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AN OVERVIEW AND DESIGN OF DYNAMIC VOLTAGE RESTORER TO IMPROVE POWER QUALITY

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ABSTRACT: In recent years the most perceptible topic for electrical engineering is power quality. Basically, Power quality is simply the interaction of electrical power with electrical equipment. If electrical equipment operates correctly and reliably without being damaged or stressed, we would say that the electrical power is of good quality. On the other hand, if the electrical equipment malfunctions, is unreliable, or is damaged during normal usage, we would suspect that the power quality is poor. Voltage sag is one of most severe problem among the power quality issue. Despite being a short duration (10ms to 1s) event during which a reduction in the RMS voltage magnitude takes place, a small reduction in the system voltage can cause serious consequences. Nonlinear loads are major source of voltage sag. A load is considered non-linear if its impedance changes with the applied voltage. The changing impedance means that the current drawn by the non-linear load will not be sinusoidal even when it is connected to a sinusoidal voltage. Most commonly non-linear loads can be primarily found in heavy industrial applications such as arc furnaces, large variable frequency drives (VFD), heavy rectifiers for electrolytic refining, etc.

In this paper a dynamic voltage restorer (DVR) system is proposed to overcome from the problem of voltage sag. Dynamic Voltage Restorer is a series connected power electronics based device that can quickly mitigate the voltage sag in the system and restore the load voltage to the pre-fault value. This paper first gives an introduction to relevant power quality problems for a DVR and power electronics controllers for voltage sag mitigation. Thereafter the operation and elements in DVR is described. In this paper proposed utilizes the error signal to control the triggering of the switches of an inverter using Sinusoidal Pulse Width Modulation (SPWM) technique. Modeling and simulation of proposed DVR is implemented in MATLAB SIMULINK.

KEYWORDS: Dynamic voltage restorer, Power Quality, Voltage Sag, SPWM, Fault.

1 INTRODUCTION

Power distribution systems, ideally, should provide their customers with an uninterrupted flow of energy at smooth sinusoidal voltage at the contracted magnitude level and frequency Power system faults, switching of large loads or energization of transformers cause voltage disturbance. Such disturbances cause short term rapid change in amplitude of voltage. A sever disturbance in voltage may lead to system crash, hardware damage, affecting the cost of customers and utilities.[1] The problem quality problems such as temporary voltage rise (Swell) or voltage reduction (Sag) are more frequent and have severe impact on power system. Sudden increase in supply voltage up 110% to 180% in rms voltage is defined as swell . This occurs at fundamental frequency of network and sustains for time period of 10 ms to 1 minute. Typical system events such energization of large capacitor bank or removal of inductive load causes swells. On the other hand sudden decrease in supply voltage down 90% to 10% of nominal voltage is called as sag. This problem is for the short duration and for time period of 10 ms to 1 minute. The rated voltage is recovered after short period of time. Voltage sag is currently the most severe power quality problem encountered because of its adverse financial impact on customers. In Peninsular Malaysia, the first case of voltage sag was reported to the electric utility of Malaysia in early 1990 in which voltage sag caused the stopping of electronic wafer fabrication process.[3]The power quality has serious economic implications for customers, utilities and electrical equipment manufacturers. Modernization and automation of industry involves increasing use of computers, microprocessors and power electronic systems such as adjustable speed drives .The power electronic systems also contribute to power quality problem (generated harmonics). The electronic devices are very sensitive to disturbances and become less tolerant to power quality problems such as voltage sags, swells and harmonics. Due to the harmonics are occurring in the system it causes losses and heating of motor. The DVR is a power quality device that has gained an increasing role in protecting industries against disturbances such as voltage sags related to remote system faults. The basic operation principle of the DVR is to inject an appropriate voltage in series with the supply through injection transformer whenever voltage sag is detected. To mitigate voltage sag, DVR has been considered as effective sag mitigation equipment and many research works have been carried out focusing in the design and control of the DVR. The main function of DVR is to inject the desired voltage quantity in series with the supply with the help of an injection transformer whenever voltage sag is detected. Power transfer ability, transient stability and damping of power oscillation is improved by using DVR in distribution system. And it is capable of generating or absorbing real and reactive power at its ac terminals. The basic principle of a DVR is simple by inserting a voltage of desired magnitude and frequency, in order to restore the load-side voltage balanced and sinusoidal. This study introduce various power quality problems and basic concept of DVR (Dynamic Voltage Restorer). This study deals with overview of a Dynamic Voltage Restore (DVR) for mitigation of voltage sags.[4]

