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SIMULATION ANALYSIS OF DYNAMIC VOLTAGE RESTORER USING Z-SOURCE INVERTER

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ABSTRACT

Voltage sag is a crucial power quality problem faced by the utility industries which has resulted in increased attention. The Dynamic Voltage Restorer (DVR) is a series power quality conditioning device used to eliminate the voltage disturbances. The DVR compensates the voltage disturbances by injecting the voltage of suitable magnitude and phase in series with the line. The compensation capability of a DVR primarily depends on the maximum voltage injection ability and the amount of stored energy available within the DVR. This topology is proposed in this paper in order to enhance the voltage restoration property of the DVR using Z-Source Inverter. A constant dc-link is ensured during voltage sag compensation by having an X-shaped impedance network with inherent shoot-through capability. The system containing DVR using Z-source inverter is simulated in PSIM software environment and the simulation results validate the efficiency of the proposed DVR configuration.

I . INTRODUCTION

Power quality problems like voltage sag, voltage swell and harmonics are the major concern of Industrial and commercial electrical consumers due to enormous loss in terms of time and money. This is due to the advent of a large number of sophisticated electrical and electronic equipments such as computers, variable speed drives etc.,[1][3]. The DVR is a custom power device with series compensation, aimed at mitigating all problems related to voltage disturbances. For stiff systems like large industrial applications, series compensation technique is preferred over shunt compensation, which is gaining much acceptance [2][4][5][6]. Generally, the conventional DVRs consist of series voltage sources (VSI), series injection transformer and energy source unit. The VSIs are greatly used in DVRs due to their proper output voltage with low harmonic level. The main disadvantage of these inverters is buck type voltage characteristics limiting the maximum output voltage that can be attained. The Z-source inverter has been an alternative to existing inverter topologies with many inherent advantages. The real power requirement of the DVR can be provided by the energy storage device in the form of a battery, capacitor bank or a flywheel [4]-[6]. In most of the DVRs capacitors are used as energy storage device, the dc link voltage will decrease with the deteriorating storage energy during compensation [11][12]. For long duration voltage sags, this could result in poor load ride- through capability. In order to overcome this drawback, a wind generator is used as a source for storage unit in order to improve the energy storage capability of the storage unit [13][14].

II. DYNAMIC VOLTAGE RESTORER WITH Z SOURCE INVERTER

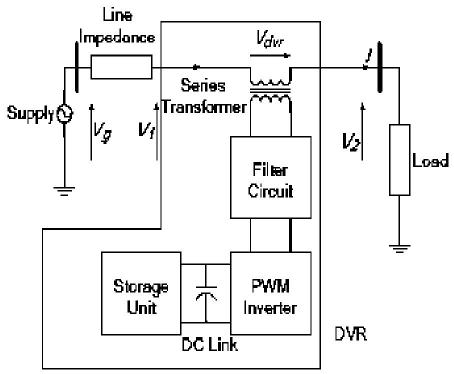


Figure 1: Schematic representation of the DVR

Vs is the source voltage, V1 is the incoming supply voltage before compensation, V2 is the load voltage after compensation, V is the series injected voltage of the DVR and I is the line current. The function of the DVR is to ensure that any load voltage disturbance can be compensated effectively and the disturbance is therefore transparent to the load. This enables full voltage restoration during sag. When everything is fine with the line voltages, the DVR operates in a standby mode with very low losses. The restorer typically consists of an injection transformer, the secondary winding of which is connected in series with the distribution line.

Z source inverter (ZSI) with filter connected to the primary of the injection transformer and an energy storage device connected at the dc-link of the inverter bridge[11][12] .The inverter bridge output is filtered in order to mitigate the switching frequency harmonics generated in the inverter. The series injected voltage of the DVR (Vdvr) is synthesized by modulating pulse widths of the inverter-bridge switches [8]. The injection of an appropriate Vdvr in the voltage disturbance requires a certain amount of real and reactive power supply from the DVR.

