Simulation of a Dynamic Voltage Restorer to Compensate Voltage Sag for Improving Power Quality

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***Abstract*-Power quality defines the strength of electric power to consumer devices i.e. voltage frequency and phase synchronization allow electrical system to function without any substantial loss in performance. The distribution networks and sensitive industrial loads are going on different type of outage and interruption which can lead to loss in production and measurable and also the non-measurable factor. The factors that are affecting power quality are voltage sag, voltage variation, interruption, swells, distortions, Harmonic, noise, voltage spikes, voltage flicker etc. Because of this reasons some deviations in the power is faced when compared with the normal standards. The above problems arises is being compensated by using custom power devices, correct its power factor or we can say compensate the power etc. and improves the quality of the supply voltage. In this paper we present the power quality improvement using Dynamic voltage restorer (DVR) to obtain Better performance which is simulated by using mat lab.**

***Keywords* - Dynamic voltage restorer (DVR), voltage Sag compensation, voltage source inverter (VSI), Energy storage device.**

I.INTRODUCTION

Power quality has the great importance in our modern environment where electricity is required. One of the major concerns in electric industry today is power quality problems. Currently major power quality problems are due to different fault conditions. These conditions causes voltage sag , voltage interruption, voltage swell and harmonics etc. These problems may cause the apparatus tripping, shutdown all domestic and industrial equipments, and miss process of drive systems. DVR is a controlled voltage source device, which compensate the power needed whenever required. DVR has very high efficiency, and if we compared, costs is also less than other devices like as uninterruptible power supply, constant voltage transformer and motor-generator. Likewise the basic voltage compensation, DVR also can also achieve the harmonics compensation and reactive power compensation. It is the most effective and popular power electronic equipment solving the problems of voltages. Therefore, DVR are not only improves power supply reliability, but also enhance the voltage stability. DVR enhance load-side power quality. At present, three types of mostly studied DVR with DC capacitor, is supposed to compensate reactive power only, otherwise, its DC voltage will decrease seriously as active power consuming. This method does not perform in kind way in voltage compensation time and degree. DVR with energy storage system, often chooses storage battery, superconducting magnetic energy or flywheel both of energy storage as energy source. By this means, Dynamic voltage restorer is able to compensate reactive power as well as active power. Whatever way, DVR exits some problems using no matter which storage system, for example, cost will increase . In DVR with the rectifying system, in order to complete long time compensation, DC capacitor is link to power supply side or load side through rectifying circuit. Whenever voltage fault occurs in supply side, the main difficulty is to maintain a constant DC voltage in DC part, and chances are that harmonics voltage or will be introduced to DVR. Behind ,if grid voltage drop seriously, the rectifying circuit cannot obtain energy through power grid , and chances are serious voltage drop will occur . This paper comes up with a new voltage compensation scheme of DVR is applied for double power supply with double load, which has the merits of DVR with energy storage system and the DVR with rectifying system.
New scheme are all built in MATLAB/ Simulink, so that we can compare the merits and demerits among them. Simulation results show that the proposed scheme can assure the load-side voltage stability, which is an effective technique for managing power quality.

POWER QUALITY PROBLEMS

(1) Voltage Sag- Decrease of the normal voltage level between 10 to 90% of the nominal Rms voltage at the power frequency, duration of 0, 5 cycle to 1 minute.

Causes-fault on the transmission or distribution network (most of the times on parallel feeders.)

(2) Long interruption- Total interruption of electrical supply for duration greater than 1 to 2 seconds.

Causes-Equipment let-down in the power system network, storms and object like trees etc ,lightning strikes.

(3) Voltage swell- Quick increase of the voltage, at the power frequency, outside the normal tolerances, with duration of more than 1 cycle and less than a few seconds.

Causes-start/stop of heavy loads, badly dimensioned power sources, badly regulated transformers .

(4) Harmonic distortion- Voltage or current waveform assumes non-sinusoidal shape. The waveform corresponds to the sum of different sine waves with different magnitude and different phase, having frequencies that are multiples of power system frequency.

Causes-electric machines working above the knee of the magnetization curve, arc-furnaces, welding machine, dc brush motors.

II.DYNAMIC VOLTAGE RESTORER

Developed in the early 1990's, A Dynamic Voltage Restorer with its excellent dynamic capabilities when installed between the supply and the load feeder, can compensate for voltage sags, restoring line voltage to its nominal value within a few m/sec and avoiding any power disruption to that load. A power electronic converter based series compensator that can protect all critical loads from all the supply side disturbances other than outages is called a dynamic voltage restorer. It injects three phase AC output voltages in series and synchronise with distribution feeder voltage. In the injected voltages, amplitude and phase angle are variable thereby allowing to control the real and reactive power exchange between the device and the distribution system.

(A)DVR properties **-** These are some reasons why DVR is preferred then other devices:

(1) SVC dominates DVR but the latter is still preferred because the SVC cannot control active power flow.

(2) DVR is less expensive as compared to UPS.

(3) The maintenance level is high in UPS because it has a problem of battery leakage.

(4) DVR has a relatively higher energy capacity and less cost as compared to SMES device.

(5) The size of a DVR is smaller.