2 Power Quality Problems, Causes And Effects

2.1 The various power quality problems are as followed

1. Transients- A transient is a temporary occurrence of a fault which is of a very short duration in a system caused by the sudden change of state.
2. Voltage sags- A voltage sag or voltage dip is a short duration reduction in rms voltage which can be caused by a short circuit, overload or starting of electric motors .A voltage sag happens when the rms voltage decreases between 10 and 90 percent of nominal voltage for one-half cycle to one minute.
3. Voltage swells- Voltage swell, which is a momentary increase in voltage, happens when a heavy load turns off in a power system.
4. Voltage interruption- Interruptions are classified as short-duration or long-duration variation. The term interruption is often used to refer to short-duration interruption, while the latter is preceded by the word sustained to indicate a long-duration. They are measured and described by their duration since the voltage magnitude is always less than 10% of nominal.
5. Harmonics- Harmonics is the integral multiple of frequencies voltages and currents in an electric power system due to non linear loads. Harmonic frequencies in the power grid are a frequent cause of power quality problems.

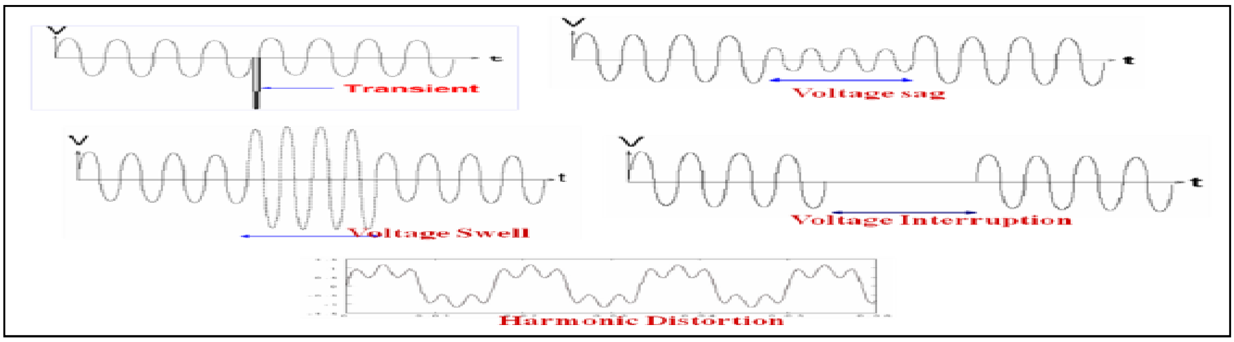

Fig. 1 Power Quality Problems

2.2 Causes of Power Quality Problems

Transient – Due to Lightning, Turning major equipment on or off, back to back capacitor energization.

Voltage Sags – Due to starting of large Motors, Energization of heavy loads, incorrect VAR compensation.

Voltage Swells – Energizing a large capacitor bank, Switching off a large load, incorrect VAR compensation

Interruption – Faults (Short circuit), Equipment failures, Control malfunctions (attempting to isolate electrical problem).

Harmonics – IT equipment, Variable frequency drives, Electro Magnetic Interference from appliances, fluorescent lighting, Arc Furnace (Any non linear load).

2.3 EFFECTS OF POWER QUALITY PROBLEMS

Transient – Tripping, Processing error, Data loss, hardware reboot required, Component failure.

Voltage Sags--Dim lights, Equipment shutdown, Data error, shrinking display screens, Memory loss.

Voltage Swells –Bright lights, Data error, shrinking display screens, Memory loss.

Interruption – Faults, Equipment failures, Control malfunctions

Harmonics – Line current increases, Losses increase, transformer and neutral conductor heating leading to reduced equipment life span.[7]

3 BASIC CONFIGURATION OF DVR

Power circuit and the control circuit are the 2 main parts of the DVR. There are various critical parameters of control signals such as magnitude, phase shift, frequency etc. which are injected by DVR.

