devices such as Thyristor Switched Capacitor (TSC) and Thyristor Controlled Reactor (TCR) can deliver and absorb the reactive power respectively is shown in Figure 1.

ANN based control can be adopted on SVC to improve dynamic stability, reactive power control and voltage control.

An initial requirement for the use of ANN in this application is to train the ANN with a number of data generated in real situations. Then ANN is tested to get desired output states from a number of input states.

In this paper, the steady state operating characteristics of the power system is obtained for a five bus system from load flow analysis using Newton-Raphson method in ETAP software for varying load conditions and power factors .The results from load flow analysis are used for training the Artificial Neural Network (ANN). In this application, ANN is trained to predict the combination of capacitors and inductor for various loads and power factors. The reactive power demand and load bus voltages are given as inputs. Thus voltage regulation in the 5 bus system is obtained by placing the SVC device in optimal position and controlling their ON/OFF condition by ANN for varying load conditions. The entire ANN is implemented in dsPIC30F4011. The switching of SVC devices are shown by LED blinking for the 3 phase 5 bus system. For the hardware, the voltage regulation in the single phase induction motor connected through the transmission line is considered. The real power, reactive power, load voltage are given as inputs to the DSPIC , which decides the combination of the fixed capacitor(as the load is inductive) and TCR with firing angle to meet the reactive power demand. High frequency pulse triggering method is used for triggering purpose.

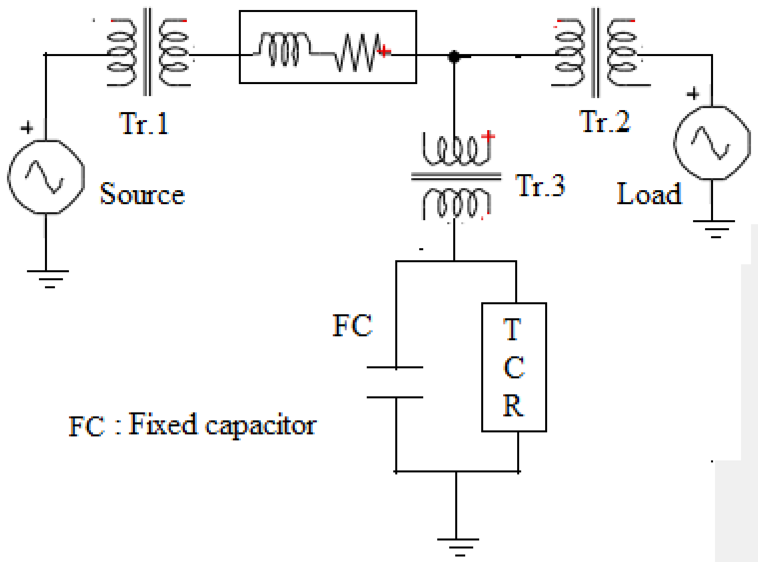

Figure 1. Single line diagram of single phase in distribution system with FC-TCR scheme

II. PROPOSED SCHEME

The term static VAR system has been adopted to apply to a number of static VAR compensation devices for use in shunt reactive control. These devices consist of shunt connected, static reactive elements (linear or nonlinear reactor and capacitor) configured into a VAR compensating system, and their distinction is that the shunt reactive power flowing in these devices is controllable over some rated range of VARs. The basic system consists of parallel combination of fixed capacitors and thyristor switch by an angle α, in each half cycle (α increased from 90° to 180°) the technique of controlling the conduction intervals of the thyristor switch, generate harmonic current components [6]. Fast response and the capability of balance load make the fixed capacitor, thyristor controlled inductor particularly advantageous for compensating those loads which present rapidly at various unbalanced conditions. In this study capability of ANN is used to recognize unbalance conditions and to provide proper firing angle as quickly as possible for thyristors which provide reactive power to balance the system. FC-TCR is shown in Figure 1.

