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D-Statcom Application to Mitigate Voltage Fluctuation and Overcome Power Blackout Risks

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***Abstract*: Controlling of voltage and reactive power is very necessary for reliable operation of power system. Reactive power is the only reason for increase in loss of distribution system and power quality problems. These various problems could lead to complete cut out of load end from supply, which increases the risks of power blackout. The fast acting device DSTATSCOM is very important device that improves power factor, maintains constant distribution voltage and mitigates harmonics in distribution network. D-STATCOM reduces the voltage variations and voltage instability of power system and can result in fast recovery of system voltage after contingency event. This paper is the continuation of my phase 1 project on "D-STATCOM Application to Mitigate Voltage Fluctuation and Overcome Power Blackout Risks", which covered the simulation part. The 2nd phase paper concludes the hardware circuit details and functions of D-STATCOM which shows the controlling technique and application for the regulation of voltage and overcome the risks of power blackout.**

***Keywords*: D-STATCOM, Distributed Generation System, Voltage Source Converter, Voltage Fluctuation, Power Blackout, Micro-Grid.**

1. INTRODUCTION

In present era, every industrialized society and economy depends on electricity for every work. Today's life has become much more vulnerable power supply interruption due to increasing demand of continuous power supply. Due to increasing number of loads, power quality issues have become more considerable. Power quality problem and loss of distribution system is caused mainly due to reactive power.

Reactive power must be controlled for reliable operation of power system which supports the voltage. The damages like motor and generator overheating, the reduction of transmission losses and to maintain system's ability to overcome disturbances interfered and to prevent voltage collapse, that can be done by proper operation of electrical equipments installed in system by keeping the voltage within defined limit.

These power quality problems can be sorted and overcome by using custom power device. Voltage source converter based FACTS device is used for various power quality issues. D-STATCOM is fast acting device of reactive power source which is used to reduce voltage variation and instability that occur in power system and it can recover the system voltage as faster as possible after eventuality event. D-STATCOM has many similar characteristics that of STATCOM which is used at transmission level. While D-STATCOM behaves as shunt active filter and is installed at load end or at distribution level. The application of D-STATCOM is to evince controlling of reactive power at high speed and to give stabilised voltage in power system. Distribution system is protected by using D-STATCOM from voltage collapse, sag and fluctuation that are resulting due to reactive current demand.

2. D-STATCOM

A D-STATCOM is basically a converter based distribution flexible AC transmission controller, that has many similar characteristics that of Static Compensator (STATCOM) which is used at transmission level. Else D-STATCOM is installed at the distribution level or at load end for dynamic compensation. A D-STATCOM is a custom device that has DC link capacitor and Voltage source converter that are shunted, that is capable to generate and/or absorb reactive power. The principles of operation of a D-STATCOM are generally based on the conventional rotating synchronous compensator. The Point of Common Coupling and VSC's AC terminal are connected with the help of inductance, which can behave as leakage reactance or filter inductance in coupling transformer.

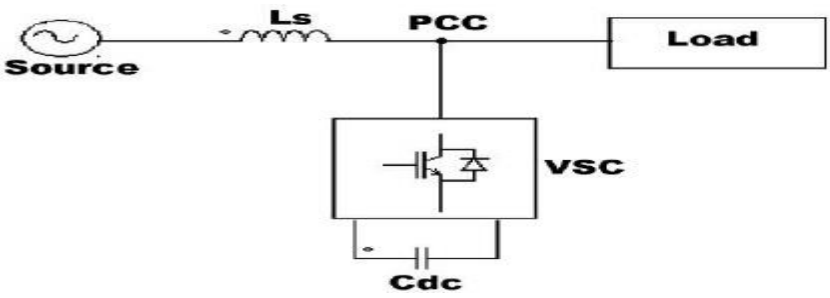

Fig.1 Schematic diagram of a D-STATCOM

The DC capacitor which carries converter's input current ripple and the reactive storage element is connected to the DC side of capacitor. The source of battery the capacitor is charged or converter can precharge it. No reactive power will be delivered to the system if the AC terminal voltage is not equal to the VSC input voltage. If the output voltage is greater than AC terminal voltage, the D-STATCOM is in the capacitive mode of operation. The difference of the two voltages is equal to the quantity of reactive power that flows.

