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Power Quality Issues Mitigation by Using DSTATCOM

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Abstract*: *In this paper, the role of FACTS (Flexible AC Transmission System) devices in addressing various power quality issues have been studied. In FACTS, power electronic devices and their switching control schemes are used for improving the power flow in the transmission network and hence improve the power quality and reliability of the low-voltage distribution network. These devices can play a significant role in maximizing the power transmission capability of the transmission network and providing high power quality at the point of common coupling (PCC) of the distribution system. The Distributed Static Compensator or DSTATCOM is a type of FACTS controller and has the function of reactive power compensation and harmonic mitigation. This paper discusses the use of DSTATCOM for mitigation of power quality issues.

***Keywords*: DSTATCOM, PWM Technique, DSPIC30F2010.**

I. INTRODUCTION

Electric utilities and end users of electrical power are becoming increasingly concerned about the quality of electric power. The term *power quality* is one of the most important factors in the power industry. The issue in electric power sector delivery is not confined to only energy efficiency and environment but more importantly on quality and continuity of supply or power quality and supply quality. Electrical Power quality is the degree of any deviation from the nominal values of the voltage magnitude and frequency. Power quality means the degree to which both the utilization and delivery of electric power affects the performance of electrical equipment. From a customer perspective, a power quality problem is a problem manifested in voltage, current, or frequency deviations that result in a power failure or misoperation of a customer of equipment. Power quality is certainly a major concern in the present era, it becomes especially important with the introduction of sophisticated devices, whose performance is very sensitive to the quality of power supply.

Modern industrial processes are based on electronic devices such as PLC and ASD. The electronic devices are very sensitive to disturbances and thus industrial loads become less tolerant to power quality problems such as voltage dips, voltage swells, harmonics, flickers, interruptions, and notches.

Below table showing some common power quality problems and their effects:

Table 1.0: Some effects of power quality problems for the voltage events

PROBLEMS	EFFECTS
Overvoltage	Overstress insulation
Under voltage	Excessive motor current
Unbalance	Motor heating
Neutral-ground voltage	Digital device malfunction
Interruption	Complete shutdown
Sag	Variable speed drive & computer trip-out
Swell	Overstress insulation
Fluctuations	Light flicker

The aim of this paper is to study the various types of power quality problems and their effects on both the utility and customer's side of the system, with more emphasis on these two namely: voltage sag and voltage swells, and how they can be mitigated with the

D-STATCOM (Distribution Static Compensator), which is also called custom power device, and its effectiveness in mitigating the named power quality problems given above.

The objectives of this paper are:

1. To investigate the mitigation techniques are suitable for voltage sags, swells, and interruptions in the event of a fault in a distribution system.
2. To observe the effect of voltage sag, swell and interruption for the techniques.
3. To suggest the suitability of the techniques used for the mitigation process.

II. POWER QUALITY

Power quality is simply the interaction of electrical power with electrical equipment. If electrical equipment operates correctly and reliably without being damaged, we can say that the electrical power is of good quality. On the other hand, if the electrical equipment malfunctions, is unreliable, we can suspect that the power quality is poor. There are two approaches to the mitigation of power quality problems. The solution to the power quality can be done from customer side or from utility side. The first approach is called load conditioning, which ensures that the equipment is less sensitive to power disturbances, allowing the operation even under significant voltage distortion. The other solution is to install line conditioning systems that suppress or counteracts the power system disturbances. A flexible and versatile solution to voltage quality problems is offered by active power filters. Currently, they are based on PWM converters and connect to low and medium voltage distribution system in shunt or in series. Series active power filters must operate in conjunction with shunt passive filters in order to compensate load current harmonics. Shunt active power filters operate as a controllable current source and series active power filters operate as a controllable voltage source. Both schemes are implemented preferably with voltage source PWM inverters with a dc bus having a reactive element such as a capacitor.