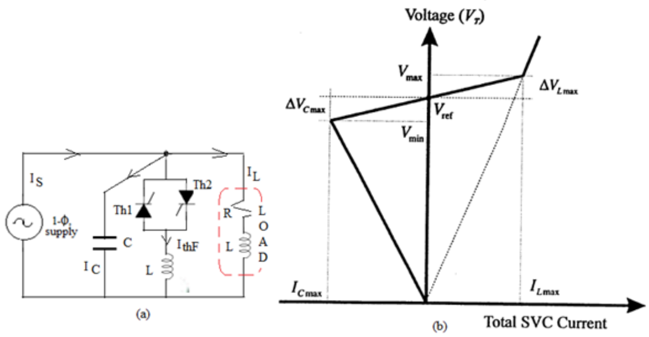

Figure 2. illustrates (a) single phase FC-TCR with load (b) VI characteristic

Figure 2 illustrates the basic configuration of single phase static compensator FC-TCR. In this case capacitor represents a switched capacitor bank either as mechanically switched or thyristor switched in binary sequential steps as explained earlier and L represents reactor with phase angle control [0].

The controllable range of TCR firing angleα extends from90^o to 180^o. In case of ideal reactor of L Henry firing angle of 90 results in full conduction with continuous sinusoidal current flow. Practically all six air cored reactors are designed with an average resistance of 10 Ω and inductance of 230 mH. The following “(5)” [5] illustrates the relation between firing angle α and the current through inductor I_L for ideal inductor having resistance tending towards zero while “(6)” represents the practical case considering resistance R Ω.

$$I_L = \left(\frac{V}{\omega L}\right)\left[1 - \left(\frac{2}{\pi}\right)\alpha - \left(\frac{1}{\pi}\right)\sin 2\alpha\right] \quad (1)$$

$$I_L(\alpha) = \frac{V_m}{\sqrt{R^2 + X_L{}^2}}\left[\frac{1}{2\pi}\left\{(\beta - \alpha) + \frac{\sin 2\alpha}{2} - \frac{\sin 2\beta}{2}\right\}\right]^{1/2} \quad (2)$$

Above equations concludes two cases such as,

Case: 1 If α = θ, then the firing angle is equal to phase angle, therefore sin(β - θ) = sin(β - θ) = 0 and conduction angle = β - α = π

Case: 2 since, conduction angle should not exceed π, therefore the control range of TCR lies between θ and π i.e. θ ≤ α ≤π

The equation (2) re rewritten as

$$I_F(\alpha) = \frac{V_L}{Z} = V_m Y_{TCR(\alpha-\theta)} \quad (3)$$

$$Y_{TCR(\alpha-\theta)} = \left[\frac{1}{2\pi}\left\{(\beta - \alpha) + \frac{\sin 2\alpha}{2} - \frac{\sin 2\beta}{2}\right\}\right]^{1/2} \quad (4)$$

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. Hence if $\alpha = \theta = 85.5^o$ continuous conduction of current take place. However, if firing angle is increased beyond this, non-sinusoidal currents are generated and hence harmonics get introduced. The rms value of nth order harmonic is expressed as

$$I_1(\alpha) = \frac{V}{Z} \times \frac{2}{\pi}\left[\frac{-2\cos(\alpha-\theta)}{n}\sin n(\alpha-\theta) + \frac{\sin(n-1)(\alpha-\theta)}{n-1} + \frac{\sin(n-1)(\alpha-\theta)}{n-1}\right] \quad (5)$$

Where, n = 2k+1 and k = 1, 2,3…

III. CONTROL STRATEGY

Figure 3(a) illustrates unique control scheme of SVC possible to implement either in small or large disturbances occurred in power system. . It comprises with different blocks based on TCR suceptance calculation, error calculation and tuning circuit.