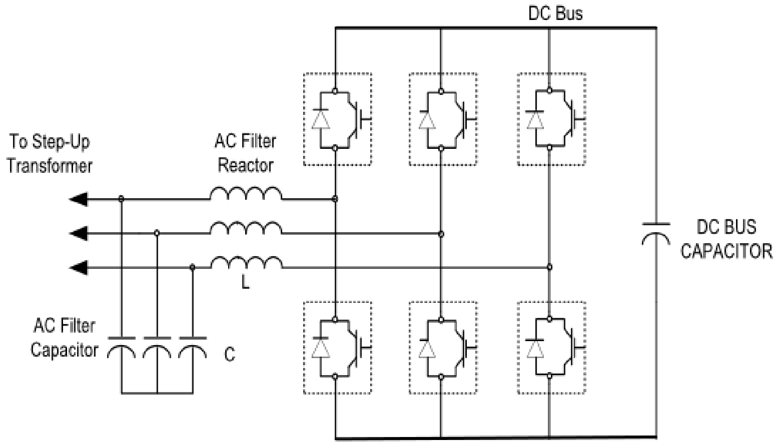

Fig.2 Single line diagram of a D-STATCOM

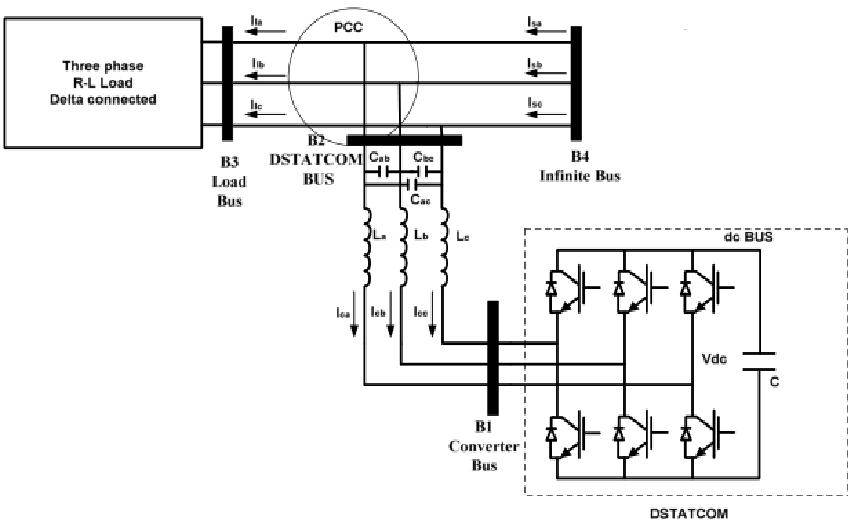

Fig.3 Schematic of a typical Distribution System compensated by DSTATCOM

The D-STATCOM system master controller provides flexible voltage and reactive power controlling techniques that supports many power system applications including reactive support and voltage control, fast voltage recovery support, enhancing system voltage stability, improving system transient stability, improving system reliability, improving line capacity utilization, minimizing system losses.

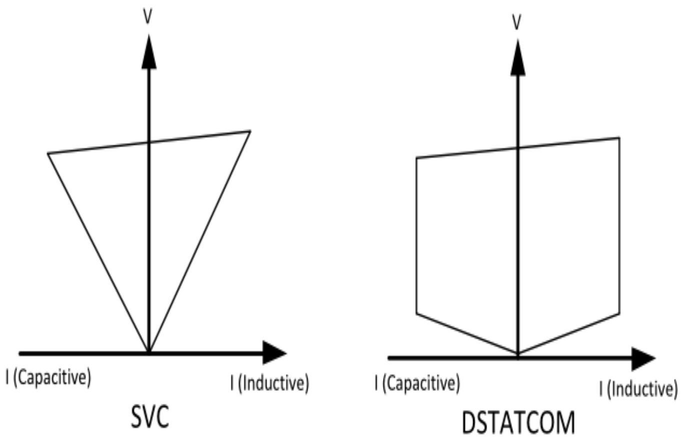

Fig.4 Voltage- Current (V-I) Characteristics of SVC vs D-STATCOM

A. Control Strategies:

Satisfactory performance, fast response, flexible and easy implementation are the main objectives of any compensation strategy. Below are the controlling techniques of D-STATCOM that are mainly implemented:

