Improvement of Voltage Profile with the Help of Dynamic Voltage Restorer

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ABSTRACT
Now a day's power quality is one of the biggest problems in whole world. In the distribution system voltage sag is a common and undesirable power quality phenomenon. It has been observed that, to minimizing the voltage sag in power distribution network the Dynamic Voltage Restorer (DVR) is the most efficient and effective modern custom power device. This paper presents modeling analysis and simulation of a Dynamic Voltage Restorer (DVR) test system using MATLAB/Simulink for minimizing the voltage sag when double line to ground fault is applied.

General Terms
Dynamic Voltage Restorer (DVR), MATLAB/Simulink, RMS

Keywords
Power quality, Dynamic Voltage Restorer (DVR), Voltage Sag, Voltage Source Converter (VSC)

1. INTRODUCTION
In modern Power System the power quality is a very vital issue for electricity suppliers in present time. It was found that the majority of power quality problems are related to issues within a facility as opposed to the utility. In electrical power system three functional areas are there, 1st is Generation, 2nd is Transmission and 3rd is distribution. Statistics shown 90% of power quality problems reason behind is electrical distribution network failure [1]. Without the proper power electrical equipment may malfunction, fail prematurely or not operate at all [2].

For industrial and commercial electrical consumers the most common behaviors that waste energy significantly and contribute to electrical disturbances include like- Reactive power, voltage variations (Sag, Swell, and Interruptions), harmonics etc. In the low power distribution system voltage sag is one of the most significant types of power quality disturbance and it could be symmetrical or unsymmetrical. Magnitude and duration are the two main attributes in voltage sag problems.

There are many method exists for compensating the voltage sag, but one of the most successful procedure for compensating the voltage sag is by the use of Dynamic Voltage Restorer(DVRs). For its fast response, lower cost and small in size make this more popular. This custom power device is most effective and efficient for voltage unbalancing problem [3]. The DVR continuously track the supply voltage, when a disturbance occurs (abnormal condition) and deviates the supply voltage from nominal value then series voltage injected through the transformer by a voltage source converter is connected to a DC power source [4].

The organization of the paper is as follows, in section II, The definition of power quality problems are describe, In section III, Objectives of the project are discussed, in section IV, The operating principle of DVR and constructional part of the DVR are briefly described. In section V, an Equation is being developed. In section VI, Result and Analysis of the proposed DVR test model are discussed and finally in section VII, a conclusion is being drawn.

2. DEFINITION OF POWER QUALITY PROBLEMS

2.1 Voltage Sag
Voltage sag (Figure 1[5]) can also be defined as a decrease of utility supply voltage magnitude between 0.1 and 0.9 p.u. in RMS value and do not go below 50% of the nominal voltage and, they normally last from 3 to 10 cycles or 50 to 170 milliseconds [6].

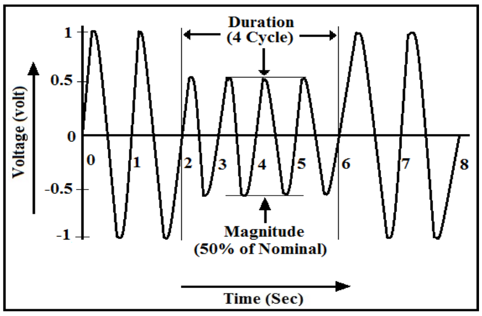

Figure 1: Voltage sag

2.2 Voltage Swell
Voltage Swell (Figure 2[7]) can also be defined as an increase of supply voltage magnitudes between 1.1 and 1.8 p.u. in RMS voltage, and the most accepted duration is from 0.5 cycles to 1 minute [7].

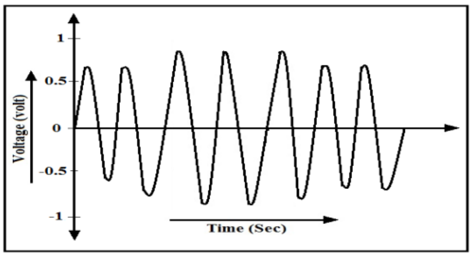

Figure 2: Voltage Swell

2.3 Voltage Interruption

Voltage interruption (Figure 3[5]) is a large decrease of supply voltage below a specified limit of 0.1 p.u. in RMS value, and the time duration is more than 1 minute.