(B)Basic configuration of a DVR- Power circuit and the control circuit are the two main parts of the DVR. There are many type of parameters for control signals like phase shift, magnitude, frequency etc. which are injected by DVR. Fig.1 is the Basic Configuration of DVR, The parameters are derived by the control circuit, in the power circuit the injected voltage is generated by the switches are based on the control signals. Furthermore the basic structure of DVR is described by the power circuit. The other parts of power circuit, their function and requirements are discussed ahead. DVR consist of the following major components.

(1) Injection Transformers
(2) Voltage source inverter
(3) Harmonic Filter
(4) Energy storing device
(5) control system

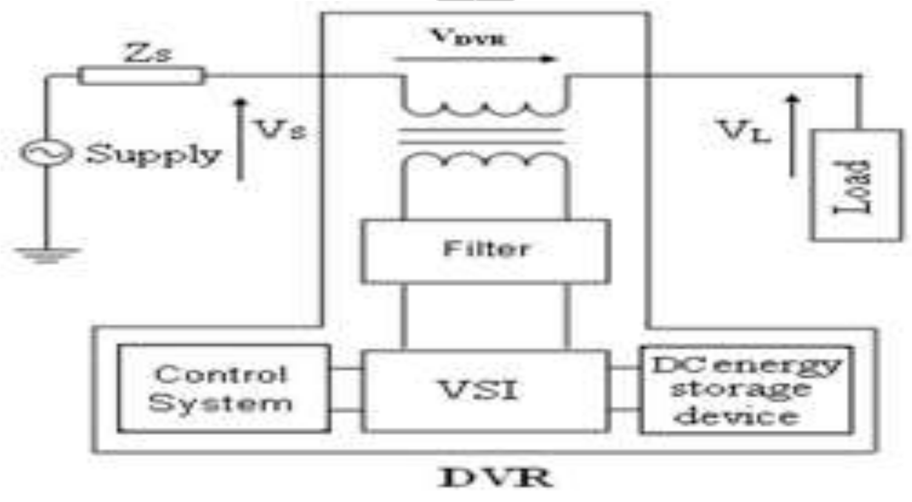


Fig 1- Basic structure of a DVR

(1)Injection / Booster transformer-The Injection transformer has basically two purposes. It joints the DVR to the distribution network through the high voltage winding and couples the injected compensating voltages generated by the voltage source inverter in series with the incoming supply side voltage. In addition, the Injection / Booster transformer is purpose of isolating the load from the VSC and control mechanism. In a transformer-less DVR is based on the multilevel inverter is presented. As a result of applying this inverter, the proposed DVR has less number of switches in comparison with other multilevel DVR network. The DVRs with transformer-less and Neutral Point uses inductors instead of transformers to inject voltage in the system and are presented as the cheapest solutions. In the suggested transformer -less DVR can satisfactorily resolve the voltage-sag problems. It also possesses a superior voltage regulation property and has lower losses.

(2)Harmonic filter-The main work of the harmonic filter is to keep the harmonic voltage content generated by the VSC below the permissible level..

(3)Energy-Storage Unit-It is responsible for the energy storage in DC form. Flywheels, battery, superconducting magnetic energy storage and super capacitors can be used as energy storage devices. Energy storage unit will supply the real power requirements of the system when DVR is used for compensation.

(4)Voltage Source Converter (VSC)-A voltage source converter is a power electronic system consisting of switching devices like a MOSFET, GTO, Insulated Gate Bipolar Transistors (IGBT), and IGCT, which can generate a sinusoidal voltage at any required frequency, magnitude, and phase angle. Voltage source converters are widely used in Variable speed drives (VSD), and also be used to mitigate voltage dips. The VSC is used to either totally replace the supply voltage or to add the missing voltage. The missing voltage is the difference between the nominal voltage and the actual voltage. Normally the VSC is not only used for voltage dip mitigation, but also used for other power quality problems like flicker and harmonics etc.

(5)Control System-The main work of the control system is to maintain a constant voltage magnitude where a sensitive load is connected, under system disturbances. It also look after the D.C. link voltages using the direct current charging unit .

(C)Operating modes of DVR-The DVR functions three modes of operation. They are: protection mode, standby mode (during steady state), and injection/boost mode.

(1)Protection Mode- If the current on the load side surpasses a allowable limit due to a short circuit on the load current, the DVR will be isolated from the systems by using the bypass switches as shown in Figure-2, switches S2,S3 were open and S1 will be closed to provide an different path for the load current.

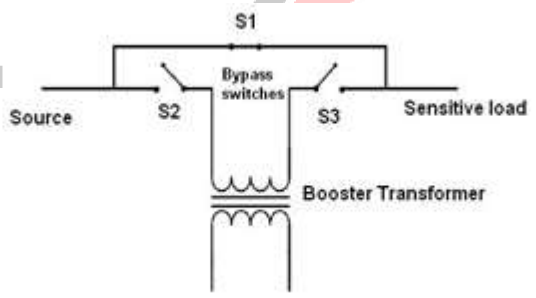


Fig 2- Protection Mode (creating another path for load current)

(2)Standby Mode- (VDVR = 0)- Standby mode the booster transformer's low voltage winding is shorted through the converter as shown in Figure-3, No switching of semiconductors occurs in this mode of operation and the full load current will permit through the primary transformer.