- Measurements of system variables and signal conditioning
- Extraction of reference compensating signals
- Generation of firing angles for switching devices

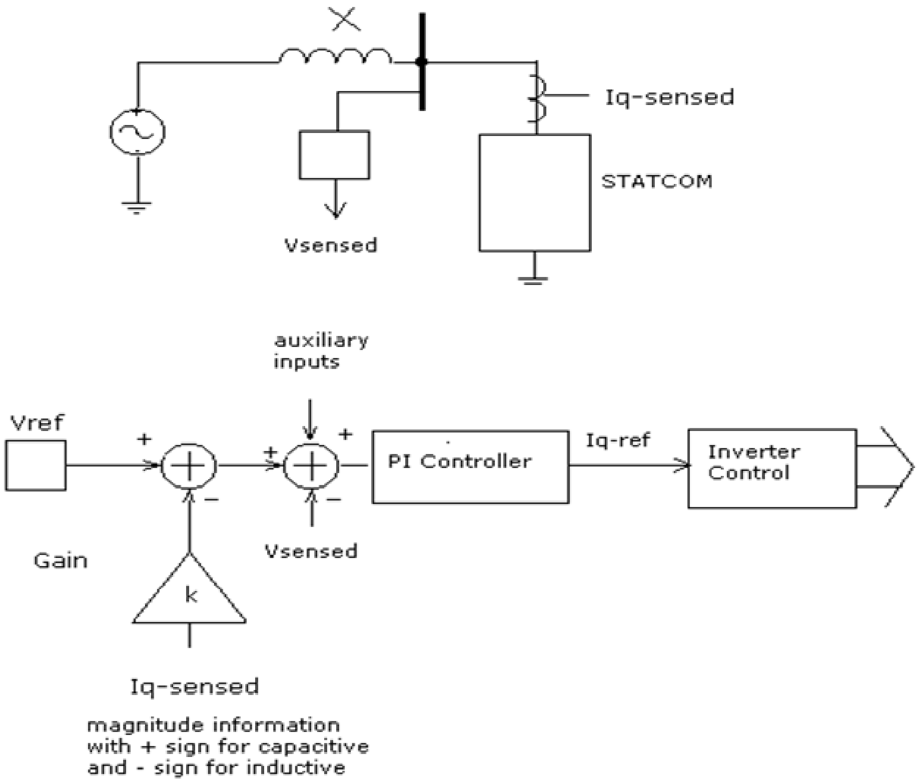

Fig.5 Schematic diagram of DSTATCOM control.

