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A Dynamic Voltage Restorer System by Modified Z-Source Inverter to Mitigate Voltage Sag

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Abstract

Dynamic Voltage Restorer (DVR) is a custom power device used in power distribution networks to protect consumers from sudden sags and swells in grid voltage. On the basis of recent developments in impedance source (Z-source) inverters the present paper proposes an integration of quasi-Z-source inverter (QZSI) with a built-in high frequency transformer. New type LCCT-Z-Source inverters are presented. Proposed inverters characterize continuous input current, improved relationship between boost coefficient and modulation index and improved EMI performance. Application of four element (Inductor - Capacitor - Capacitor - Transformer) LCCT impedance network provides higher voltage gain than obtained in quasi-Z-source inverter. The advantage of proposed topology over other recently developed Z-source inverters is that two built-in capacitors block DC currents in transformer windings and prevents core saturation. Simulation results are shown to verify the proposed topologies.

INTRODUCTION

The voltage sag / swell is the most common power quality related problem among the industries. Such voltage sag / swell have a major impact on the performance of the microprocessor based loads as well as the sensitive loads. In a power line voltage sags / swells can occur as a result of load switching, motor starting, faults, lightning, non-linear loads, intermittent loads, etc.. IEEE 519-1992 and IEEE 1159-1995 describe the Voltage sags / swells as shown in Table 1 and within which controlling equipment should be connected together with the critical loads as corrective measures [1]. DVR is a commercially available cost effective device, which is capable of addressing the above voltage sag problem effectively

DEFINITIONS FOR VOLTAGE SAG AND SWELL

Type of disturbance	Voltage	Duration
Voltage Sag	0.1 - 0.9 pu	0.5 - 30 cycles
Voltage Swell	1.1 - 1.8 pu	0.5 - 30 cycles

EXISTING SYSTEM

The voltage sag / swell is the most common power quality related problem among the industries. Such voltage sag / swell have a major impact on the performance of the microprocessor based loads as well as the sensitive loads. In a power line voltage sags / swells can occur as a result of load switching, motor starting, faults, lightning, non-linear loads, intermittent loads, etc..describe the Voltage sags / swells as shown in Table 1 and within which controlling equipment should be connected together with the critical loads as corrective measures [1]. DVR is a commercially available cost effective device, which is capable of addressing the above voltage sag problem effectively.

PROPOSED SYSTEM

An integration of quasi-Z-source inverter (QZSI) with a built-in high frequency transformer. New type LCCT-Z-Source inverters are presented. Proposed inverters characterize continuous input current, improved relationship between boost coefficient and modulation index and improved EMI performance. Application of four element (Inductor - Capacitor - Capacitor - Transformer) LCCT impedance network provides higher voltage gain than obtained in quasi-Z-source inverter. The advantage of proposed topology over other recently developed Z-source inverters is that two built-in capacitors block DC currents in transformer windings and prevents core saturation.

DYNAMIC VOLTAGE RESTORERS

A DVR is a device that injects a dynamically controlled voltage Vinj(t) in series to the bus voltage by means of a booster transformer as depicted in Figure1. The amplitudes of the injected phase voltages are controlled such as to eliminate any detrimental effects of a bus fault to the load voltage VL(t). This means that any differential voltage caused by transient disturbances in the AC feeder will be compensated by an equivalent voltage generated by the converter and injected on the medium voltage level through the booster transformer. The DVR works independent of the type of fault or any event that happens in the system, provided that the whole system remains connected to the supply grid, i.e. the line breaker does not trip. For most of the time the DVR has, virtually, "nothing to do," except monitoring the bus voltage.

This means it does not inject any voltage (Vinj(t)= 0) independent of the load current. Therefore, it is suggested to particularly focus on the losses of a DVR during normal operation. Two specific features addressing this loss issue have been implemented in its design, which are a transformer design with low impedance, and the semiconductor devices used for switching voltage and Vinj(t) is the voltage injected by the mitigation device as shown in Fig. 2. Under nominal voltage conditions, the load power on each phase is given by

SL = ILVL*= PL - jQL (2)

Where I is the load current, and, PL and QL are the active and reactive power taken by the load respectively during a sag. When the mitigation device is active and restores the voltage back to normal, the following applies to each phase

SL =PL-j QL=(PS-j Qs) +(Pinj-jQinj) (3)

where the sag subscript refers to the sagged supply quantities. The inject subscript refers to quantities injected by the mitigation device.

