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Cascade-H Bridge Multilevel Inverter based Dynamic Voltage Restorer to Improve Power Quality during Voltage Sag

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Abstract: Power quality related issues in distribution network can be effectively taken care by Dynamic Voltage Restorer (DVR). The DVR is one of the costumed power devices which find application in mitigating voltage swell, sag, harmonic and other power quality issues. Among above mentioned PQ issues voltage sag is frequently occurring events in the distribution network due to short circuit faults and heavy load in the network. This paper presents simulation of dynamic voltage restorer connected to distribution network to mitigates voltage sag and restores of voltage stability under the condition of single and three phase fault. The DVR has many advantages like lower cost, smaller size, and its fast dynamic response to the disturbance.

I. INTRODUCTION

Power quality (PQ) has turned into a noteworthy issue of concern due to modernization and urbanization in electrical power market. The PQ issues influence the microchip based loads, delicate electric segments which are profoundly sensitive to variation in voltage level and supply frequency. The voltage sag that is most widely recognized PQ issues these days. Voltage sag may result in complete shut-down of any voltage sensitive equipment affecting the industrial process. For better productivity and the working of the process equipments we have to conquer such issues. The best method to beat these issues is the custom power devices (CPDs). Custom power gadgets are utilized by the clients and are put on the distribution side. Dynamic Voltage Restorer (DVR) is one of the CPDs which have been discovered to be most proficient and successful in the power distribution systems. It is an arrangement associated with a control unit that can rapidly reduce the voltage aggravations in the framework and reestablish the load voltage to the pre-fault value. The principle operation of a DVR is to monitor the load voltage waveform always and if any dip or swell happen, the compensating voltage is infused to reinstate the pre-specified load (pre-fault) voltage. The fundamental favorable arrangement of the DVR is to providing the clients with a consistent voltage.

This paper will present and analysis the performance of DVR based on cascade H-bridge multi-level inverter (CHB-MLI) The control of CHB-MLI will be accomplished by feed forward controller. The gate pulses are generated through Sinusoidal Pulse Width Modulation (SPWM) technique: Alternative phase opposition deposition (APOD) PWM. The proposed system is analyzed with the help of MATLAB tool. Feed forward controller process the error flag and produce the pulse for CHB-MLI when fault is recognized. In this paper operation of DVR is studied to analyze the performance of DVR with CHB-MLI to enhance voltage profile with reduced harmonics. The performance is analyzed under: single and three phase fault to compensate sag.

II. DYNAMIC VOLTAGE RESTORER (DVR)

The schematic diagram of DVR is presented in Figure 1. The main purpose of DVR is to improve system voltage at the point where it is connected in the condition of voltage sag. DVR is generally connected distribution side to maintain the voltage profile at customer end so that voltage sensitive equipments can be safeguard under the condition of voltage disturbance. The DVR is a series connected device that injects additional voltage required by load into the supply system in order to adjust the load voltage to the desired amplitude and waveform even when the source voltage is unbalanced or distorted [9-10].This process involves insertion of real/reactive power from DVR to distribution feeder for voltage compensation [11]. The general configuration of the DVR consists of power circuit and control circuit.