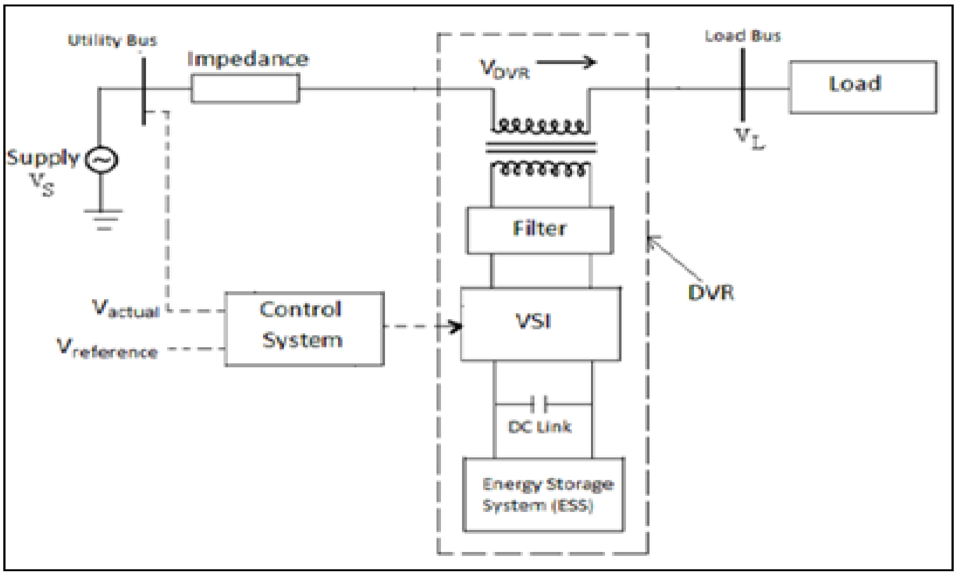

Fig.2 Basic Configuration of DVR

A Dynamic Voltage Restorer (DVR) is a recently proposed series connected solid state device that injects voltage into the system in order to regulate the load side voltage. Its main function is to monitor the load voltage waveform constantly by injecting missing voltage in case of sag. To obtain above function a reference voltage waveform has to be created which is similar in magnitude and phase angle to that of supply voltage. During any abnormality of voltage waveform it can be detected by comparing the reference and the actual waveform of the voltage. The DVR usually consists of an injection transformer, which is connected in series with the distribution line, a voltage sourced PWM Converter Bridge which is connected to the secondary of the injection transformer and an energy storage device connected at the dc-link of the converter bridge. A typical schematic of the DVR is shown in Fig.2 [8,9]. The converter bridge output is filtered before being fed to the injection transformer in order to nullify switching frequency harmonics. The series injected voltage with a variable amplitude, phase and frequency of the DVR is synthesized by modulating pulse widths of the converter bridge switches. The injection of an appropriate series voltage component in the face of a voltage disturbance requires a certain amount of real and reactive power supply by the DVR .The real and reactive power supplied by the DVR however depends on the type of voltage disturbance experienced as well as the direction of the DVR injected voltage componentwith reference to pre-sag voltage. The fidelity of the DVR output voltage depends on theaccuracy and dynamic behavior of the pulse width modulated(PWM) synthesis scheme and the control system adopted. Traditionally, closed loop control PWM schemes have been used for various types of ac power conditioning systems. The general requirement of such control scheme is to obtain an ac waveform with low total harmonic distortion and good dynamic characteristics against supply and load disturbances. Although conventional sinusoidal PWM schemes and programmed optimal PWM schemes have performed reasonably well for linear loads, the voltage waveforms tendto get distorted for nonlinear loads.

4 SINUSOIDAL PWM-BASED CONTROL OF THE DVR

The sinusoidal pulse width modulation (SPWM) switching technique is used to control the AC output voltage by Comparing a sinusoidal reference signal with a triangular carrier wave so as to get the pulses per half cycle. Figure 1 shows the pulses generated by using the SPWM in which a carrier signal is compared with a modulating signal. The fundamental frequency is 50 Hz and the phase locked loop provides a voltage-synchronizing signal, which is multiplied by a switching frequency of 1650 Hz. Thus, the frequency of the voltage-synchronizing signal is 33 times the fundamental frequency of 50Hz. The carrier signal is converted into a triangular signal with amplitude between -1 to +1. [1]

