Hardware Model of Single Phase Dynamic Voltage Restorer

Geeta Awad¹, Suhas Jawale²
PG Student, EPS¹, Assistant Professor²
Department of EEP
Jawaharlal Nehru Engineering College, Aurangabad, Maharashtra, India

Abstract:
Harmonic disturbances are the frequently occurring Power Quality problems in the distribution system. Dynamic Voltage Restorer is normally employed as a solution for mitigation of harmonic voltage. The proposed system has less number of switching devices and has good compensating capability in comparison with commonly used compensators. The Static Series Compensator (SSC), commercially known as Dynamic Voltage Restorer (DVR), is best suited to protect sensitive loads against such incoming supply disturbances. This project presents the hardware implementation of single phase Dynamic voltage restorer in mitigating harmonic voltage. Harmonics are created by using nonlinear load. Single phase inverter based on IGBT is designed and firing pulse to the device using micro controller based PWM generation. Energy storage device used in this work is DC supply which acts as input to the inverter. DVR model compensates the voltage with efficient and effective manner.

Keywords: Dynamic Voltage Restorer (DVR), micro controller, Power Quality, Pulse Width Modulation (PWM), Voltage Sag.

I. INTRODUCTION

Power quality means maintaining nearly sinusoidal voltage at frequency 50 Hz. Harmonic voltages and currents in an electric power system are a result of non-linear electric loads. Harmonic frequencies in the power grid are a frequent cause of power quality problems. Harmonics in power systems result in increased heating in the equipment To prevent nonlinear load from harmonic interruption in the source side, a series connected custom power device is used. SSSC (static synchronous series compensator) and DVR both are presently used for series voltage compensation. Operating principle and functioning of these devices differ significantly as the SSSC injects a balance voltage in series whereas the DVR compensates the unbalance in supply voltage of different phases. The DVR supplies the active power with help of DC energy storage and required reactive power is generated internally without any means dc storage. DVR can compensate voltage at both transmission and distribution sides. Usually a DVR is installed on a critical harmonic distortion. During the normal operating condition (without sag condition) DVR operates in a low loss standby mode [1]. During this condition the DVR is said to be in steady state. When a disturbance occurs (abnormal condition) and supply voltage deviates from nominal value, DVR supplies voltage for compensation and is said to be in transient state. The DVR is connected in series between the load and the supply voltage [2]. It basically supplies the voltage difference to transmission line and maintains the normal values condition in the load sides [3]. Use of DVR is proposed in low and medium voltage distribution network to protect nonlinear load from sudden change in voltage [4]. Pulse width modulated inverter is used to vary the amplitude and the phase angle of the injected voltages, thus allowing the control of both real and reactive power exchange between the distribution system and the load [5]. For proper compensation it is necessary to derive suitable and fast control scheme for inverter switching. The general requirement of a control scheme is to obtain an AC waveform with minimum total harmonic distortion (THD) and best dynamic response against supply and load disturbance when the DVR is operated for voltage compensation [6].

II. OPERATING PRINCIPLE OF DVR

The DVR is designed to inject the missing voltage into the distribution line. Its basic idea is to dynamically inject a voltage \( u_d(t) \) as shown in Figure 1. As figure shows a simplified single-phase equivalent circuit of a distribution feeder with a DVR, where the supply voltage \( u_s(t) \), the DVR injection voltage \( u_d(t) \) and the load voltage \( u_l(t) \) are in series. So, the DVR is considered to be an external voltage source where the amplitude, the frequency and the phase shift of \( u_d(t) \) can be controlled. The purpose is to maintain the amplitude of the load voltage fixed and prevent phase jumps.