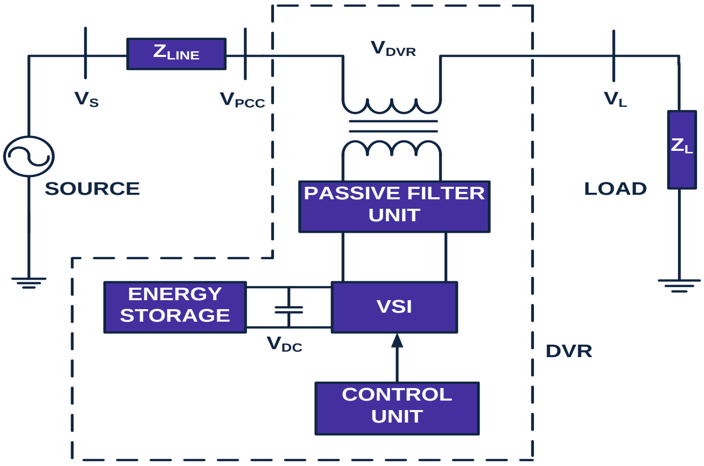

Figure 1 Schematic diagram of basic DVR

III. PROPOSED WORK

This work is carried out to design and simulate DVR for the purpose to restore system voltage under the condition of system fault. A mathematical model of DVR is predicted for 400 V distribution system. The main components of the DVR are passive filter, storage unit, inverter and control circuit to control the output of the DVR. In the basic circuit of DVR, 2-level VSI is replaced by 5-level CHB-MLI to reduce the harmonics. The block diagram of proposed system is shown in figure 2. The system has been analysed under the condition of fault to obtain desired output voltage with less harmonics after introducing DVR at the distribution side.

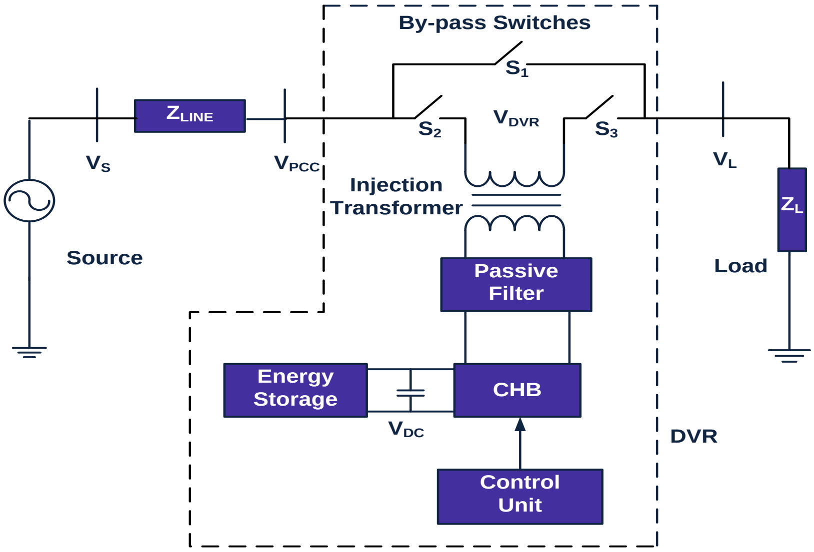

Figure 2 Block diagram of proposed DVR system

In the DVR, direct feed forward type control is used to minimize the response time and maximize the dynamic performance as it is easy to implement and fast. The voltage regulation, low harmonic distortion and no interruptions are realized with this type of control architecture. In this controller, a 3-phase software phase locked loop (PLL) is used in order to track the angular frequency and phase shift of 3-phase voltage. The dqo conversion or Park's transformation is utilized in the controller of DVR. This method provides the information about sag deepness and phase shift along with its start and end time. It can be easily realized in real time control system. The basic purpose of a controller used in a DVR is the finding of sag events in the load voltage; computation of the required voltage for compensation and then generation of gating pulses for VSI accordingly. The work has been carried out in following steps;

1. To design and simulate the mathematical model of the Dynamic Voltage Restorer for 400V distribution line.
2. Detection of voltage sags in the distribution system network.
3. To select the best suitable control technique for DVR, by which DVR operates in order to obtain desired performance.

4. To use multilevel inverter (Cascade H Bridge) in place of 2-level voltage source inverter (VSI) to reduced total harmonic distortion (THD) within permissible limit.
5. To design and tune a low pass L-C filter to filter out the harmonics from the output of the inverter and get the pure sinusoidal voltage for feeding the distribution system through transformer.

IV. SIMULATION AND RESULT DISCUSSION

Complete simulation model of the system is shown in figure 3. Complete simulation model of the system is shown in figure 5.2. The DVR consist of 3-phase five level CHB-MLI connected with the help of delta connected coupling transformer to the distribution system. Control is designed for all the three phases. The parameter specification is given in table 5.1. The system is analyzed for 1-phase and 3-phase short circuit fault. The output voltage for before and after fault by connecting DVR is presented.