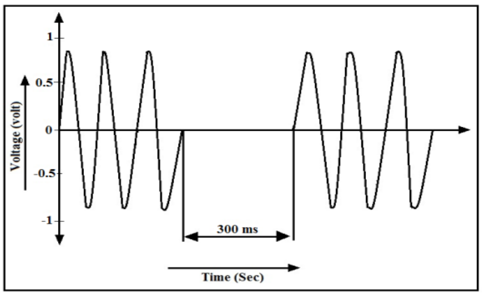

Figure 3: Voltage interruption

Table 1. Types of interruption

Types of Interruption	Duration	Magnitude
Instantaneous	0.5 cycles – 30 cycles	Below 0.1 p.u.
Momentary	30 cycles – 2 sec	Below 0.1 p.u.
Temporary	2 sec – 2 minutes	Below 0.1 p.u.
Sustained	Greater than 2 minutes	Below 0.1 p.u.

2.4 Harmonic Distortion

If the voltage or current wave shape is not sinusoidal, it is considered distorted. The main cause of harmonics in electrical power system is present of non linear electric loads. Non linear loads create disturbances in the fundamental frequency, which produce all types of harmonics.

3. OBJECTIVE OF THE PROJECT

A. To study the various types of power quality problems and their effect on both utility and customer side of the system.

B. To observe the effect on the characteristics of voltage sag and swell for the techniques.

C. To study the operation of the DVR system.

D. To analyze the voltage sag problems and solve it by DVR system, using MATLAB/Simulink software.

4. DYNAMIC VOLTAGE RESTORER

The Dynamic Voltage Restorer is discovered in 1990's but it was first installed in the year of 1996. The DVR is a solid state power electronic switching device, which is connected in series with the load voltage [8]. The main aim of DVR is to regulate the voltage at the load terminals irrespective of sag, distortion or unbalance in the supply voltage. It is generally installed in a distribution system between the supply and the load feeder. In healthy condition when no short circuit is occurs in power system network a capacitor will be charging in between rectifier and inverter is shown in figure (4)[9].

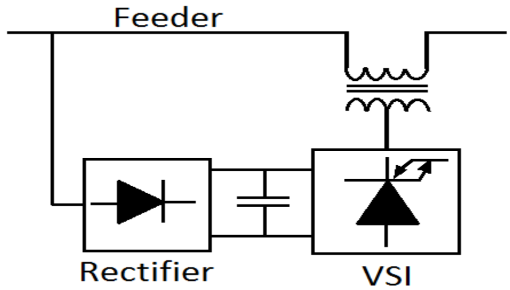

Figure 4: DVR Structure

When voltage sag is happened, the capacitor is placed in between rectifier and inverter will discharge to maintain load voltage supply. During the disturbance the nominal voltage is compared with the supply voltage variation in order to calculate the voltage to be injected by the DVR to maintain the supply voltage within limits. Voltage sag is one of the dangerous power quality problems. The concept of custom power is introduced to overcome these types of problems. The custom power is formally defined as the employment of power electronic or static controller in distribution systems rated up to 38 KV [10].

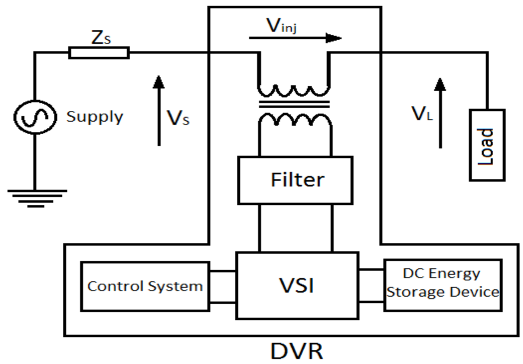

Figure 5: Schematic Diagram of a DVR system

The figure (5)[11] shows a schematic diagram of a typical DVR system, it consists of,

4.1 A DC Energy Storage Device

4.2 Voltage Source Converter (VSC)

4.3 An Injection Transformer

4.4 LC Filter

4.5 Pulse Generator

4.1 A DC Energy Storage Device

The main function of this device is to provide the desired real power during voltage sag. Various storage devices are used to compensate the voltage sag including Fly wheels, Batteries, Super-Capacitors, Super Conducting magnetic Energy Storage (SMES) etc. This energy storage device directly determines the duration of the voltage sag and it compensate by the DVR.

4.2 Voltage Source Converter (VSC)

This is a power electronic device. You know that the energy storage device generates a DC voltage. The Voltage Source Inverter (VSI) is used to convert this DC voltage into an AC voltage. The VSI is used in DVR system to generate the part of the supply voltage which is missing [12].

4.3 An Injection Transformer

Three single-phase injection or booster transformers are used to inject the compensating voltages generated by the Voltage Source Inverter (VSI) to the incoming supply voltage. An injection transformer primary side is connected to the distribution line while the secondary side is connected to the DVR system [13-14]. When voltage sag occurs then transformer inject the voltage with required magnitude and frequency. To integrate the injection transformer correctly into the DVR system, the primary winding voltage, current ratings, MVA ratings, turn- ratio of the transformers are required.

