Power Quality Improvement Using Dynamic Voltage Restorer

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Abstract: **The main objective of this paper is to improvement the power quality on low voltage distribution side and also This paper describes the effectiveness of using dynamic voltage restorer (DVR). Dynamic Voltage Restorer can provide the most cost effective solution to mitigate voltage sags and swells by establishing the proper voltage quality level that is required by customer. This device is connected in series with the distribution feeder at medium voltage. The proposed control scheme is very effective to detect any disturbance in low voltage distribution systems. Simulation results using Matlab/Simulink are presented to verify the effectiveness of the proposed scheme.**

Keywords: **Dynamic Voltage Restorer (DVR), voltage sags, sensitive load .**

I. INTRODUCTION

In power systems, especially the distribution systems, have numerous nonlinear loads, which significantly affect the quality of power supplies. As a result of the nonlinear loads, the purity of the waveform of supplies is lost .This ends up producing many power quality problems.

A Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure or a mis-operation of end use equipments. Power quality problems are associated with an extensive number

of electromagnetic phenomena in power systems with broad ranges of time frames such as long duration variations, short duration variations and other disturbances. Short duration variations are mainly caused by either fault conditions or energization of large loads that require high starting currents. Depending on the electrical distance related to impedance, type of grounding and connection of transformers between the faulted/load location and the node, there can be a temporary loss of voltage or temporary voltage reduction (sag) or voltage rise (swell) at different nodes of the system. Therefore, these power quality problems can be improved in distribution system by using custom power devices like DVR, D-STATCOM, and SSTC.

1. Voltage Dips:

Voltage sag is defined as a sudden reduction of supply voltage down 90% to 10% of nominal, followed by a recovery after a short period of time. A typical duration of sag is, according to the standard, l0 ms to 1 minute . Voltage sag can cause loss of production in automated processes since voltage sag can trip a motor or cause its controller to malfunction. An appearance of r.m.s voltage sag is shown in Figure 1.

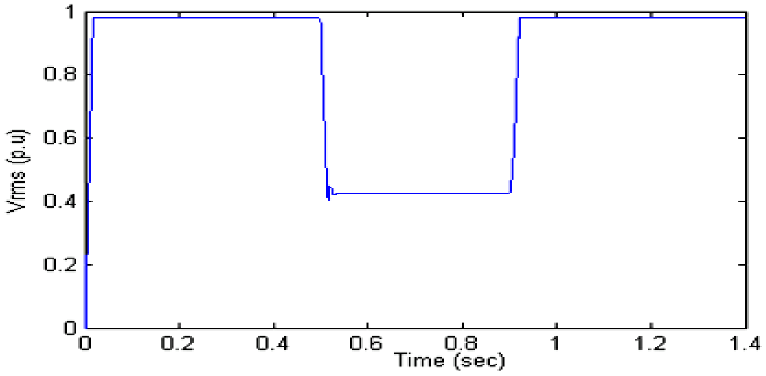


Figure.1

2. Voltage Swells:

Voltage swell, on the other hand, is defined as a sudden increasing of supply voltage up 110% to 180% in rms voltage at the network fundamental frequency with duration from 10 ms to 1 minute. Switching off a large inductive load or energizing a large capacitor bank is a typical system event that causes swells. An appearance of r.m.s voltage swell is shown in Figure 2.

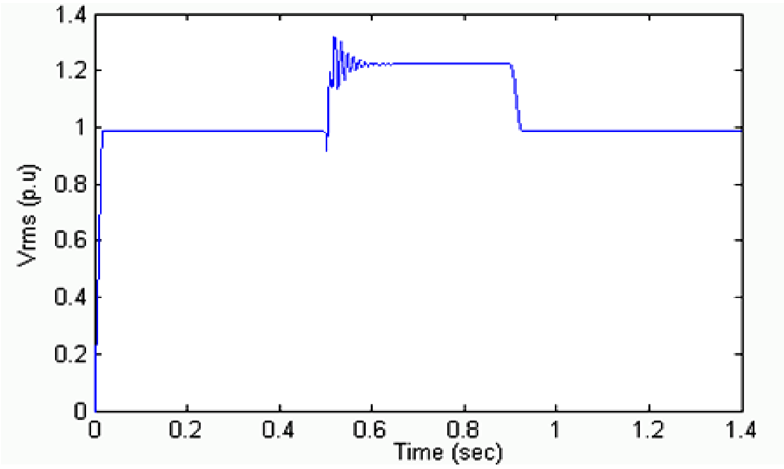


Figure.2

3.Voltage Interruptions:

An interruption occurs when the supply voltage or load current decrease to less than 0.1 pu for a period of time not exceeding one minute. The interruptions are measured by their duration since the voltage magnitude always less than 10 percent of nominal. An appearance of r.m.s voltage swell is shown in Figure3.

