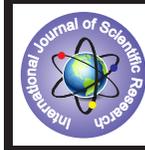


Voltage Sag Compensation Using Switched-Inductor Z-Source Inverters Based Dynamic Voltage Restorer



Engineering

KEYWORDS : DVR, Voltage sag, power quality, Z source inverter

V.Deepalakshmi

Assistant professor, Panimalar Institute of technology, chennai

ABSTRACT

This paper presents the application of dynamic voltage restorer (DVR) on Power distribution systems for mitigation of voltage sags at critical loads. DVR is one of the compensating types of custom power devices. The impedance source inverter employs a unique impedance network couple with inverter main circuit and rectifier. In this paper, a new Z-source inverter (ZSI) topology is developed to improve a voltage boost ability of conventional ZSI. A technique based on Embedded switched-inductor Z-source inverters have become a research hotspot because of their single-stage buck-boost inversion ability, and better immunity to EMI noises. However, their boost gains are limited because of higher component-voltage stresses and poor output power quality. To overcome these drawbacks, a new high-voltage boost impedance-source inverter called a switched-coupled-inductor quasi-Z-source inverter (SCL-qZSI) is proposed. The proposed inverter employs a unique impedance network couple with inverter main circuit and rectifier. By controlling the shoot through duty cycle, the proposed inverter system provide ride through capability during voltage sags and swells, reduces line harmonics, and improves power factor and high reliability. Simulation results are presented to illustrate and understand the performances of DVR in supporting load voltages under voltage sags conditions.

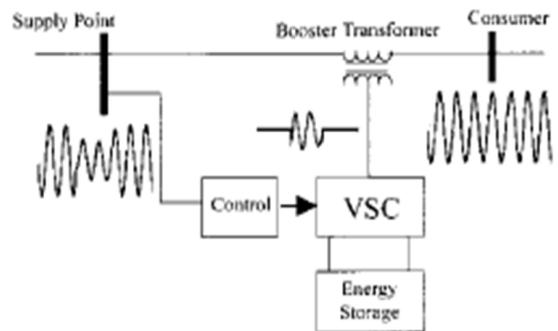
I Introduction:

The need of the electrical power is increasing and simultaneously the problems while transmitting the power through the distribution system are also increasing. Voltage fluctuations are considered as one of the most severe power quality disturbances to be dealt with. Even a short-duration voltage fluctuation could cause a malfunction or a failure of a continuous process. There are several types of voltage fluctuations that can cause the systems to malfunction, including surges and spikes, sag, swell, harmonic distortions, and momentary disruptions. Among them, voltage sag and swell are the major power-quality problems. Voltage swell is the sudden increase of voltage to about more than 110% amplitude of the supply voltage, whereas the voltage sag is the sudden decrease of voltage to about 90% amplitude of supply voltage. This is caused due to the sudden reduction or addition of the load across that particular feeder. This change of voltage is compensated by injecting the voltage in series with the supply from another feeder at the time of disturbances using DVR. In this paper the modeling and control of voltage sag compensation using new control technique based dynamic voltage restorer are simulated using MATLAB software. The simulation results are presented to show the effectiveness of the proposed control method.

II. Dynamic Voltage Restorers

A DVR is a device that injects a dynamically controlled voltage $V_{inj}(t)$ in series to the bus voltage by means of a booster transformer as depicted in Figure 1. The amplitudes of the injected phase voltages are controlled such as to eliminate any detrimental effects of a bus fault to the load voltage $V_L(t)$. This means that any differential voltage caused by transient disturbances in the AC feeder will be compensated by an equivalent voltage generated by the converter and injected on the medium voltage level through the booster transformer. The DVR works independent of the type of fault or any event that happens in the system, provided that the whole system remains connected to the supply grid, i.e. the line breaker does not trip. For most practical cases, a more economical design can be achieved by only compensating the positive and negative sequence components of the voltage disturbance seen at the input of the DVR. This option is reasonable because for a typical distribution bus configuration, the zero sequence part of a disturbance will not pass through the step down transformers because of infinite impedance for this component. For most of the time the DVR has, virtually, "nothing to do," except monitoring the bus voltage. This means it does not inject any voltage ($V_{inj}(t) = 0$) independent of the load current. Therefore, it is suggested to particularly focus on the losses of a DVR during normal operation. Two specific features addressing this loss issue have been implemented in its

design, which are a transformer design with low impedance, and the semiconductor devices used for switching