One of the most common power quality problems today is voltage dips. A voltage dip is a short time (10 ms to 1 minute) event during which a reduction in r.m.s voltage magnitude occurs. It is often set only by two parameters, depth/magnitude, and duration. The voltage dip magnitude is ranged from 10% to 90% of nominal voltage (which corresponds to 90% to 10% remaining voltage) and with a duration of half a cycle to 1 min. In a three-phase system, a voltage dip is by nature a three-phase phenomenon, which affects both the phase-to-ground and phase-to-phase voltages. A voltage dip is caused by a fault in the utility system, a fault within the customer's facility or a large increase of the load current, like starting a motor or transformer energizing. Typical faults are single-phase or multiple-phase short circuits, which leads to high currents. The high current results in a voltage drop over the network impedance. At the fault location, the voltage in the faulted phases drops close to zero, whereas in the non-faulted phases it remains more or less unchanged. Voltage dips are one of the most occurring power quality problems. Of course, for an industry, an outage is worse, than a voltage dip, but voltage dips occur more often and cause severe problems and economic losses. Utilities often focus on disturbances from end-user equipment as the main power quality problems. This is correct for many disturbances, flicker, harmonics, etc., but voltage dips mainly have their origin in the higher voltage levels. Faults due to lightning is one of the most common causes to voltage dips on overhead lines. If the economic losses due to voltage dips are significant, mitigation actions can be profitable for the customer and even in some cases for the utility. Since there is no standard solution which will work for every site, each mitigation action must be carefully planned and evaluated. There are different ways to mitigate voltage dips, swell and interruptions in transmission and distribution systems. At present, a wide range of very flexible controllers, which capitalize on newly available power electronics components, are emerging for custom power application. Among these, the distribution static compensator and the dynamic voltage restorer are most effective devices, both of them based on the VSC principle. A new PWM-based control scheme has been implemented to control the electronic valves in the two-level VSC used in the D-STATCOM.

III.POWER QUALITY PROBLEMS

1. VOLTAGE DIPS (SAGS)

A voltage dip is a sudden reduction in the r.m.s voltage between 0.1 and 0.9 pu at a point in the electrical system, and lasting for 0.5 cycles to several seconds. Dips with durations of less than a cycle are regarded as transients. Figure 2.1 shows a waveform depicting a voltage sag.

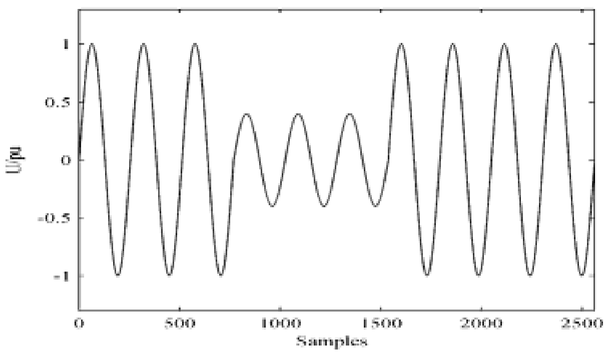

Fig 2:- voltage sag

A voltage dip may be caused by switching operations associated with a temporary disconnection of supply, the flow of heavy current associated with the starting of large electric motors or the flow of fault currents or the transfer of load from one power source to another. These events may emanate from customers' systems or from the public supply network. The main cause of momentary voltage dips is probably the lightning strike. Each of these cases may cause a sag with a special characteristic (magnitude and duration

2. VOLTAGE SWELL

The increase of voltage magnitudes between 1.1 and 1.8 p.u is called Swell, it sometimes accompanies voltage sags. The most accepted duration of a swell is from 0.5 cycles to 1 minute. They appear on the switching off of a large load; energizing a capacitor bank, or voltage increase of the un faulted phases during a single line-to-ground fault. Fig. 2 shows a waveform of voltage swell.