4.4 LC Filter

In previous Voltage Source Inverter (VSI) section allready discuss to convert the DC voltage into an AC voltage the Voltage Source Inverter (VSI) is used. During the DC to AC conversion in VSI which will also distort the compensated output voltage. So, not only this reason or to eliminate the unwanted noise signals, high-frequency switching harmonics and the DVR to improve the quality of power etc we use LC filter in this DVR system.

4.5 Pulse Generator

To generate pulses for simulating logic circuit use the pulse generator in this system. In order to supply the required pulse a considerable degree of adjustment is required for it in terms of amplitude, frequency, period (sec), pulse width and phase delay.

5. OPERATING MODES OF DVR

The DVR has divided into three operating modes, which are as follows,

- 5.1 Protection Mode
- 5.2 Standby Mode (V_{DVR} =0)
- 5.3 Injection or Boost Mode

5.1 Protection Mode

Due to short circuit on the load, the DVR is protected from the over current in the load side. When over current of the load side cross the permissible limit, then bypass switches (S_2 and S_3 will be open) remove the DVR from the system, and supplying another path for current (S_1 will be closed) as shown in figure (6)[15].

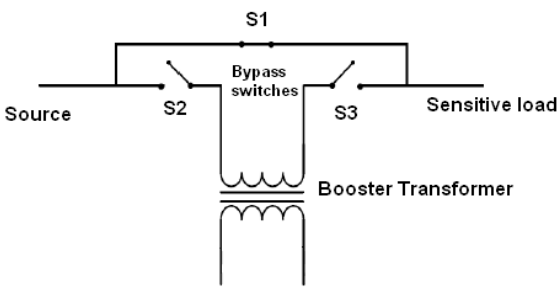

Figure 6: Protection Mode

5.2 Standby Mode (V_{DVR} =0)

In this mode of operation the booster transformer low voltage winding is shorted through the converter, that's why in this mode of operation no switching of semiconductors occurs and full load current pass through the primary. As shown in figure (7)[15].

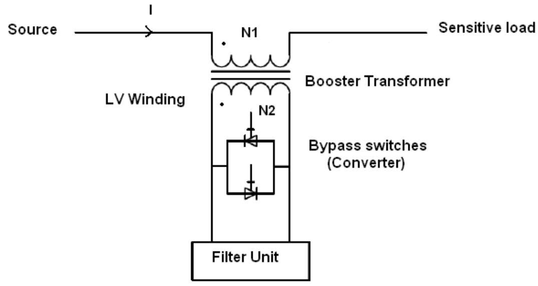

Figure 7: Standby Mode of DVR

5.3 Injection or Boost Mode

When sag is detected, the DVR goes into injection mode. At that time the difference voltage will be injected by DVR system to restore the load voltage supply.

6. EQUATIONS

An equivalent circuit diagram of the DVR and principle of series injection for sag/swell compensating is derived by in **figure (8)**[16].

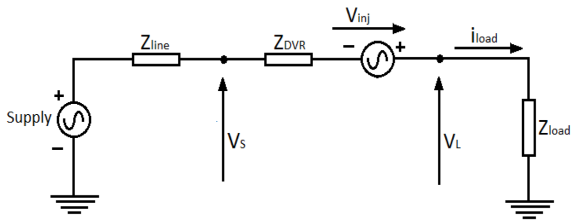

Figure 8: Equivalents circuit of DVR

The load voltage is $V_L=V_S + V_{inj}$ (1)

Where,

V_S =Supply voltage

V_{inj} =Injection voltage

Under normal condition, the load power on each phase

$$S_L=V_L I_L^* =P_L - JQ_L \quad (2)$$

Where,

I_L =Load current

P_L =Real Power

Q_L =Reactive power

When the DVR is in active or working mode and restores the voltages in its normal condition then,

$$\begin{aligned} S_L &= P_L - JQ_L \\ &= (P_{Sag} - JQ_{Sag}) + (P_{inj} - JQ_{inj}) \end{aligned} \quad (3)$$

Where, sag means the voltage sagged quantities and inj means the voltage quantities injected by the compensating device (DVR) [16].

7. RESULT AND ANALYSIS OF THE PROPOSED DVR TEST MODEL

In this section the various types of results are obtained after analyzing and discussing the simulation. The comprehensive simulations are performed on the DVR test system using MATLAB/Simulink software. The results of simulation are shown separately in each case. The test system has been examined by the faulty condition of double line to ground fault.