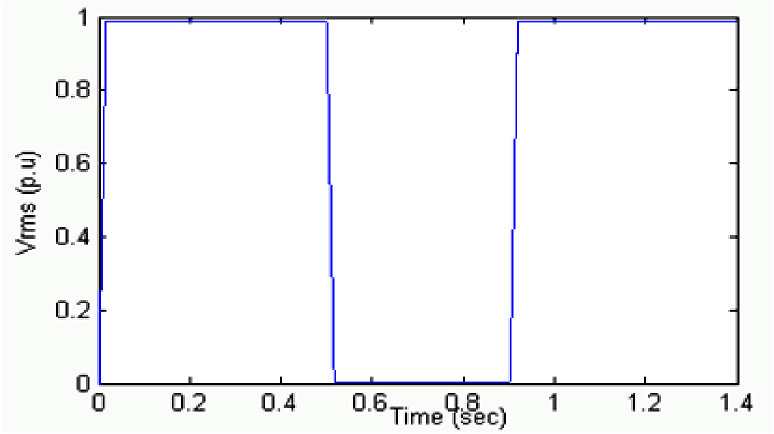


Figure.3

Power circuit of dynamic voltage restorer:

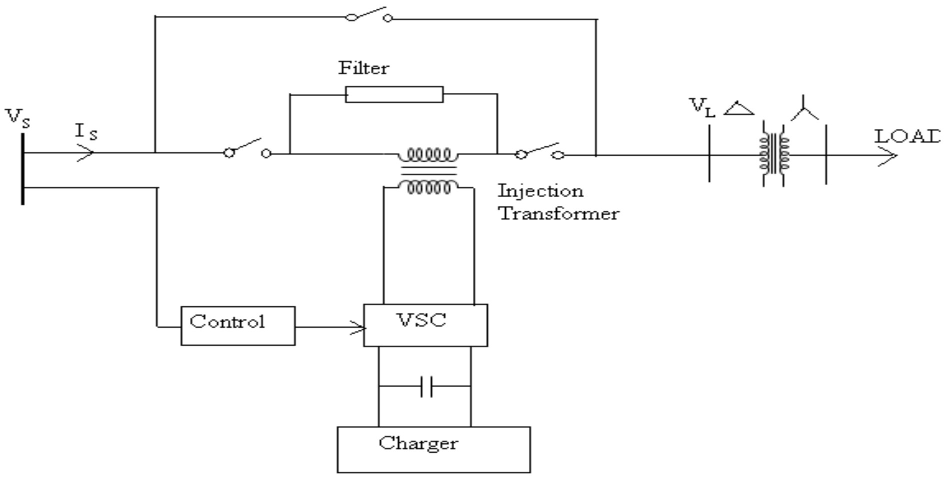


Figure.4 Dynamic Voltage Restorer

The DVR is a custom power device that is connected in series with the distribution system as shown in figure.The main components of the DVR consists of an injection transformer, harmonic filter,Vsc(voltage source converter) series VSI , an energy storage and control system(as shown in figure).

The DVR is made of solid-state dc to ac switching power converter (inverter), usually a voltage source inverter (VSI) that injects a set of 3-phase ac output voltages in series and synchronism with the distribution feeder voltages. The dc input terminal of the DVR is connected to energy source or an energy storage device of appropriate capacity. The reactive power exchanged between the DVR and the distribution system is internally generated by the DVR without ac passive reactive components. The real power exchanged at the DVR output ac terminals is provided by the DVR input dc terminal by an external energy source or energy storage system.

Energy storage device:

This is required to provide active power to the load during deep voltage sags. Lead-acid batteries, flywheel or SMES (super conducting magnetic energy storage systems) can be used for energy storage. It is also possible to provide the required power on the DC side of the VSC by an auxiliary bridge converter that is fed from an auxiliary AC supply.

Injecting transformer:

The basic function of this transformer is to connect the DVR to the distribution network via the HV-windings and couples the injected compensating voltages generated by the voltage source converters to the incoming supply voltage.

