ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Website: www.ijareeie.com

Vol. 6, Issue 4, April 2017

Power Compensation in Transmission Line Using Thyristor Switched Reactor

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ABSTRACT:Day by day energy consumption is increasing. Hence, it is an urgent need to increase power generation and in turn increase in power transmission capability. This can be achieved by Flexible AC Transmission System (FACTS) which is an emerging technology and can improve power transfer scenario around the world. It improves the power transfer capability of existing transmission system which enhances reliability and security of the system. It also achieves better controllability with stability in power transmission networks. In place of building new transmission line, installing FACTS devices in existing networks is more economical. To confine on system stability and reliability, the reactive power compensation is the fundamental way. The variations of reactive power have an effect on the generating units, lines, circuit breakers, transformers, relay and isolators. Therefore, the local Volt-Ampere Reactive (VAR) compensator which is comprised of shunt reactors is used in transmission and distribution system for reactive power compensation. The conventional electro-mechanical reactive power compensator is not suitable for its slow switching action which cannot proportionate with the rapidchanging system load. The electronic reactive power compensator (FACTS devices) uses fast switching action than the conventional relay. Here, microcontroller is used for fast and precise switching of the Thyristor Switched Reactor (TSR).

KEYWORDS: Flexible AC Transmission System(FACTS), Thyristor Switched Reactor (TSR), Volt-Ampere Compensator (VAR).

I.INTRODUCTION

VAR compensation is defined as the management of reactive power to improve the performance of AC power systems. The concept of VAR compensation embraces an extensive and diversified field of both system and customer problems, especially related with power quality issues, since most of power quality problems can be minimized or solved with a sufficient control of reactive power. Generally, the problem of reactive power compensation is observed from two aspects, load compensation and voltage support. In the loading point of view, compensation the objectives are to increase the value of the system power factor, to balance the real power drawn from the AC supply, compensate voltage regulation and to eliminate harmonics produced by fluctuating non-linear industrial loads. The voltage support is generally required to reduce voltage fluctuation at a given terminal of a transmission line. The reactive power compensation in transmission systems also improves the stability of the AC system and improves HVDC conversion terminal performance, increases transmission efficiency, controls steady-state and temporary over voltage and can avoid terrible blackouts. Series and shunt VAR compensation are used to modify the natural electrical characteristics of AC power systems. Series compensation modifies the transmission or distribution system parameters, while shunt compensation hangs the equivalent impedance of the load. In both cases, the reactive power flows through the system can be effectively controlled for improving the performance of the overall AC power system which is essential for FACTS.

Conventionally, rotating synchronous condensers and fixed or mechanically switched capacitors or inductors have been used for reactive power compensation. However, recently, static VAR compensators employing thyristor switched capacitors and reactors to manage the reactive power of the power system. Also, the use of self-commutated Pulse Width Modulation (PWM) converters with an appropriate control scheme permits the implementation of static

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compensators capable of generating or absorbing reactive current components with a time response faster than the fundamental power network cycle. Based on the use of reliable high-speed power electronics, powerful analytical tools, advanced control and microcomputer technologies [3], the FACTS have been developed and represent a new concept for the operation of power transmission systems. The shunt capacitor is generally required when the system inductive load increases, thereby the system voltage and frequency decrease with increase of lagging reactive power. On the other hand, when the system inductive load decreases or at no load condition, the system voltage and frequency increases with decrease of lagging reactive power then the shunt inductor bank is required for the increment of lagging current. The connected capacitor and inductor is beneficial for the system which provide reactive power support, voltage profile improvements, line and transformer loss reductions, release of power system capacity and reduction of energy loss. Low voltage and frequency may cause power losses in the system, low performance in the appliances andindustrial machineries.

II.THYRISTOR SWITCHED REACTOR

A. FLEXIBLE AC TRANSMISSION SYSTEM (FACTS)

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 FACTS is a concept based on power-electronic controllers, which enhance the value of transmission networks by increasing the use of their capacity. As these controllers operate very fast, they enlarge the safe operating limits of a transmission system without risking stability. The FACTS technology is essential to alleviate some but not all of the difficulties of transmission by enabling utilities to get the most service from their transmission facilities and enhance grid reliability. It must be stressed, however, that for many of the capacity expansion needs, building of new lines or upgrading current and voltage capability of existing lines and corridors will be necessary. As these controllers operate very fast, they enlarge the safe operating limits of a transmission system without risking stability. The basic applications of FACTS-devices are: power flow control, increase of transmission capability, voltage control, reactive power compensation, stability improvement, power quality improvement, power conditioning, flicker mitigation, interconnection of renewable and distributed generation and storages. The main objectives of FACTS controllers are i. Regulation of power flows in prescribed transmission routes, ii. Secure loading of transmission lines nearer to their thermal limits, iii. Prevention of cascading outages by contributing to emergency control, iv. Damping of oscillations that can threaten security or limit the usable line capacity.

