# Dynamic Voltage Restorer Based Five Level Cascaded Multilevel Inverter

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**Abstract:** ***Modern industrial devices are mostly supported electronic devices like programmable logic controllers and electronic drives .The electronic devices are very sensitive to disturbances and subsided tolerant to power quality problems such as voltage sags, swells and harmonics. Among the entire power quality issues, voltage sag and voltage swell occupy a major role. So my project deals with compensating voltage sag, voltage swell and Interruption at load side using 5-level multilevel inverter as a Dynamic Voltage Restorer***

**Keywords:** Power Quality, Dynamic Voltage Restorer (DVR), Multilevel Inverter, Simulation and Hardware Result

## 1. Introduction

Modern electrical power systems area unit advanced networks with many generating stations and thousands of load centres area unit interconnected through long power transmission and distribution networks. Power quality is major concern in industries these days owing to monumental losses in energy and cash. With the appearance of myriad refined electrical and equipment, like computers, programmable logic controllers and variable speed drives that area unit terribly sensitive to disturbances and non-linear masses at distribution systems produces several power quality issues like voltage sags, swells and harmonics and also the purity of sin wave shape is lost.

Power distribution systems, ideally, ought to give their client with associate uninterrupted power flow at smooth sinusoidal voltage at the contracted magnitude level and frequency .A momentary disturbance for Sensitive electronic devices cause voltage reduction at load finish resulting in frequency deviations which ends up in interrupted power flow, disorganized knowledge, surprising plant shutdowns and failure. Voltage raise up at a load are often achieved by reactive power injection at the load purpose of common coupling (PCC). The common technique for this can be to put in automatically switched shunt capacitors within the primary terminal of the distribution electrical device. The mechanical switch could also be on a schedule, via signals from a superior management and knowledge acquisition (SCADA) system, with some temporal arrangement schedule, or with no switch the least bit. The disadvantage is that, high speed transients cannot be paid. Some sag isn't corrected inside the restricted time-frame of mechanical switch devices.

Another power electronic answer to the voltage regulation is that the use of a dynamic voltage preserver (DVR). DVR's area unit a category of custom power devices for providing reliable distribution power quality. They use a series of voltage boost technology victimization solid state switches for compensating voltage sags/swells.

## 2. Sources and Effects of Power Quality Problem

Power Quality problems has a wide range of disturbances such as voltage sags/swells, flicker, harmonics distortion, impulse transient, and interruptions, etc. which are discussed below

a) **Voltage dip:** A voltage dip is employed to ask short-run reduction in voltage of but 0.5 a second.
b) **Voltage sag:** Voltage sags will occur at any instant of your time, with amplitudes starting from ten – ninetieth and a period lasting for 0.5 a cycle to 1 minute.
c) **Voltage swell:** Voltage swell is outlined as a rise in rms voltage or current at the facility frequency for durations from zero.5 cycles to one min.
d) **Voltage impulses:** These area unit terms accustomed describe abrupt, terribly temporary will increase in voltage price.
e) **Voltage transients:** they're temporary, undesirable voltages that seem on the facility supply route. Transient's area unit high over-voltage disturbances (up to 20KV) that last for an awfully short time.
f) **Harmonics:** curved element of a periodic wave having a frequency that's associate integral multiple of the basic frequency.
g) **Flickers:** Visual irritation and 0introduction of the many harmonic elements within the provide power and their associated sick effects.

**Causes of Dips, Sags and Surges**

1) Rural location remote from power source
2) Unbalanced load on a three phase system switch of significant masses
3) Long distance from a distribution electrical device with interposed masses.
4) Unreliable grid systems
5) Equipment's not appropriate for native provide.

**Causes of Transients and Spikes**

1) Lightening 2.Arc attachment
2) Switch on significant or reactive equipment's like

motors, transformers, motor drives
3) Electrical grade switch, etc.

## 3. Solutions to Power Quality Problems

There are measure two approaches to the mitigation of power quality issues. Initial approach is termed load acquisition that ensures that the instrumentality is a smaller amount sensitive to power disturbances, permitting the operation even beneath vital voltage distortion. The opposite resolution is to put in line acquisition systems that suppress or counteracts the ability system disturbances. Presently they're supported PWM converters and connect with low and medium voltage distribution system in shunt or serial. a number of the effective and economic measures may be known as following.