Fig(1) Schematic diagram of DVR System

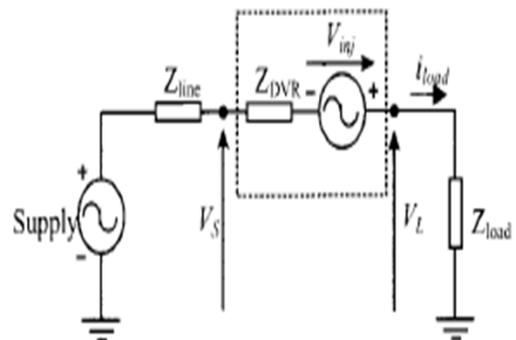


Fig (2). Equivalent circuit of DVR

Mathematically expressed, the injection satisfies

$$V_L(t) = V_s(t) + V_{inj}(t) \tag{1}$$

Where $V_L(t)$ is the load voltage, $V_s(t)$ is the sagged supply voltage and $V_{inj}(t)$ is the voltage injected by the mitigation device as shown in Fig. 2. Under nominal voltage conditions, the load power on each phase is given by

$$S_{L} = I_L V_L^* = P_L - jQ_L \tag{2}$$

Where I is the load current, and, P_L and Q_L are the active and re-

active power taken by the load respectively during a sag. When the mitigation device is active and restores the voltage back to normal, the following applies to each phase

$$S_L = P_L - j Q_L = (P_s - j Q_s) + (P_{inj} - j Q_{inj}) \tag{3}$$

where the sag subscript refers to the sagged supply quantities. The inject subscript refers to quantities injected by the mitigation device.

The real and reactive power is given by

$$P_p = |V_p| \sum_{q=1}^n |V_q| (G_{pq} \cos \delta_{pq} + B_{pq} \sin \delta_{pq}) \tag{5}$$

$$Q_p = |V_p| \sum_{q=1}^n |V_q| (G_{pq} \sin \delta_{pq} - B_{pq} \cos \delta_{pq}) \tag{6}$$

III. Modified Z-source inverter:

Fig. 3 shows the circuit of the proposed SCL-qZSI, which is obtained by replacing inductor in the classical qZSI with a combination of SC (C₃) and a three-windings (N₁, N₂, and) SCL (obtained by adding winding and diode to the SC and the two-winding SCL cell in [10]). The proposed inverter consists of three diodes (D_m, D₁, and D₂), three capacitors (C₁, C₂, and C₃), an input inductor L₁, and an SCL with three windings (N₁, N₂, and N₃). Windings N₁ and N₂ have the same number of turns (N₁- N₂), and the turn ratio of windings N₃ to N₁ (or N₂) is n, (n=N₃/N₁=N₃/N₂)

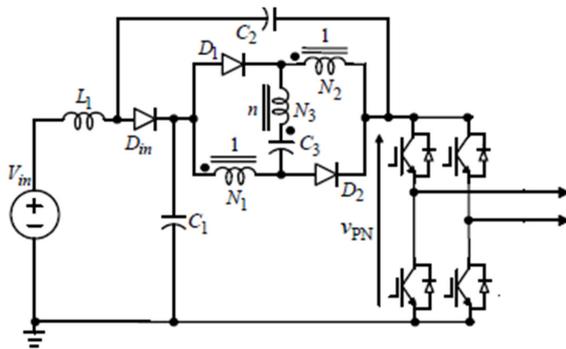


Fig. 3.Proposed switched-coupled-inductor quasi-Z-source inverter (SCL-qZSI).