The microcontroller [3] on reception of this signal checks for the safe distance condition and drives both motors in forward direction if condition satisfies. If the distance is less than the safe distance both motors are held stall. As the user moves left the left receiver starts reception and output a high signal to microcontroller. The microcontroller now gives more drive to the right motor thus turning the cart left. Now when user moves right, the right receiver starts reception and output a high signal to microcontroller. The microcontroller gives more drive to the left motor thus turning the cart left. This dynamic process continues in a loop and the cart follows the customer all the while maintaining a safe distance.

B. STATIC VAR SYSTEM

In Extra High Voltage (EHV) and Ultra High Voltage (UHV) transmission practice, when the voltage at a bus falls below the reference value, capacitive VARs are to be injective. When the bus voltage becomes higher than the reference value, inductive VARs are supplied to lower the bus voltage. In conventional methods of shunt compensation, shunt inductors are connected during low loads and shunt capacitors are connected during heavy loads and such switching operations are very slow because of the greatertime required for the operation of the circuit breakers. Moreover, circuit breakers are not suitable for frequent switching during voltage variations. These limitations havemitigated by Static VAR Systems (SVS). In a static VAR system, thyristor are used as switching devices instead of circuit breakers. The thyristor switching is faster than mechanical switching and also it is possible to have transient free operation by controlling the instant switching. The advantage of high-speed, high-current switching has made possible by thyristors which has introduced a new concept in providing reactive compensation for optimum EHV/UHV system performance. The static VAR compensators' (SVC) use combinations of shunt reactor and shunt capacitor with thyristors of high voltage and current rating for obtaining fast and accurate control of reactive power ow. The static VAR compensation (SVC) is also known as static VAR system(SVS).

C. THYRISTOR CONTROLLED REACTOR

Fig-1, shows the scheme of a static compensator of the Thyristor Controlled Reactor (TCR) type. Each of the three phase branches includes an inductor L, and the thyristor switches T1 and T2[1]. Reactors can be both switched and phase-angle controlled. When phase angle control is used, a continuous range of reactive power consumption is obtained [2]. It results, however, in the generation of odd harmonic current components during the control process. Full conduction is achieved with a gating angle of 90°. Partial conduction is obtained with gating angles between 90° and 180°. By increasing the thyristor gating angle, the fundamental component of the current reactor is reduced. This is equivalent to increase the inductance, reducing the reactive power absorbed by the reactor. However, it should be pointed out that the change in the reactor current may only take place at discrete points of time, which means that adjustments cannot be made more frequently than once per half-cycle. Static compensators of the TCR type are characterized by the ability to perform continuous control, maximum delay of one half cycle and practically no transients. The principal disadvantages of this configuration are the generation of low frequency harmonic current components, and higher losses when working in the inductive region.

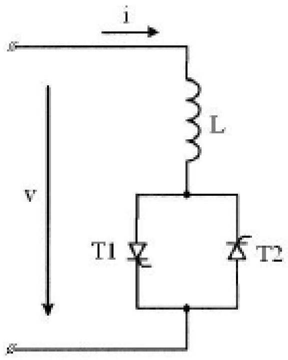

Fig. 1Thyristor Controlled/Switched Reactor

D. THYRISTOR SWITCHED REACTOR

Thyristor Switched Reactors are shunt compensators that can absorb reactive power [4]. The TSRs have followingproperties: its operating principle simple, delay of one halfa cycle and no generation of harmonics. Filters aretraditionally used to absorb harmonic generated by the SVC structure and large industrial loads. In order to abstain harmonic generation TSR is used instead of a TCR. Also, with choice of TSR both voltage stability and stepwise control of bus voltage have been provided. Actually, the configuration of both TSR and TCR are same the difference being TSR is switched reactor and TCR is controlled reactor, where firing angle is controlled.