III. **Z-SOURCE INVERTER**

In conventional method, VSI topology is used as it gives good output voltage with low harmonic levels. The main disadvantage of VSI topology is its buck type output voltage characteristics limiting 516 C. The maximum voltage that can be attained. Therefore, the use of VSI inverter topology alone in DVR systems with dwindling DC-link voltage in the energy storage device would pose a problem [3]-[6]. The Z-source inverter has been a alternative to the existing inverter topologies with many inherent advantages [10]. The Z-source converter employs a unique impedance network to couple the converter circuit to the power source, thus providing unique features that cannot be obtained in the traditional voltage-source and current-source converters.

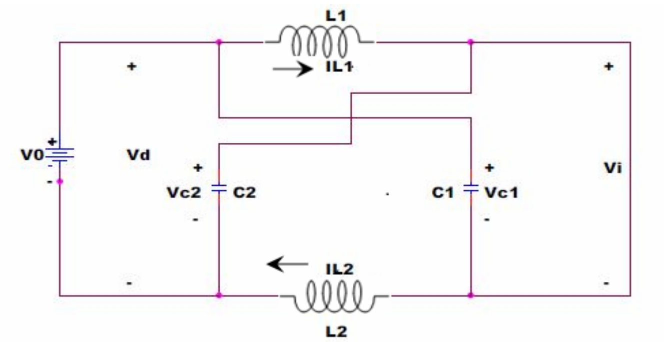


Figure 2:Impedence network of the ZSI

It facilitates the turning ON of both switches in the same inverter phase leg (shoot-through state) without damaging the inverter switches [7]. In this project, voltage type Z-source inverter based topology is proposed where the storage energy in the storage device can be utilized during the process of voltage compensation with use of buck boost property of the inverter. Even with DVR topologies using a shunt connected auxiliary supply, the voltage rating of the shunt transformer, shunt converter and the dc-link capacitor can be kept smaller with the adoption of Z-source inverter. v A series diode is connected between the source and impedance network, which is required to protect the source from a possible reverse current flow. The equivalent circuit of the Impedance source inverter is shown in Fig. 2. The inverter bridge is equivalent to a short circuit when the inverter bridge is in the shoot-through zero state. The equivalent switching frequency from the Impedance source network is six times the switching The impedance source network is a combination of two inductors and two capacitors. This combined circuit network is the energy storage or filtering element for the impedance source inverter. This impedance source network provides a second order filter frequency of the main inverter, which greatly reduces the required inductance of the impedance source network.

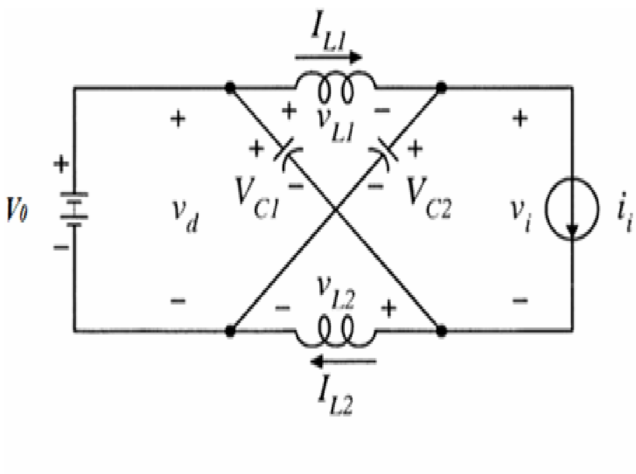


Figure 3: Equivalent circuit of the ZSI

. This is more effective to suppress voltage and current ripples. The inductor and capacitor requirement should be smaller compare than the traditional inverters [10].When the two inductors (L1 and L2) are small and approach zero, the impedance source network reduces to two capacitors (C1 andC2) in parallel and becomes traditional voltage source. Therefore, a traditional voltage inverter's capacitor requirements and physical size is the worst case requirement for the impedance source inverter. Considering additional filtering and energy storage provided by the inductors, the impedance source network should require less capacitance and smaller size compare with the traditional voltage source inverter. Similarly, when two capacitors (C1 and C2) are small and approach zero, the impedance source network reduces to two inductors (L1 and L2) in series and becomes a traditional current source. Therefore a current source inverter's inductor requirements and physical size is the worst case. Voltage source inverter (VSI) and current source inverter (CSI) used in only buck or boost operation of inverter Whereas Z source inverter used in both buck and boost mode operation of the inverter. Both CSI and VSI cannot accept misfiring of switches but for Z source, sometimes misfiring of switches are acceptable. Compared to VSI and CSI, Z source inverter is less affected by the EMI noise. [10] Design and Implementation of Z-Source Inverter Based DVR.