![Figure 1. DVR operational principle](image)

III. BLOCK DIAGRAM OF DVR

A schematic diagram of the DVR incorporated into a distribution network is shown in Figure 2. \( V_s \) is the source voltage, \( V_l \) is the incoming supply voltage before compensation, \( V_2 \) is the load voltage after compensation, \( V_{DVR} \) is the series injected voltage of the DVR, and \( I \) is the line current. The DVR typically consists of an
injection transformer, the secondary winding of which is connected in series with the distribution line. The injection of an appropriate DVR in the face of an upstream voltage disturbance requires a certain amount of real and reactive power supply from the DVR. The mostly control of industrial loads is mainly based on semiconductor devices, which causes such loads to be more sensitive against power system disturbances [7, 8]. Power electronic loads inject harmonic currents in the AC system and increase the overall reactive power demanded by the equivalent load, also, modern industrial equipment’s are more sensitive to these power quality problems than before and need higher quality of electrical power.

The Injection / Booster transformer serves the concern for industrial customers.

IV. CONFIGURATION OF DVR

A) Injection/ Booster transformer
The Injection/ Booster transformer is a specially designed transformer that attempts to limit the coupling of noise and transient energy from the primary side to the secondary side. Its main tasks are:

a. It connects the DVR to the distribution network via the HV-windings and transforms and couples the injected compensating voltages generated by the voltage source converters to the incoming supply voltage.

b. In addition, the Injection / Booster transformer serves the purpose of isolating the load from the system (VSC and control mechanism).

B) Harmonic Filter
The main task of harmonic filter is to keep the harmonic voltage content generated by the VSC to the permissible level.

C) Voltage Source Converter
A VSC is a power electronic system consists of a storage device and switching devices, which can generate a sinusoidal voltage at any required frequency, magnitude, and phase angle [9, 10]. In the DVR application, the VSC is used to temporarily replace the supply voltage or to generate the part of the supply voltage which is missing. There are four main types of switching devices: Metal Oxide Semiconductor Field Effect Transistors (MOSFET), Gate Turn-Off thyristors (GTO), Insulated Gate Bipolar Transistors (IGBT), and Integrated Gate Commutated Thyristors (IGCT). Each type has its own benefits and drawbacks. This converter is designed with IGBTs.

D) Control System
The control mechanism of the general configuration typically consists of hardware with programmable logic. All protective functions of the DVR should be implemented in the software. Here microcontroller PIC16F877A is used.

V. DVR HARDWARE MODEL

In single phase DVR using injection /booster transformer for injecting voltage during abnormal condition. IGBT Inverter, Voltage regulators, IGBT driver, LED driver for indication. Microcontrollers are very important part of this project. Here microcontroller PIC16F877A is used.

Figure 2. Block diagram of DVR

Tripping of voltage sensitive loads such as PLCs and adjustable-speed drives due to voltage sag is a serious power quality concern for industrial customers.

This is the hardware implementation of Dynamic Voltage Restorer (DVR) designed for mitigation of harmonic voltage. In this the arrangement is of various sub circuits as shown in the model. 4 IGBT’s for inverter, DVR coupling network, Isolation IC, Isolated power supply circuit, Lamp load, microcontroller circuit, 1:1 isolated transformer, Supply transformer, Control circuit transformer. In the block diagram, the 230V, 50 Hz supply is isolated by means of a 1:1 isolation transformer. This isolated voltage is treated as the line voltage, which supplies power to the load. To have maximum effect of voltage across the load, nonlinear load is connected. After main load, a switch is connected, through which the load can be connected or disconnected. In the return path, the DVR output is connected, by means of the output winding of the coupling transformer developed. This output from the DVR is connected in series with the load, and mitigates the nonlinear load effects, i.e., in this case the voltage drop caused by it. The DVR circuit has to check the load voltage and need to be connected to the micro controller circuit and correct the voltage if there is any shortage or excess when compared to a reference voltage, by injecting appropriate voltage into the circuit by means of the coupling network. In this hardware model 15 watt bulb is used as load which is connected in series with the inductance having inductance of 10mH. The functioning and designing of different blocks of dynamic voltage restorer is discussed herewith.