MODIFIED Z- SOURCE INVERTER

Z-source inverters (ZSI) are one stage energy processing buck-boost inverters that contain unique passive input circuits (impedance networks) and utilize the shoot-through of the inverter bridge to boost DC input voltage. The impedance network of ZSI serves as power storage and guarantees double filtration grade at the input of the inverter. The ZSI topology features a DC link consisting of asymmetrical lattice network with two inductors and two capacitors. Two topologies of 3-phase ZSI and modified ZSI are shown.The voltage gain G mentioned in the introduction of ZSI can be written as

G=Vout/(VD.C/2) =M.

where Vout denotes amplitude of AC output line-to-line voltage. Using the maximum constant boost control (MCBC) the boost factor B can be defined as:

B=1/(1-2D)

Design of DVR

The aim of the control scheme is to maintain constant voltage magnitude at the point where a sensitive load is connected under system disturbances. The control system only measures the r.m.s voltage at the load point, i.e., no reactive power measurements are required. The proposed control scheme based on comparison of actual supply voltage and desired load voltage. The error is determined dynamically based on difference between desired and measured value. In the control scheme the actual voltage is measured and also the desired voltage. These voltages are converted in dq0 with the Parks transformation

$$f_{dqo} = K_s f_{abc} \qquad \text{Where } (f_{dqo})^T = (f_d\ f_q\ f_o)$$

$$\text{Where } (f_{abc})^T = (f_a\ f_b\ f_c)$$

$$K_s = \frac{2}{3}\begin{bmatrix} \cos\theta & \cos(\theta-(2\pi/3)) & \cos(\theta+(2\pi/3)) \\ Sin\theta & \sin(\theta-(2\pi/3)) & \sin(\theta+(2\pi/3)) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix}$$

$$\omega = d\theta/dt$$

The control system employs abc to dqo transformation to dq0 voltages. During normal condition and symmetrical condition, the voltage will be constant and d-voltage is unity in p.u. and q-voltage is zero in p.u. but during the abnormal conditions it varies. After comparison d-voltage and q voltage with the desired voltage error d and error q is generated. These error component is converted into abc component using dq0 to abc transformation. Phase Locked Loop(PLL) is used to generate unit sinusoidal wave in phase with main voltage. This abc components are given to generate three phase Pulses using Pulse Width Modulation (PWM) technique. Proposed control technique block is shown.