***Mechanical Switching Shunt Capacitors*:**
It is put in primary terminal of distribution electrical device. However some sag isn't corrected among restricted time-frame of mechanical change capacitors. Electrical device faucets are also used, however faucet dynamical below load is dear.

***Thyristor Based Static Switches:***
To correct quickly for voltage spikes, sags or interruptions, the static switch will switch to one or additional of devices like capacitance, filter, alternate power cable, energy storage systems etc. The static switches are often utilized in the alternate power cable applications

***Energy Storage Systems:***
Storage systems are generally used to sensitive production equipment's from shutdowns caused by voltage sags or momentaneous interruptions. These area unit sometimes DC storage systems like UPS, batteries, superconducting magnet energy storage (SMES), storage capacitors or maybe fly wheels driving DC generators. The output of those devices is equipped to the system through Associate in nursing electrical converter.

### 3.4. Dynamic Voltage Restorer

Dynamic Voltage trained worker (DVR) is that the best and effective fashionable custom power device and DVR could be a series connected solid state device and is connected in an exceedingly distribution system between the provision and also the crucial load feeder at the purpose of common coupling (PCC).

## 4. Dynamic Voltage Restorer

The general configuration of the DVR consists of:
1) An Injection/ Booster transformer
2) A Harmonic filter
3) Storage Devices
4) A Voltage Source Converter (VSC)
5) DC charging circuit
6) A Control and Protection system

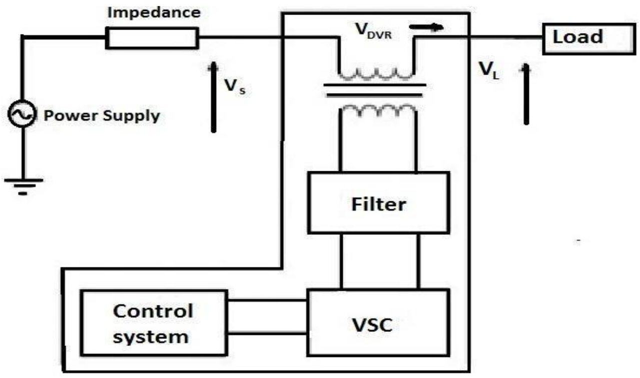


**Figure 4.1:** Schematic diagram of DVR

***The Injection / Booster transformer:***
The Injection / Booster electrical device could be a specially designed electrical device that makes an attempt to limit the coupling of noise and transient energy from the first aspect to the secondary aspect. Its main tasks are: It connects the DVR to the distribution network via the HV-windings and transforms and couples the injected compensating voltages generated by the voltage supply converters to the incoming offer voltage. Additionally, the Injection/ Booster electrical device serves the aim of uninflected the load from the system (VSC and management mechanism).

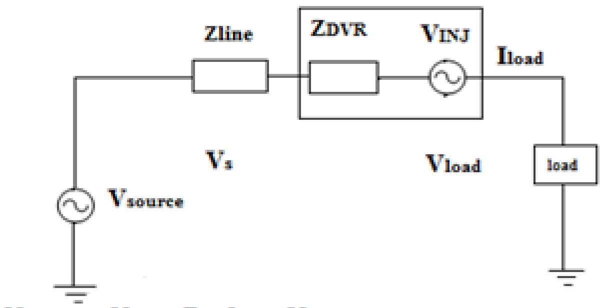
***Filter:***
The nonlinear characteristics of semiconductor devices cause distorted waveforms related to high frequency harmonics at the electrical converter output. To beat this downside provide prime quality energy supply, a harmonic filtering unit is employed. This may cause fall and part shift within the elementary part of the electrical converter output and must be accounted for within the compensation voltage.

***Voltage Source Converter:***
In the DVR application, the VSC is utilized to quickly replace the availability voltage or to return up with the a district of the availability voltage that's missing

***DC Charging Circuit:***
The dc charging circuit has 2 main tasks: the primary task is to charge the energy supply when a sag compensation event. The second task is to take care of dc link voltage at the nominal dc link voltage.