a) Single phase voltage source bridge inverter
Single phase, 12 volt, 10mA, voltage source inverter is used. The voltage source inverter used in the DVR circuit makes the

http://ijesc.org/
induction of required voltage with required phase possible. This inverter uses dc voltage as the supply and can switch at a high frequency to generate a signal which will mitigate the voltage across the load.

b) Microcontroller circuit
5volt, 10mA, PIC16F877A controller is used. The microcontroller circuit is the heart of the system, and is responsible for generating 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. As the voltage induced through the coupling transformer, generated by the bridge inverter, the resulted voltage across the load will be a pure sinusoid of required voltage.

c) Driver circuits
Driver IC IR2110 is used to drive the inverter circuit. It operates on 5 volts. Driver IC’s are generally used when spikes are generated and this is depend on load.

d) Isolation circuit
Isolation ICs are used to isolate power supply for microcontroller and for inverter circuit. Microcontroller needs 5volts supply while inverter circuit needs 12 volt supply for its operation. The voltage waveform for mitigating the voltage variations in the load circuit is achieved with the voltage source inverter, coupling transformer and an interfacing filter. The coupling transformer needs to transfer energy from the voltage source inverter to the load and at the same time need to provide low impedance on the load side. In order to trigger the IGBTs, it is required to apply a +12V pulse to make it turn „ON” and -12V pulse to turn it „OFF” to the gate with respect to its emitter. Thus, in order to provide triggering pulses to each and every IGBT, it is required to have four isolated power supplies of ± 12V which can be used to apply trigger pulses to the respective IGBTs. This inverter provides the required outputs, which can be used to drive the IGBT gate.

e) Isolated power supplies for filter elements
Three different power supplies are required, to provide power to various blocks of the over-all DVR circuit. The microcontroller requires basically a 5V supply. But, the op-amp circuit associated with the potential divider circuit requires a ±12 volts supply. This supply is generated from a step-down transformer connected to the mains. The DVR inverter requires a separate power supply.

Inverter driving circuitry

VI. RESULT AND DISCUSSION
Under normal condition load voltage is 209volts. As there is no voltage harmonics so that supply voltage is equals to load voltage. During this condition DVR is at stand still condition.

TABLE 1. COMPONENTS AND ITS RATINGS

<table>
<thead>
<tr>
<th>Component</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply transformer</td>
<td>230v,50Hz,2A</td>
</tr>
<tr>
<td>Injection transformer</td>
<td>12v,0.5A</td>
</tr>
<tr>
<td>Step down transformer</td>
<td>230v/12v,0.5A</td>
</tr>
<tr>
<td>DC Supply</td>
<td>12v,1.3Ah</td>
</tr>
<tr>
<td>Microcontroller</td>
<td>PIC16F877A</td>
</tr>
<tr>
<td>Lamp load</td>
<td>15watt,230v,50Hz</td>
</tr>
</tbody>
</table>

When nonlinear load is connected to the load through switch, harmonics are generated so that load voltage is continuously...
changing. As bulb is used as a load, so that bulb will start to blink continuously. Below image shows the reading of load voltage when nonlinear load is connected to the circuit.

**Figure.8. When nonlinear load is connected load voltage is 202v**

As the load voltage changes continuously, load voltage and reference voltage is 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.

**Figure.9. When nonlinear load is connected load voltage is 209v**

**Figure.10. When nonlinear load is connected load voltage is 205v**

**Figure.11. DVR injects required voltage so load voltage is 208v.**

**VII. CONCLUSION**

The implementation of DVR system using microcontroller has been presented. DVR is an effective custom power device for harmonic voltage mitigation. The impact of harmonics on nonlinear equipment is severe. Therefore, DVR is considered to be an efficient solution due to its low cost, small size and fast response. The hardware results indicate that the implemented control strategy compensates for voltage harmonics in seconds. The results show that the control technique is simple and efficient method for voltage compensation.

**VIII. REFERENCES**


[7]. Smitha Sethumadhavan,"Hardware implementation of MLI based dynamic voltage restorers", International Journal of Science and Research (IJSR).