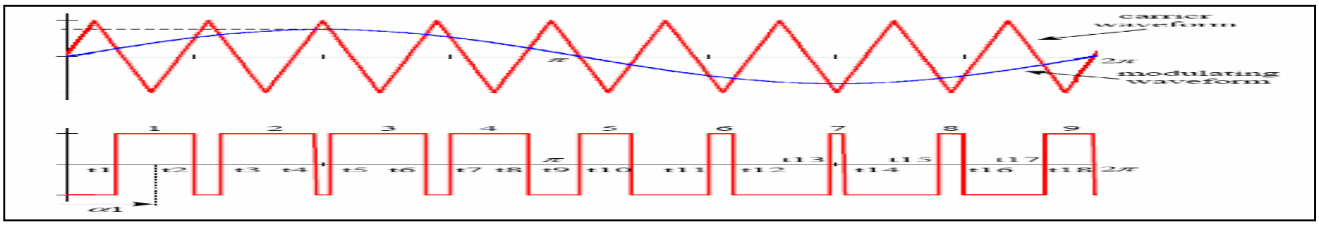

Fig. 3. Sinusoidal pulse-width modulation

The aim of the control scheme is to maintain a constant voltage magnitude at the point where sensitive load is connected under the system trouble. The control system only measures the rms voltage at load point in example, no reactive power measurements is required . The VSC switching strategy is based on a sinusoidal PWM technique which offers simplicity and good response. Since custom power electronics device is a relatively low-power application, PWM methods offer a more flexible option than the fundamental frequency switching (FFS) methods favored in FACTS applications. Besides, high switching frequencies can be used to improve the efficiency of the converter, without incurring significant switching losses. Fig. 7 shows the control scheme implemented in MATLAB. The DVR control system exerts voltage angle control as follows: an error signal is obtained by comparing the reference voltage with the rms voltage measured at the load point.[2]

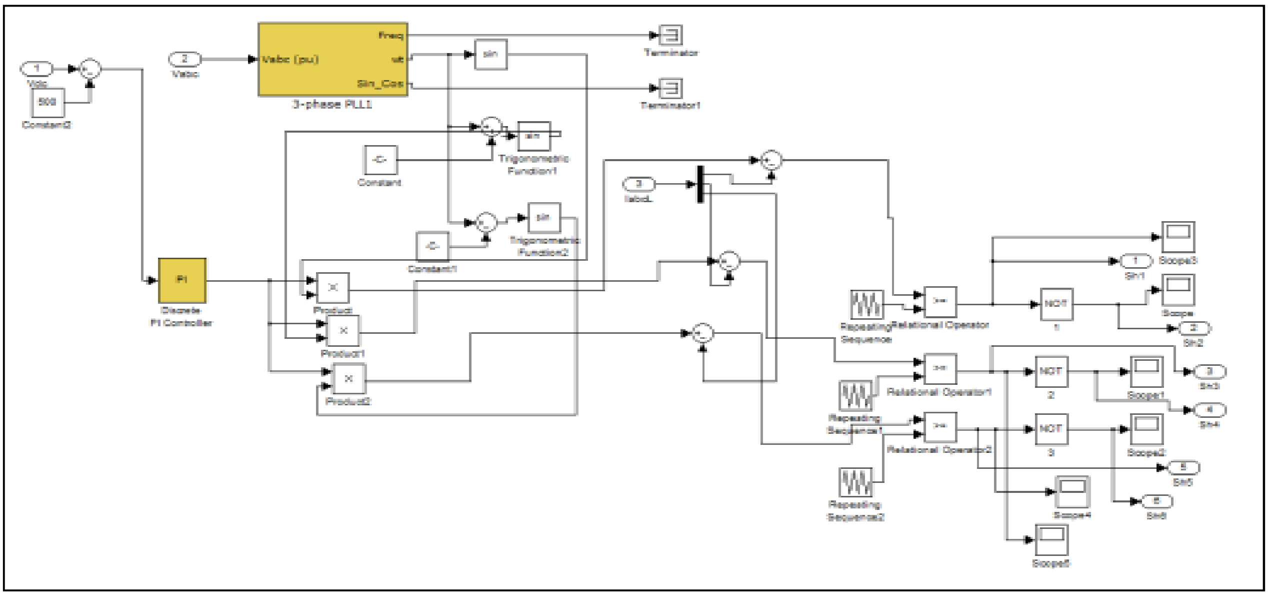

Fig 4 Simulink model of SPWM

The PI controller processes the error signal and generates the required angle δ to drive the error to zero, in example, the load rms voltage is brought back to the reference voltage. In the PWM generators, the sinusoidal signal, Vcontrol, is phase modulated by means of the angle δ or delta. The modulated signal, Vcontrol, is compared against a triangular signal (carrier) in order to generate the switching signals of the VSC valves.The main parameters of the sinusoidal PWM scheme are the amplitude modulation index, ma, of signal Vcontrol, and the frequency modulation index, mf, of the triangular signal.

