IOSR Journal of Electrical and Electronics Engineering
e-ISSN : 2278-1676, p-ISSN : 2320-3331
PP 45-50
www.iosrjournals.org

Mitigating Voltage Sag Using Dynamic Voltage Restorer

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ABSTRACT: *Power quality is the most important issue in the distribution system. It has become important, especially for sophisticated device, whose performance is very sensitive to the quality of power supply. Most of the quality problems in the distribution system are related to voltage sag. To improve the power quality, custom power device is used. The device considered is the DVR. This paper presents modeling, analysis and simulation of the DVR test system using MATLAB. In this paper dq0 control algorithm is used for detection of sag and SPWM (Sinusoidal Pulse Width Modulation) technique is used to obtain appropriate switching of the VSI (Voltage Source Inverter) for the desired output. In this paper topology of DVR i.e. DVR with energy storage system are used. Finally, computational result and the mathematical result for 80% voltage sag are compensated.*

Keywords - *Power quality problem, Injection transformer, ESS, VSI, SPWM.*

I. INTRODUCTION

Even a few years back, the main concern of consumers of electricity was the reliability of supply. Here reliability is defined as the continuity of the electric supply. Even though the power generation in most of the advanced countries is fairly reliable, the distribution is not always so. It is however not only reliability that the consumers want these days, quality too is very important to them.

Initially for the improvement of power quality or reliability of the system FACTS devices like Static Synchronous Shunt Compensator (STATCOM), Static Synchronous Series Compensator (SSSC), Interline Power Flow Controller (IPFC), and Unified Power Flow Controller (UPFC) etc. are introduced. These FACTS devices are designed for the transmission system. But nowadays more attention is on the distribution system for the improvement of power quality, these devices are modified and known as custom power devices. The main custom power devices which are used in distribution system for power quality improvement are Distribution Static Synchronous Compensator (DSTATCOM), Dynamic Voltage Restorer (DVR), Active Filter (AF), Unified Power Quality Conditioner (UPQC) etc.

In this paper from the above custom power devices, DVR is used with dq0 control algorithm and SPWM control technique for the power quality improvement in the distribution system.

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II. DYNAMIC VOLTAGE RESTORER (DVR)

DVR is the series connected device that has the same structure as that of an SSSC. The main purpose of this device is to protect sensitive loads from sagging/swell, interruption in the supply side. This is accomplished by rapid series voltage injection to compensate for the drop/rise in the supply voltage. Since this is the series device, it can also be used as a series active filler. Even though this device has the same structure as that of an SSSC the operating principles of the two devices differ significantly. While the SSSC injects a balance voltage in series, the DVR may have to inject unbalance voltages to maintain the voltage at the load terminal in case of an unbalance sag in the supply side. Furthermore, when there is distortion in the source voltage, the DVR may also have to inject a distorted voltage to counteract the harmonic voltage.

Dynamic voltage restorer is the power electronic base device that has been designed to protect critical loads from all supply side disturbances other than outrage. It is connected in series with a distribution feeder and it is capable of generating or absorbing real and reactive power at its AC terminal. It is generally installed in a distribution system between the supply and the critical load feeder at the point of common coupling (PCC).

2.1 Operating principle of DVR

The basic principle of operation of the DVR is that by injecting a voltage of required magnitude and frequency in the system restored the load side voltage to desired amplitude frequency as shown in figure.2.1

DVR injects a controlled voltage generated by a forced commuted converter in a series to the bus voltage by means of an injecting transformer. A DC to AC inverter regulates this voltage by sinusoidal PWM technique. All through normal operating condition, the DVR injects only a small voltage to compensate for the voltage drop of the injection transformer and device losses. However, when voltage sag occurs in the distribution system, the DVR control system calculates and synthesizes the voltage required to preserve output voltage to the load by injecting a controlled voltage with a certain magnitude and phase angle into the distribution system. Figure 2.2 shows the phasor diagram in which DVR injects the missing voltage between sag voltage and pre-sag voltage [3].

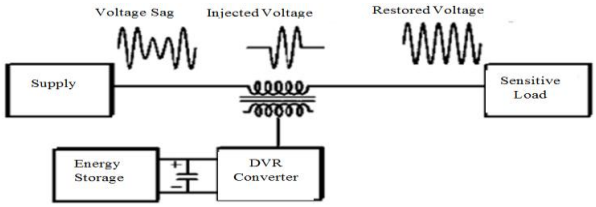


Figure: 2.1 Principle of Operation of DVR System

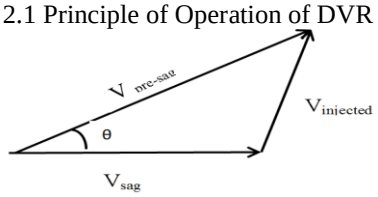


Figure: 2.2Vector Diagram of Operating Principle of DVR

III. SYSTEM MODEL

In this paper, the control system of Dynamic Voltage Restore (DVR) has been developed. This includes the Simulink models of topology of DVR *i.e*. DVR with an energy storage system. The model of Dynamic Voltage Restorer has been developed.