***Control and Protection:***
This management mechanism of final configuration generally consists of hardware with programmable logic all protecting functions of the DVR ought to be enforced within the computer code. Differential current protection of the electrical device, or contact current on the client load facet are solely 2sample of several protection functions chance.

## 5. Equations Related to DVR




$$V_{DVR} = V_L + Z_{th} I_L - V_{th}$$

Where:
VL: The desired load voltage magnitude Zth: The load impedance.
IL: The load current
Vth: The system voltage during fault condition

**Realization of Compensation Technique: Carrier Phase Shifting Pulse Width Modulation Technique**

Carrier phase shift sinusoidal pulse width modulation switching scheme operates the switches in the system. Optimum harmonic cancellation is done by phase shifting each carrier by, Where K is Kth and n is no of series connected single phase inverters,

N = (L-1)/2.

Fig 0.1 shows the PSCPWM, a structure electrical converter with m voltage levels needs (m–1) triangular carrier. within the PSCPWM, all the triangular carriers have an equivalent frequency and also the same peak to-peak amplitude, however there's a part shift between any 2 adjacent carrier waves, given by φ=360/ (m–1). The modulating signal is sometimes a three-phase curving wave with adjustable amplitude and frequency. The gate signals square Measure generated by examination the modulating wave with the carrier waves. It suggests that for five-level electrical converter, four triangular carriers square measure required with a 90° part displacement between any 2 adjacent carriers. During this case the part displacement of Vcr1 =0°, Vcr2 = 90°, Vcr1- = 180° and Vcr2- = 270°.

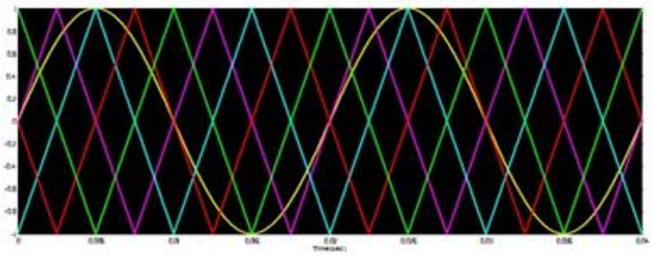


**Figure 5.1:** Phase shift carrier PWM

## 6. Simulation and Results

**Table 1:** Simulation result

| Sr. No. | System quantities | Standards |
|---|---|---|
| 1 | Three phase source | 11KV, 50Hz. |
| 2 | Step-up transformer | Y-Δ , 11/115KV |
| 3 | Transmission line parameter | R=0.001ohms,L=1.33e-6H |
| 4 | Step-down transformer | Δ-Y, 115/11KV |
| 5 | Load 1 &2 | 13.82KW, 400VAR |
| 6 | Inverter00 | 5 level<br>8 IGBT for single phase, amplitude=1, f=50Hz Dc battery= 100 V<br>Carrier Frequency =1000Hz, Internal resistance= 1e- 3ohms<br>Snubber resistance= 1e5ohms |
| 7 | Resistance | R=10ohms |
| 8 | DC battery | 250V |