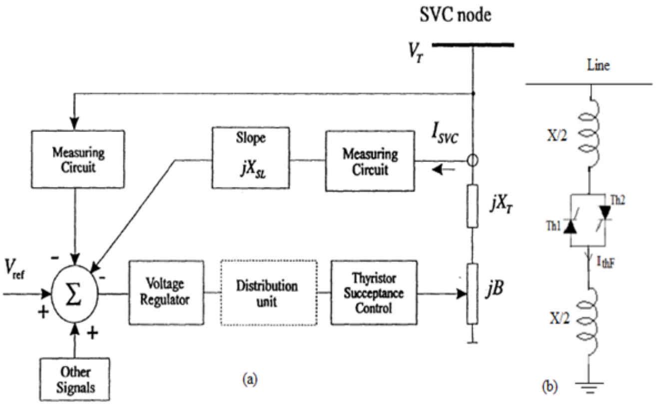

Figure 2. SVC control block diagram

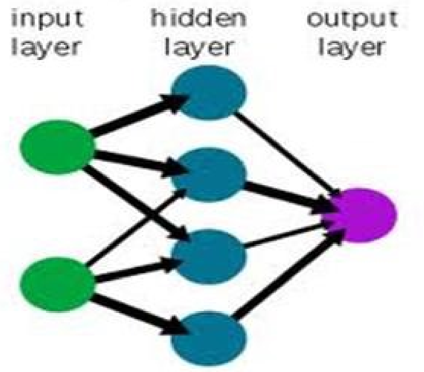

Figure 3. structure of ANN

In order to implement ANN as a decision making block of this control, ANN should trained in such way that firing angle of TCR with respect to suceptance variations. Therefore the total suceptance of the TCR divided into different intervals and calibrated with delay angleα, whereαlies between zero and maximum of 90^oi.e. $0 < \alpha < \frac{\pi}{2}$. If we want to the control over 180^o degree the TCR split into two halves as shown in Figure 3(b). The control range could vary between zero degrees to 180 degree by making the reactance value of reactor into two half and connect the thyristors as shown in Figure 3(b)

3.1 Implementation of ANN

Consequence of above cited calculation could be carried out by artificial neural network (ANN) is a network of simple processing elements called neurons, which can exhibit complex global behaviour determined by the connection between the processing elements. This is an artificial representation of our human brain. The back propagation algorithm is used in layered feed-forward ANN. This means that the artificial neurons are organized in layers, and send their signals "forward", and then the errors are propagated backwards. These models have the three subgroups of processing elements such as Input layer, Hidden layer and Output layer. Different activation functions can be used in these layers to get the output of ANN. Figure 4 shows the structure of ANN.

In this paper, hyperbolic tangent sigmoid transfer function is used for input layer. Log-sigmoid transfer function is used for hidden layers and output layers. Gradient descent with momentum back propagation strategy is used for ANN.

IV. MATLAB BASED SIMULATION OF SINGLE PHASE FC-TCR

The proposed scheme of single phase FC-TCR as shown in Figure 2 (a) is constructed using the power system tool box of MATLab/Simulink version 16 is shown in Figure 5 and Figure 6. Designed value of TCR, fixed capacitor and load is shown in Table-1

Table 1. Designed Values Of Fcr

TCR inductance	:	65mH
Fixed capacitor	:	65 Micro Farads
Load resistance	:	4.5 ohm
Load Inductance	:	60 mH
Line inductance	:	10mH
voltage	:	230V
frequency	:	50 Hz

2.1. Without FC-TCR

A load resistance of 4.5 ohm and inductance of 60mH connected across a source voltage of 230 volts along with a series inductance of 10 mH. This series inductance represents the line inductance of the transmission line is shown in Figure 5. The source and load considering as a sending end and receiving end respectively of a transmission line for this study.

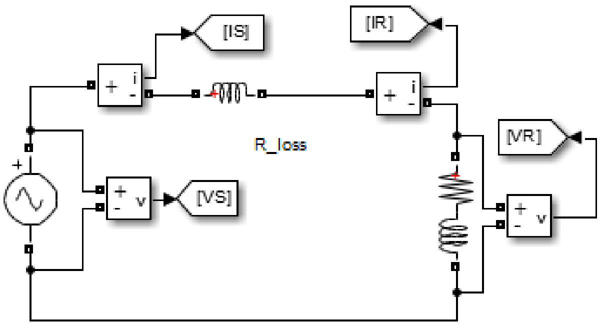

Figure 4. Simulink connection of simple power system model

Figure 6 illustrates the measuring blocks of the proposed study single phase power system as shown in Figure 5. RMS values of both measured current and voltage is calculated by using a RMS block is shown in Figure 6.

