

# MODELLING AND SIMULATION OF DYNAMIC VOLTAGE RESTORER FOR POWER QUALITY



## Engineering

**KEYWORDS :** Dynamic Voltage Restorer, voltage sag and swell, three phase programmable voltage source, three phase transformer, three phase fault, three phase RLC load.

**Minaxi L. Patel**

Assistant Professor, Electrical Engineering Department, Government Engineering College, Dahod. (GUJARAT)

**Prof. Sanjay R. Vyas**

Associate Professor, Electrical Engineering Department, LDRP Institute of Technology and Research, Gandhinagar. (GUJARAT)

### ABSTRACT

*This Paper presents modeling, analysis and simulation of a Dynamic Voltage Restorer (DVR) using MATLAB. A PI controller and Discrete PWM pulse generator was used in this model. The main aim of the DVR is to regulate the voltage at the load terminal irrespective of sag/swell, distortion, or unbalance in the supply voltage. The DVR is a power electronic based device that provides three-phase controllable voltage source, whose voltage vector (magnitude and angle) adds to the source voltage during sag event, to restore the load voltage to pre-sag conditions. An adequate modeling and simulation of DVR, including controls in MATLAB, show the flexibility and easiness of the MATLAB environment in studying and understanding such compensating devices.*

### INTRODUCTION

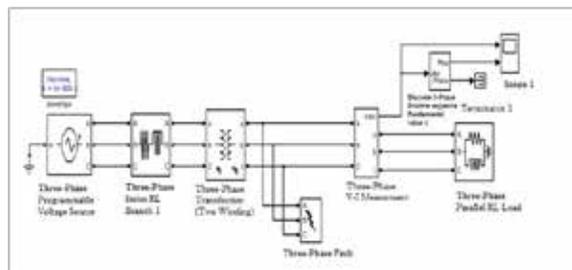
The DVR is a power quality device, which can protect the industries operating in a highly competitive business environment against the bulk of these disturbances, i.e. voltage sags and swells related to remote system faults. In some cases, these disturbances can lead to a complete shutdown of an entire production line, in particular at high tech industries like semiconductor plants, with severe economic consequences to the affected enterprise. A DVR compensates for these voltage excursions, provided that the supply grid does not get disconnected entirely through breaker trips. Modern pulse-width modulated (PWM) inverters capable of generating accurate high quality voltage waveforms form the power electronic heart of the new Custom Power devices like DVR. Because the performance of the overall control system largely depends on the quality of the applied control strategy, a high performance controller with fast transient response and good steady state characteristics is required. The wide area solution is required to mitigate voltage sags and improve power quality. One new approach is using a DVR. The basic operation principle is detecting the voltage sag and injecting the missing voltage in series to the bus.

DVR has become a cost effective solution for the protection of sensitive loads from voltage sags. The DVR is fast, flexible and efficient solution to voltage sag problems. DVR consists of energy storage unit, PWM inverter, and filter and injection transformer.

### MODELING AND SIMULATION OF DVR

The modeling of DVR has been done in the MATLAB simulink environment. A system is modeled which consist of a power source, three phase transformer and three phase RLC load. Modeling is done for sag with and without DVR which are as follows.

### MODELING FOR SAG WITHOUT DVR

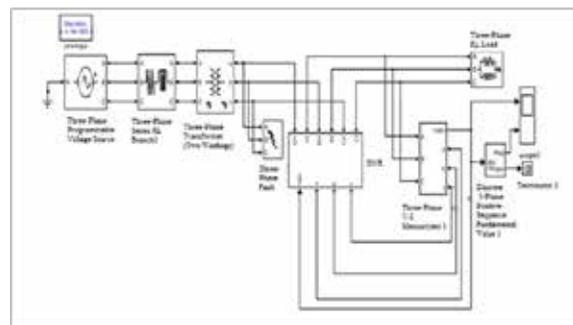


**Fig.1 System under fault condition without DVR**

Fig.1 shows that due to some interruption suddenly three phase fault occur, and system define as under fault condition without DVR. The system consists of 11kV, 50 Hz source with the step down transformer of 11kV/440V is shown in fig.1. To verify the working of Dynamic Voltage Restorer, three phase line-ground fault occurs with the fault impedance of 0.004Ω. As shown fig.1, fault occurs at 0.15 sec to 0.35 sec. During this period voltage sag occurs. The modeling parameters are given as below mentioned detail :-

- Supply Source = 3-Phase, 11 KV, 50 Hz.
- Line Impedance = [R=0.01Ω, L=5mH].
- Step Down Transformer=11KV/440 v.
- Load= 1 KW, 100 Var.
- Series Injection Transformer = 440/400 V.
- Filter L = 0.01 H, C= 0.11 mF.
- DC Voltage Source = 600 V.