3. HARDWARE CIRCUIT DETAILS

A. Driver Circuit:

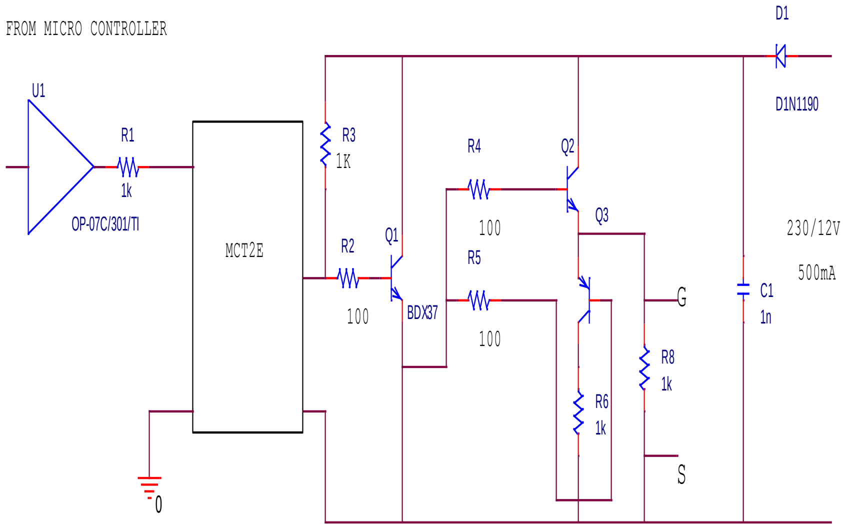

Fig. 6 Circuit diagram of driver circuit

By the use of step up transformer of 230V/12V AC supply is given to the driver circuit. The use of driver circuit in this project is for the amplification of pulse output coming from the microcontroller circuit

The output from pin 1 and 2 of PIC16F877A is passed to the buffer IC CD4050 .The buffer IC acts as a NOT gate, the output from the buffer IC is passed to the two optocoupler respectively. The optocoupler is used to isolate the voltages between the main circuit and microcontroller circuit. This signal is passed to the transistors CK100 and 2N2222 which is connected in a Darlington pair model. The driver circuit has two legs. First leg is connected to switch-1 Sm and the second leg is connected to switch-2 Sa. Thus the MOSFET switch receives the 12V voltage that is amplified from 5V pulse from microcontroller circuit.

B. POWER SUPPLY UNIT:

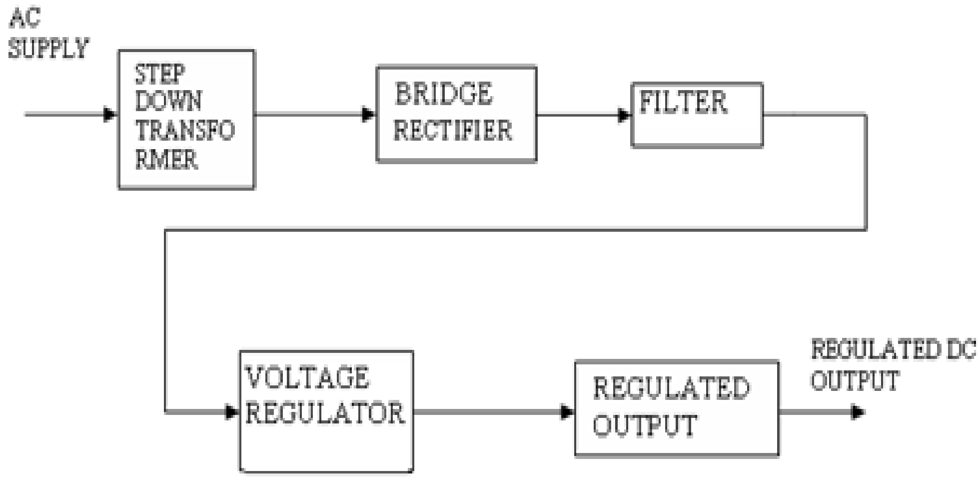

Fig. 7 Block diagram of power supply unit

Without the power source any latest invention of technology can't be activated. Hereby proper power source is necessarily required for particular requirement in this fast moving world. All components whether it is electronics components that is from diode to Intel IC's only work with a DC supply between ±5v to ±12v range. Energy source of 230v-50Hz that are commonly available and are cheap are mainly utilized for stepping down, rectifying, filtering and regulating the voltage.