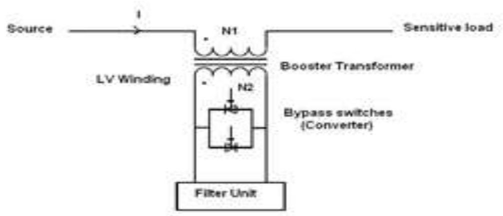


Fig 3-Standby Mode

(3)Injection/Boost Mode- (VDVR≠0)-In Injection/Boost mode the DVR is injecting a compensating voltage through the injecting transformer after detecting a fault in the supply voltage.

(D)Voltage Injection Methods of DVR-The dynamic voltage restorer (DVR) or a series booster is used during the voltage injection mode depends on many preventive factors like DVR power rating, load conditions, and voltage sag type. For example, some types of loads are sensitive to phase-angle jumps, and some others are sensitive to a change in voltage magnitude. Therefore the control strategies applied are totally depends upon the load characteristics. The four different methods used for DVR voltage injection are:

(1)Pre -Sag/ dip compensation method.

(2)In-phase compensation method

(3)In-phase advanced compensation method.

(4)Voltage Tolerance Method

(1)Pre-Sag/Dip Compensation Method (PDC)- The pre-sag/dip method track the supply voltage continuously and if detects any type of disturbances in that voltage it injects the missing voltage b/w the sag or voltage at the PCC and the ideal pre-fault condition. In this procedure, restored the load voltage back to the pre-fault conditions. Compensation of voltage sags in phase -angle and an amplitude sensitive load has to be achieved by pre-sag compensation method. In this method, the active power injected by the DVR, and the injected power cannot be controlled and is determined by the external conditions such as the type of faults and load conditions. Figure-4 shows the single phase vector diagram of this compensation method.

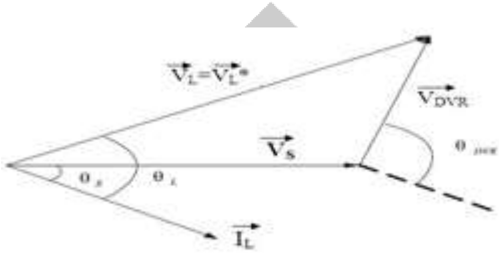


Fig 4- Single-phase vector diagram of the PDC method

(2)In-Phase Compensation Method (IPC)- In this method the injected voltage is in phase with the PCC voltage of the load current and pre fault voltage. The phase angles of the pre-sag and load voltage are different but the main aim is placed on maintaining a constant voltage magnitude on the load. One of the advantages of IPC method is that the amplitude of DVR injection voltage is minimum for a certain voltage sag in comparison with other strategies. Practical application of this method is in loads but which are not sensitive to phase-angle jumps. Figure-5 shows the single-phase vector diagram of this method .

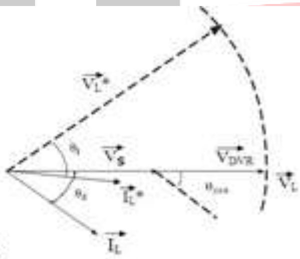


Fig 5- Single-phase vector diagram of the IPC method

Where V Pre-sag voltage, ⟶ Pre-sag load current,
$\theta_1 = \theta_S$

(3)In-Phase Advanced Compensation Method (IPAC)- This method the real power spent by DVR is minimized by decreasing the power angle between the load current and the sag voltage . In the two previous cases, namely pre -sag and in-phase compensation, the active power is injected into system by the DVR during disturbances. The active power supplied is limited to the stored energy in the DC link and this is one of the most expensive parts of the DVR. By making the injection voltage phasor is perpendicular to the load current phasor we achieved minimization of injected energy. In this process the values of load current and voltages are fixed in the system so that one can change only the phase of the sag voltage . In short, IPAC method uses only reactive power and unluckily, not all the sags can be mitigated without real power; as a result, this method is only suitable for a limited sag range.

(4)Voltage Tolerance Method- Generally voltage magnitudes between 90%-110% of the nominal voltage and phase angle variations between the 5%-10% of the normal state will not disturb the operation characteristics of loads. This method will maintain the load voltage and in this method the tolerance area with small change of voltage magnitude as shown in Figure. Fig. Voltage tolerance method with minimum energy injection.