IV. DVR CONTROL

The Z-source inverter topology is now proposed. The fidelity of the DVR output voltage depends on the accuracy and dynamic behavior of the pulse width modulated (PWM) voltage synthesis scheme and the control system adopted. The general requirement of such control scheme is to obtain an ac waveform with low total harmonic distortion and good dynamic response characteristics against supply and load disturbances. the control voltage of the DVR is derived by comparing the supply voltage against a reference waveform. The purpose of designing closed-loop controllers is to achieve good output voltage tracking and disturbance rejection. Z-source impedance network act as boost converter with large boosting factor. However both the control parameters are dependent on each other to some extent as change in one parameter imposes a limitation on the changeability of the other.

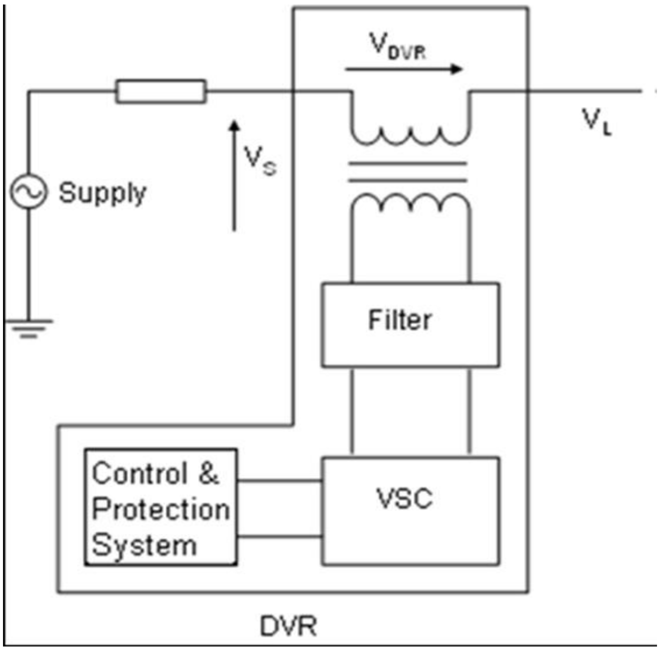


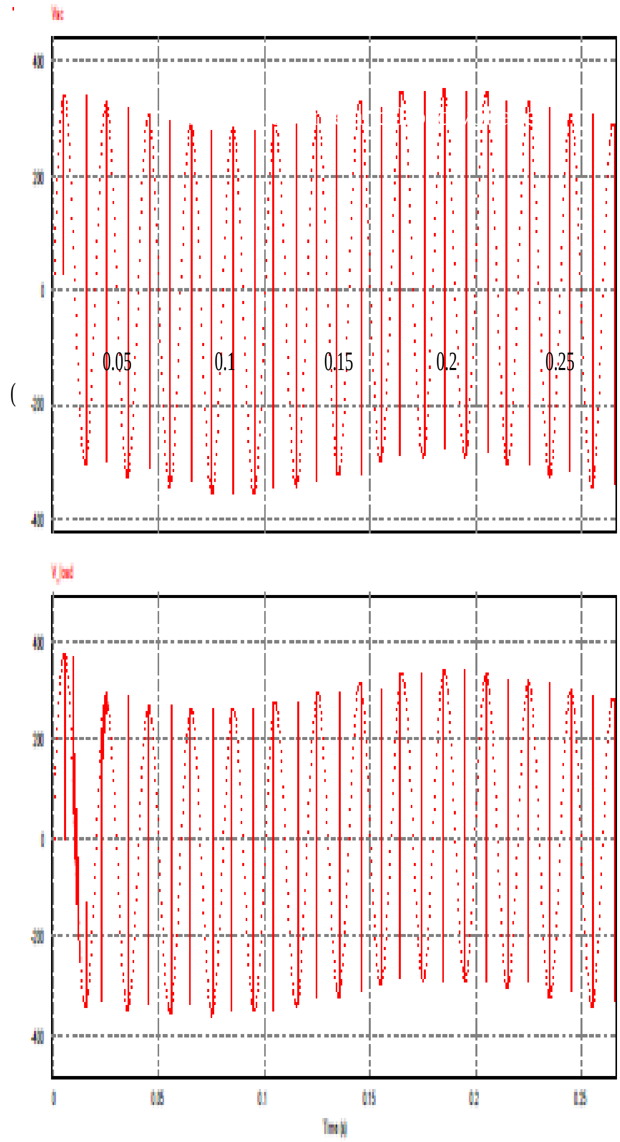
Figure 4:Structure of the DVR

The purpose of designing closed-loop controllers is to achieve good output voltage tracking and disturbance rejection. Hence control variables are changed continuously with the variations in system inputs and outputs. However for simplicity in controller design the inverter system was considered as two independent units, voltage source inverter (AC side) and boost converter (DC side). The inverter operates as buck converter by changing the modulation index from the set point, and Z- source impedance network act as boost converter with large boosting factor.

V. SIMULATION RESULTS AND DISCUSSION

A detailed simulation and experimental investigations of the DVR system were performed using power Sim and prototype built in the laboratory to verify the effectiveness of the proposed design. The experimental set-up was designed with a scaled down model of an actual system and as such simulations were carried out with the same parameters listed in Table I. The filter inductors and capacitors are selected to attenuate switching harmonics while avoiding the resonance It shows the voltage sag due to non linear load. The DVR is allowed to compensate the resultant voltage sag at t=0.4seconds. It can be observed that from the instant of DVR operation, the load voltage is maintained at its rated voltage. The converter generates the required voltage to compensate the sag in