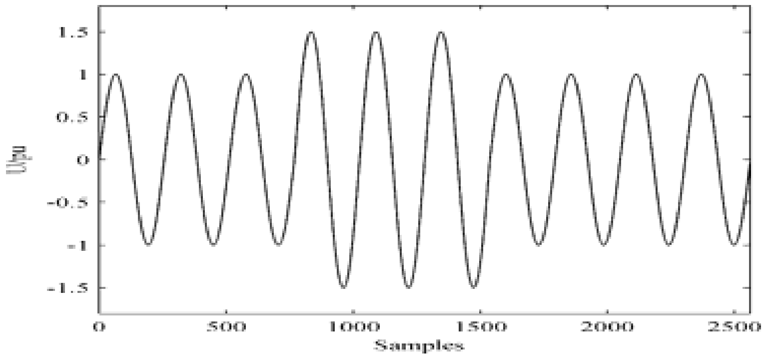

Fig 3: Voltage Swell

Swells can upset electric controls and electric motor drives, particularly common adjustable-speed drives, which can trip because of their built-in protective circuitry. Swells can also put stress on delicate computer components and shorten their lifespan.

3. INTERRUPTIONS

Interruptions occur when the supply voltage decreases to less than 0.1 up for a minute or less. Some causes of interruptions are equipment failures, control malfunction, and blown fuse or breaker opening due to fault on a system

IV. POWER QUALITY ISSUES MITIGATION TECHNIQUE

1. **VOLTAGE SOURCE CONVERTERS (VSC)**

A voltage-source converter is a power electronic device, which can generate a sinusoidal voltage with any required magnitude, frequency, and phase angle. Voltage source converters are widely used in adjustable-speed drives, but can also be used to mitigate voltage dips. The VSC is used to either completely replacing the voltage or to inject the 'missing voltage'. The 'missing voltage' is the difference between the nominal voltage and the actual. The converter is normally based on some kind of energy storage, which will supply the converter with a DC voltage. The solid-state electronics in the converter is then switched to get the desired output voltage. Normally the VSC is not only used for voltage dip mitigation, but also for other power quality issues, e.g. flicker and harmonics.

2. DYNAMIC VOLTAGE RESTORER (DVR)

A DVR, Dynamic Voltage Restorer is a distribution voltage DC-to-AC solid- state switching converter that injects three single-phase AC output voltages in series with the distribution feeder, and in synchronism with the voltages of the distribution system. By injecting voltages of controllable amplitude, phase angle, and frequency (harmonic) into the distribution feeder in instantaneous real time via a series- injection transformer, the DVR can restore the quality of voltage at its load side terminals when the quality of the source side terminal voltage is significantly out of specification for sensitive load equipment. It is designed to mitigate voltage sags and swells on lines feeding sensitive equipment. A viable alternative to uninterruptible power systems (UPS) and other utilization solutions to the voltage sag problem, the DVR is specially designed for large loads of the order of 2 MVA to 10 MVA served at distribution voltage. A DVR typically requires less than one-third the nominal power rating of the UPS. DVR can also be used to mitigate troublesome harmonic voltages on the distribution network. DVR comprises of three main parts:

1. Inverter
2. DC energy storage
3. Control system

The basic configuration of a DVR is shown in Fig 2.3

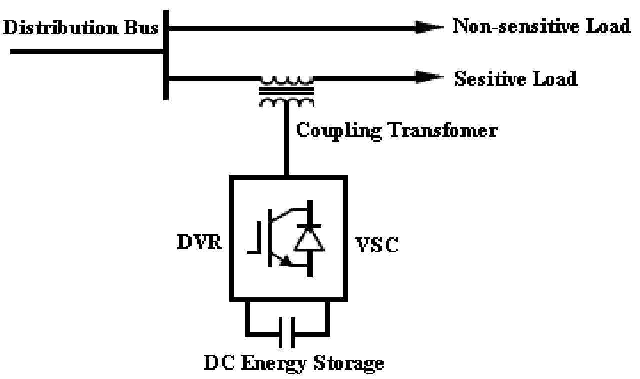

Fig 4:-Basic Configuration of DVR

A D-STATCOM (Distribution Static Compensator), which is schematically depicted in Figure, consists of a two-level Voltage Source Converter (VSC), a dc energy storage device, a coupling transformer connected in shunt to the distribution network through a coupling transformer. The VSC converts the dc voltage from the storage device into a set of three-phase ac output voltages. These voltages are in phase and coupled with the ac system through the reactance of the coupling transformer. Suitable adjustment of the phase and magnitude of the D-STATCOM output voltages allows effective control of active and reactive power exchanges between the D-STATCOM and the ac system. Such configuration allows the device to absorb or generate controllable active and reactive power.