5 TEST SYSTEMS AND DVR MODELS IN MATLAB

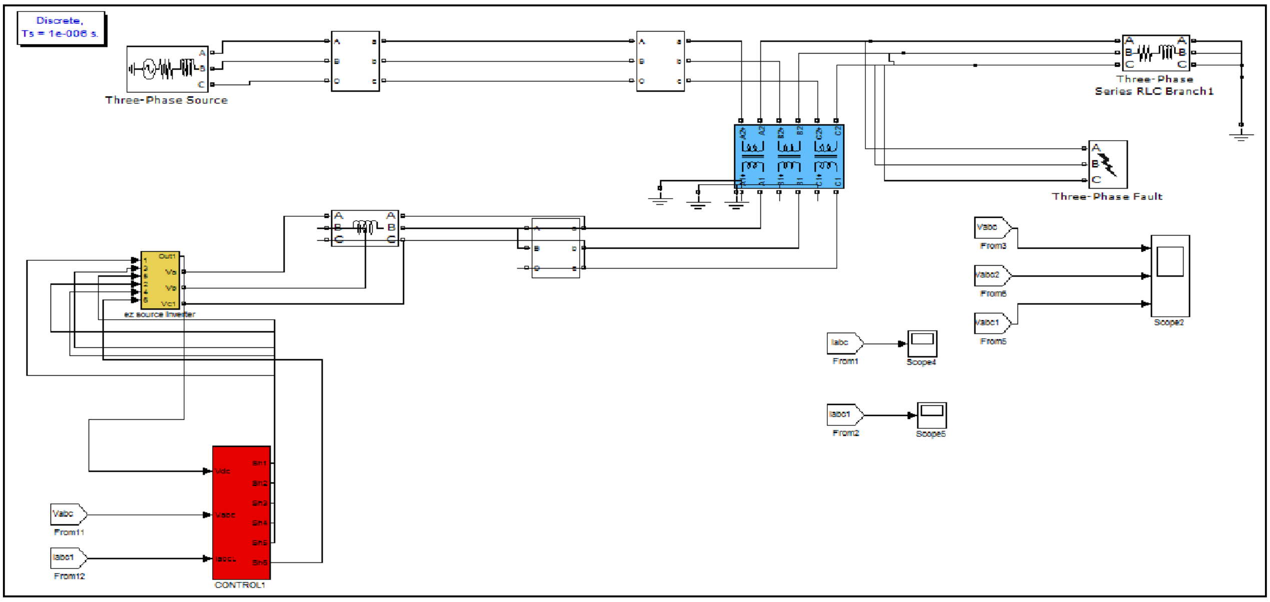

Fig 5 Matlab Simulink of Test System

Fig. 5 depict the test system implemented in MATLAB to carry out the simulations for the A fore mentioned mitigation technique. It consists of main components such as Source, injection transformer, three phase voltage source converter,controller. The test system comprises of a 15 kilovolt, 50 Hertz transmission system, represented in Thevenin equivalent, feeding into the secondary side of a 3-winding transformer. The load is connected to the secondary side of the transformer.The DVR is connected in series using transformers in delta to the lines. Fig. 5 will show the DVR in connected the test system.