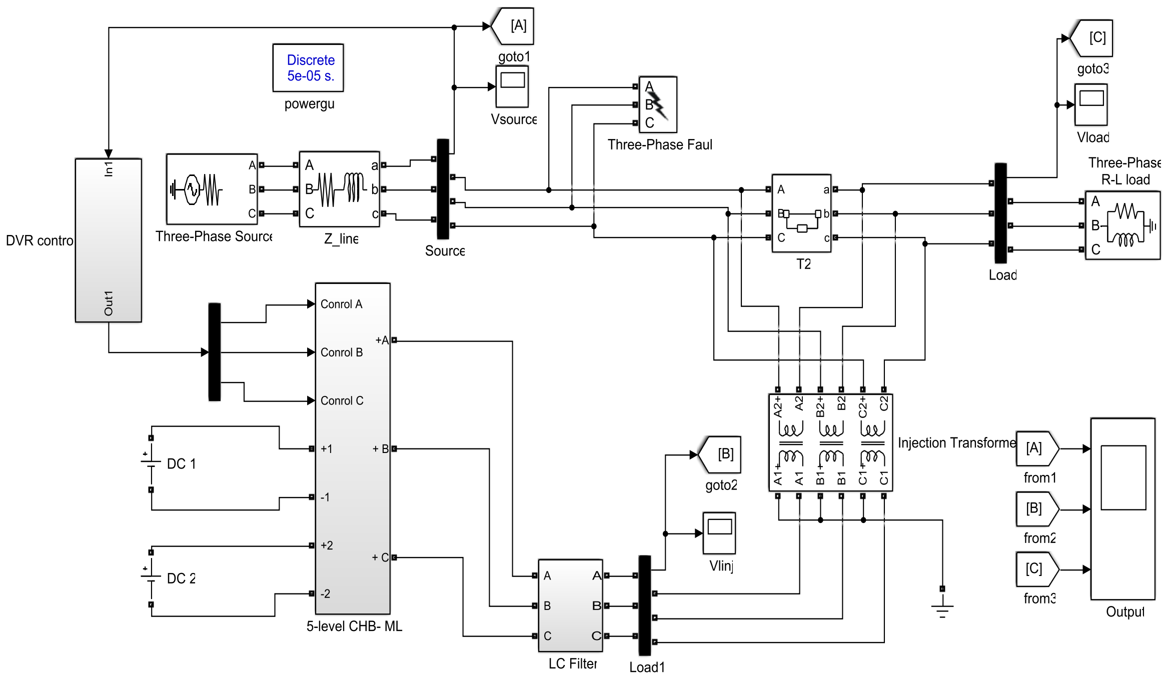

Figure 3 Simulation model of the system

Table 1 DVR Parameter Specification

S.No.	System Parameter	Rating/Values
1	Nominal DC bus voltage	600V
2	Main supply voltage (line-line, rms), frequency	400V, 50Hz
3	PI controller gain [Kp, Ki] of PLL	[0.5, 50]
4	3-phase transformer power , turn ratio and frequency	30 kVA, 1:1, 50Hz
5	L and C of passive filter	20mH, 120µF

The system has been analysed for three conditions; pre-fault, during fault without DVR and post-fault with DVR. The results are shown below;

- **Pre-Fault Condition**

The source voltage at pre-fault condition is shown in figure 4, the magnitude of source voltage at pre-fault condition is 326.48 V (maximum/phase) and its harmonics analysis is shown in figure 5.