The VSC connected in shunt with the ac system provides a multifunctional topology which can be used for up to three quite distinct purposes:

1. Voltage regulation and compensation of reactive power;
2. Correction of power factor; and
3. Elimination of current harmonics.

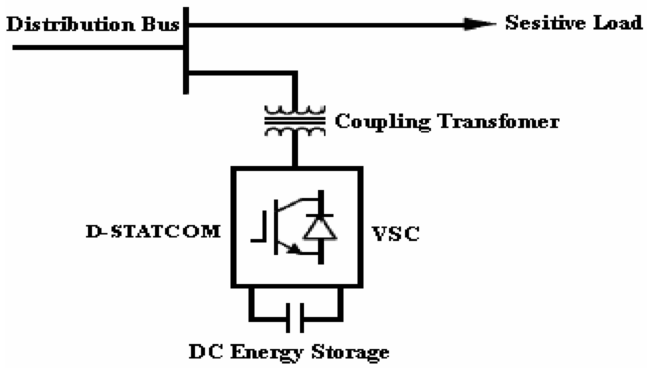

Fig .5:- Configuration of a D-STATCOM

Here, such device is employed to provide continuous voltage regulation using an indirectly controlled converter. The basic configuration of the D-STATCOM is shown in the diagram below, Figure.4

In order to improve the survivability of solar energy system, D-STATCOM or Distribution Static Compensator can be used, which reduces the impact of pulsed loads on the bus voltage and thus keeps the bus voltage at the desired level. D-STATCOM is a voltage-source inverter (VSI) based shunt device generally used in the distribution system to improve power quality. The main advantage of D-STATCOM is that it has a very sophisticated power electronics based control which can efficiently regulate the current injection into the distribution bus. The second advantage is that, it has multifarious applications, e.g. I) canceling the effect of poor load power factor, ii) suppressing the effect of harmonic content in load currents iii) regulating the voltage of distribution bus against sag/swell etc. IV) Compensating the reactive power requirement of the load and so on. The performance of the D--STATCOM is very much dependent on the DSTATCOM controller.

1. BASIC CONFIGURATION OF DSTATCOM

A DSTATCOM is a controlled reactive source, which includes a Voltage Source Converter (VSC) and a DC link capacitor connected in shunt, capable of generating and/or absorbing reactive power. The operating principles of a DSTATCOM are based on the exact equivalence of the conventional rotating synchronous compensator.

The AC terminals of the VSC are connected to the Point of Common Coupling (PCC) through an inductance, which could be a filter inductance or the leakage inductance of the coupling transformer, as shown in figure 1. The DC side of the converter is connected to a DC capacitor, which carries the input ripple current of the converter and is the main reactive energy storage element. This capacitor could be charged by a battery source, or could be recharged by the converter itself. If the output voltage of the VSC is equal to the AC terminal voltage, no reactive power is delivered to the system. If the output voltage is greater than the

AC terminal the compensation should be such that the supply currents show al voltage, the DSTATCOM is in the capacitive mode of operation and vice versa. The quantity of reactive power flow is proportional to the difference in the two voltages.

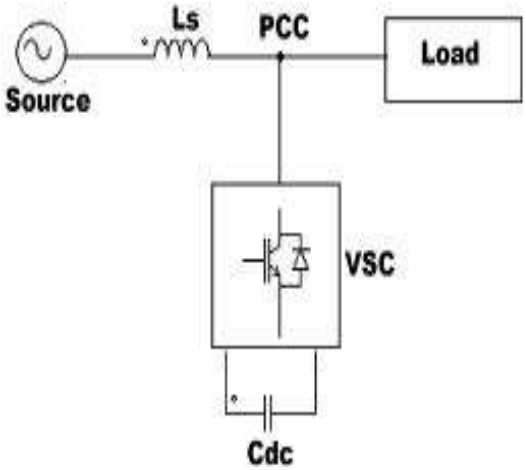

Fig 6 - Basic principle of DSTATCOM

It is to be noted that voltage regulation at PCC and power factor correction cannot be achieved simultaneously. For a DSTATCOM used for voltage regulation at the PCC, ld lead the supply voltages; whereas, for power factor correction, the supply current should be in phase with the supply voltages. The control strategies studied in this paper are applied with a view to studying the performance of a DSTATCOM for power factor correction and harmonic mitigation.