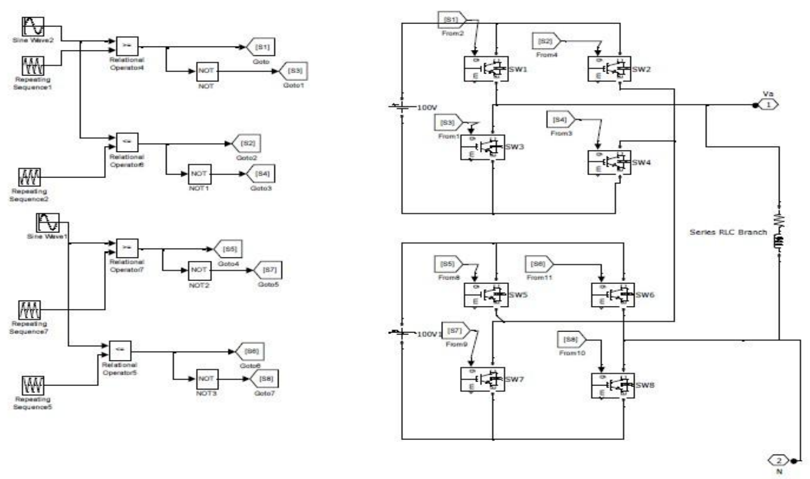


**Figure 5.2:** Single phase 5 level inverter with CPSPWM

**Table 2:** Harmonic number h (n) vs. individual harmonic distortion

| Frequency (Hz) | Harmonic Number h(n) | Three phase inverter with 2 level IHD% | Three phase inverter with multilevel IHD % |
|---|---|---|---|
| 0 | (DC) | 0.05 | 37.62 |
| 50 | (Fundamenta l) | 100 | 100 |
| 100 | (h2) | 0.16 | 75.50 |
| 150 | (h3) | 0.23 | 0.25 |
| 200 | (h4) | 0.10 | 40.11 |
| 250 | (h5) | 0.27 | 21.61 |
| 300 | (h6) | 0.32 | 4.81 |
| 350 | (h7) | 0.22 | 14.15 |
| 400 | (h8) | 0.18 | 17.65 |
| 450 | (h9) | 0.17 | 0.78 |
| 500 | (h10) | 0.22 | 16.99 |
| 550 | (h11) | 0.22 | 10.95 |
| 600 | (h12) | 0.03 | 4.91 |
| 650 | (h13) | 0.18 | 8.34 |
| 700 | (h14) | 0.43 | 9.34 |
| 750 | (h15) | 0.16 | 1.36 |
| 800 | (h16) | 0.13 | 11.24 |
| 850 | (h17) | 0.14 | 7.96 |
| 900 | (h18) | 0.05 | 5.09 |
| 950 | (h19) | 0.24 | 6.90 |
| 800 | (h16) | 0.13 | 11.24 |

The Multi-Level Inverters have blessings on two-level inverters like High Power rating, Low Harmonics in order that they offer the upper potency. The various topologies of Multi-Level Inverters are Neutral-point clamped (NPC) or Diode Clamped (DC) electrical converter, flying condenser electrical converter and Cascade electrical converter. Because the level will increase, NPC need additional clamping diodes therefore the management of real power flow becomes terribly troublesome.

The cascaded construction inverters have additional blessings than higher than mentioned topologies, as a result of it doesn't need any leveling capacitors and diodes. Cascaded inverters want separate DC sources for every H-Bridge, thus there's novoltage leveling drawback however isolated DC sources don't seem to be without delay offered, this can be the most downside of this topology. We have a tendency to reducing the doctorate but five hitter in each single part construction electrical converter and 3 part construction electrical converter.

The primary simulation was evaded DVR and results are obtained as shown in figure