3.1 Basic Configuration of DVR

Dynamic Voltage Restorer mainly consists of following components:

(a) Control System
(b) Energy Storage Unit
(c) Voltage Source Inverter
(d) Harmonic Filter
(e) Injection Transformer

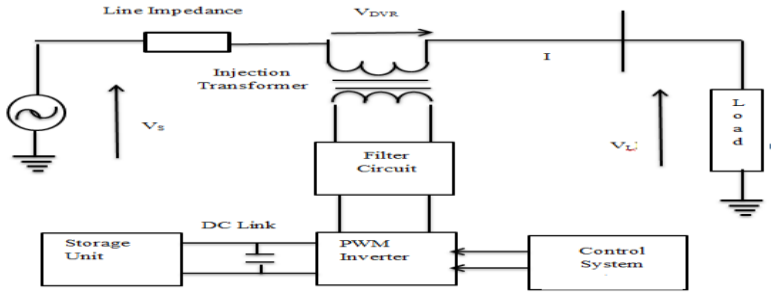


Figure: 3.1Schematic Diagram of DVR

(a) Control system

The control system is a herd of DVR. The controller is used for proper operation of the DVR. Generally control system with DVR operates in two tasks. The first task of the controller is detected of sag/swell in the system and Second task of the controller is to generate appropriate switching to inverter so that it will produce sinusoidal 50 HZ desired voltage at the load end.

(b) Energy storage unit

It is responsible for energy storage in DC form. Battery, SMES, super capacitor, capacitor bank, flywheel capacitor use as an energy storage unit. It supplies the real power requirement of the system when DVR is the use of compensation.

(C) Voltage source inverter

The variable output voltage is achieved by a voltage source inverter (VSI). Solid state semiconductor devices like Thyristors, GTO, MOSFET, IGBT, and IGCT with turn off capability are used in inverter circuit.

(D) Filter circuit

Passive filters are used to convert the inverter PWM waveform into a sinusoidal waveform. Generally lower order harmonics are eliminated by SPWM but higher order harmonics are remains as it is in the system so to eliminate this higher order harmonics passive filters are used.

(E) Injection transformer

Three phase or three single phase transformers are connected in series with the distribution feeder. It links the DVR system to the distribution network and it transfers the compensating voltages generated by the voltage source converters to the incoming supply voltage. In addition, the Injection transformer also serves the purpose of isolating the load from the DVR system.

3.2 Parameters of DVR Test Model

Electrical circuit model of DVR test system is shown inFig.3.1 System parameters are listed in Table 1. Voltage sag is created at load terminals via different faults as shown inFig.3

Table 1: System Parameters

Sr. No.	System Quantities	Standard
1	Main Supply Voltage (Ph-Ph)	400 V
2	Series Transformer Turns Ratio	1:01
3	Vdc	640 V
4	Source resistance	0.01
5	Line frequency	50Hz
6	Line impedance	.o165
7	Filter inductance	500 mH
8	Filter capacitance	40F
9	Inverter Speciation	IGBT base,3 arm, Sample time 5s6 pulses Carrier frequency 2.5 kHz,
10	Load	400 V, 1kW, 500 VAR
11	Induction Motor	400V,50Hz,20HP

IV. SIMULINK MODEL AND RESULT

4.1 Simulink model of DVR system

This section will briefly highlight of modeling a DVR in MATLAB against voltage sags based on published literature and show the result of mitigation obtained.