The boost factor of the proposed SCL-qZSI is given by

$$B = \frac{V_R}{V_n} = \frac{n + 2}{(1 - (3 + n)D)} \tag{1}$$

IV Voltage sag compensation in DVR

The performance of the designed DVR as shown in Figure(4) and figure(5) is evaluated using Matlab/Simulink. The proposed method was tested for voltages sag in the low voltage distribution system

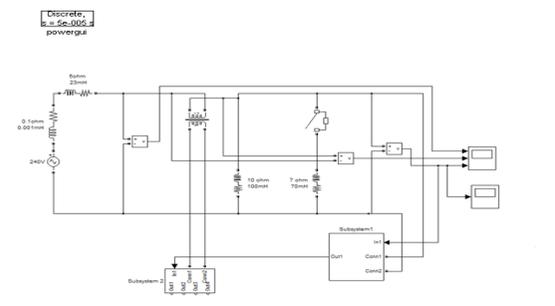


Fig 4 Closed Loop Control of Voltage Sag Compensation in a DVR System

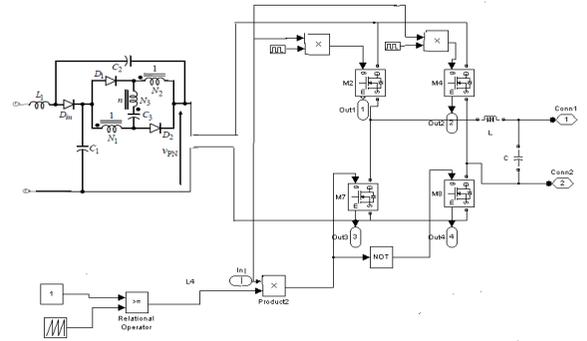


Fig 5 Modified Z-source inverter

In case of voltage sag, the source voltage has decreased about 20-25% of its nominal value It shows the grid voltage which has dropped to 25% at t=0.3 sec and the sag lasts 0.7 sec and then voltage will restore back to its normal value. The function of the DVR will injects the missing voltage in order to regulate the load voltage from any disturbance due to immediate distort of source voltage. Total harmonic distortion of proposed system is 0.81%

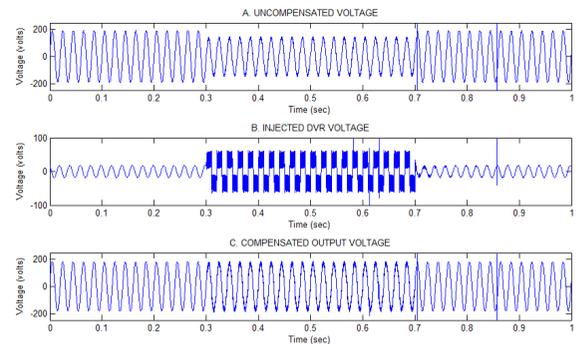


Fig 6 Simulation results of 1 DVR under 25% sag (A)Source Voltage, (B). Injected DVR Voltage, (C). Load Voltage)

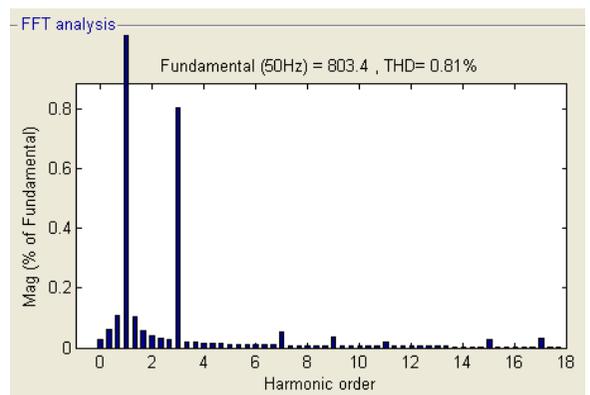


Fig 7 FFT Analysis

V Conclusion:

The modeling and simulation of a DVR using MATLAB/SIMLINK has been presented. The simulation results showed clearly the performance of the DVR in mitigating voltage sags. The efficiency and the effectiveness in voltage sags compensation showed by the DVR makes it an interesting power quality device compared to other custom power devices. The simulation results show that the developed control technique with proposed single phase

DVR was simple and efficient. From the simulation results it was observed that dynamic voltage restorer compensates 25% voltage sag.

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