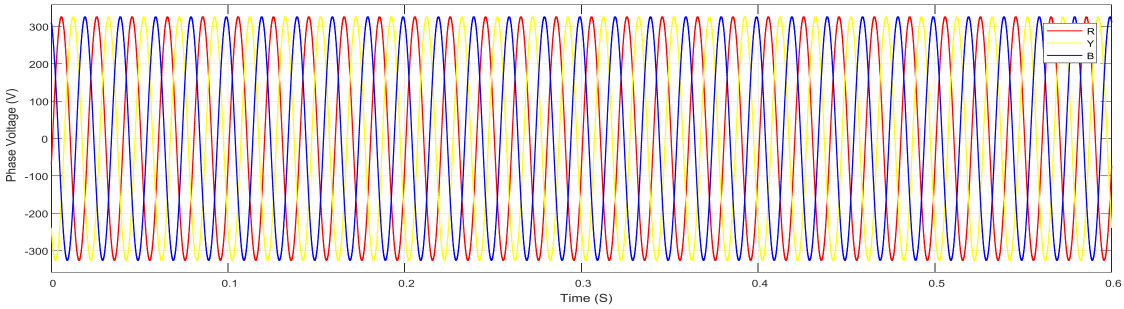

Figure 4 Source voltages at pre-fault condition

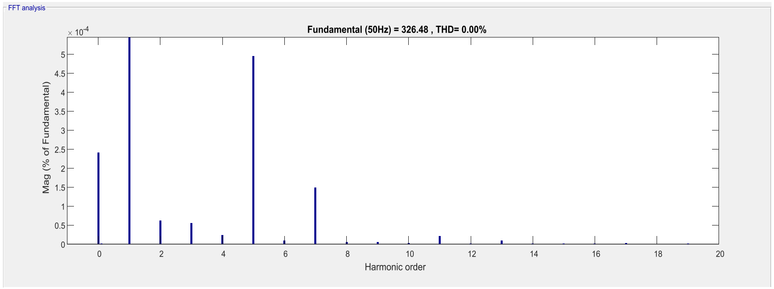

Figure 5 Harmonics analysis of source voltage at pre-fault condition

- **Faulty Condition**

The faults are created and analysed for sag created by 1-phase and 3-phase fault. All the voltages are represented in terms of maximum line to neutral (phase voltage).

- **Performance of CHB-MLI based DVR during 1-phase fault**

When the single phase-ground occurs during the time 0.2 to 0.4 (in seconds) in the phase R, the source voltage after the sag is dropped to 148.4 V (less than 50%) as shown in figure 6.

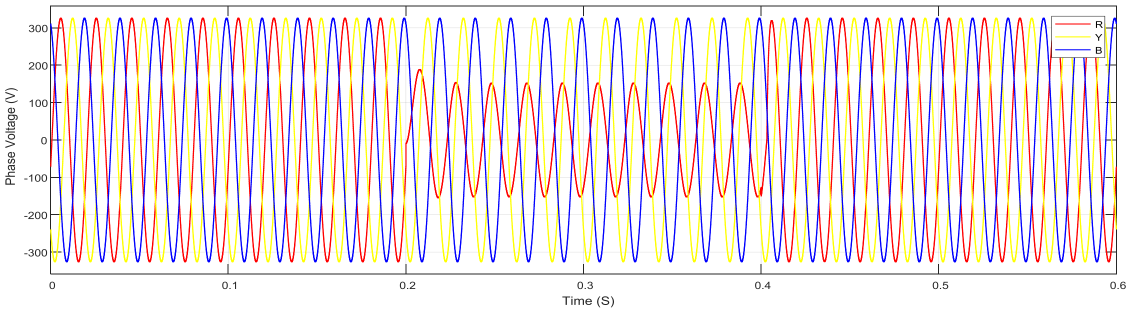

Figure 6 Source voltage after 1-phase fault

To compensate the drop, proposed DVR will operate during 0.2 S to 0.4 S, and injects the voltage as shown in figure 7, this compensate for the sag and restore 320.2 as shown in figure 8 with the 5.27 % THD. The harmonics analysis of load voltage is shown in figure 9.