Filters:

The filters can be placed either on the high voltage side or the converter side of the boost transformers. The advantages of the converter side filters are

1.The components are rated at lower voltage.

2.Higher order harmonic currents (due to the VSC) do not flow through the transformer windings.

Voltage source inverter:

Voltage source inverter (VSI) can be used to generate the ac voltage at desired frequency with controllable amplitude and phase angle. This generated voltage can’t be directly fed into the line as inverter output voltage has switching harmonics.

Control unit:

The control unit of DVR is solely responsible for controlling the compensating voltage generation by controlling the PWM pulses to the gates of semiconductor switches of the VSC. To maximize dynamic performance of DVR, efficient control architecture capable of achieving fast compensation is necessary .The protection unit of DVR generally consists of By- pass switches, breakers, measuring and protection relays etc. Depending upon the operating conditions, the control and protection unit maximizes the system performance and minimizes the losses associated with the operation of DVR.

Voltage Injection Techniques:

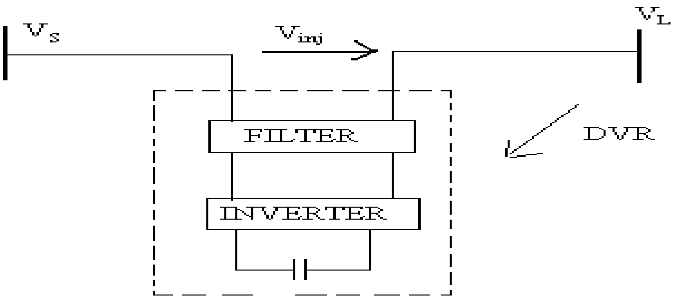


Figure.5 Block Diagram of Series Compensation.

Fig.5 shows the general topology of DVR connected in series with the line. V_S denotes the source voltage, VL denotes the load voltage and V_{inj} denotes the series voltage injected by the DVR. Depending on the reactive amplitude and phase of the injected, injection techniques are classified in three broad categories [7]. Aim of all these techniques is to maintain the load voltage magnitude at a nominal value of V_{nom}. These techniques posses various degrees of accuracy in terms of voltage magnitude and phase shift correction. Selection of the appropriate technique in a given situation is primarily decided by the load. These three injection techniques are

1. Minimal Energy Injection Technique.
2. Phase Compensation Technique.
3. Pre-sag Compensation Technique.

Above the techniques pre –sag compensation technique was used in this paper.

Pre-sag Compensation Technique:

Some voltages are sensitive not only to rms value of the load but also to the phase of load voltage. In this case, illustrated in the Fig.6, DVR injects voltage such that the compensated load voltage is in the phase with pre-sag voltage.

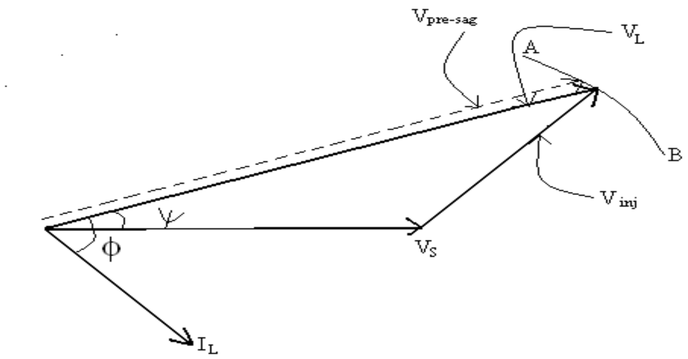


Figure.6 Phasor Diagram of Pre-sag Compensation Technique.

The minimum source voltage that can be boosted to Vnom is

$$\left|V_S^{\min}\right| = \left|V_{nom}\right|.\cos\Psi - \sqrt{\left(\left|V_{inj}\right|^2 - \left|V_{nom}\right|^2 \sin^2\Psi\right)} \quad (1)$$

Where,

V_{inj} is the maximum injection capability of the DVR.

This technique also requires active power from the DVR, so load power factor affects the duration that the DVR can maintain the load bus voltage at V_{nom}.

$$T_{dur2} = E_{DC} / \left(\left|I_L\right|.\left(\left|V_{nom}\right|.\cos\phi - \left|V_S\right|.\cos(\phi \pm \Psi)\right)\right) \quad (2)$$

Where,

E_{DC} is disposable energy of the storage device.