E. CONCEPT OF DESIGN

The reactive power of the system is increased due to the increase of load in the transmission line, the current is lagging with respect to voltage. Again, when the line is unloaded or lightly loaded, the current is leading with respect to voltage in transmission line. Since the system voltage, frequency, real and reactive power change with the variation of load therefore in order to supply quality power it is necessary to keep the system voltage and frequency constant by compensating the reactive power. For this purpose, capacitor and inductor bank are required to compensate lagging and leading current respectively according to the compensation of reactive power. The size of the capacitor and inductor bank depends on how much reactive power is to be compensated according to the system load on transmission line. The system voltage and frequency change with the rapid change of load which causes the system current either lagging or leading and thereby the connected capacitor and inductor are switched on and off accordingly. In case of electromechanical switches, the timedelay and harmonic effect cause stability problem and desired compensation of reactive power cannot be achieved according to the system requirement. Therefore, electronicswitching is more reliable than conventional electromechanical switches which provides instant switching and diminish harmonics effect. In order to perform the switching action properly it is necessary to control the switching devices according to the variation of load and reactive power. Different electronic switches like thyristor, MOSFET, J-FET etc. can be used as a switch whose switching characteristics depends on gate pulse of those electronic devices. The thyristor is used as very good

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Vol. 6, Issue 4, April 2017

alternative of mechanical switch due to low transient and fast response. The major drawback of an SCR is that it conducts in one direction only (either positive or negative cycle of the input AC supply) and SCR cannot handle a large amount of current whereas a MOSFET can handle large amount of current thanSCR. Therefore, controlling of alternating current in a load, MOSFET is used.

III.SIMULATION AND RESULTS

The system was simulated as a three-phase system by creating a sag. The whole system is modelled as a real power system and the power compensation is done at one end of the transmission side. The system was simulated as a three-phase system by creating a sag. The whole system is modelled as a real power system and the power compensation is done at one end of the transmission side. The input before the sag was introduced, was 230V taken from a step-down transformer which represents the distribution side. The sag which was created was 0.8 times lesser than the original voltage and it was created from 0.3 ms to 0.8 ms. The sag which was created from 0.3 ms to 0.8 ms has been compensated and the magnitude of the voltage is brought back to initial level i.e. 230V.