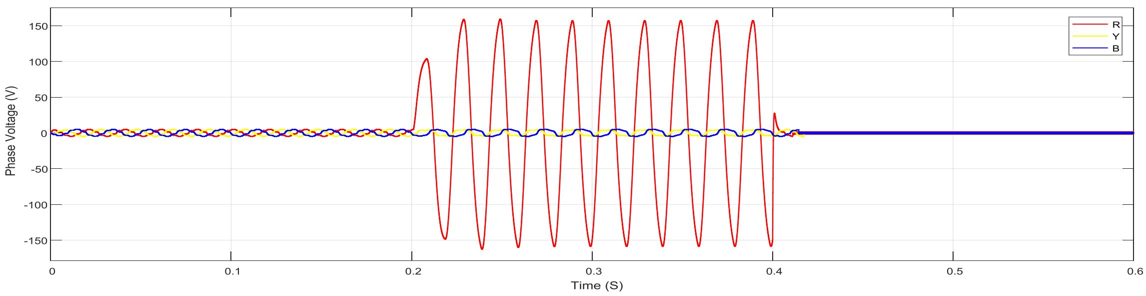

Figure 7 DVR injected voltage during fault

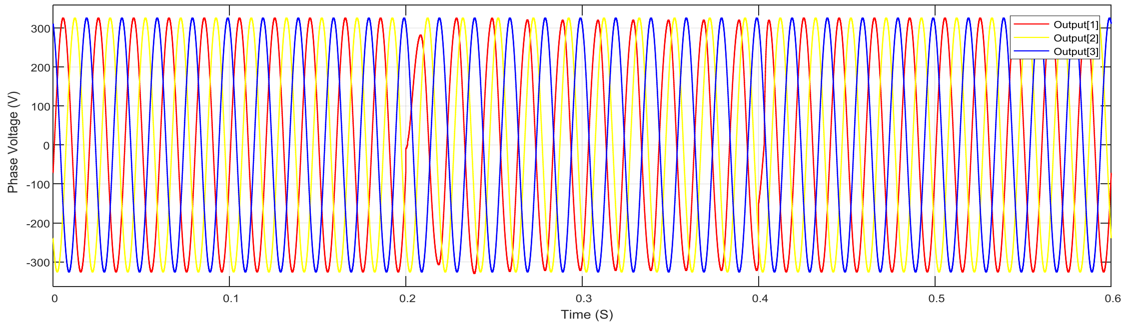

Figure 8 Load voltage during 1-phase fault condition with CHB-MLI based DVR

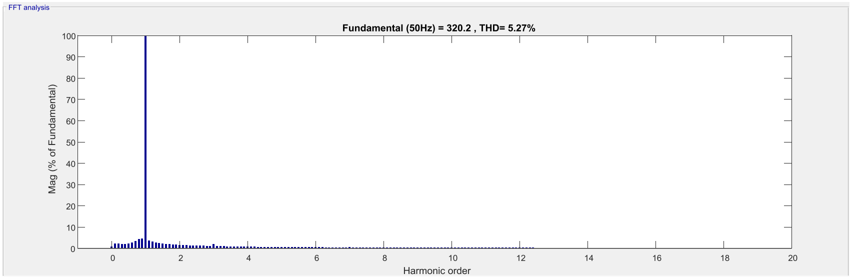

Figure 9 Harmonics analysis of load voltage with CHB-MLI based DVR

- **Performance of CHB-MLI based DVR during 3-phase fault**

When the 3-phase to ground faults occurs in the line during the time 0.2 S to 0.4 S, the source voltage in all the three-phases after sag is dropped to 164 V (approximate 50%) as shown in figure 10. To compensate the dropped voltage , proposed DVR will operate from 0.2 S to 0.4 S, and inject the required voltage as shown in figure 11 to compensate for the sag and DVR restores 323.2 V as shown in figure 12 with the 2.22 % THD. The harmonics analysis of source load voltage is shown in figure 13.