**Voltage Sag- Open Loop System**

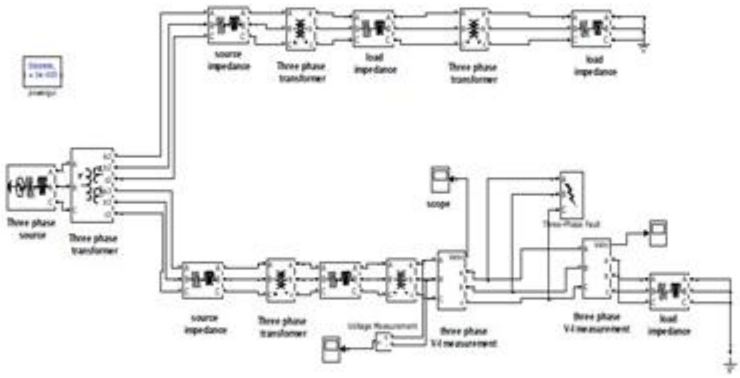


**Figure 5.3 (A):** Simulink diagram of open loop system for voltage sag

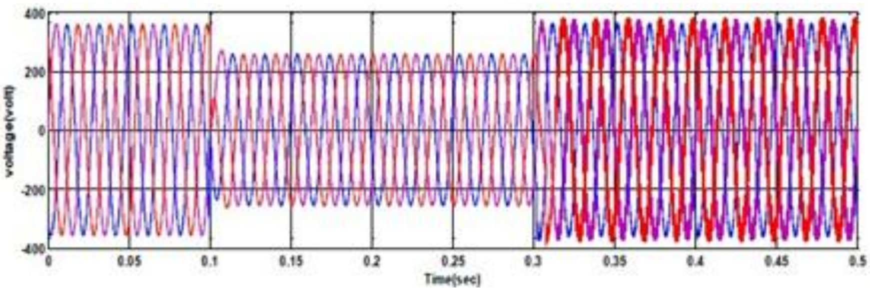



**Figure 5.3 (B):** Load voltage waveform

After the MATLAB Simulation of faults in transmission line, it was observed that the voltage and current waveforms are transient.

***Voltage Sag –Closed Loop System:***

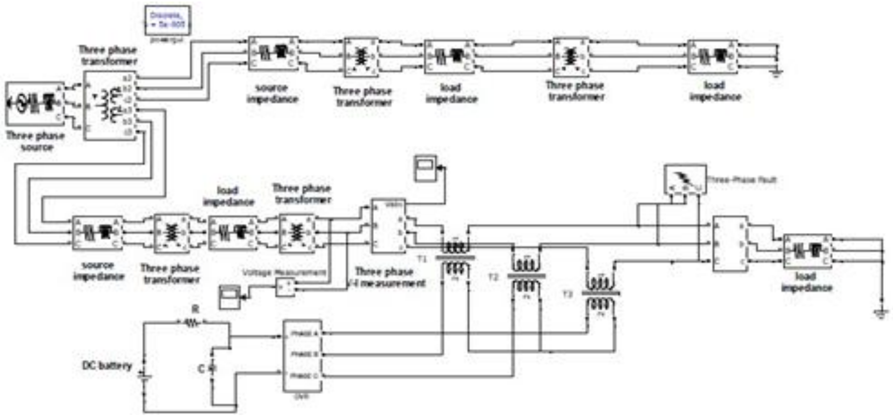


**Figure 5.4 (A):** Simulink diagram of close loop system for voltage sag

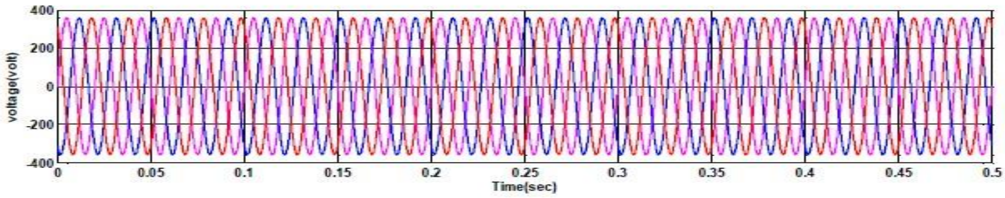


**Figure 5.4 (B) Compensator load voltage waveform**

Fig 5.4(B) shows the Simulink diagram of closed loop system using Dynamic Voltage Restorer with cascade multilevel inverter with CPSPWD technique the reference voltages are generated. It observing Fig 2.7 we can say that voltage sag is eliminated by using Dynamic Voltage Restorer so as to maintain load voltage constant. Fig 2.7 shows the voltage waveforms generated by the compensator during voltage sag so as to maintain load voltage constant. Figures and Tables

## 7. Hardware Implementation and Results

The complete hardware model as shown in fig.6.1. It consist of of single-phase Dynamic Voltage Restorer to mitigate the voltage sag consist of single-phase Power supply, Driver & inverter circuit, control circuit, Isolated power supply (Battery), Isolation transformer, load and 9V step down transformer to supply Zero crossing detector circuit. The Power circuit and Control circuits and its functioning are discussed here.