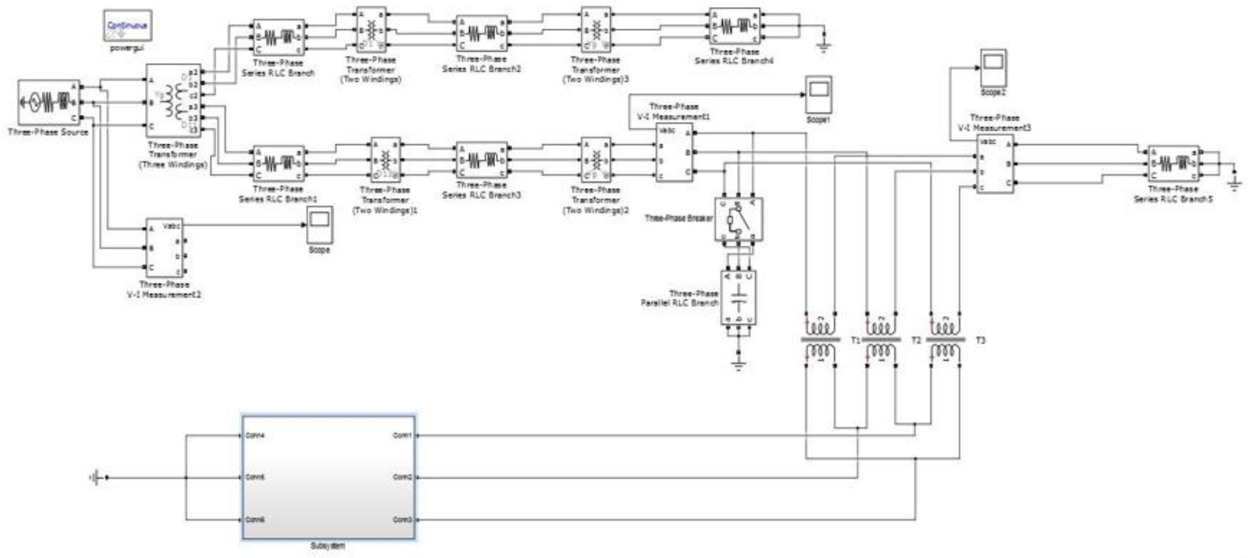

Fig. 2 Simulink Model of the System

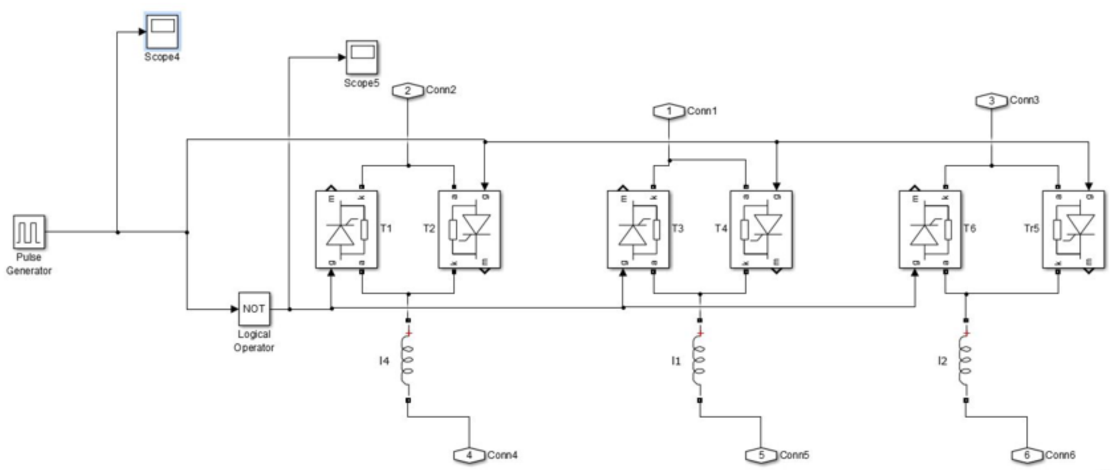

Fig. 3 Simulink Model of the Sub-circuit

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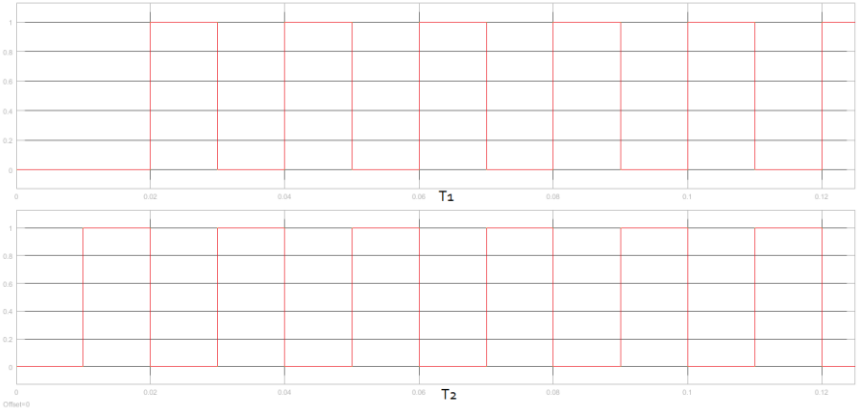