Ψ is the angle between load voltage and source voltage.

EQUIVALENT CIRCUIT OF THE DVR:

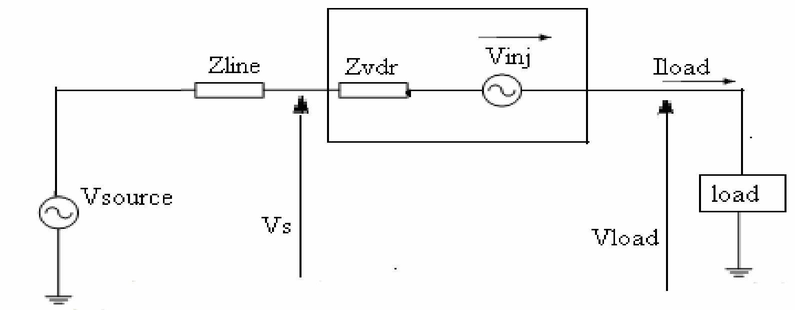


Figure. 7

Figure-7 shows the equivalent circuit of the DVR, when the source voltage is drop or increase, the DVR injects a series voltage Vinj through the injection transformer so that the desired load voltage magnitude VL can be maintained.

The series injected voltage of the DVR can be written as

Vinj=VL+Vs (3)

Where,

VL is the desired load voltage magnitude

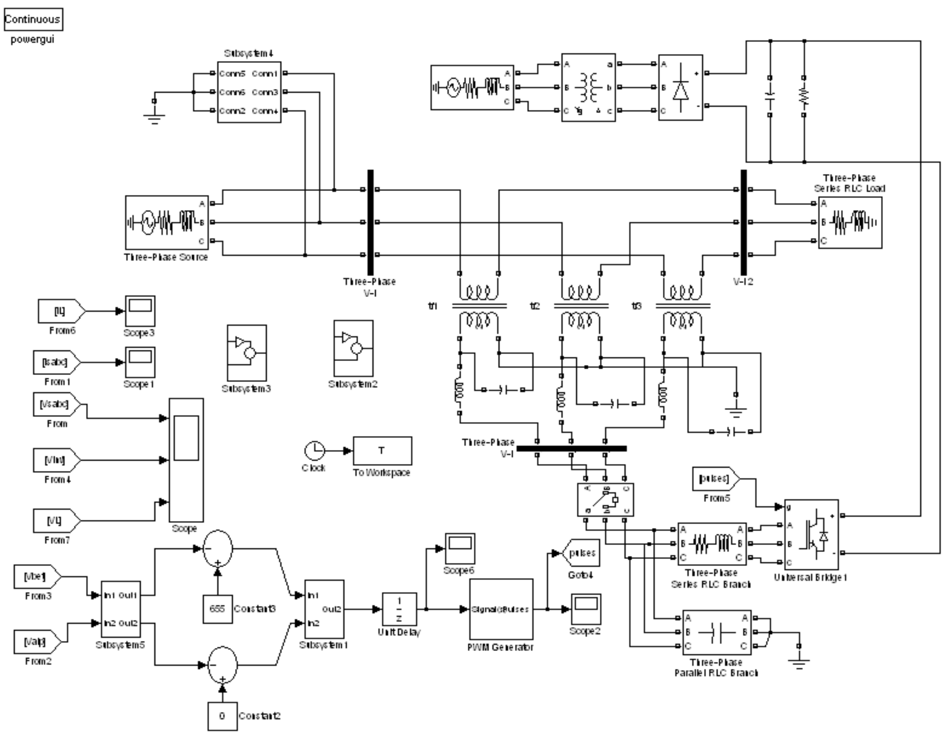
Vs is the source voltage during sags condition .

The load current IL is given by,

IL = (PL+_ J*XL)/VL

II. PROPOSED METHOD

A. Main circuit:



III. RESULTS

VOLTAGE SAG at BALANCED LOAD:

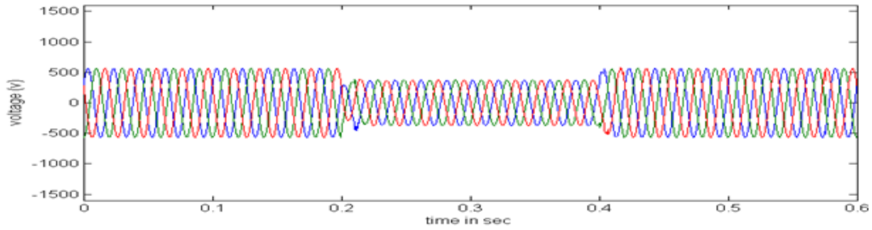


Fig (a) 3-Phase voltage at PCC Balanced Load.