6 SIMULATION RESULTS

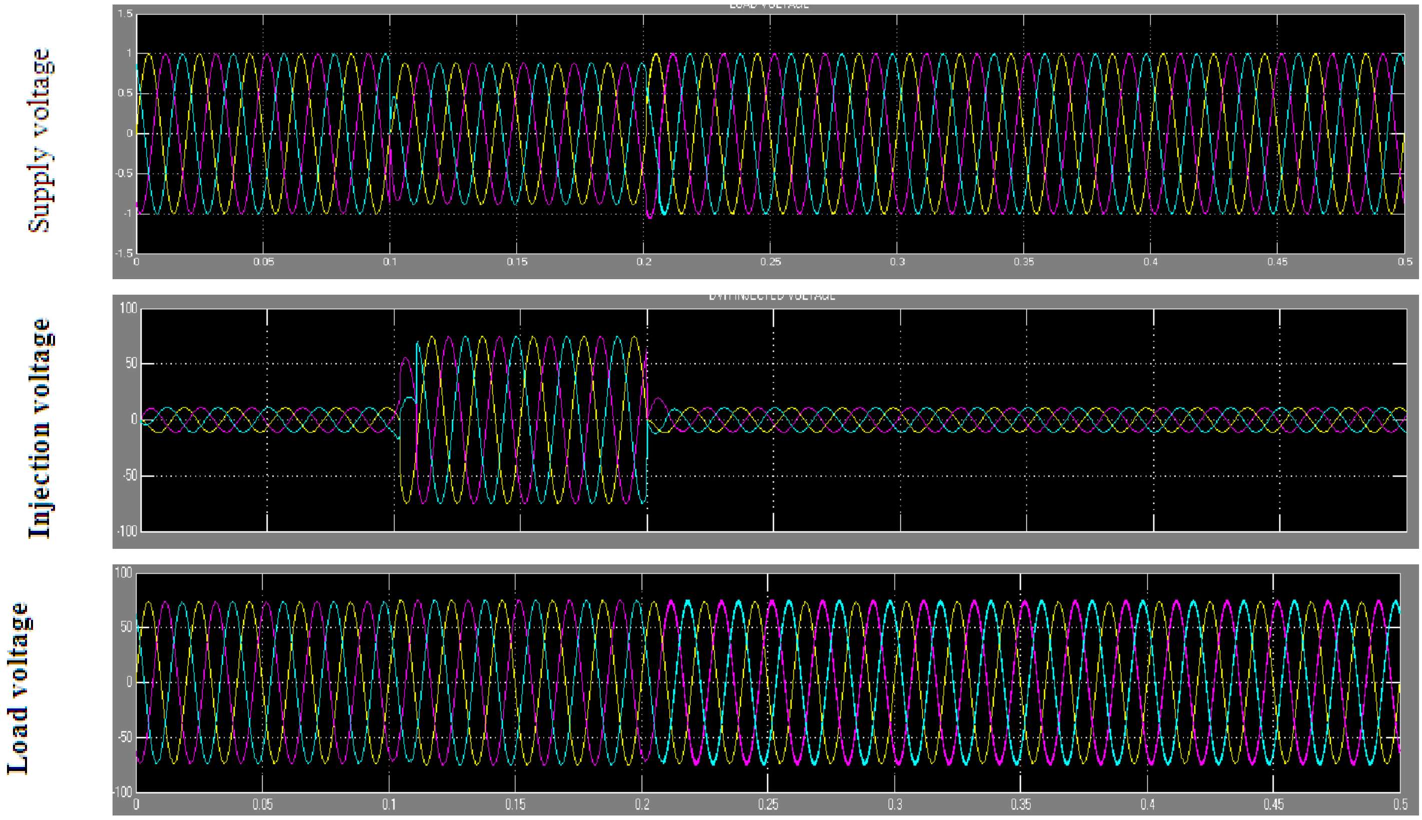

Fig. 6 DVR response to balanced voltage Sag

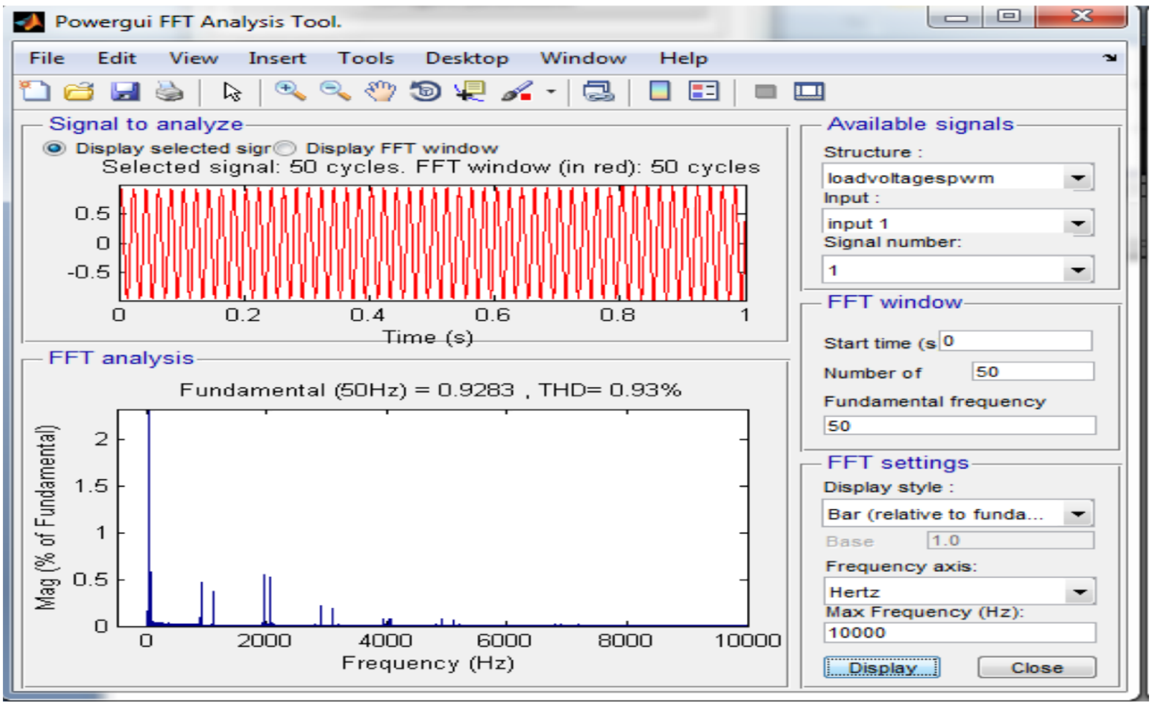

Fig.7 waveforms of showing the FFT analysis of load voltage of spwm

To illustrate a typical response of injection transformer of DVR with the proposed control strategy, a simple 50 Hz power distribution system with a sensitive load as shown in Fig. 2 is considered. Basically three phase fault is created from 0.1 to 0.2

s which result in voltage sag on supply side as shown in supply voltage graph . The load voltage and the injected voltage by DVRare also shown in Fig. 6 As can be seen from the figure, the proposed control strategy is able to drive the DVR to inject the appropriate three phase voltage component with correct phase to remove the supply voltage anomalies due to three phase fault. It quickly injects necessary voltage components to smoothen the load voltage upon detecting voltage sag.

7 CONCLUSION

This paper has presented electromagnetics transient modelof power electronic based equipment DVR and that power quality characteristics were studied. Using the facilities available in MATLAB, the DVR several aspects of voltage sag mitigation study have been examined. First, a DVR using six-pulse inverter and three phase rms voltage measurement and sine wave PWM control was described. It presents excellent performance to protect critical loads