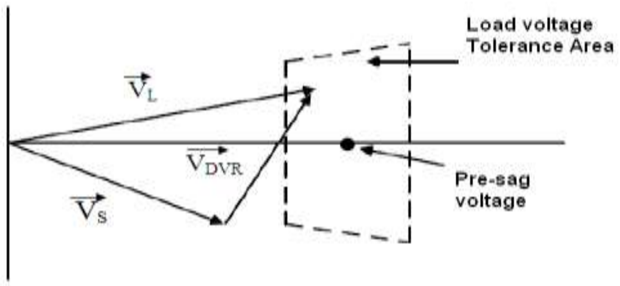


Fig-Voltage tolerance method with minimum energy injection

III.SIMULATION MODEL

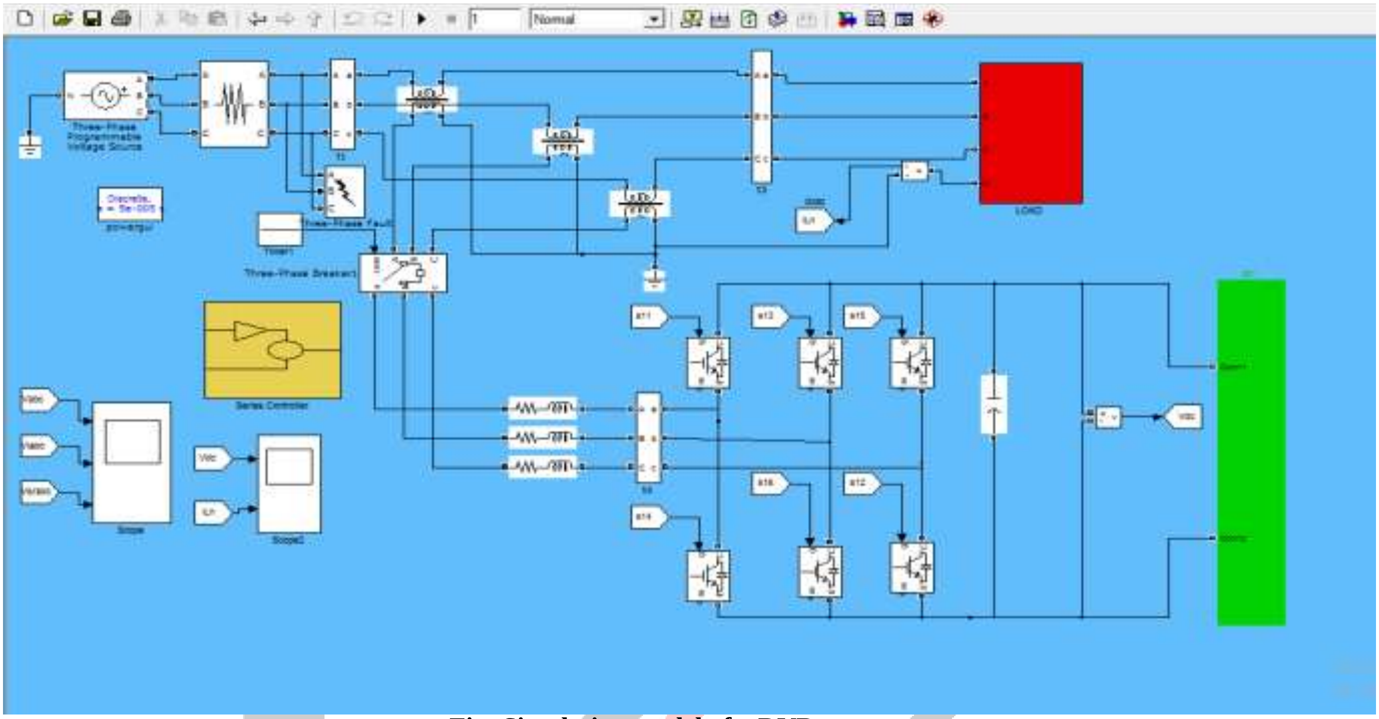


Fig- Simulation model of a DVR

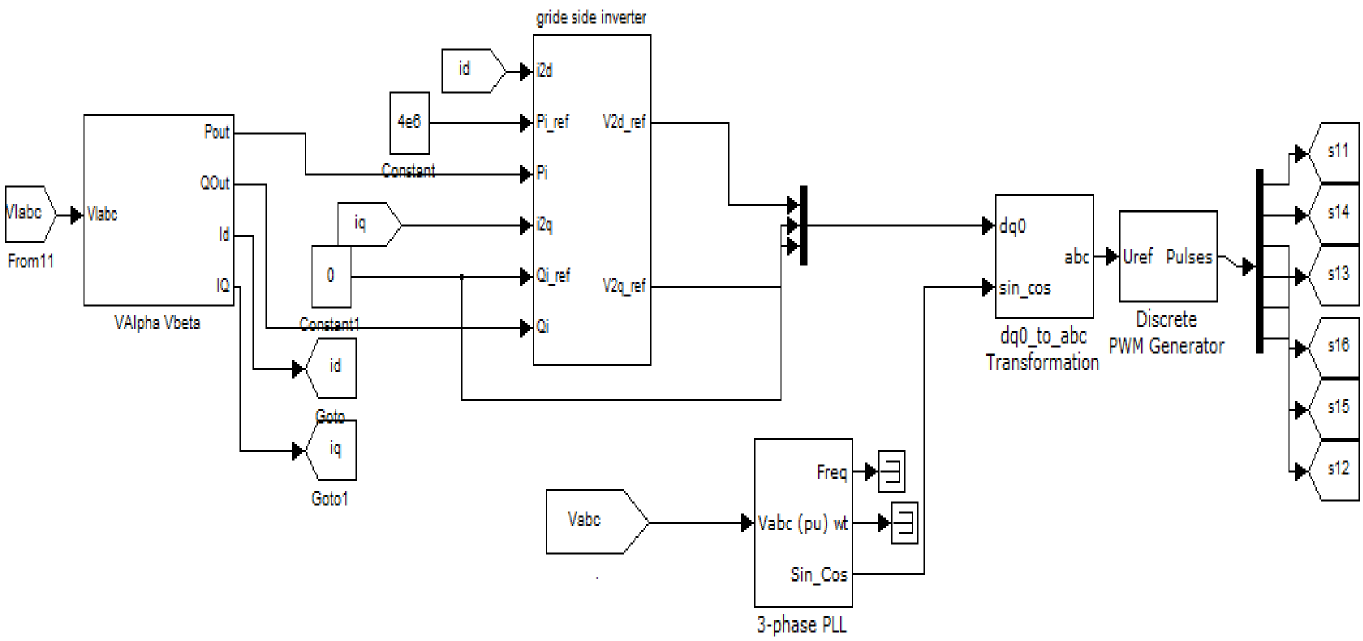


Fig- Subsystem for Series Controller

IV. SIMULATION RESULTS

In this paper the effects of voltage sag on power system is observed and by using a solid state device named dynamic voltage restorer helps to mitigate voltage sag completely and maintains power system stability.In this paper voltage drop below the nominal voltage is seen and corrected by DVR. We observed that voltage Drop of 50% is seen for 10 seconds during a period of 0.1 to 0.2 seconds for a complete simulation period of 1 minute. When a 50% drop is seen DVR is compensating that Voltage during a period of 0.1 sec to 0.2 sec The FFT analysis of DVR is seen with a Signal of a fixed step 4.88978e-006 sec. The total harmonic distortion is seen 0.49% with a 60 hertz frequency.