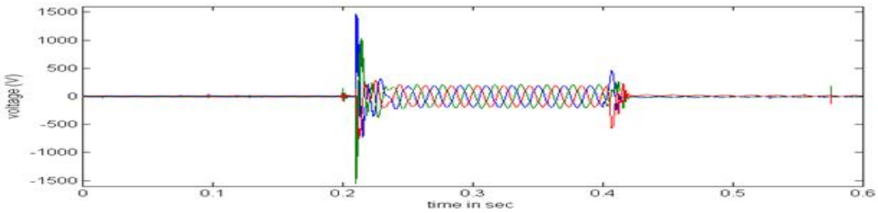


Fig (b) 3-Phase injected voltage.

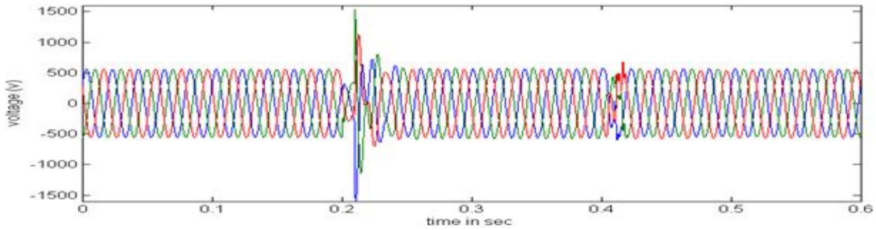


Fig (c) 3-Phase voltage at load point.

VOLTAGE SAG at UNBALANCED LOAD:

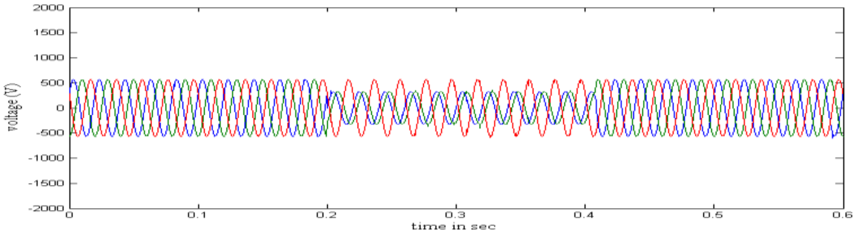


Fig (a) 3-phase voltage at PCC Unbalanced Load.

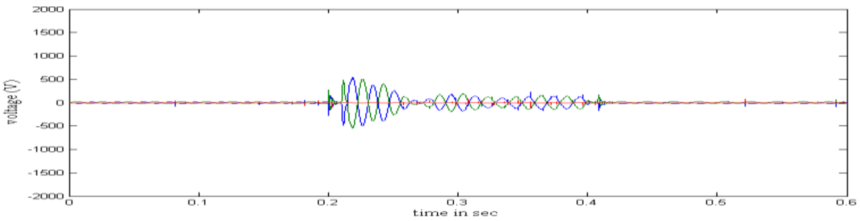
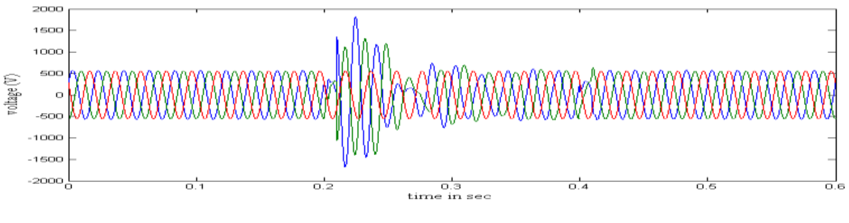


Fig (b) 3-phase injected voltage of the DVR.



Figure(c) 3-phase voltages at load point.

CURRENTS at BALANCED LOAD:

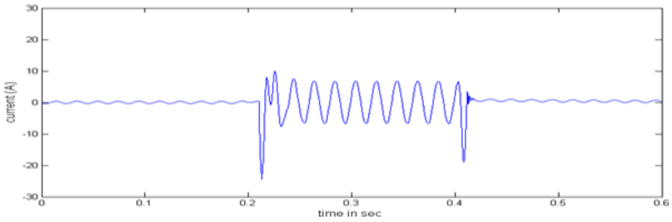


Fig (1) Phase 'A' load current.

