

# INTERLINE DYNAMIC VOLTAGE RESTORER FOR VOLTAGE SAG COMPENSATION USING SPWM TECHNIQUE

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**ABSTRACT :** The Dynamic voltage restorer [DVR], a custom power device has been used to protect sensitive loads from the effect of voltage sags /swells on the distribution feeder. The IDVR proposed in this paper provides a way to compensate the voltage sag caused in the power line. The main function is to inject the difference in voltage to the power line and thus maintain the load side voltage at the optimum value. This paper presents the modeling aspects of the IDVR system with the MLI working against voltage sags by simulation. The modelling and simulation of single phase IDVR using sinusoidal pulse width modulation is presented. The digital simulation is carried out using MATLAB/SIMULINK. dc/dc converter is used to adjust the DC link voltage considering the amount of voltage sag so that the maximum possible output voltage levels are generated for a wide range of voltage sags. Closed loop control of voltage sag for simple IDVR system is modeled and simulated using MATLAB software.

**Keywords-** Powerquality, Interline Dynamic voltage Restorer[IDVR],Multilevel Inverter[MLI],Sinusoidal Pulse width modulation[SPWM],Total harmonic distortion[THD].

## I. INTRODUCTION

A common characteristic of most electronics is that they are sensitive to voltage variations. Computers and other sensitive loads can lower their performance or even shutdown the process they are in control due to those variations. Voltage variations can be classified as disturbances that produce voltages below the nominal value, which are called voltage sags, and disturbances that produce voltages above the nominal value, which are called voltage swells.

Voltage sag is defined as a sudden reduction of supply voltage down 90% to 10% of nominal, followed by a recovery after a short period of time. Atypical duration of sag is 10ms to 1 minute. Voltage sag can cause loss of production in automated processes since voltage sag can trip a motor or cause its controller to malfunction. Voltage swell is defined as sudden increasing of supply voltage up 110% to 180% in RMS voltage at the fundamental frequency with duration from 10ms to 1 minute. Switching off a large inductive load or energizing a large capacitor bank is atypical system event that causes swells. During power disturbances Dynamic Voltage Restorer (DVR) installed in front of a critical load will appropriately provide correction to that load only. Also DVR cannot provide compensation during full power interruptions. Voltage sag is a momentary decrease in RMS voltage lasting between half a cycle to a few seconds. It is generally caused by faults in the power system and is characterized by its magnitude and duration. Voltage sag magnitude is defined as the net RMS voltage during voltage sag, which is usually in per unit of the nominal voltage level. The voltage sag magnitude depends on various factors like the type of fault, the location of the fault and the fault impedance.

Voltage sag is most important power quality problems challenging the utility industry can be compensated and power is injected into the distribution system. By injecting voltage with a phase advance with respect to the sustained source-side voltage, reactive power can be utilized to help voltage restoration [1]. Dynamic Voltage Restorer, which consists of a set of series and shunt converters connected back-to-back, three series transformers, and a dc capacitor installed on the common dc link [3]. The Pulse-width modulation of Z-source inverter has recently been proposed as an alternative power conversion concept as they have both voltage buck and boost capabilities [4]. The Z-source converter employs a unique X-shaped impedance network on its dc side for achieving both voltage-buck and boost capabilities this unique features that cannot be obtained in the traditional voltage-source and current-source converters. The proposed system is able to compensate long and significantly large voltage sags [2], [5] and [9].

Passivity-based dynamical feedback controllers can be derived for the indirect stabilization of the average output voltage. The derived controllers are based on a suitable stabilizing "damping injection" scheme [7]. Transformerless self-charging dynamic voltage restorer series compensation device used to mitigate voltage sags.

A detailed analysis on the control of the restorer for voltage sag mitigation and dc-link voltage regulation are presented [8]. Installation of the world's first Dynamic Voltage Restorer (DVR) on a major use. Utility system to protect a critical customer plant

load from power system voltage disturbances. The installed system at an automated yarn manufacturing and weaving factory provides protection from disturbances [10].

The modeling and simulation of ZSI based DVR is presented [11] and [13]. The modeling and simulation of IDVR is presented [12] and [15]. Simulation of MLI based DVR is presented in [16]. In this paper the modeling and implementation of Multilevel inverter based dynamic voltage restorer for voltage sag compensation is presented. The simulation results are presented to show the effectiveness of the proposed control method.