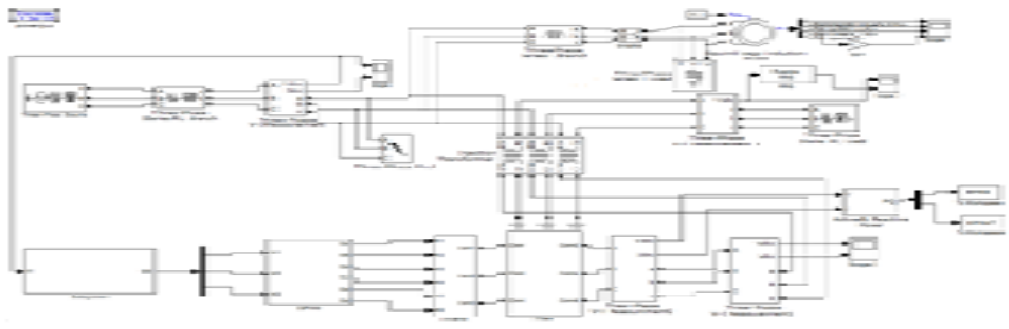
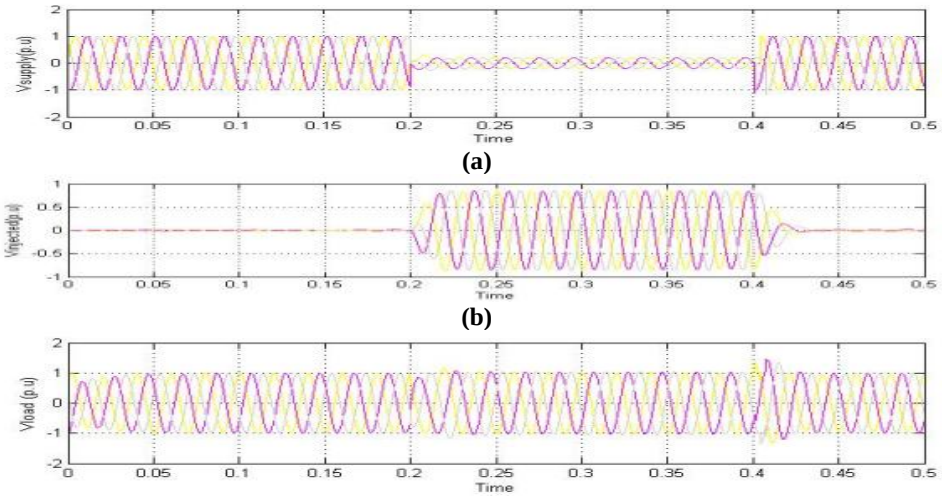


Fig: 4.1 Simulink Model using DVR

4.2 Simulation results of DVR.

In this analysis, we have investigated the performance of DVR under the various sag conditions. Also, we have seen the nature of load voltage with DVR and without DVR during the disturbances**.** For the investigation of performance of DVR under various sag conditions, the system has been developed as shown in figures below.

4.2.1 Simulation results of mitigation of voltage sag due to three phase to ground fault



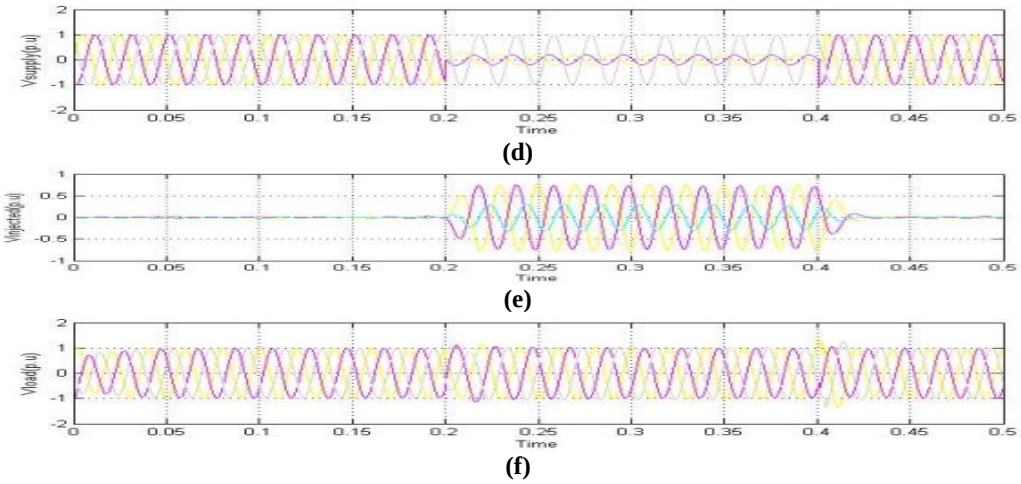
(a)

(b)

(c)

Figure: 4.2.1 Simulation Results for Three- Phase Voltage Sag
(a) Supply Voltage (b) Injected Voltage by DVR (c) Restored Load Voltage