### MODELING FOR SAG WITH DVR



**Fig 2. Three phase system with DVR.**

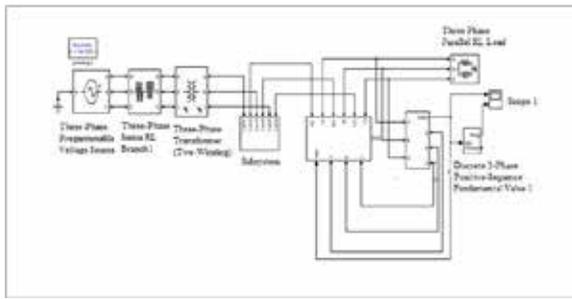
Above fig.2 shows the three phase system with DVR. Now the function of DVR would be to inject a compensating voltage, which would result in fairly constant voltage across the load terminal. With the use of the fast acting power electronics converters, DVR is capable to inject voltage for such a small duration of few cycles.

The main function of the DVR is the protection of sensitive loads from voltage sags/swells coming from the network. The DVR is shown in fig.-2 which consists of the injection transformer, filter unit, PWM inverter, and energy storage and control system that is used to mitigate voltage sag in power distribution system.

In above figure Three phase Programmable Voltage Source block is shown which implements a three phase Zero impedance voltage source. The common node (neutral) of the three source is accessible via input 1 (N) of the block. Time Variation of the Amplitude

,phase, and frequency of the fundamental can be pre-programmed. In addition two harmonics can be superimposed on the fundamentals.

**MODELING FOR SWELL WITH DVR**

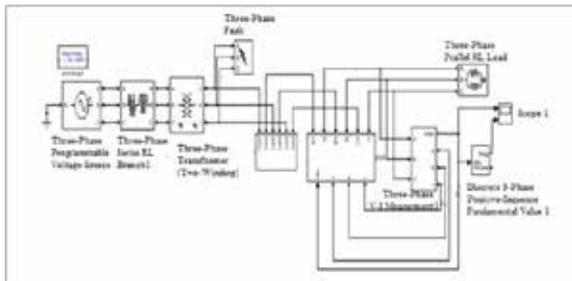


**Fig.3 System under swell condition with DVR**

Fig.3 shows the diagram of when power system distribution network found under voltage swell condition due to some interruption or sudden remove large load and DVR is connected with it. The sudden removal of large loads or application of large capacitor banks may lead to transient voltage rise. This increase in voltage (swell), although not as common as sags, may lead to insulation failure of the equipment upon times. The DVR must respond to this disturbance as well. A three phase balanced voltage swell is simulated by increasing the line to line voltage on each phase for a duration of 0.20 seconds from t=0.15 sec. till t=0.35 sec.

**MODELING FOR CONSECUTIVE SAG AND SWELL**

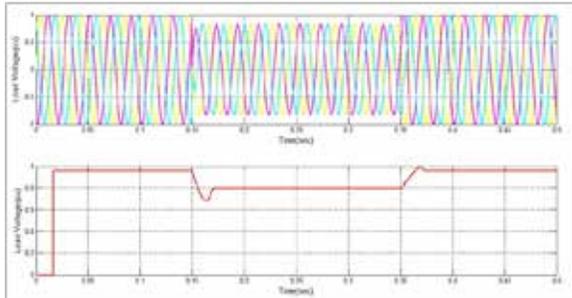
Fig.4 shows the modeling diagram of when sudden variation of large load on the power system distribution network and due to three phase fault, system make under consecutive sag and swell condition as DVR connected. Here in this case both the voltage sag and voltage swells occurs for certain duration. After the injection of the voltage by the DVR the voltage across the line remains constant such that the sensitive loads are not affected by the voltage sags or voltage swells.



**Fig.4 System under consecutive sag and swell condition with DVR**

**RESULT AND DISCUSSIONS**

**I RESULT OF VOLTAGE SAG WITHOUT DVR**



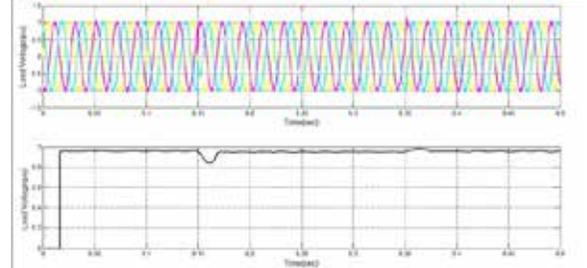
**Fig.1 Voltage sag under fault condition**

Fig.1 shows the waveform against load voltage & duration of time period at load point when the system operates with no

DVR and a three phase fault is applied to the system. It persists for 20 msec. It shows three phase voltage waveform under fault condition without DVR. In this figure due to fault condition voltage sag shown at a time duration between 0.15 sec. to 0.35 sec.

The first simulation was done with no DVR and a three phase fault is applied to the system at point with fault impedance of 0.004 ohm for a time duration of 0.15 to 0.35 sec. The second simulation is carried out at the same scenario as above but a DVR is now introduced at the load side to compensate the voltage sag occurred due to the three phase fault applied. When the DVR is in operation the voltage interruption is compensated almost completely and the rms voltage at the sensitive load point is maintained at normal condition.