## II. INTERLINE DYNAMIC VOLTAGE RESTORER

The IDVR system consists of several DVRs in different feeders, sharing a common DC-link. A two-line IDVR system shown in Fig.1 employs two DVRs are connected to two different feeders where one of the DVRs compensates for voltage swell/sag produced, the other DVR in IDVR system operates in power-flow control mode. The common capacitor connected between the two feeders act as the common DC supply.

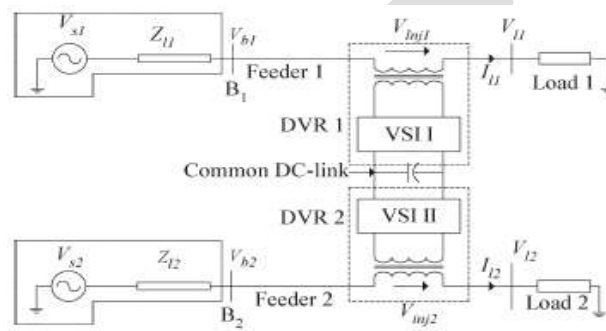


Fig.1. Schematic diagram of IDVR

Voltage swell/sag in a transmission system are likely to propagate to larger electrical distance than that in a distribution system. Due to these factors, the two feeders of the IDVR system in Fig.1 are considered to be connected to two different grid substations. It is assumed that the voltage distortion in Feeder1 would have a lesser impact on Feeder2. The upstream generation-transmission system is applied and the two feeders can be considered as two independent sources. These two voltage sources Vs1 and Vs2 are connected in series with the line impedances Z11 and Z12 which is in-turn connected to the buses B1 and B2 as in Fig. 1. The DVR is connected in series with the feeder and the DVRs across different feeders are connected by a common DC-link. The load across each feeder is connected in series to the DVR, where V11 and V12 are the voltages across the load.

The injection of an appropriate voltage needs a certain amount of real and reactive power which must be supplied by the DVR. Supply of real power is met by means of an energy storage facility connected in the DC-link. Large capacitors are used as a source of energy storage in most of the DVRs. Generally, capacitors are used to generate reactive power in an AC power system. However, in a DC system, capacitors can be used to store energy. When the energy is drawn from the energy storage capacitors, the capacitor terminal voltage decreases. Hence, large capacitors in the DC-link energy storage are needed to effectively mitigate voltage swell of large depths and long durations. The pulse can be generated using various modulation techniques. In this paper, the pulse for the switch is generated using SPWM.

## III. VOLTAGE SAG COMPENSATION IN INTERLINE DYNAMIC VOLTAGE RESTORER USING SPWM TECHNIQUE

The IDVR system with two back-to-back connected DVR stations was implemented with a closed loop control of inverter switches. Fig.2 shows the Simulink model of the closed loop controlled IDVR.

The rectifier- inverter system is shown as a subsystem. The subsystem 1 consists of a full bridge inverter with a filter. Subsystem 2, shows the rectifier output voltage

The SPWM control technique is used to reduce the harmonic content in the output voltage. The driving sine pulses for the switches are shown in Fig.3.

Fig.4 (a) shows a 32.6 % voltage sag initiated at 300ms and it is kept until 600ms, with a total voltage sag du-duration of 300ms in low voltage feeder 1.

Fig.4 (b) and (c) show the voltage injected by the DVR 2 and the compensated load voltage respectively. Due to the presence of the IDVR, the load voltage remains constant throughout the voltage sag period.

Fig.5 shows the common DC link voltage waveform. Fig.6 shows the FFT analysis of the closed loop IDVR system for sag. The Total Harmonic Distortion (THD) value is 4.81%.