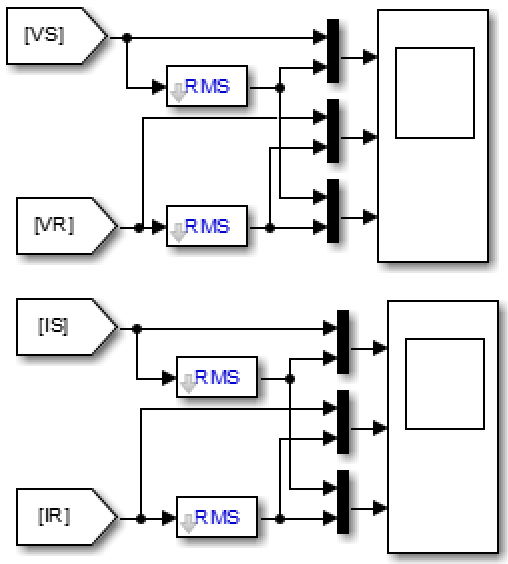

Figure 5. measurement blocks of single phase power system as shown in Figure 5

2.2. With FC TCR

A load resistance of 4.5 ohm and inductance of 60mH connected across a source voltage of 230 volts along with a series inductance of 10 mH. This series inductance represents the line inductance of the transmission line is shown in Figure 7. The source and load considering as a sending end and receiving end respectively of a transmission line for this study. In order to compensate the reactive power drawn by the load is compensated by shunt connected FC-TCR. A 65 micro farad capacitor directly connected to the source after the series inductance, another 65 milli henry inductance is connected across the fixed capacitor so called fixed capacitor thyristor controlled reactor is shown in Figure 7, Capacitor current is controlled by controlling the fundamental current flowing through the reactor. Thus capacitive currents are controlled so that burden of the source is reduced.

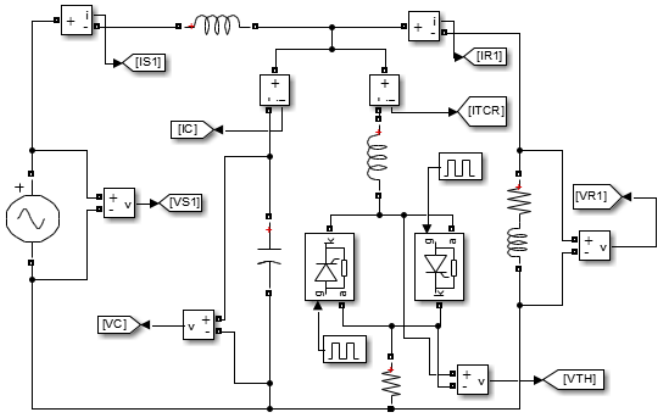

Figure 6. Simulink connection of FC-TCR

Figure 8 illustrates the measuring blocks of the proposed study single phase power system as shown in Figure 7. RMS values of both measured current and voltage is calculated by using a RMS block is shown in Figure 8.

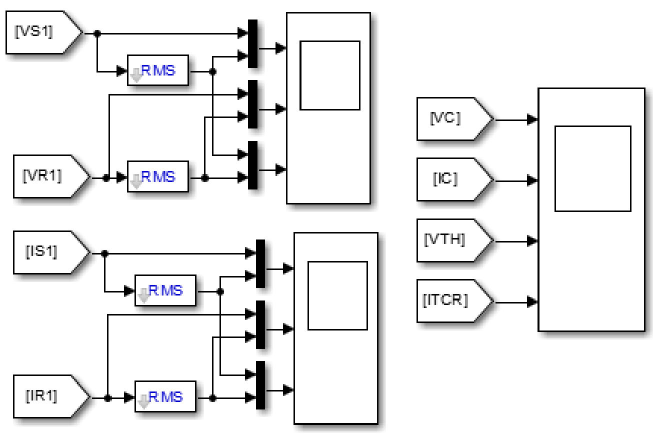

Figure 7. measuring block of FC-TCR connection as shown in Figure 7.

The above cited circuits are connected in MATLab/Simulink software version 16 and completed the simulation for 3 seconds of simulation time. The results are presented in forth coming sections.