C. PIC MICROCONTROLLER:

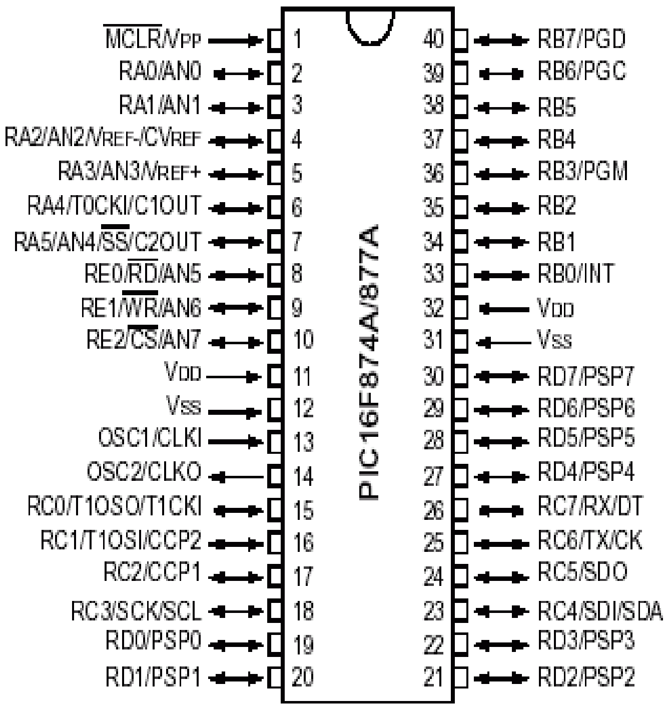

Fig. 8 Pin diagram of PIC16F877A Microcontroller PINOUT

The processor is required to perform different conversions and various operations that is required for switching, controlling and monitoring the device. Microprocessors, microcontrollers or embedded controllers are the types of processor. As we require generating clock pulse so the microcontroller PIC16F877A is used in this project.

D. MOSFET SWITCHES IRF- 840:

In our project the MOSFET switch is connected to the main circuit. Here we have two switches namely

- Main switch Sm
- Auxiliary switch Sa

The pulse to these switches is given using micro controller PIC16F877A through a driver circuit. In PIC16F877A the pulse of 5V is generated which is sent to driver circuit, these signal is amplified to about 12V DC, that is sent to the MOSFET switch Sm and Sa respectively.

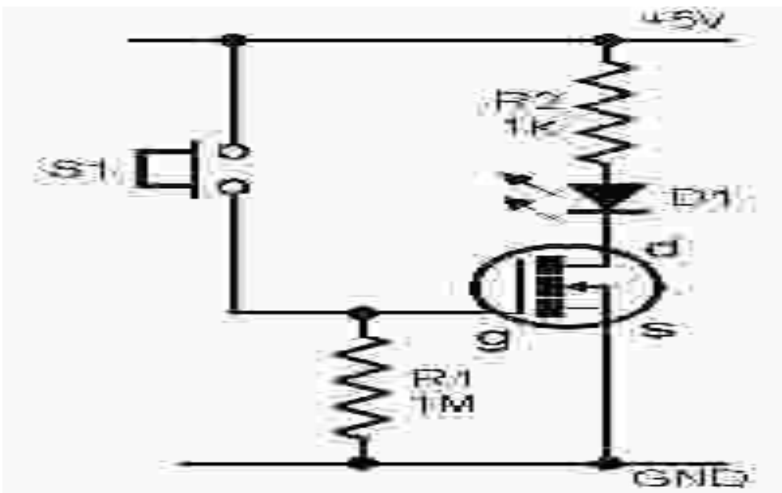

Fig. 9 MOSFET used as switch

The logic level MOSFET is used in this project that is directly driven from microcontroller output line. For these experiments, N channel BS270 MOSFET is used which is designed for logic level inputs. It is turned off when gate and ground are connected and turns on when gate is connected to 5V. As the current is very low that is whatever the input voltage could be (if kept within 0 to 5 volts) there is no need of resistor that could be used between gate and push button switch.