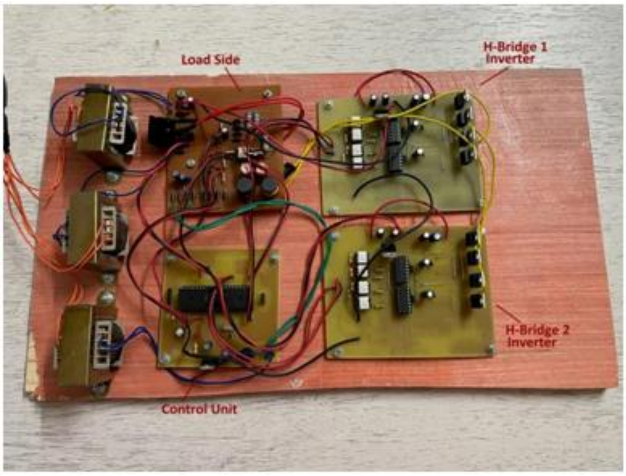



**Figure 6:** Hardware Model

**Power Circuit**
The Single phase power supply is obtained by using a step transformer of 230/12V, 1A to step-down the AC mains 230V to 12V AC supply. Here we require rectified DC power supply for powering the various electronic basic components from available AC mains supply. The circuit diagram shown in fig.6.1(a) clearly shows that A Bridge rectifier is used an Alternating Current (AC) to Direct Current (DC) converter that rectifies mains AC input to DC output. The 7805-voltage regulator IC is used to produce a regulated 5V as output. The power supply circuit used four diode (1N4007) and capacitor rating 220μF & 100μF. 1N4007 electrical characteristics include reverse voltage, reverse current, forward voltage, forward current etc.

**Regulator 7805**
This series of fixed-voltage integrated-circuit voltage regulators is designed for a wide range of applications. These applications include on-card regulation for elimination of noise and distribution problems associated with single-point regulation. Each of these regulators can deliver up to 1.5 A of output current. The internal current-limiting and thermal- shutdown features of these regulators essentially make them immune to overload. In addition to use as fixed-voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents and can be used as the power-pass element in precision regulator.

**Control Circuit**
Control circuit includes zero crossing detector, pic16f877a controller, driver circuit, inverter circuit which are discussed in details below,

**Zero Crossing Detector**
Zero crossing detector is one type of voltage comparator used to detect a sine waveform transition from positive and negative that coincides when input crosses the zero voltage condition. Here, 9V transformer is used to supply ZCD

which bridge and zener diodes. It is used for In phase injection.Fig.8.2 (a) shows the circuit diagram for Zero cross detector used in hardware model

**PIC16F877A Controller**

The Microcontroller PIC 16F877A is used in control circuit. The pin diagram of PIC 16F877A and interfacing connections are as shown in Fig. 8.2(b). It operates on 5V supply. It generates the reference voltage waveform from the voltage waveform that is sampled from the sensing network, which it has obtained from the reference voltage sensing circuit. This reference voltage waveform is generated keeping the zero crossing as the reference to maintain the phase relationship of the load and correcting voltage. The voltage induced by the bridge inverter is injected through isolation transformer to maintain the load side voltage. The technology used in PIC 16F877 is FLASH technology, so that data is retained even when the power is switched off. Easy programming and erasing are the other features of PIC 16F877.