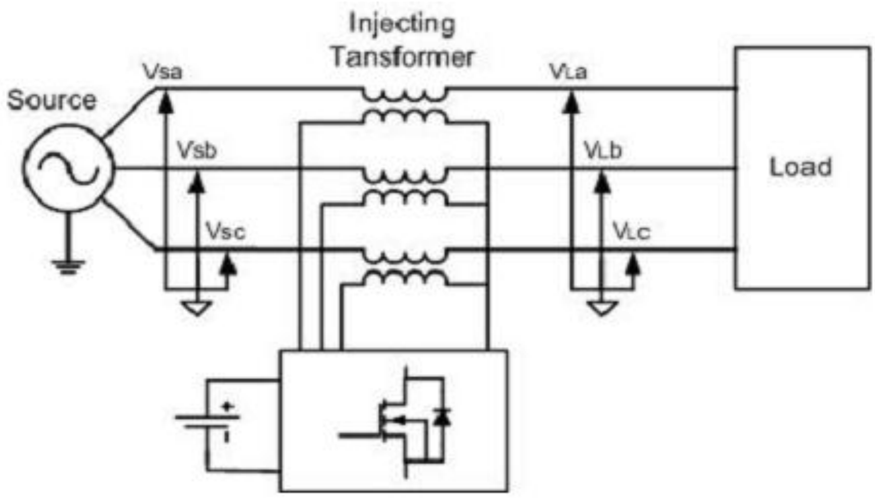

Figure 1. Circuit diagram

Schematic diagram of DVR system

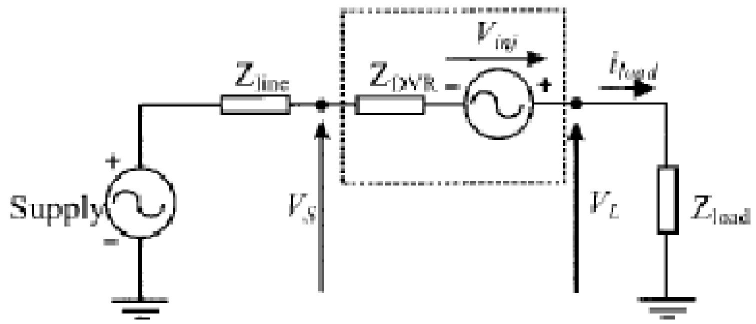

Figure 1.2 Equivalent circuit of DVR system

MODIFIED Z- SOURCE INVERTER

Z-source inverters (ZSI) are one stage energy processing buck-boost inverters that contain unique passive input circuits (impedance networks) and utilize the shoot-through of the inverter bridge to boost DC input voltage. The impedance network of ZSI serves as power storage and guarantees double filtration grade at the input of the inverter. The ZSI topology features a DC link consisting of asymmetrical lattice network with two inductors and two capacitors. Two topologies of 3- phase ZSI and modified ZSI are shown in Fig.2 and Fig. 2.1

Z SOURCE INVERTER:

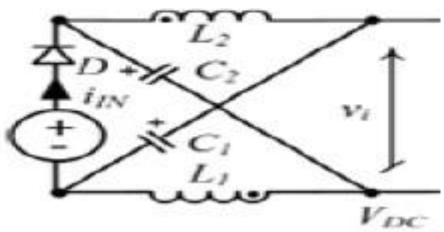

Figure 2. Z SOURCE INVERTER

MODIFIED Z- SOURCE INVERTER

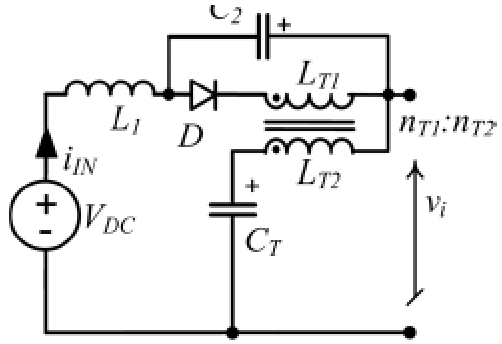

Figure 2.1. MODIFIED Z- SOURCE INVERTER

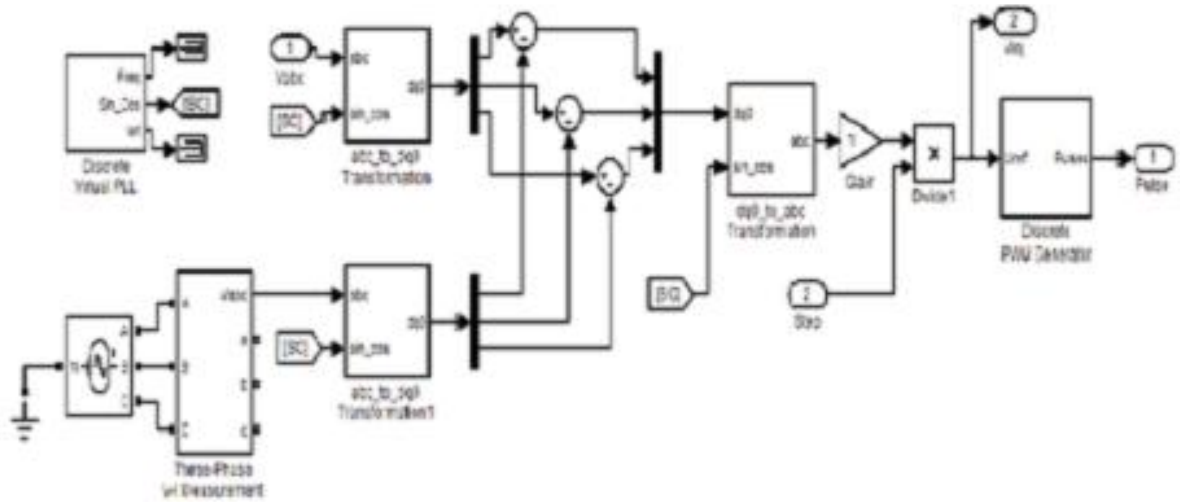

Figure 3. Control block diagram

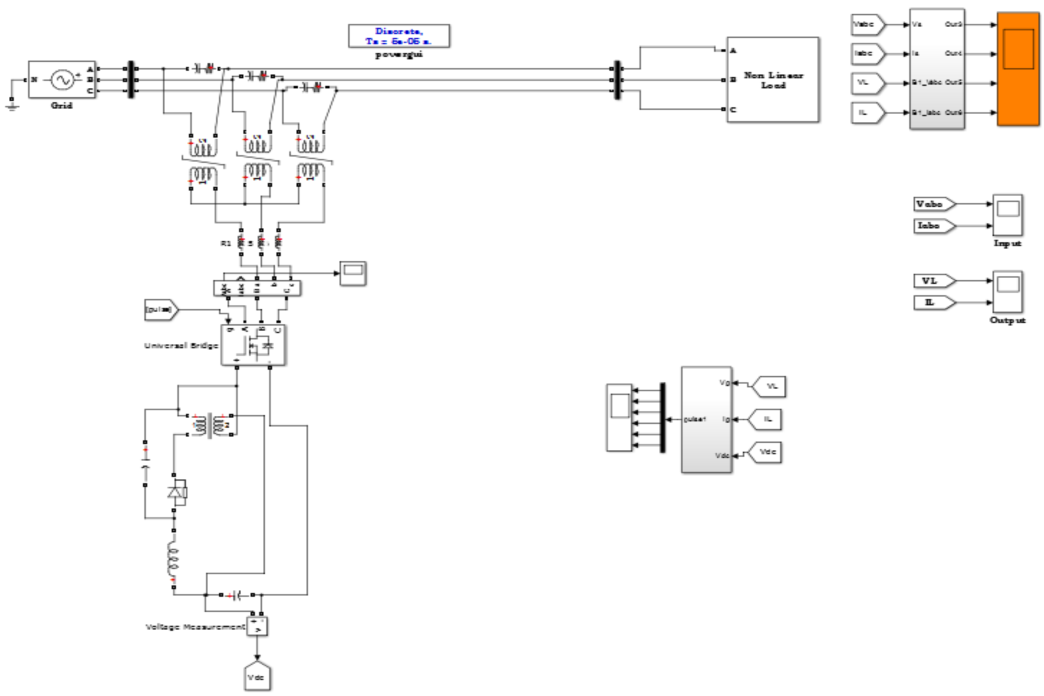

Figure 4. Simulation

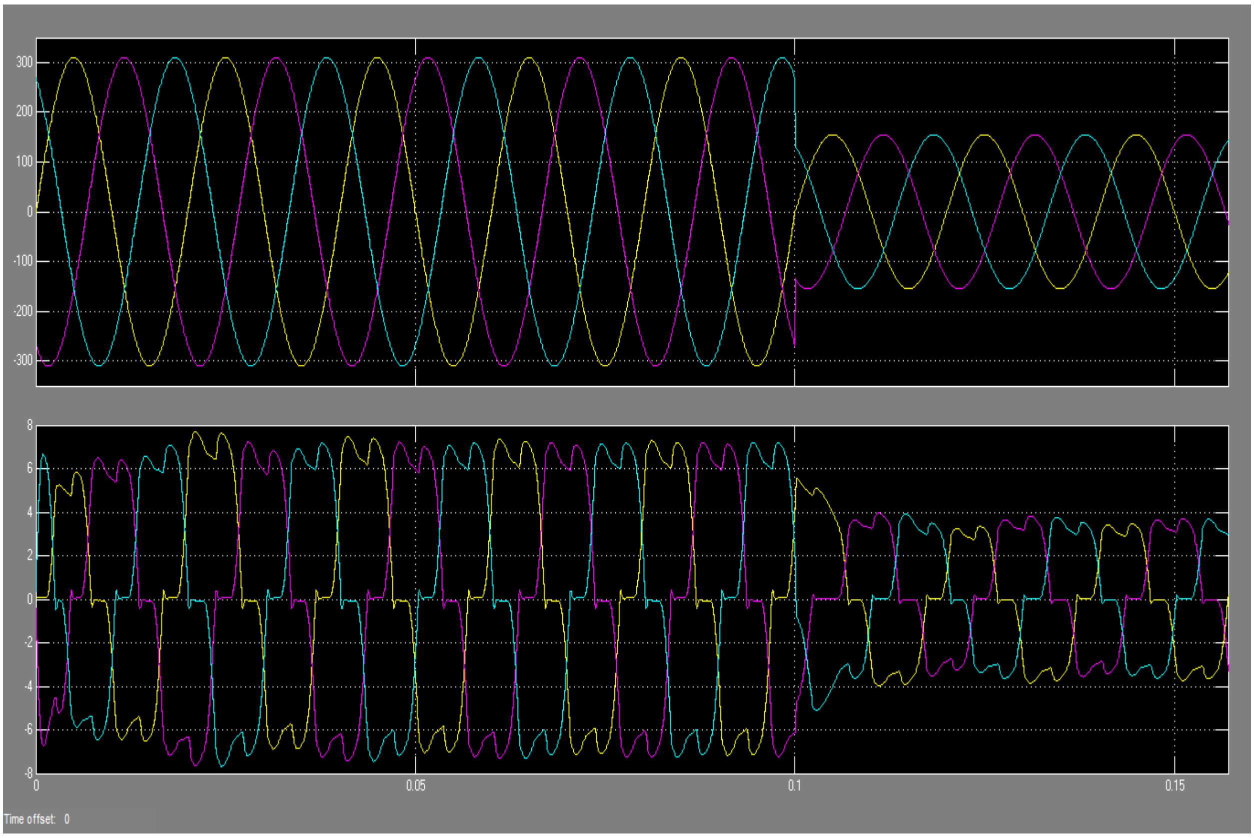

Figure 4.2. Source voltage

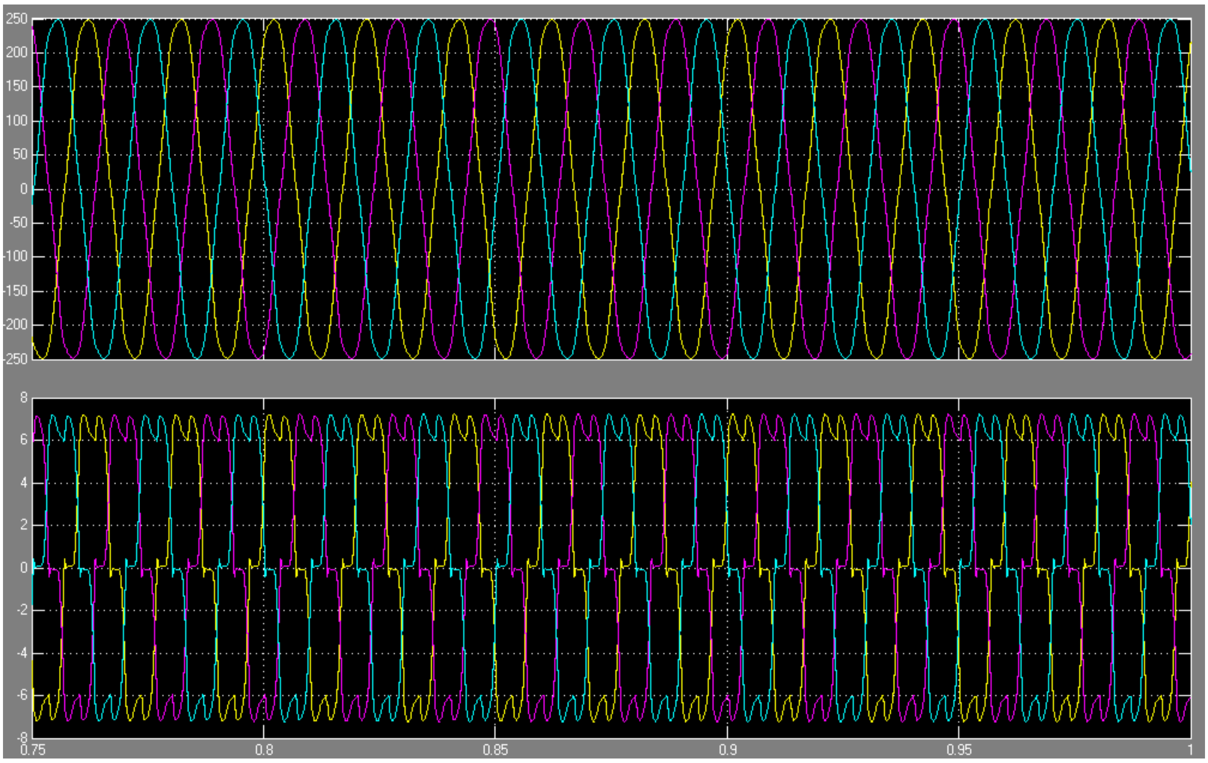

Figure 4.3. Load voltage and current