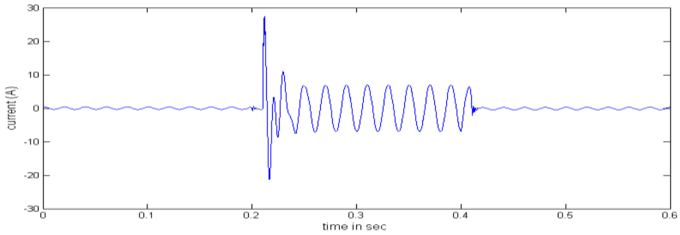


Fig (2) Phase 'B' load current.

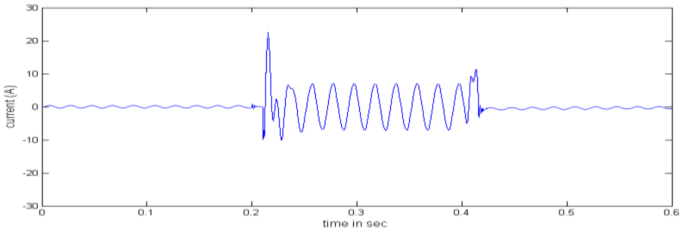


Fig (3) Phase 'C' load current.

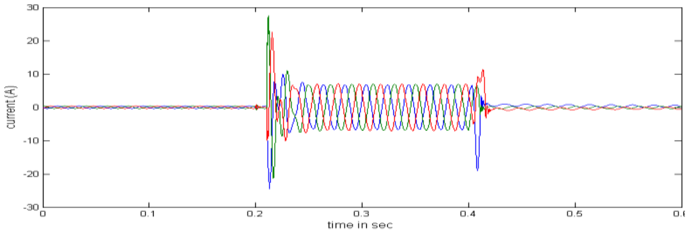


Fig (4) Three phase load current.

CURRENTS at UNBALANCED LOAD:

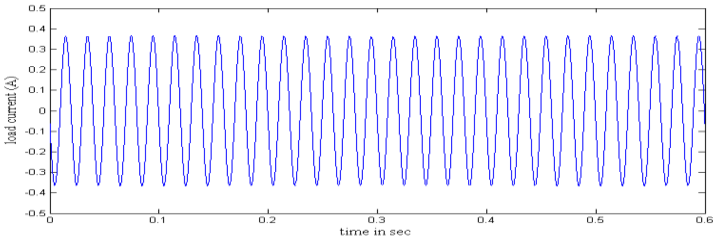


Fig (1) Phase 'A' load current.

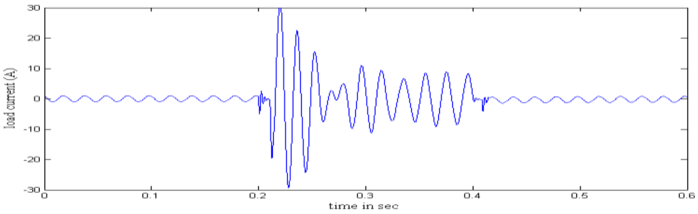


Fig (2) Phase 'B' load current.

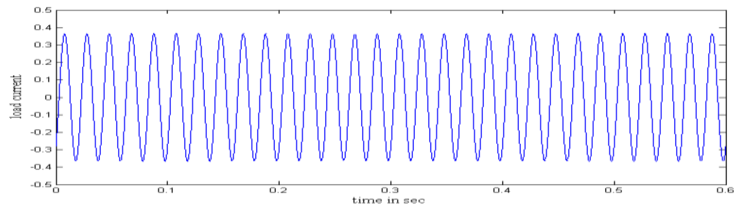


Fig (3) Phase 'C' load current.

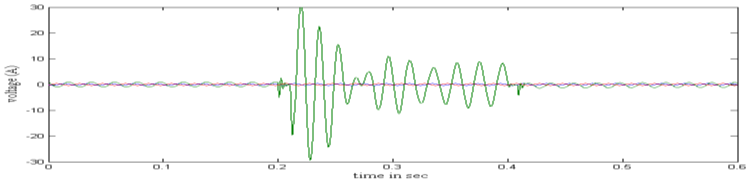


Fig (4) Three phase load current.