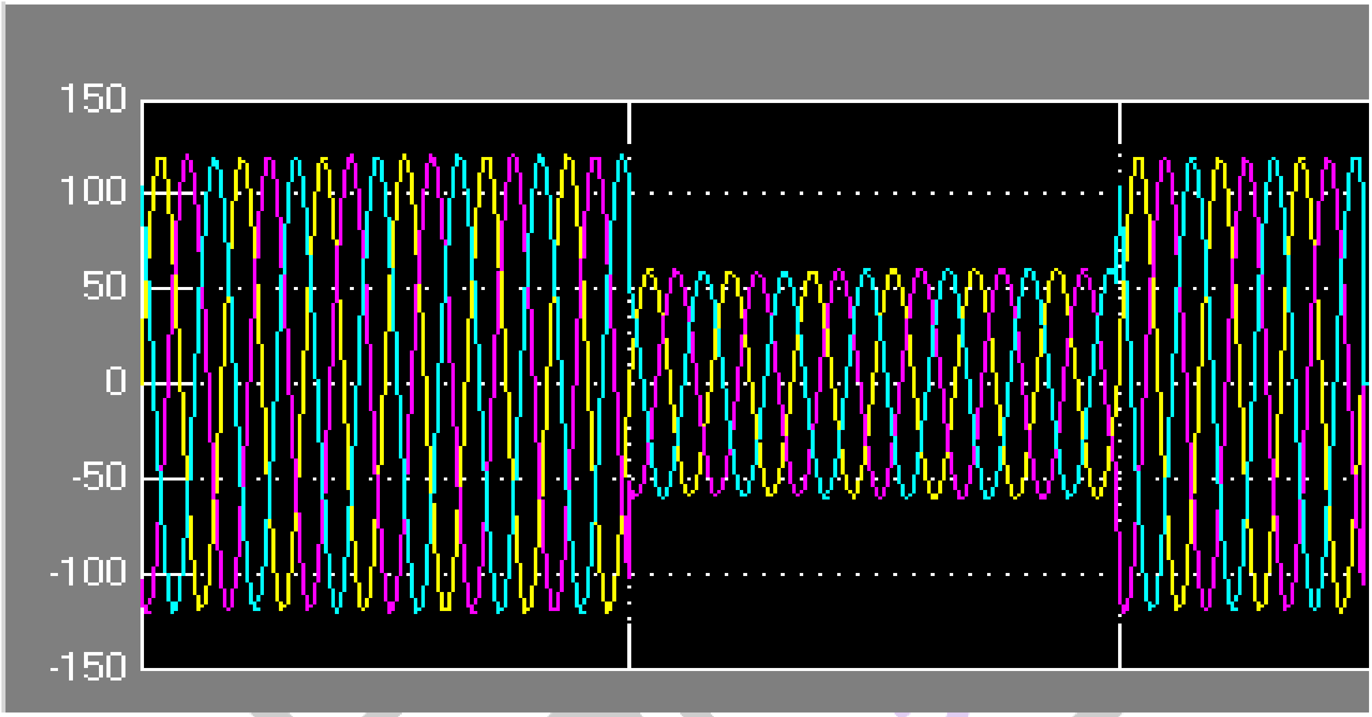
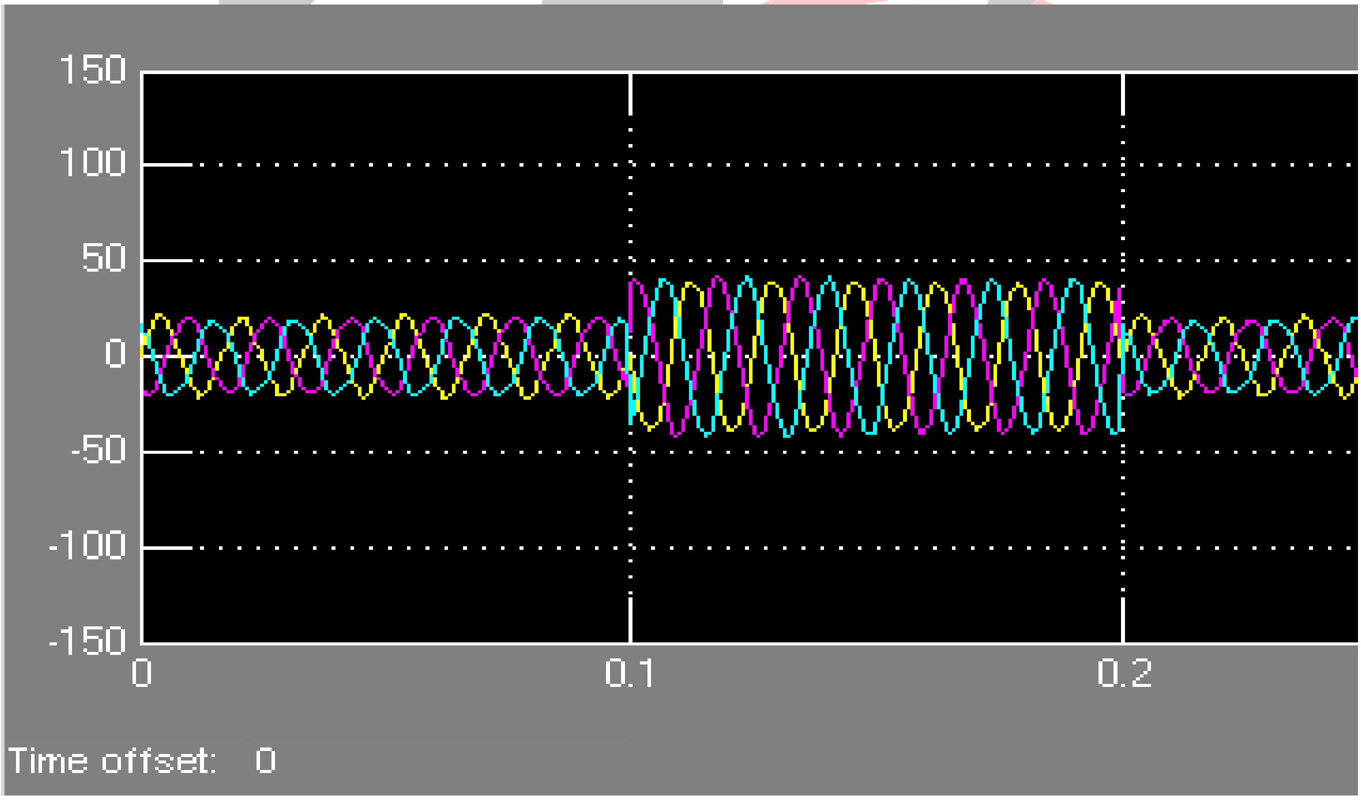