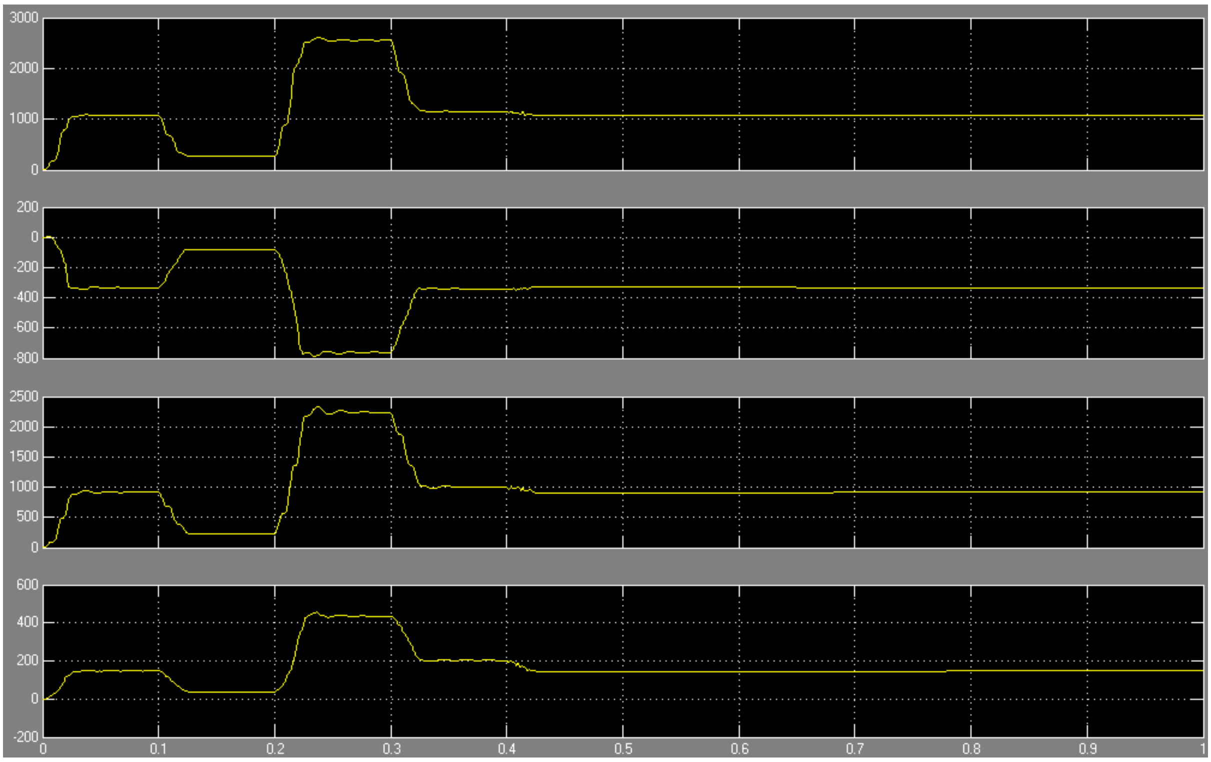

Figure 4.4 Real and reactive power

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RESULTS:

The voltage waveform when the DVR is ON , the observed waveform is at the coupling network is clearly shown in fig. 5

Figure 5. Voltage waveform at the DVR Coupling network

The voltage waveform when initially the supply is given without any load connections shown in fig.5.1

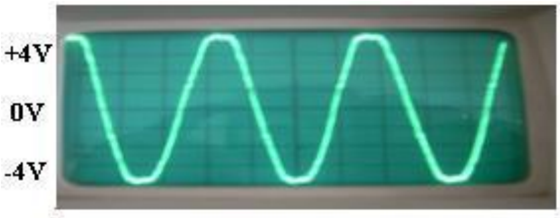

Figure 5.1 Voltage waveform when the supply is given without any load connections

The voltage waveform when the lamp load (200) is connected the drop in voltage is 1.2V as shown infig5.2

Figure 5.2. Voltage waveform after switching ON of Lamp load

The obtained sag is compensated the compensation of voltage waveform with clear graphical fluctuations are shown in the fig 5.3

Figure 5.3. The compensation Voltage waveform after switching ON of the DVR when the DVR is ON.