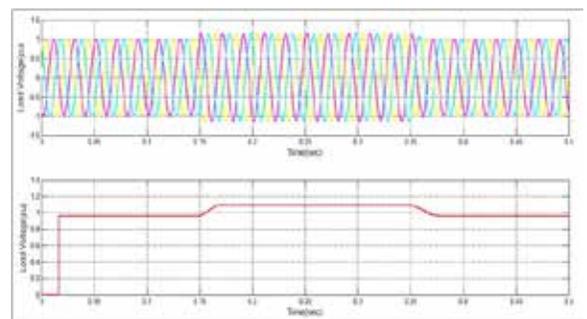
**2.RESULT OF VOLTAGE SAG WITH DVR**



**Fig.2 Load Voltage after sag compensation**

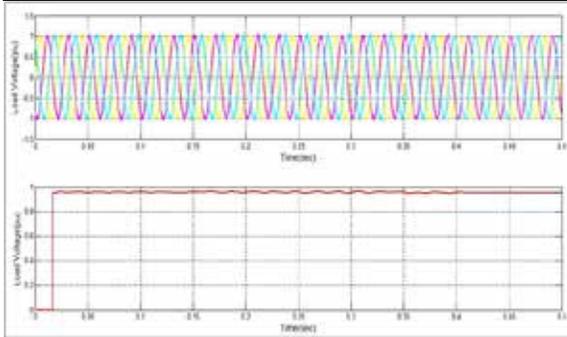
Fig.2 shows the waveform result of load voltage after sag compensation as voltage injected by DVR during the time period of 0.15 sec. to 0.35 sec., and it will shown constant voltage across the line in between that time period at which voltage sag occur. The positive sequence amplitude of it has been compared with 1 and the difference has been given to a PI controller to produce reference voltage. This voltage is produced by an inverter and three single-phase transformers with delta connection. Fig.2 show load voltage waveforms after sag compensation output voltage of the inverter and simulated system.

**3. RESULT OF VOLTAGE SWELL WITH DVR**



**Fig.3 Load voltages under swell condition**

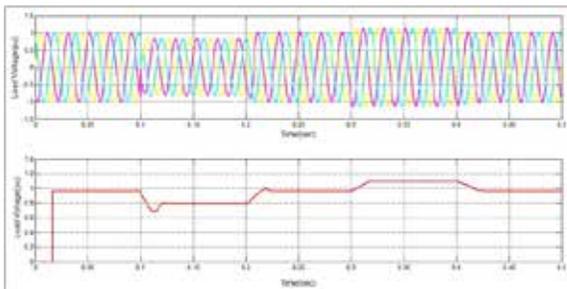
Here as shown in fig.3 voltage swells occurs for 20 msec. (from 0.15 sec to 0.35 sec.) .Now DVR has capability of the injection of the voltage such that the output of the voltage remains constant and sensitive load is not affected by the voltage swell. As shown in fig.-6.6 waveform due to voltage swell load voltage fluctuate & increase its p.u. value during time period of 0.15 sec. to 0.35 sec. so, it will need to inject voltage to be compensate swell.



**Fig.4 Load voltages after swell compensation**

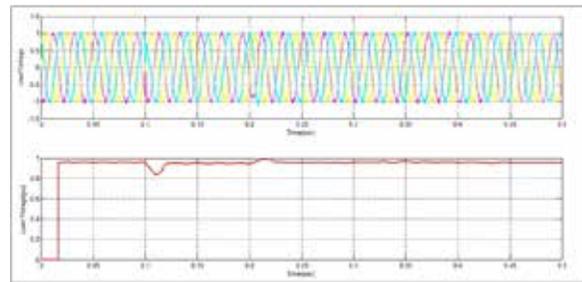
After this voltage injection through DVR as shown in fig.4 voltage swell compensate during time period of 0.15 sec. to 0.35 sec. and voltage remain constant as well as sensitive load not affected.

**4 RESULTS FOR CONSECUTIVE SAG AND SWELL**



**Fig.5 Load Voltages under sag and swell condition**

As shown in fig.5 there is a waveform result of fault occur across three phase line and due to that found load voltage under sag as well as swell condition in which voltage sag from 0.1 sec to 0.2 sec. and after some time there is a voltage swell from 0.3 sec to 0.4 sec. now DVR has a capability to compensate both the voltage sag and voltage swell condition.



**Fig.6 Load voltages after consecutive sag and swell compensation**

Fig.6 shows waveform result of the Constant load voltage as above discussion due to some fault find out some voltage sag as well as swell in the system which is compensate by DVR.

**CONCLUSION :-**

In this study the modeling and simulation of a DVR with SPWM based controller has been developed by using the facility available in MATLAB/SIMULINK. In this simulation, In-phase voltage injection method is preferred for compensation of voltage sags. PI controller is used to get the compensating signal for Sinusoidal Pulse Width Modulation Technique. The simulation results show the performance of DVR under fault condition that causes voltage sag and voltage swell.

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