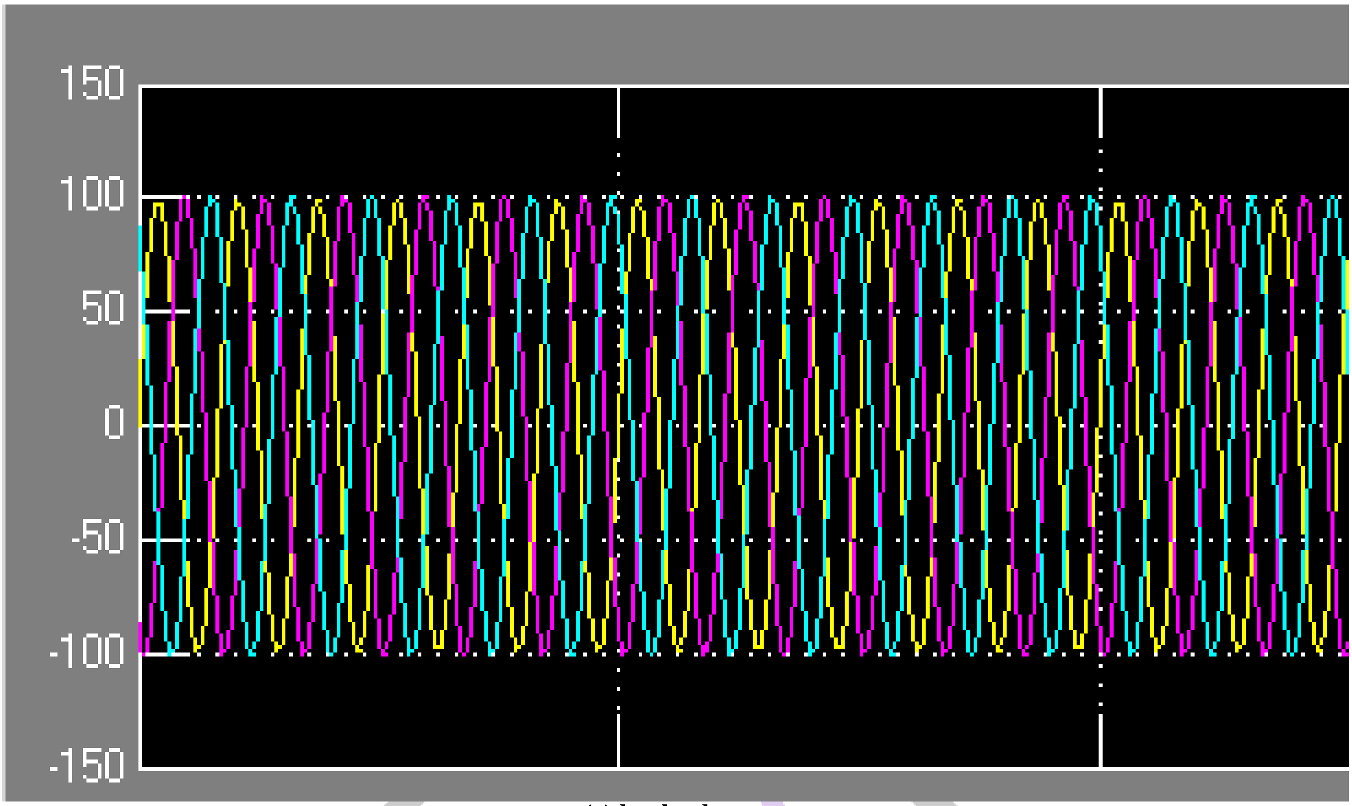