V. RESULTS

Simulation experiment is completed by using the designed parameters as shown in Table-1. Figure 9 illustrates the voltage waveforms of both sending (source side) end and receiving end (load side) of the proposed study system and its RMS values also. It shows source voltage magnitude is slightly more than the load side voltage.

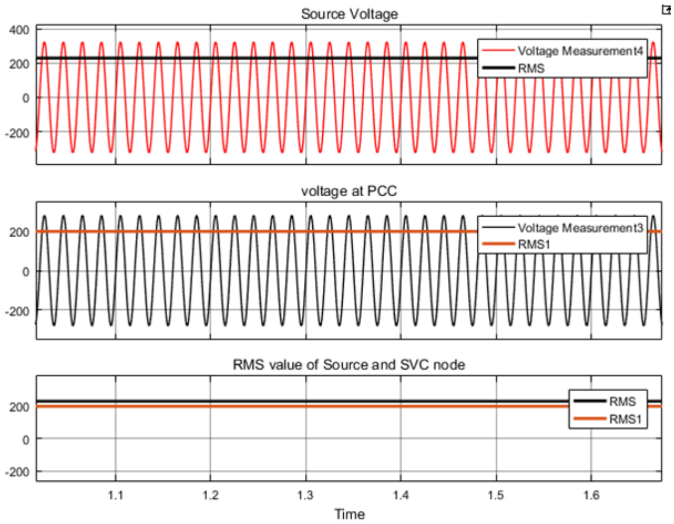

Figure 8. simulated voltage waveforms at source and load side (receiving end) without FC-TCR

Figure 10 illustrates the current waveforms having same magnitude. Obviously it is true because no other devices are connected between source and load.

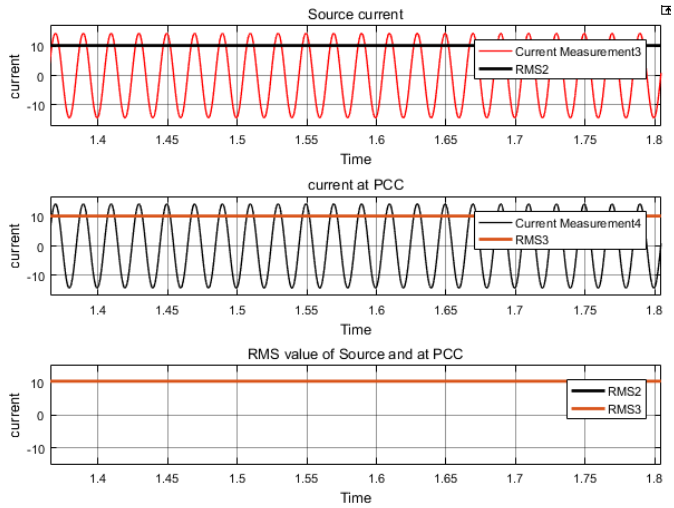

Figure 9. simulated current waveforms at source and load side (receiving end) without FC-TCR

Figure 11 illustrates the voltage waveforms of both sending (source side) end and receiving end (load side) of the proposed study system with FC-TCR and its RMS values also. It shows source voltage magnitude is slightly more but less than earlier load side voltage. Obviously it is correct because shunt connected devices not able to increase the voltage magnitude until external active source is not connected or if source is connected externally voltage profile will increase at point of common coupling (PCC).

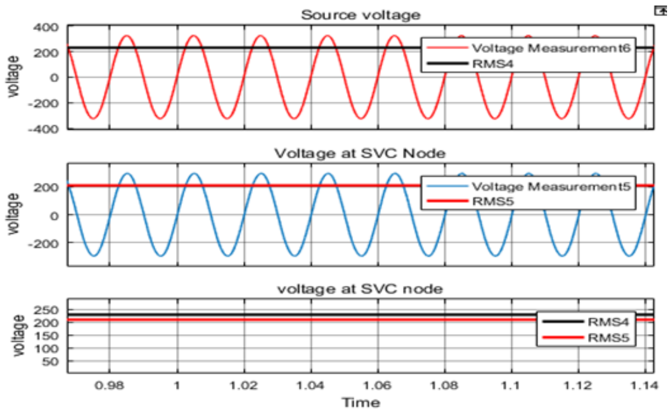

Figure 10. simulated voltage waveforms at source and load side (receiving end) with FC-TCR

Figure 12 illustrates the current waveforms having less magnitude in source and load current is same value shows that FC – TCR supplying reactive current required by the load. Obviously it is true because shunt connected SVC delivering the controllable current component either leading or lagging at PCC.