against balanced voltage sags. When the DVR is in operation the voltage sag is mitigated almost completely, and the rms voltage at the sensitive load point is maintained at about 90% . The PWM control scheme controls the magnitude and the phase of the injects voltages, restoring the rms voltage very effectively. The sag mitigation is performed with a smooth, stable and rapid DVR response. So, DVR can be widely applied in distribution power Systems.

APPENDIX

Main Supply Voltage Per Phase 15 kv, Line Impedance Ls = 0 .006 H , Rs=0.002Ω , Series Transformer Turns Ratio 1:1 , Load Resistance 40 Ω , Load Inductance 0.04 H, Line Frequency 50HZ, Inverter Specifications IGBT based 3 arms, 6 Pulse, Frequency =1080 Hz, Carrier Frequency=1024 HZ ,Sample Time= 0.5 sec.

FUTURE PROSPECTUS OF THE STUDY

(a) The application of the model presented in this work may be extended to other power Electronics loads used in modern hi-tech industry.

(b) The regenerative power system network consisting of an active load (such as photo voltaic system or wind turbine system) with better power quality and less power Disturbance using DVR can be explored.

(c) Investigation of the multi-level of DVR can be investigated.

(d) For this model of DVR auxiliary voltage supply is used instead capacitors can be used as a source and relative simulations can be carried out and studied.

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