Fig- (a) source voltage



(b) DVR injected voltage



(c) load voltage

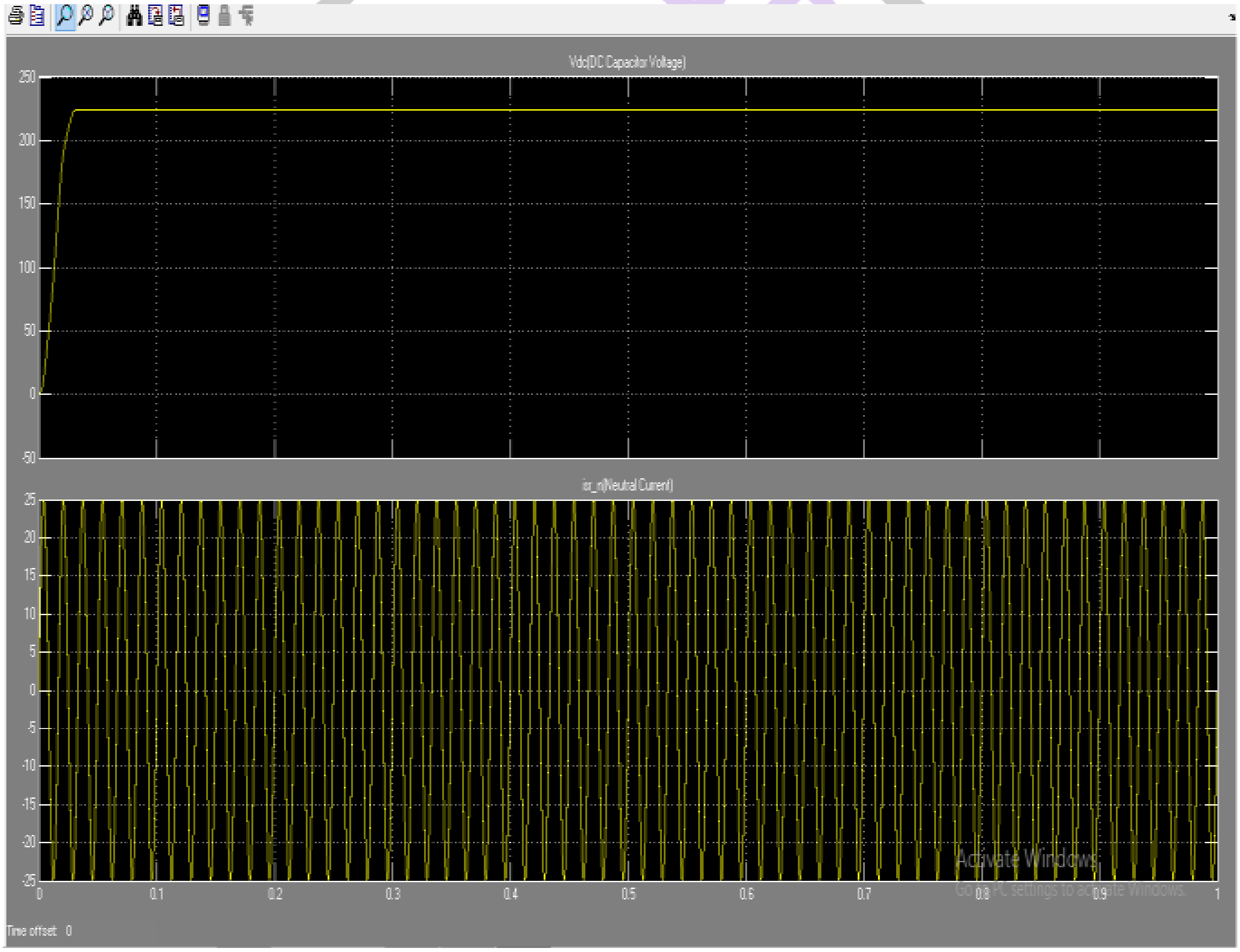


Fig- (a) Dc capacitor Voltage (b) Neutral current

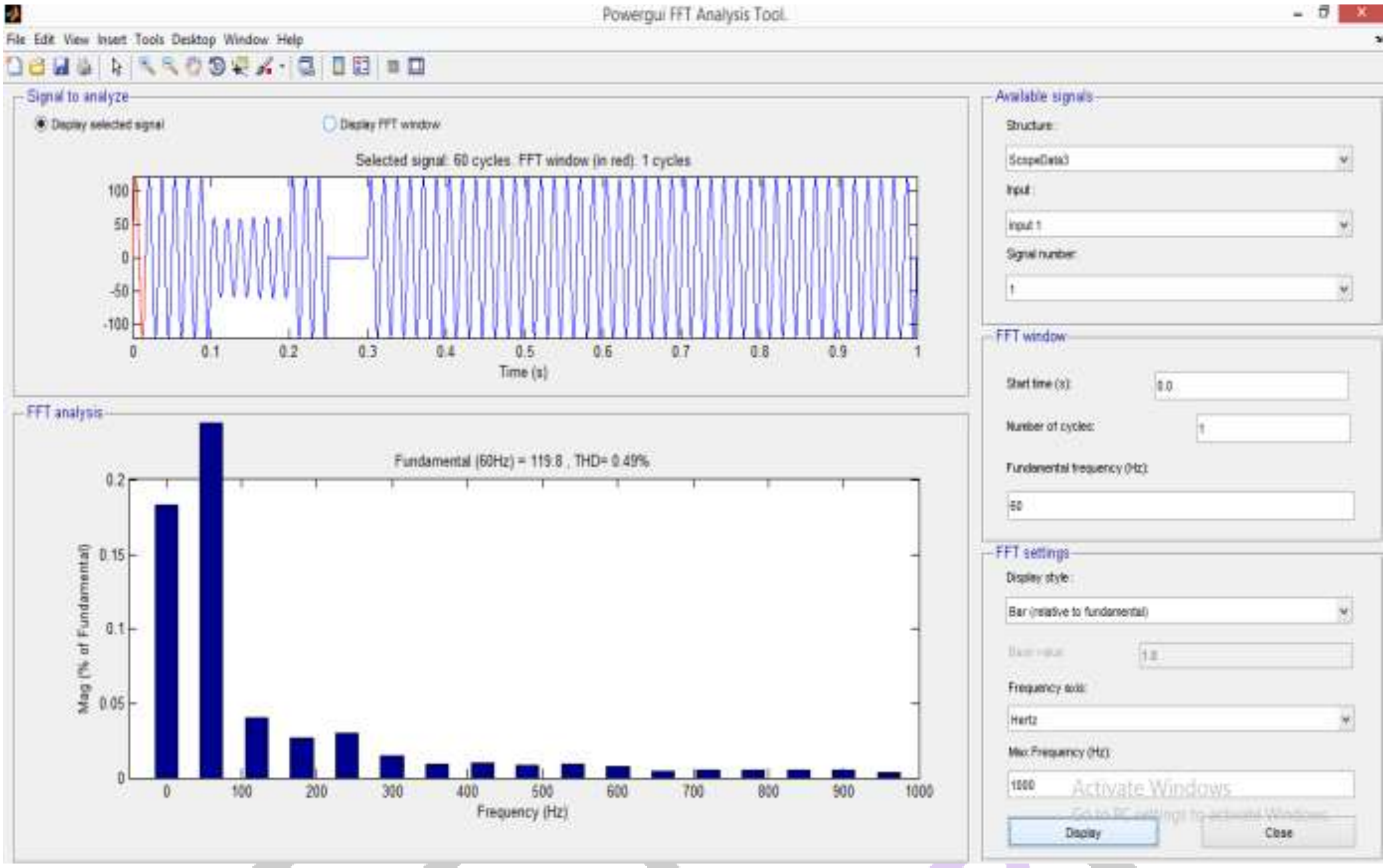


Fig- FFT analysis of a DVR

CONCLUSION-

Voltage sag is major and frequently problems in present power grids. And it is never acceptable for sensitive loads because voltage sag, power loss for sensitive loads, which is a costly problem. currently due to increase integration for the sensitive loads in power grid, providing high quality power is an important requirement. For outcome the problem of voltage sag, DVRs are the device which are suitable for compensate these voltage sags, protect sensitive loads and restore their voltage when the voltage sag problems cameout. One of the important topics in DVR is the procedure and method of voltage compensation. Basically four types of compensation methods including in-phase, pre-sag, energy minimized, hybrid compensation methods. This paper has reviewed and discussed in details the mentioned compensation methods and provided a comparison.

The simulation shows that the DVR performance is Satisfactory in mitigating Voltage sags. The DVR handle balanced and unbalanced situations without any difficulty and injects the voltage component. From Simulation results show the DVR compensates the sags quick and easily and gives excellent voltage regulation. From this project and simulation result it is clear that the performance in the source voltage, load voltage and injected DVR compensate voltage waveform gets improved using DVR. The MATLAB/Simulink was used to carry out extensive simulation studies on DVR.

FUTURE WORK SCOPE

There are many ways in which research can be pursued to enhance the capability of the present control schemes applied in custom power devices using FPGA controller In this research, the basic inverter has been considered, inverter has a switching frequency, voltage rating and power capacity limited by the rating of the particular or specific switches. many switches combination can address one or more of the inverter limitations. Thus, the UPQC configurations applying multi-step and multilevel inverter topologies must be examined. Performance comparison of power quality detection and base signal generation methods by experimentally. In DVR the stored energy can be supplied from different kinds of renewable energy storage systems and also we can do the closed loop system may be simulated using the neural network controller the coordination of FACTs controllers can also be studied in future.

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