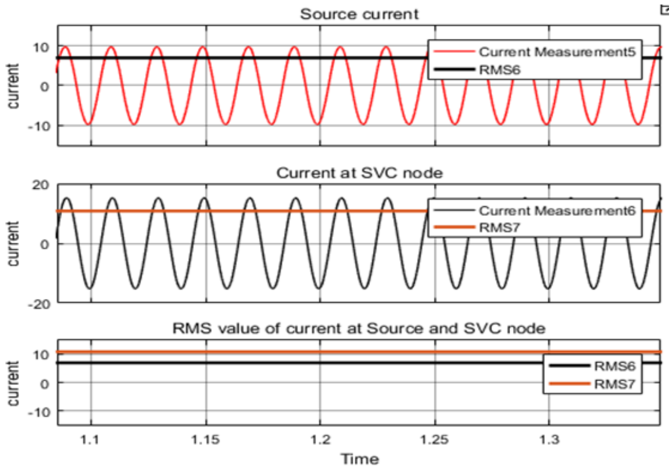

Figure 11. simulated current waveforms at source and load side (receiving end) with FC-TCR

Figure 13 illustrates the voltage and current waveforms of fixed capacitor, voltage across the thyristor and current flowing through the TCR for the delay angle of 30^{o}.

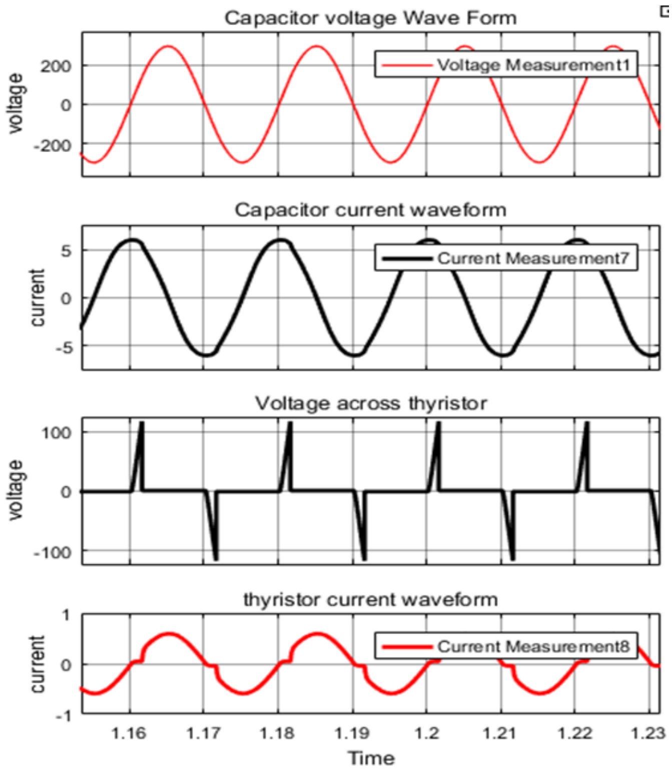

Figure 12. simulated waveforms across fixed capacitor, TCR

VI. CONCLUSIONS

Thus from the above result it is conclude that the Static VAr compensator(SVC) will control the voltage stability of the system and also maintains the dynamic performance of the system by controlling the suceptance of the reactor in such a way that the current drawn by the capacitor is controlled. The control range can be decided by the thyristor controlled reactor and fixed capacitor. From the simulation results it is observed that reactive power variation is smoother by using FC-TCR.

VII. ACKNOWLEDGEMENTS

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[12]. D.Pugazhendi. AMIE., MBA., currently he is pursuing his Master of Engineering (Electrical) with specialization in power system from SCSVMV University, Tamilnadu.
[13]. M. Mahendran.M.E(Ph.D) working on Asst.Professor, Dept. Of EEE Engineering in SCSVMV University for more than 11 years.