7.1 Simulation Model and Waveforms

Case-1

Simulation model of the proposed system with fault is shown in figure (9). In this proposed model, the simulation time is 0.2 sec, supply voltage 100 volt and frequency was 50HZ is taken respectively. The figure (10) shows the simulation waveform of the input voltage and figure (11) shows the simulation waveform of the faulted section. When a fault occurs the input voltage remains almost the same as before but you will see that the load voltage changes a lot. The Y-Axis and X- Axis show the magnitude of the voltage and simulation time respectively. In this waveform you see that a voltage sag occurs between 0.02 sec to 0.08 sec and also see that the two lines get affected.

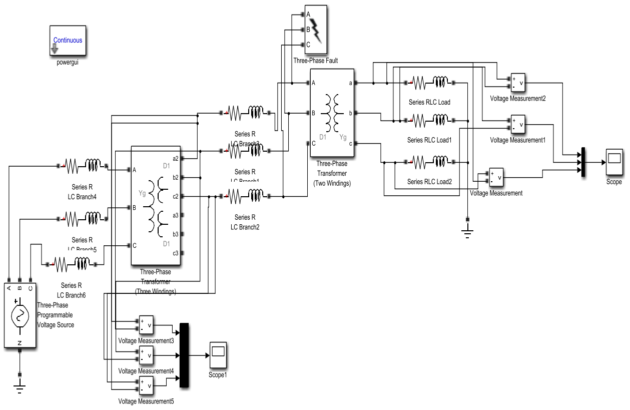

Figure 9: Simulation model with fault

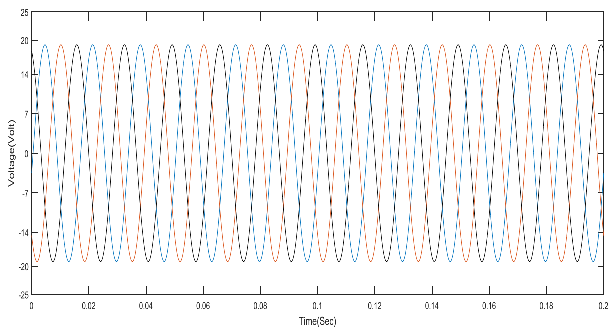

Figure 10: Input Voltage

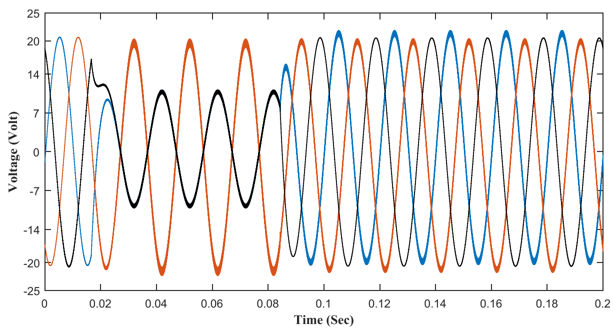

Figure 11: Load Voltage with fault

Case -2

In this section another simulation model is being analyzed and discussed. In the second simulation model, an opposite terminal is connected through transformer. The second simulation model is being performed by the same load in the opposite terminal without DVR & the same fault occurs as shown in the figure (12). The Ground Resistance is 0.01 second and fault Resistance is 0.001 second respectively. The supply voltage is taken as 100 volt & frequency as 50 HZ, same as the previous case. In this simulation model are comparing the first simulation model result with the second simulation model opposite terminal without the DVR result.

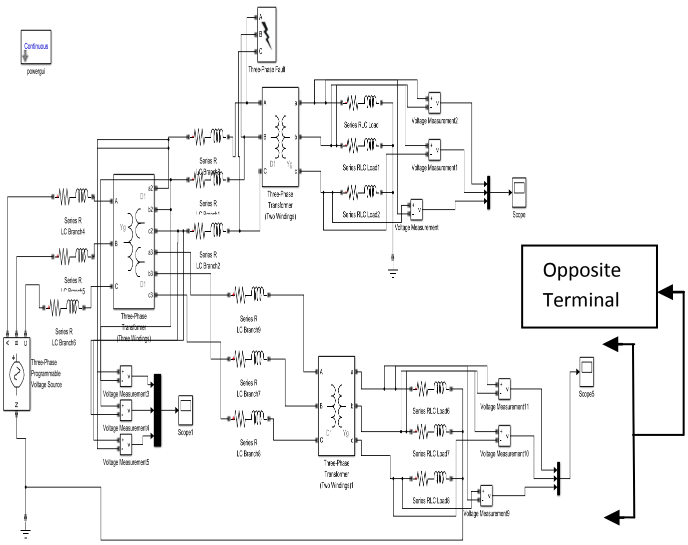

Figure 12: Simulation model with Opposite Terminal without DVR

The figure (13) shows the simulation result waveform of the opposite terminal without DVR. The Y- Axis shows the magnitude of the voltage and X- Axis shows the simulation time. From this waveform you see that the load in the opposite terminal is also affected because of the fault, but in figure (13) the effect of fault is less than that of figure (11).