4. HARDWARE CIRCUIT DETAILS AND FUNCTION

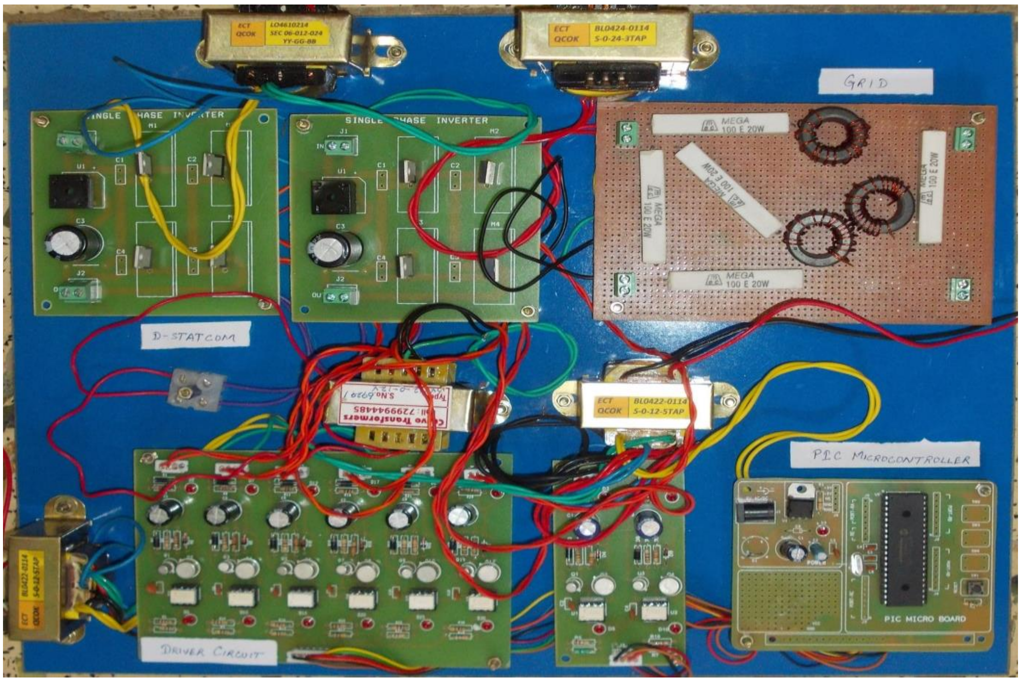

Fig. 10 working hardware circuit

The hardware circuit comprises four units they are:-

A. PIC microcontroller,

B. Driver circuit,

C. D-STATCOM

D. Grid.

A. PIC Microcontroller:

A 12V supplied voltage is converted from AC to DC by using half wave rectifier. This converted DC voltage is pulsating and have ripples, to make it fixed and to get smooth DC voltage capacitor filters are used that has 1000 µF rating. This capacitor filter minimizes ripples and makes DC voltage smooth and fixed. Here the supplied voltage ranges between 12 to 9 volts which is higher than the voltage required for PIC microcontroller used.7805 PIC microcontroller is used here that is designed to provide 5 volts output. To get this 5 volts supply for 7805 PIC microcontroller voltage regulator is used. The voltage regulator reduces this 12 to 9 volts into 5 volts which is supplied to PIC microcontroller. With the use of crystal oscillator we give clock pulse to PIC microcontroller. 7805 PIC microcontroller has 40 pins and 35 instructions set. It has 5 ports, port A, port B, port C, port D, and port E. In which ports A and D is used for analog to digital conversion, port B is used for interrupt, port C is used for pulse generation and port E is used for serial communication. Port C is used to get the pulse wave form. The pulse generated in port C is given to the driver circuit. The waveform of pulse generated from port C is taken is given in fig 10

B. Driver Circuit:

The driver circuit gets 12 volts AC supply which is converted into DC by using half wave rectifier. Generated pulse from PIC microcontroller is given to the driver circuit. This driver circuit comprises of Optocoupler, Darlington amplifier, Diode and Zener diode. The optocoupler is used to amplify the 5V signal to 12V. Darlington amplifier is a combination of p-n-p and n-p-n junction that is used to reduce the switching losses. Pn junction diode is conducting forward direction to signal from PIC to converter. Zener diode is used to restrict reverse current. The amplified signal waveform is taken from driver circuit and is given in fig 10

C. D-STATCOM:

12 volt AC is connected to D-STATCOM. Bridge rectifier is used to convert the supplied AC into pulsating DC. To get fixed DC capacitor filter is used. D-STATCOM consists of IRF840 MOSFETS. It has 8 MOSFETS that performs switching action to give pulse to the D-STATCOM.