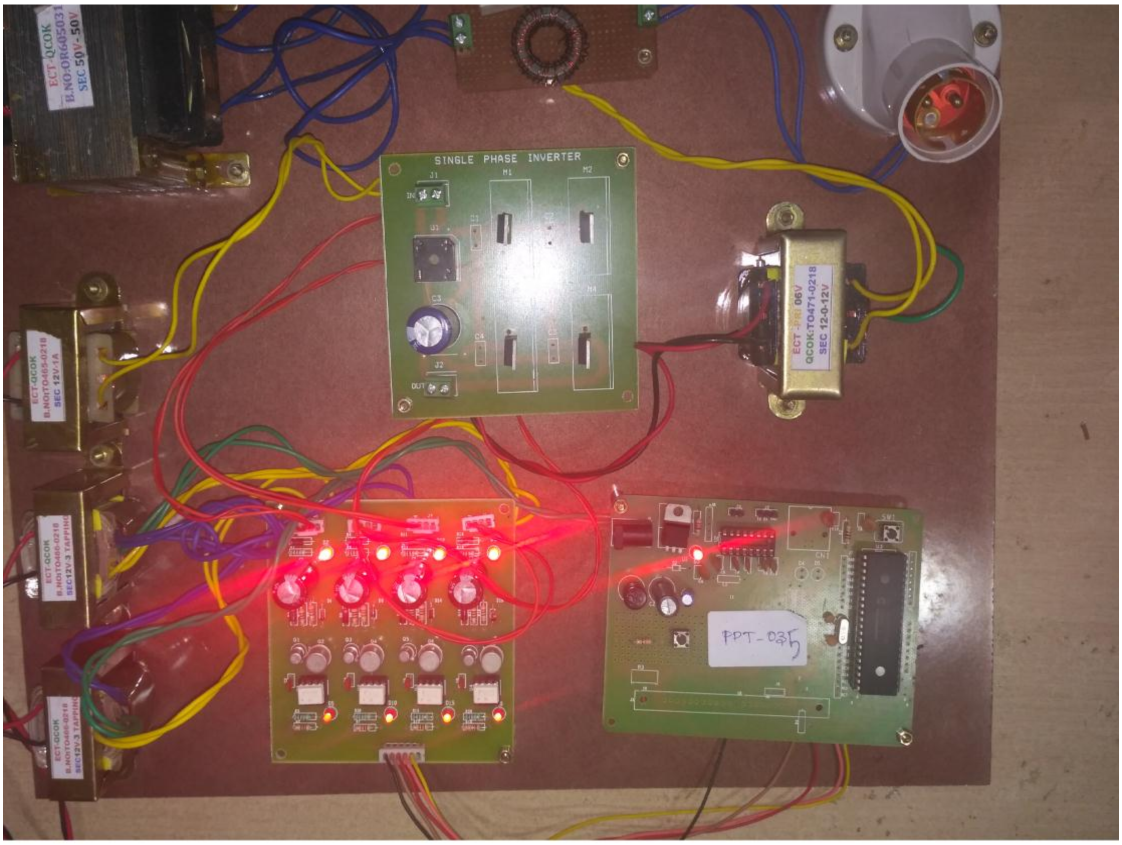

Figure 6. Hardware module of Dynamic voltage restorer (DVR)

CONCLUSION

This paper has proposed the modeling and simulation of DVR using simulink in MATLAB. The simple abc to dqo based control technique used. The performance of DVR is studied under voltage sag /swells. The simulation results show that the DVR compensates the voltage disturbances such as sag and swell quickly and provides excellent voltage regulation.. For high switching frequencies expected in future applications (e.g. 200 kHz silicon carbide SiC JFETs, SiC MOSFETs and SiC Schottky Diodes) the proposed LCCT-ZSI can be further developed using integrated planar passive technology

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