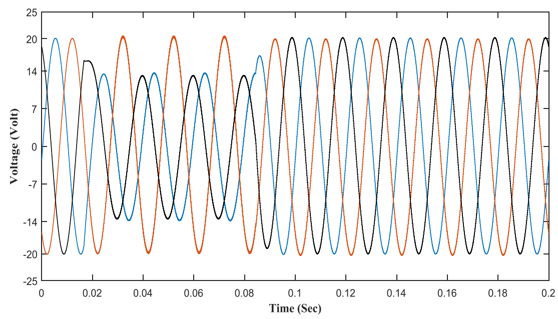

Figure 13: Opposite Terminal without DVR

Case-3

The figure (14) shows the MATLAB/Simulink of power system grid under the faulty condition being connected to a Dynamic Voltage Restorer (DVR). In the third simulation model DVR is now introduced at the opposite terminal of the load side to compensate or mitigate the voltage sag which occurred when double line to ground fault is applied. In this simulation model you see that the result of opposite terminal waveform, when DVR is being connected to the opposite terminal and compare with the waveform result of opposite terminal without DVR of second simulation.

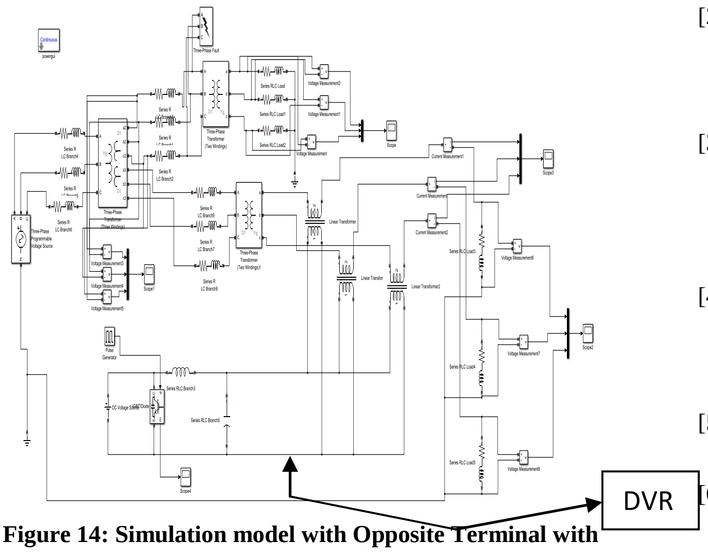

Figure 14: Simulation model with Opposite Terminal with DVR

The figure (15) shows the simulation result waveform of the opposite terminal with DVR. In comparison of figure (13) & figure (15), it is shown that the proposed DVR can improve the voltage sag during the fault.

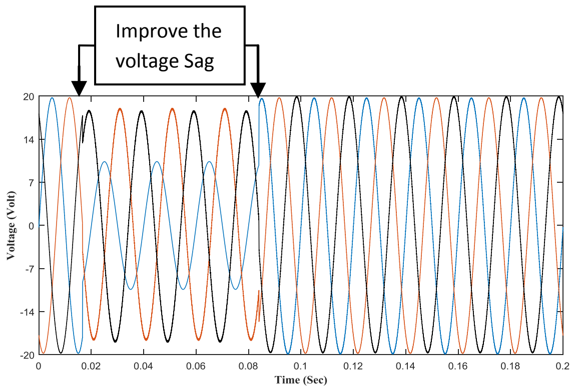

Figure 15: Opposite Terminal with DVR

8. CONCLUSION

By Using MATLAB/Simulink software the simulation of a DVR is presented in this paper. For low power distribution system mitigating or compensate the voltage sag is most promising and effective custom power device. The main advantages of the proposed DVR are small in size, simple control, fast response and lower cost. In this paper the simulation result shows clearly that the DVR works properly and can compensate the voltage sag.

The presented work can be extended in other following related areas: i) Custom power device can be tested against various loads.

ii) The more advanced controllers are used in DVR for mitigating the voltage sag such as PI controller, Fuzzy controller, Artificial neural network etc.

iii) Distributed generation is used in Dynamic Voltage Restorer for compensate the voltage sag.

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