Fig. 4 Pulses to T1 and T2

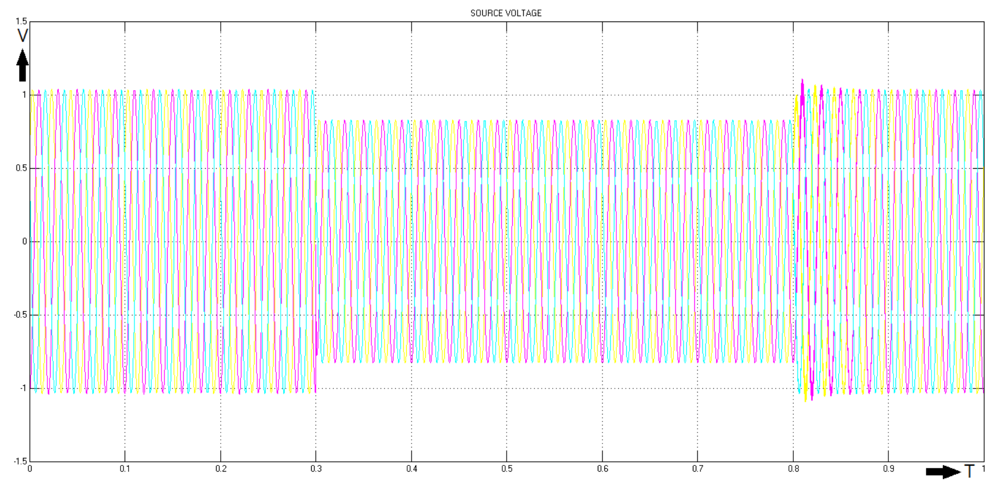

Fig. 5 Uncompensated Waveform with Sag

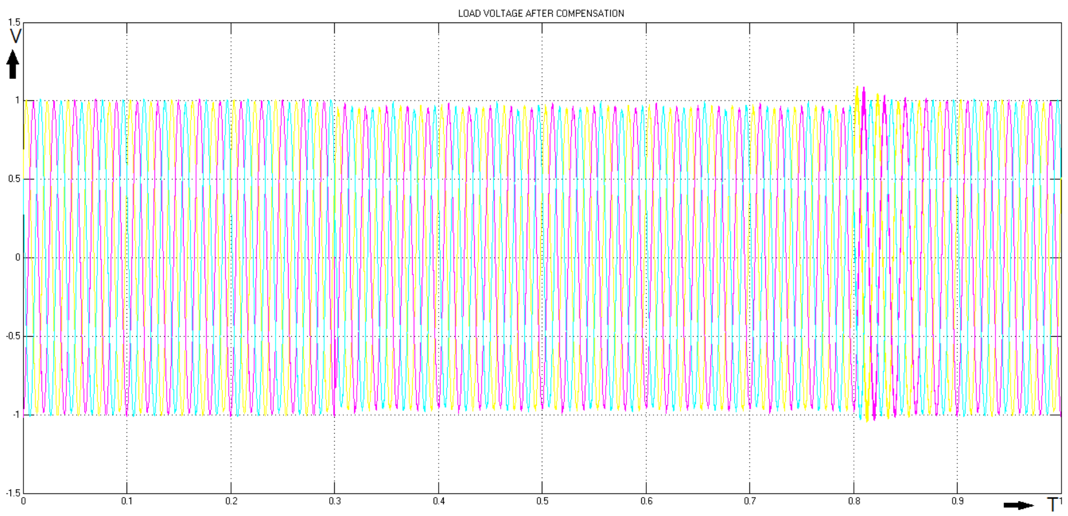

Fig. 6Compensated Waveform

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IV.EXPERIMENTAL SETUP AND RESULTS

The experimental setup consists of MOSFET IRFP460, PIC microcontroller, Transformer, Regulator ICs, Zero-CrossingDetector etc. The AC voltage is step down to 12 V and it is converted to DC by using bridge rectifier. The 12 V and 5 V is regulated by using regulator ICs and 5 V is given as VCC to PIC microcontroller and as a reference and 12 V is used byzero-crossing detector as one reference input and VCC. The other reference input is taken from output by stepping down the output to 12 volts and converting it to DC. If there is any mismatch between the input and output voltage, then an error signal is produced which is given to the PIC microcontroller. The microcontroller then gives the pulse waveform as the output for firing the TSR. The compensation by TSR is done to the DC equivalent voltage of the input. For that, the AC voltage is converted to DC, without stepping it down, and after the compensation by the TSR it is converted back to AC using an inverter.

A. FLOWCHART OF PROGRAM

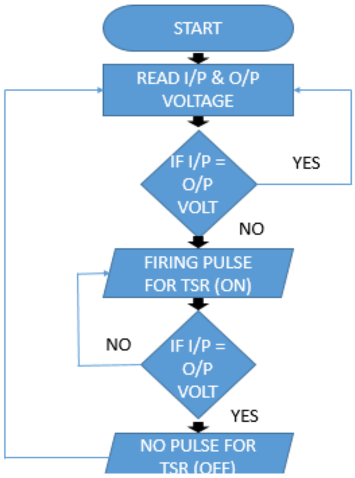

Fig. 7Flowchart of the Program

The flowchart depicts the basic working of the program. First it reads the input and output voltage magnitude of the system. Then after comparing these values if there is any error signal produced then the TSR is switched on till the output voltage becomes equal to input voltage. It continuously checks for this condition and when it happens then TSR is switched off.

B. EXPERIMENTAL RESULTS

The experimental setup is shown in the figure 9 and also the circuit diagram is given in the Figure 8. The duty ratio varies according to the sag is created. Here in Figure 10, shows the duty ratio when the input sag voltage is 5V and the second Figure 11, shows the duty ratio when the input sag voltage is 15V.