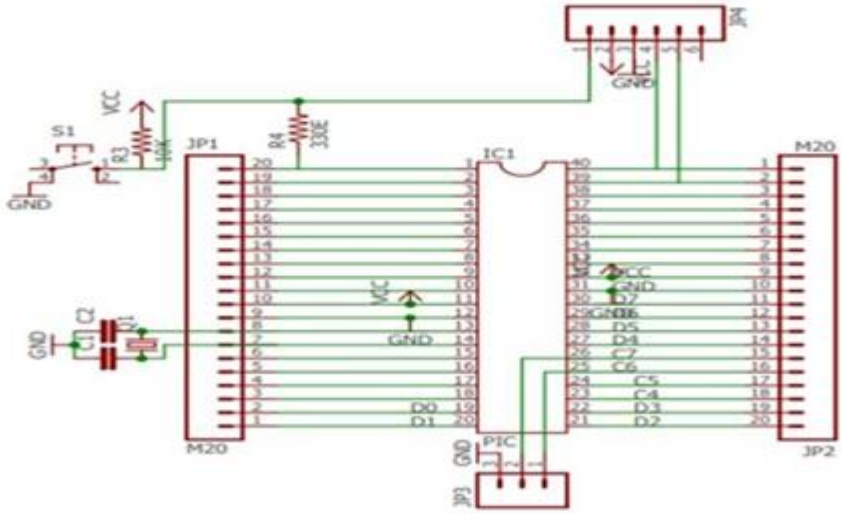



**Figure 6.4.2 (b)** PIC16F877A

**Driver Circuit**

Driver IC 2110 are used to drive MOSFET's in high side and low side. It has a floating circuit to handle the bootstrap operation. Driver IC requires 5V supply.

**Inverter Circuit**

The Inverter circuit converts DC to AC. Inverter circuit operates on 12V Supply. Two Full H brigde inverter circuit using four MOSFET'S that switches the polarity of a voltage applied to a load. The Fig.6.4.4 shows the schematic diagram of Driver and Inverter circuit.

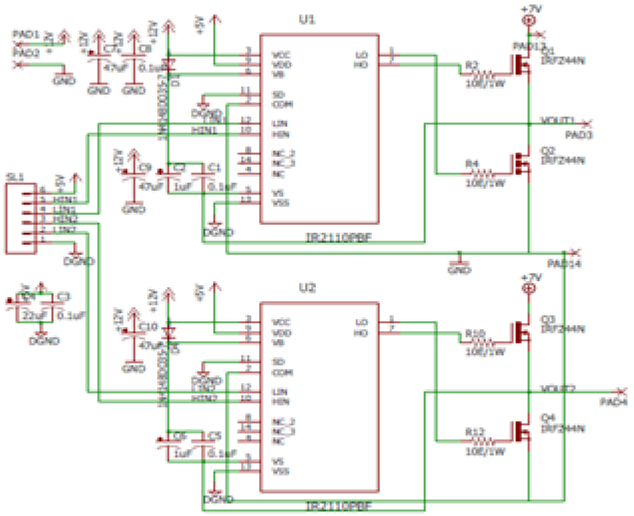



**Figure 6.4.4:** Inverter circuit

Fig. 6.4.4 shows the experimental set up of single-phase DVR. Under normal operating condition the load voltage is 12V.When nonlinear load is connected through switch, then harmonics are generated so that load voltage is continuously changing. As the load voltage changes continuously, load voltage and reference voltage are sensed by sensor and these difference in voltage is given to the controller. Controller compares voltage and finds the difference between them which gives command to the PWM circuit to generate required voltage.

When nonlinear load is connected through switch harmonics are generated, 50% sag is created in system as shown in fig 6.4.4(a)

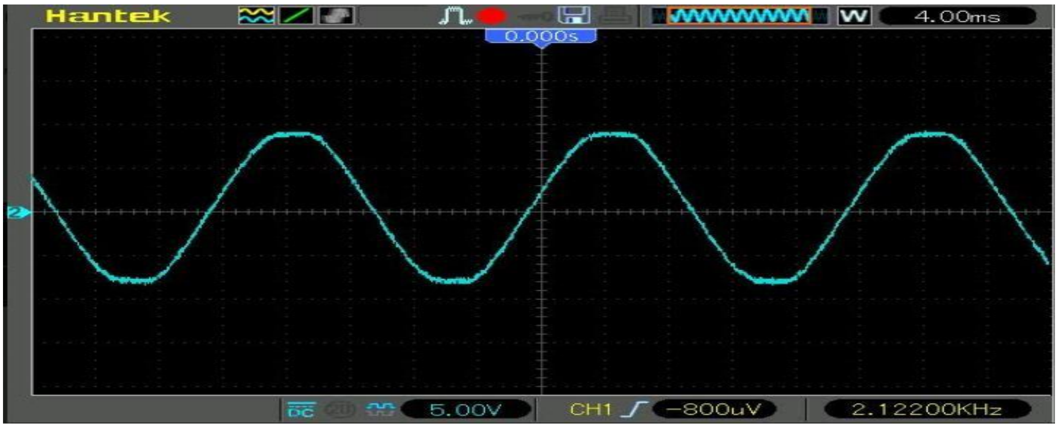



**Figure 6.4.4 (a):** Voltage waveform during normal operation

As the load voltage changes continuously, load voltage and reference voltage are sensed by sensor and these difference in voltage is given to the controller. Controller compares voltage and finds the difference between them which gives command to the PWM circuit to generate required voltage. External DC source is used to inject required voltage through inverter. Inverter gives dropped voltage to the load through injection transformer, so that load voltage is maintain constant.