D. GRID:

The grid contains inductor of 1μH and resistor of 100Ω. 24 volt supply is given to the grid from 24volt step up transformer. The inductor used here reduces this 24V supply and the waveform of this reduced voltage output is taken which is shown in fig 14. When 24volt supply is reduced due to inductor the D-STATCOM starts working and regulates this voltage fluctuation. The waveform of regulated voltage by using D-STATCOM is taken that can be seen in fig 15

In this hardware we are using multi-inverter of 7 level and the waveform of 7 level multi- inverter is shown in fig 13. The 7 level multi- inverter is mainly used to reduce the harmonics.

5. OUTPUT WAVE FORMS OF HARDWARE CIRCUIT

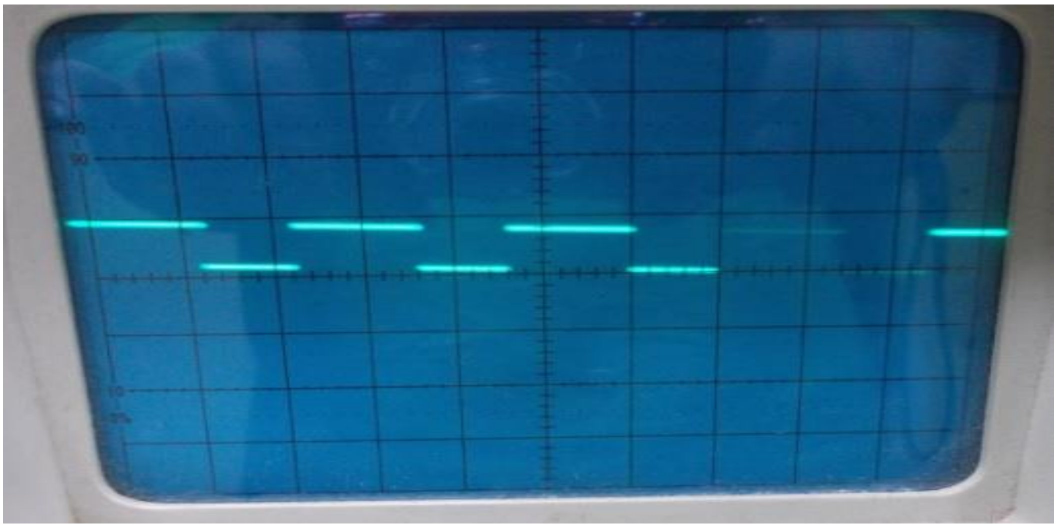

Fig. 11 5V Pulse waveform generated from port C of 7805 PIC microcontroller