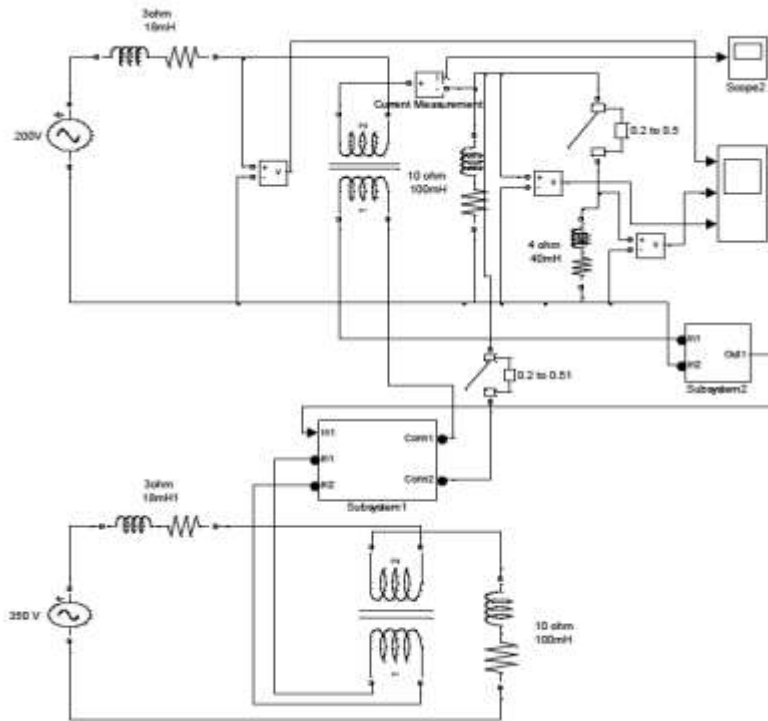


Fig.2 Simulation Circuit of IDVR

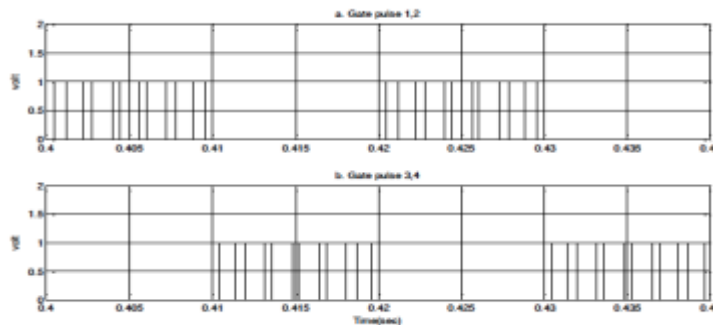


Fig.3 Driving pulses of inverter switches

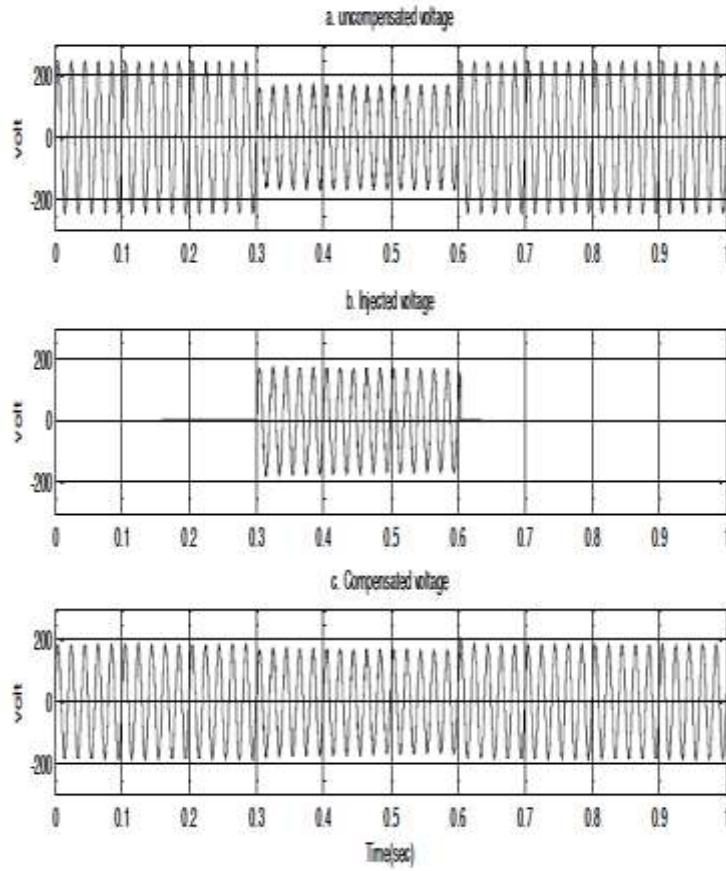


Fig.4 Response of IDVR to a voltage sag

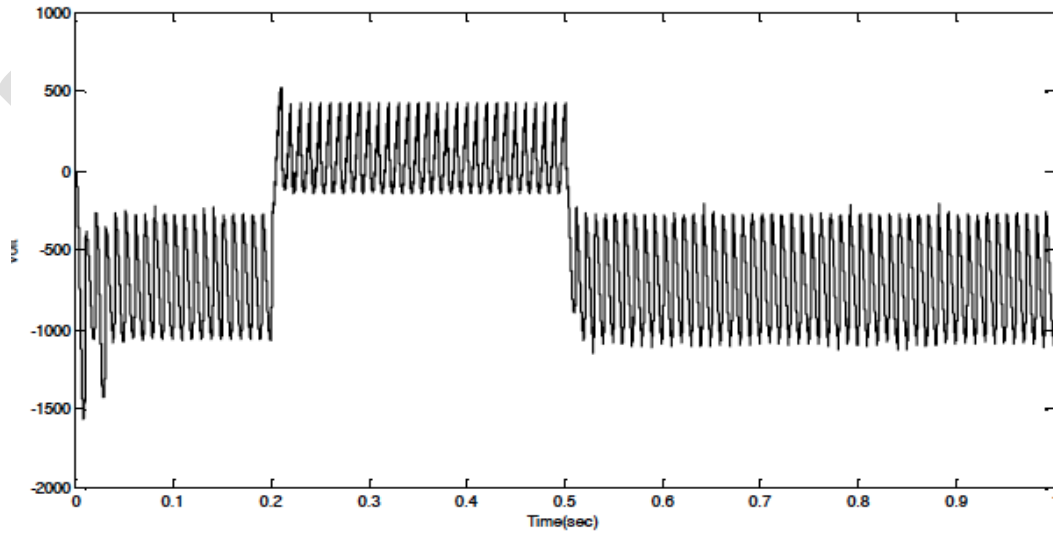


Fig.5 Common DC link voltage for sag

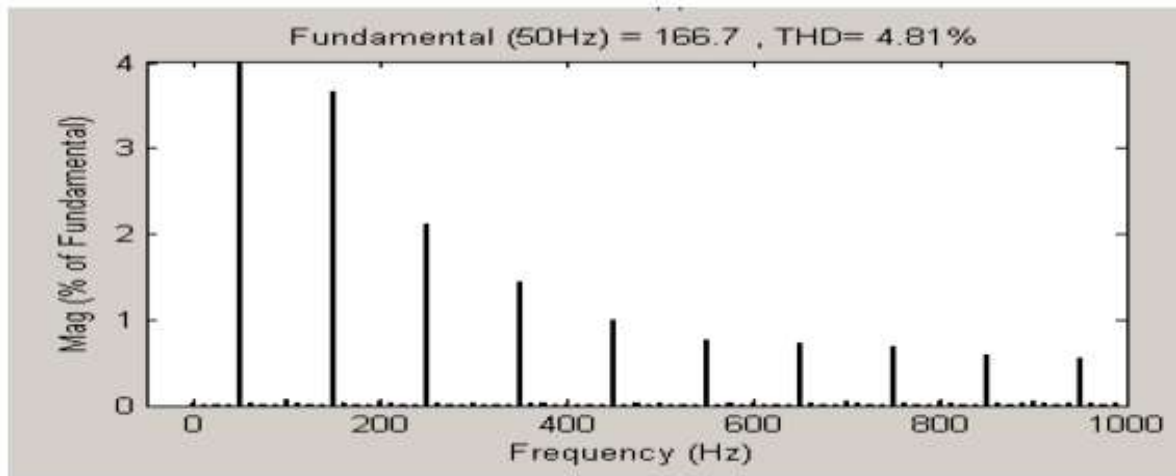


Fig.6 FFT analysis of IDVR for sag

#### IV. CONCLUSION

The simulink models of the closed loop controlled IDVR system with the H bridge inverter using SPWM technique for sag conditions are developed and the simulation results are presented. The modelling and simulation of a IDVR system using MATLAB has been presented. IDVR is an effective custom power device for voltage sag mitigation. The impact of voltage sag on sensitive equipment is severe. Therefore, IDVR is considered to be an efficient solution due to its low cost, small size and fast response. The simulation results indicate that the implemented control strategy compensates for voltage sags with high accuracy. The results show that the control technique is simple and efficient method for voltage sag compensation.

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