V. METHODOLOGY

1. Main Hardware

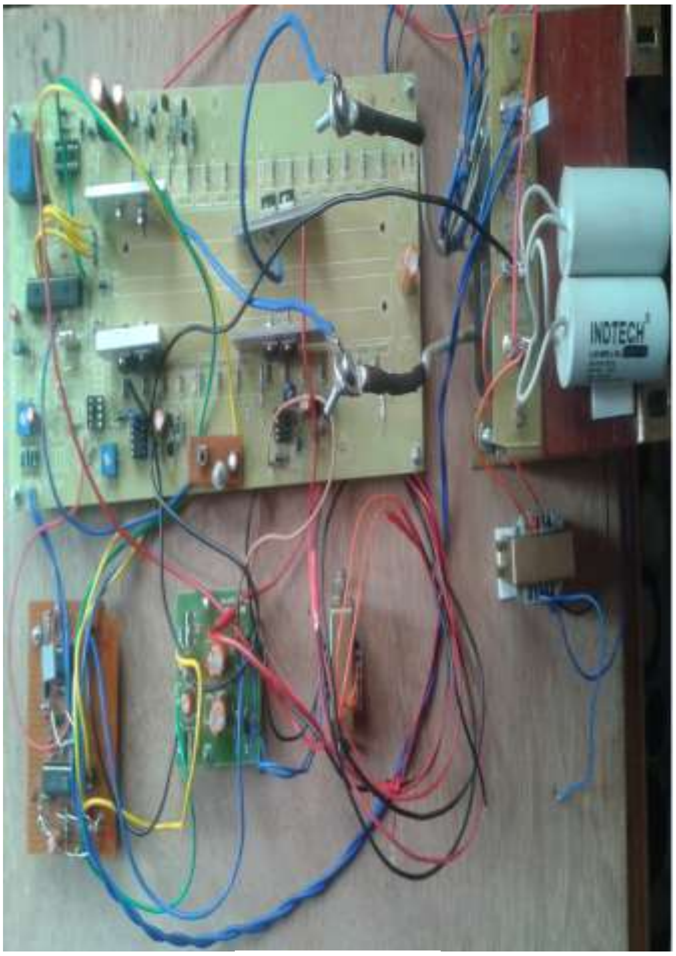

Fig 7: Main Hardware

VI. RESULT

1. GATE PULSES OF MOSFET 1 AND MOSFET 3:

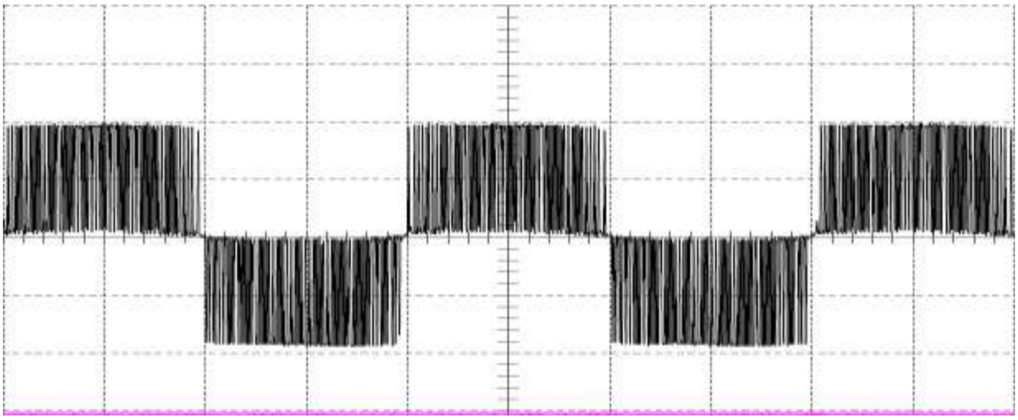

Fig 8: Gate Pulses of MOSFET 1 and MOSFET 3

2. GATE PULSES OF MOSFET 3 AND MOSFET 4

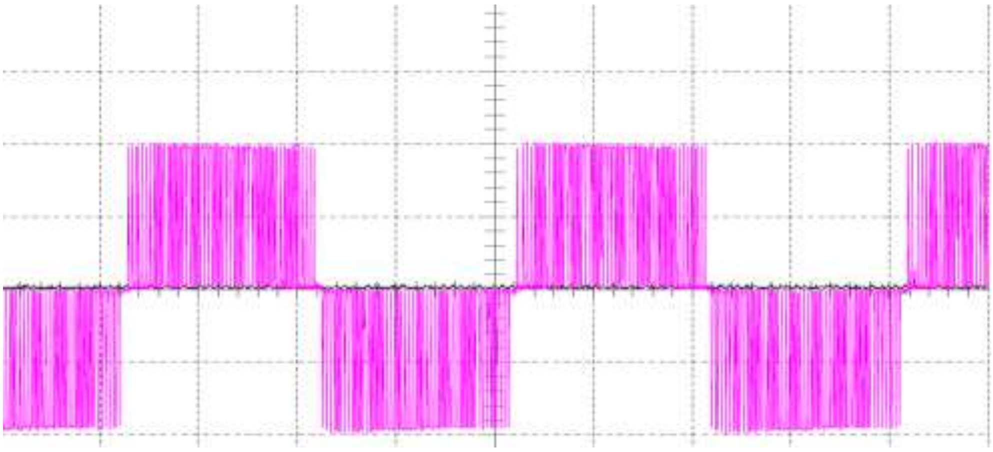

Fig 9: Gate Pulses of MOSFET 2 and MOSFET 4

3. SYNCHRONISATION OF SQUARE WAVE

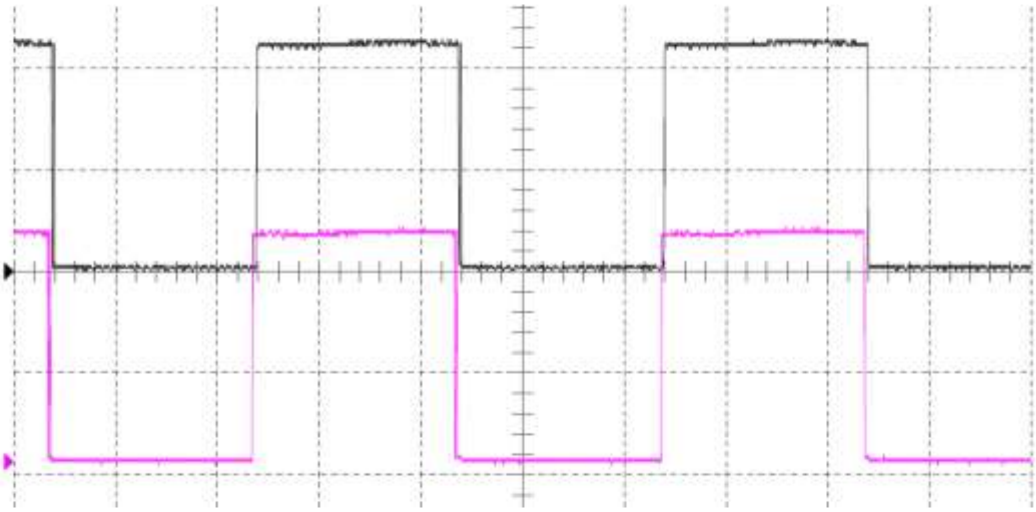

Fig 10:- Synchronization of Square Wave

4. SYNCHRONIZATION OF OUTPUT AND INPUT WAVEFORM

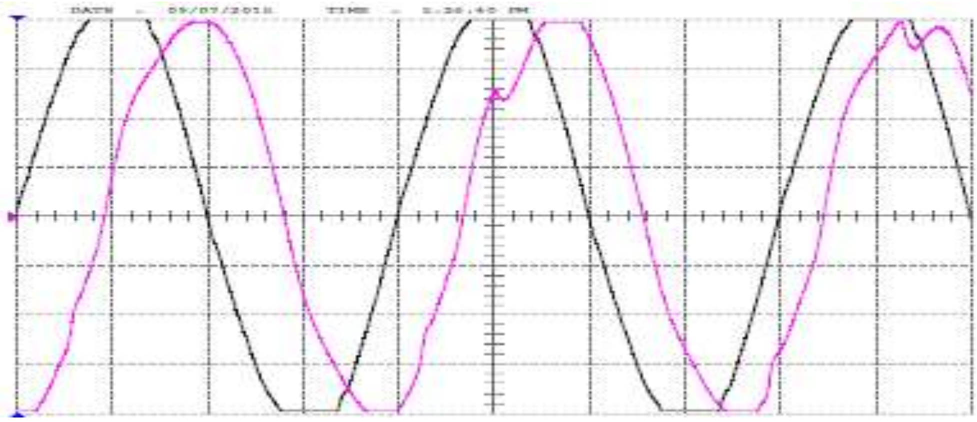

Fig 11: Synchronization of Input and Output Waveform

5 OUTPUT WAVEFORM

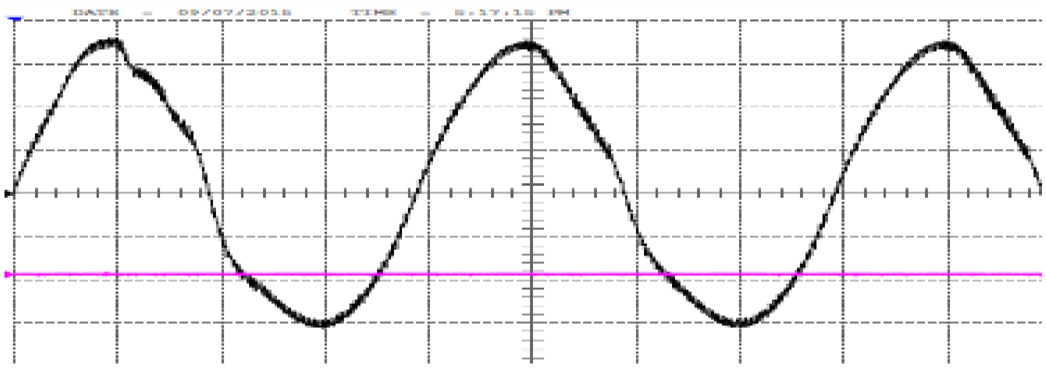

Fig 12:- Output Waveform

CONCLUSION

This paper presents a comprehensive technique for the mitigation of power quality problems such as low power factor, shortage of reactive power, poor voltage, voltage and current harmonics due to sudden change in field excitation of synchronous alternator, suddenly increased in load, sudden fault occurs in the system are solved by FACTS controllers such as D-STATCOM. This report also presents the current status of mitigation of power quality problems by FACTS controllers.

Suitable Adjustment of the phase and magnitude of the D-STATCOM output voltages allows effective control of active and reactive power exchanges between the D-STATCOM and the ac system. Such configuration allows the device to absorb or generate controllable active and reactive power. The VSC connected in shunt with the ac system provides a multifunctional topology which can be used for three quite distinct purposes:

1. Voltage regulation and compensation of reactive power;
2. Correction of power factor and
3. Elimination of current harmonics.

D-STATCOM rectifies the corresponding problems. Thus we concluded that the usage of compensating device like D-STATCOM gives a greater advantage to solve these problems which occur in power quality. D-STATCOM is the best technique for reducing power quality problems in the solar energy system.

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