4.2.2 The simulation results of mitigation of voltage sag due to two phases to ground fault



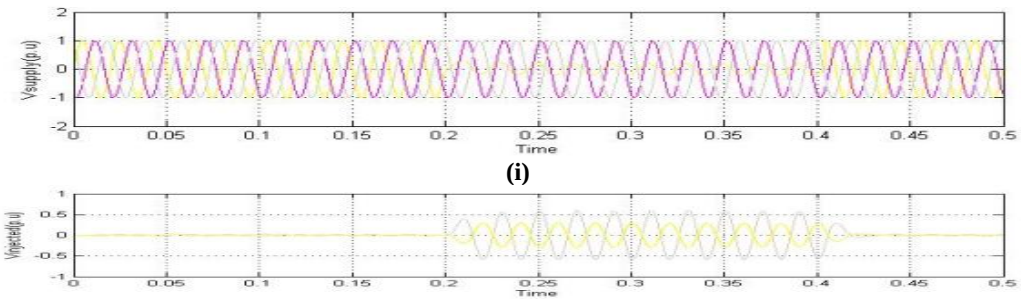
(d)

(e)

(f)

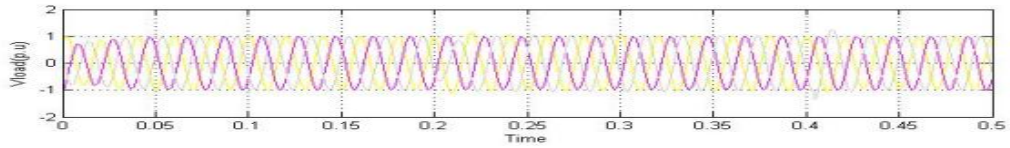
Figure: 4.2.2 Simulation Results for Two- Phase Voltage Sag
(d) Supply Voltage (e) Injected Voltage by DVR (f) Restored Load Voltage

4.2.3 The simulation results of mitigation of voltage sag due to single phase to ground fault



(i)

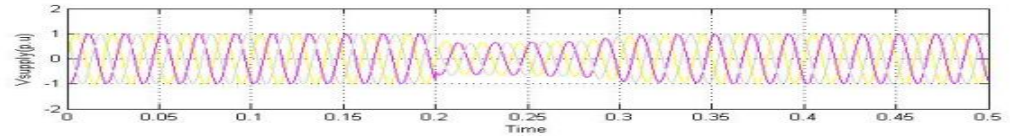
(j)



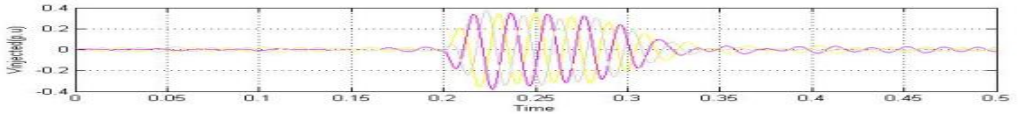
(k)

Figure: 4.2.3 Simulation Results for Single- Phase Voltage Sag
(i) Supply Voltage (j) Injected Voltage by DVR (k) Restored Load Voltage

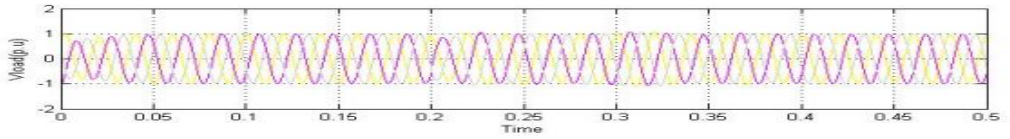
4.2.4 Simulation results of mitigation of voltage sag due to 3-phase Induction Motor load



(l)



(m)



(n)

Figure: 4.2.4 Simulation Results for 3-phase Induction Motor load
(l) Supply Voltage (m) Injected Voltage by DVR (n) Restored Load Voltage

Applications

1. Dynamic Voltage Restorer is an effective and relatively inexpensive custom power device so it can be used in industrial applications as well as transmission and distribution system to provide the best power quality.
2. Also Dynamic Voltage Restorer is a good voltage stabilizer and a voltage regulator so it can be used for commercial and domestic purposes to protect expensive and sensitive equipments from power quality problems.

V. CONCLUSION

To maintain Power quality is a majour technical issue for electrical researchers .This paper presents DVR as costum power device to mitigate voltage sag in distribution system. Voltage sag (0.8pu) due to single phase to ground fault, two phase to ground fault, three phase to ground fault and motor load created using MATLAB Simulink are mitigated by finding the error with the control circuit associated with Dynamic voltage restorer(DVR).

Also simulation results shows that DVR mitigate sag quickly and provides excellent voltage regulation.

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