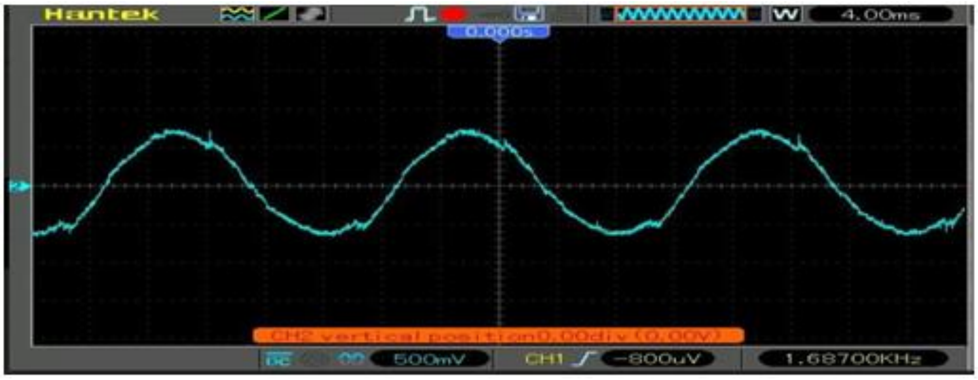



**Fig. 6.4.4(b):** Voltage waveform during sag condition

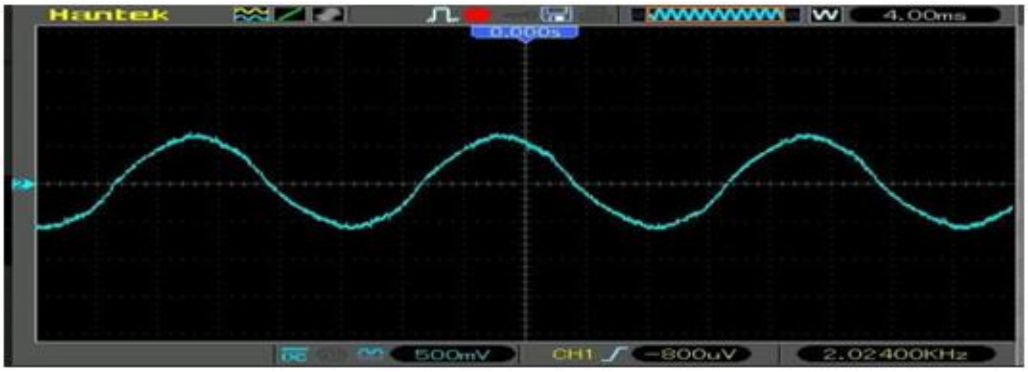



**Figure 6.4.4 (c):** Voltage waveform with operation of DVR

Fig.9.5 shows the voltage waveform with DVR operated, and load voltage gets maintained.

## 8. Conclusion

In this project voltage sag compensate by cascaded H-Bridge five level multilevel inverter is implemented as Dynamic Voltage Restorer. Closed loop control of Dynamic Voltage Restorer is designed for better regulation of the load voltage. Reference signal is generated using CPSPWM technique with multilevel inverter voltage Sag are compensated using Dynamic Voltage Restorer and MATLAB simulations are carried for the above to maintain load voltage constant. . In this work a single phase Hardware Implementation of DVR using cascaded H-bridge has been presented. The hardware results also show clearly that the DVR is a very fast responsive and less expensive device than other custom power devices. The proposed technique achieved better performance in Voltage Sag compensation as compared to conventional techniques

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