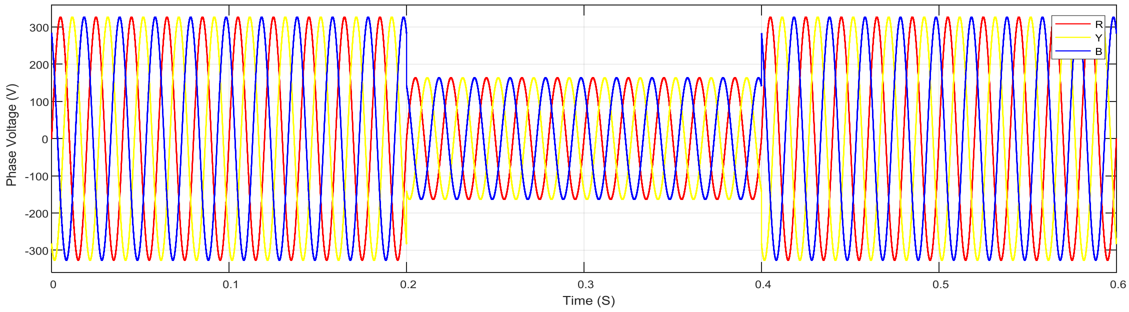

Figure 10 Source voltage at three phase fault condition

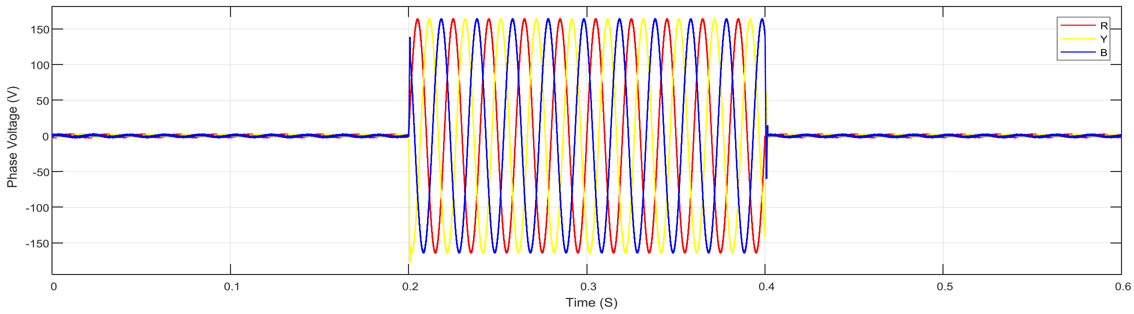

Figure 11 DVR injected voltage during fault

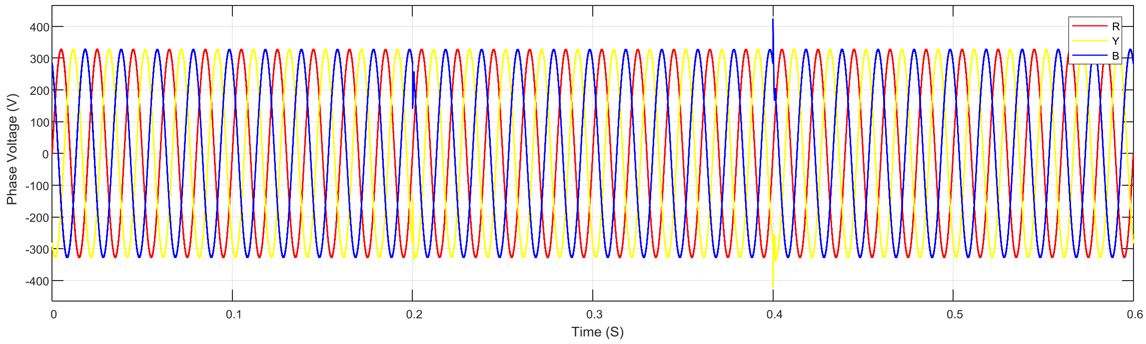

Figure 12 Load voltage with 3-phase fault with CHB-MLI based DVR

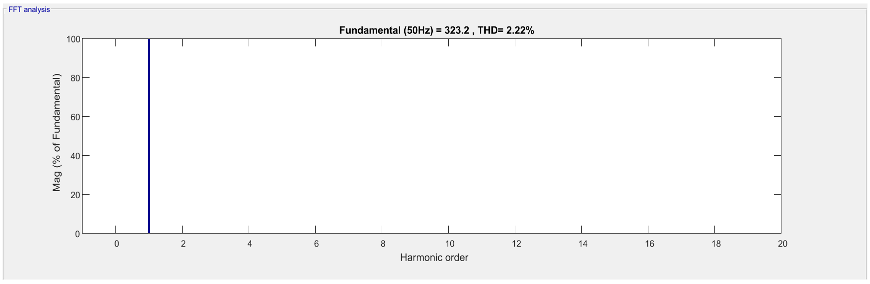

Figure 13 Harmonics analysis of load voltage 3-phase to ground fault with DVR

V. CONCLUSION

A three phase distribution system has been analyzed for three operating conditions namely; normal (pre-fault) operation, fault condition: a 1- phase ground and 3-phase to ground faults. The DVR has been modeled in Matlab simulink using three phase five level cascaded H bridge MLI with sinusoidal PWM technique: Alternative phase opposition deposition (APOD). It is observed that CHB-MLI based DVR can restore the magnitude of load voltage satisfactorily above 95%. Also, the harmonic contents (%THD) are reduced within the prescribed codes of the IEEE Std. 519-2014. The proposed topology also reduces the size of filter.

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