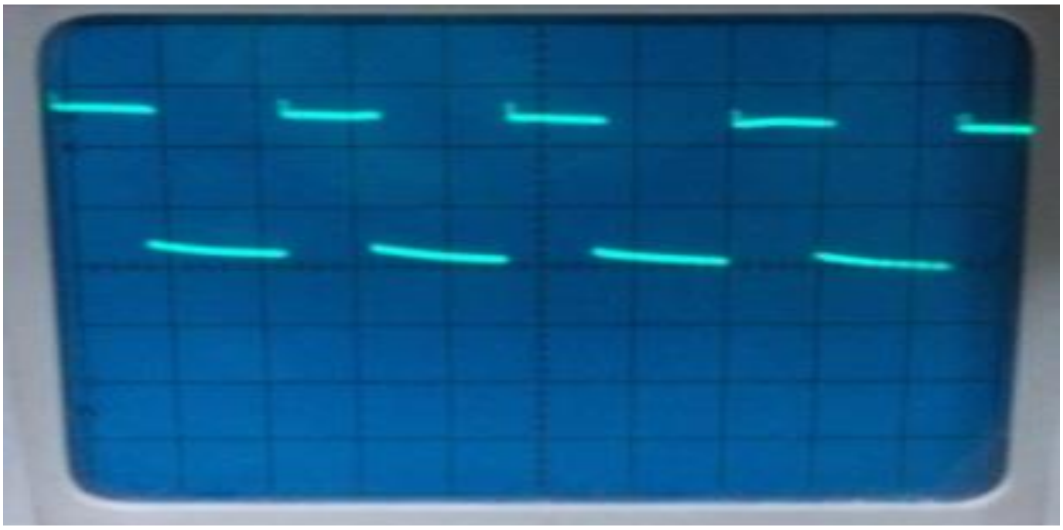

Fig.12 12V Amplified pulse waveform

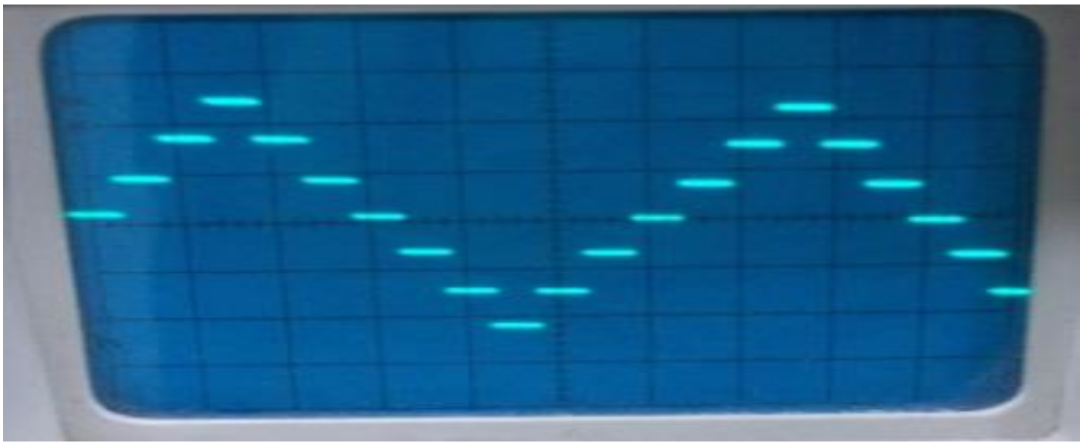

Fig.13 7 level multi- inverter waveform

Fig.14 Reduced 24V Output waveform without D-STATCOM

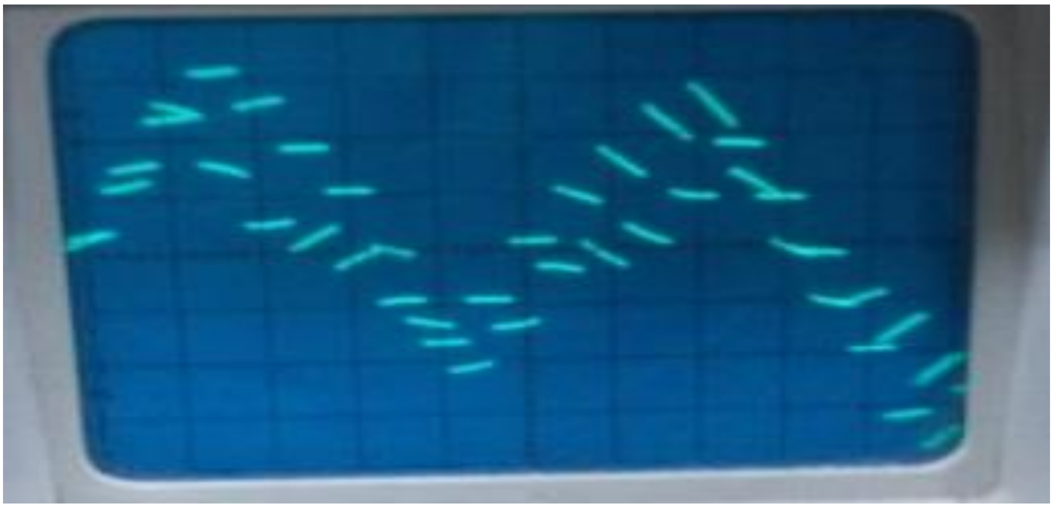

Fig.15 24V Output waveform with D-STATCOM

6. CONCLUSION

The control techniques used for controlling DSTATCOM, with their relative advantages and disadvantages are shown in this paper. The details of hardware and its function for linear and nonlinear loads with the help of waveforms. Hardware result shows the suitability of AC/DC bus voltage regulation for harmonic suppression and reactive power compensation to achieve improved power quality levels at the distribution end.

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