HARMONICS of LOAD VOLTAGE:

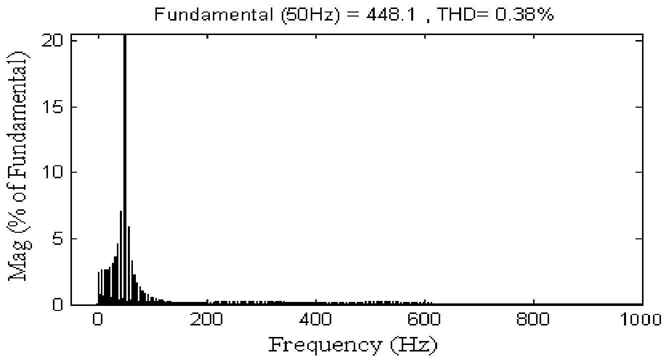


Figure 5(a): Harmronic analysis of load voltage with sag.

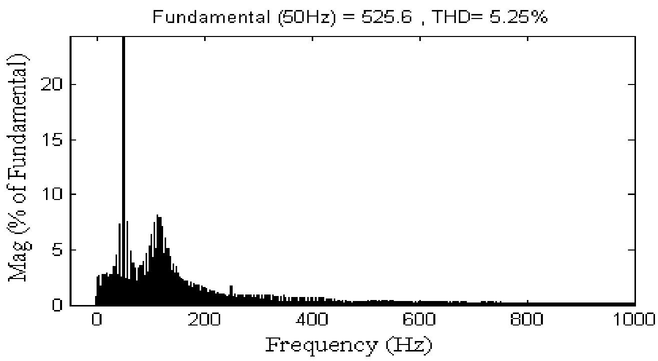


Fig5(b) Harmonic analysis of load voltage with compensated sag.

HARMONICS of LOAD CURRENT:

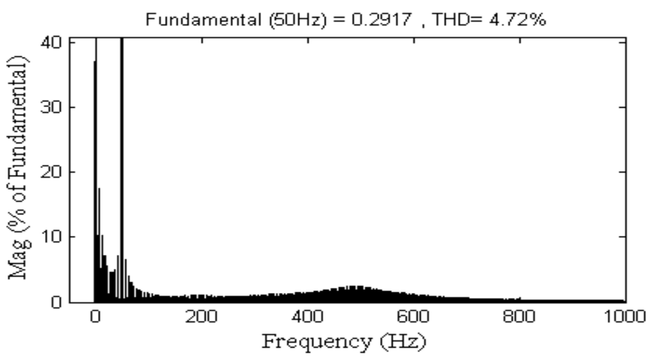


Figure 6.(a) Harmonic analysis of load current with sag.

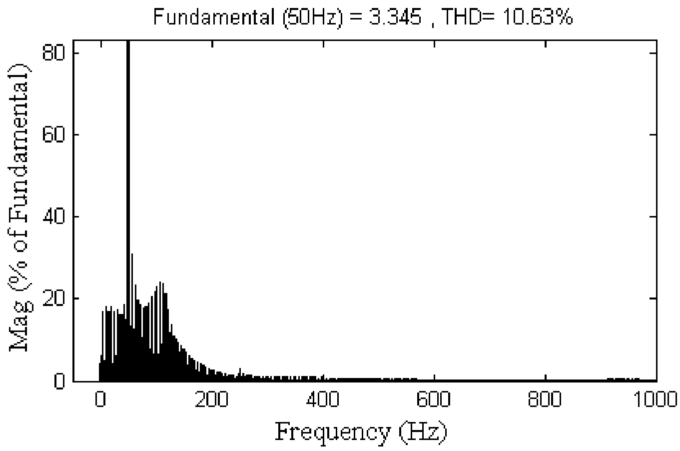


Figure 6.(b) Harmonic analysis of load current with compensated sag.

IV. CONCLUSIONS

The modeling and simulation of a DVR using MATLAB/SIMULINK has been presented. A control system based on dqo technique which is a scaled error of the between source side of the DVR and its reference for sags l correction has been presented. The simulation shows that the DVR performance is satisfactory in mitigating voltage sags. The main advantage of this DVR is low cost and its control is simple. It can mitigate long duration voltage sags efficiently. Future work will include a comparison with a laboratory experiments in order to compare simulation and experimental results.

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