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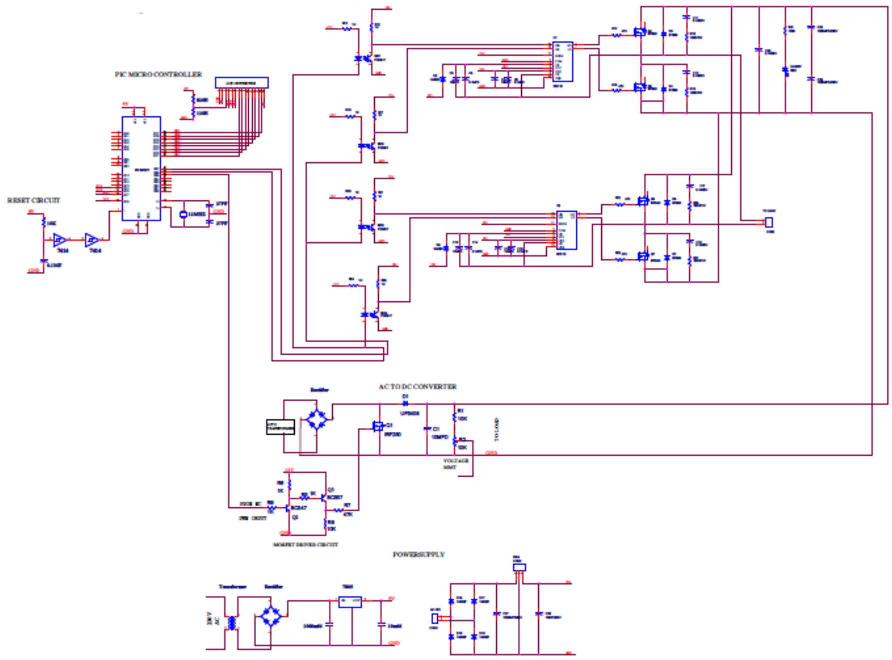

Fig. 8Circuit of Experimental Setup

Fig. 9Experimental Setup

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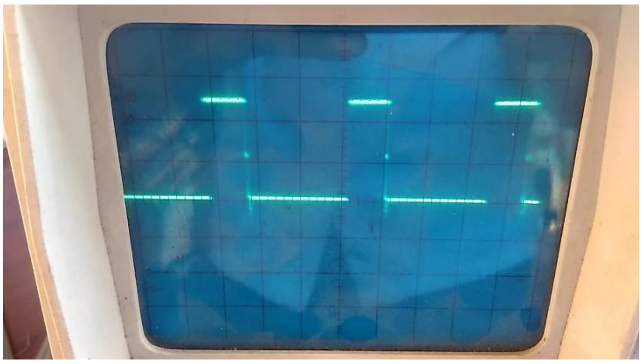

Fig. 10Duty Ratio at 5 V

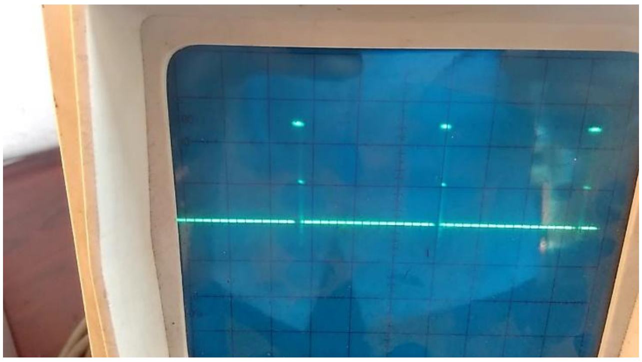

Fig. 11Duty Ratio at 15 V

V. CONCLUSIONS

This project is a microcontroller based FACTS compensator using TSR. The reactive power compensator can be used for both HVDC and HVAC system. The concept of FACTS for EHV system arises in order to ensure reliability with minimum supervision by using advanced technology as well as very fast switching action. The SVC is designed for utilization of semiconductor devices like thyristor for faster switching ofconnecting capacitor and inductor bank with the transmission according to the system requirement without interference of harmonics due to switching. Here PIC 16F877A microcontroller has been used for faster control and mosfet was used for faster switching. The voltage sag which was created and it was effectively compensated by using TSR in shunt configuration mode.

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