load voltage with fast time response. Also, it can be observed that output voltage. the purpose of analysis, two different loads are considered. Load1 is a purely resistive load and load2 is a combination of resistance and inductance. The mload1 is connected to the circuit at time t=0 seconds. The load2 is connected to the circuit at t=0.2 seconds. It can be

The hardware configuration of the prototype DVR is shown in Fig. 10. A -phase low voltage programmable power source supplies the R-L load through a bank of series injection transformers. The injection transformer primary windings are connected to the PWM Z-source inverter via the LC low-pass filter. The inverter consists of six IGBT switches with anti paralleled diodes connected across each switch. The dc-link of the inverter is fed by a separate power supply. The source and load voltages as well as the filter capacitor currents are measured by transducers for controlling AC side. Inductor current and voltage across the capacitor of Z-source impedance network were measured for DC side controlling. The measured voltages and currents are interfaced to DSP though A/D converters in the DSP. The closed loop controller was implemented in the DSP. The measured signals are used to generate the six reference signals that are needed for generating the PWM signals. Generated output signals are interfaced to external logic board through D/A converters where they compared with a triangular carrier to generate PWM signals. The sampling frequency of the control system is set at 10 kHz for the real time controlling. The modulation was done based on the PWM scheme proposed in [7].



observed that
from the time t=0 to t= 0.2 seconds, the load voltage is at its rated value of 325V.

Vc

CONCLUSION

As been discussed. In the closed loop performance of the system, the ac output voltage is controlled by a PI controller. At first stage, in order to have a good performance, the values of inductances and capacitors are calculated by linearization of the inductance's currents and capacitor's voltages. Also, the current is almost sinusoidal and it is in phase with that of the line voltage. Simulation results demonstrate the performance of the proposed DVR using Z-source inverter in terms of factor response and fewer ripples in both input and output sides of inverter.

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