Australian Journal of Basic and Applied Sciences, 8(3) March 2014, Pages: 146-150

AENSI Journals

Australian Journal of Basic and Applied Sciences

ISSN:1991-8178

Journal home page: www.ajbasweb.com

Multilevel Inverter Based Dynamic Voltage Restorer for Voltage Sag Compensation

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ARTICLE INFO

Article history:
Received 25 January 2014
Received in revised form 8 March 2014
Accepted 10 March 2014
Available online 3 April 2014

Keywords:
Power Quality, Dynamic Voltage Restorer (DVR), Multi Level Inverter (MLI), Pulse Width Modulation (PWM), Total Harmonic Distortion (THD).

ABSTRACT

Background: The dynamic voltage restorer, with its excellent dynamic capabilities, when installed between the supply and a critical load feeder, can compensate for voltage sag/swells, restoring line voltage to its nominal value within few milliseconds and hence avoiding any power disruption to the load. In earlier, Voltage Source Inverter (VSI) based DVR and Z Source Impedance (ZSI) based DVR's are modeled. The drawbacks of the two inverters are the output voltage is not pure sinusoidal, hence the Total Harmonic Distortion (THD) in both are more. The proposed method of Multi Level Inverter (MLI) based DVR produces output voltage closer to sinusoidal and the quality of voltage is better. **Objective:** To model and simulate multilevel inverter based DVR for voltage sag compensation using MATLAB / SIMULINK. **Results:** Simulation results shows the response of uncompensated load voltage, injected voltage and compensated voltage. Initially the system was subjected to 26% voltage sag at t=200ms and remains up to t=300ms with the total voltage sag duration of 500ms. The THD of the voltages in the proposed MLI based DVR is considerably lower than that of a VSI and ZSI based DVR. In the proposed DVR, the dc voltage is adjusted according to the amount of voltage sag which leads to higher number of voltage levels and inversely lower THD. **Conclusion:** The simulation results show that the developed control technique with proposed MLI based DVR was simple and efficient. From the simulation results, it was observed that dynamic voltage restorer compensates 26% voltage sag. THD of the proposed MLI based DVR with the VSI and ZSI based DVR's shows a significant improvement in the quality of voltage. The results obtained from simulation of a seven level inverter based DVR demonstrate the proposed DVR.

To Cite This Article: Dr. P. Usha Rani., Multilevel Inverter Based DVR. ***Aust. J. Basic & Appl. Sci.,*** *8(3): 146-150, 2014*

INTRODUCTION

Modern power systems are complex networks, where hundreds of generating stations and thousand of load centers are interconnected through long power transmission and distribution networks. The main concern of customer is the quality and reliability of power supply at various load centers. Even though power generation in most well-developed countries is fairly reliable, the quality of supply is not. Power distribution system should ideally provide their customers an uninterrupted flow of energy with smooth sinusoidal voltage at the contracted magnitude and frequency. However, in practice power system especially the distribution system, have numerous non linear loads, which are significantly affect the quality of power supply. As a result, the purity of waveform of supply lost. This ends up producing many power quality problems. Apart from non-linear loads, some system events, both usual (capacitor switching, motor starting) and unusual (faults) could also inflict power quality problems. The consequence of power quality problems could range from a simple nuisance flicker in electric lamps to a loss of thousand of rupees due to power shutdown. A power quality problem is defined as any manifested problem in voltage or current of leading to frequency deviations that result in failure or miss operation of customer equipment. Power quality problems associated with an extensive number of electromagnetic phenomena in power systems with broad ranges of time frames such as long duration variations, short duration variations and other disturbances. Short duration variations are mainly caused by either fault conditions or energisation distance related to impedance type of grounding and connection of transformer between the faulted location and node, there can be temporary load of voltage reduction (sag) or voltage rise (swell) at different nodes of the system.

Voltage sag is defined as a sudden reduction in supply voltage to between 90% and 10% of the nominal value, followed by a recovery after a short interval. The standard duration of sag is between 10 milliseconds and 1 minute. Voltage sag can cause loss in production in automated processes since voltage sag can trip a motor or cause its controller to malfunction. Voltage swell is defined as sudden increase in supply between 110% and

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180% of the nominal value of the duration of 10 milliseconds to 1 minute. Switching off a large inductive load or energizing a large capacitor bank is a typical system event that causes swells. To compensate the sag/swell in a system, appropriate devices need to be installed at suitable locations.

The DVR is operated in such a fashion that it does not supply or absorb any active power during the steady-state operation (Arindam Ghosh, 2004). It is desirable to have a minimum VA rating of the DVR, for a given system without compromising compensation capability (Anil Kumar, R. and G. Siva Kumar, 2009). Control algorithm for dynamic voltage restorer (DVR) to improve voltage quality problems such as voltage sags/swells in distribution systems has been proposed (Boonchiam, P. and N. Mithulananthan, 2006). The DVR consists of three inverters sharing the same DC link via a capacitor bank. Each inverter has an individual inner control loop for generating the gate signals for the switches (Carl Ngai and Man Ho, 2010).

The voltage-restoration process involves real-power injection into the distribution system, the capability of a particular DVR topology, especially for compensating long-duration voltage sags, depends on the energy storage capacity of the DVR (Mahinda Vilathgamuwa, D., 2006). The main factor which limits capabilities of a particular DVR in compensating long-duration voltage sags is the amount of stored energy within the restorer (Mahinda Vilathgamuwa, D., 2004).

Voltage swell compensation using PWM technique for an interline dynamic voltage restorer is presented in (Usha Rani, P., 2014). Modeling and simulation of IDVR using multiple PWM for voltage sag/swell compensation is presented in (Usha Rani, P. and S. Rama Reddy, 2011; Sudha, R., 2011; Usha Rani, P., 2011). The MATLAB simulation of DVR using multiple PWM technique is presented in (Usha Rani, P. and S. Rama Reddy, 2009). Z source impedance based DVR and IDVR modeling and simulation is presented in (Rajkumar, M., 2001; Usha Rani, P., 2011).

The literature (Arindam Ghosh, 2004) to (Boonchiam, P. and N. Mithulananthan, 2006) does not deal with DVR system using multilevel inverter. An attempt is made in the present work to model and simulate multilevel inverter based dynamic voltage restorer for voltage sag compensation using MATLAB/SIMULINK.

Principle of Mli Based DVR:

Dynamic voltage restorer was originally proposed to compensate for voltage disturbances on distribution systems. A typical DVR scheme is shown in Fig. 1. The restoration is based on injecting AC voltages in series with the incoming three-phase network, the purpose of which is to improve voltage quality by adjustment in voltage magnitude, wave-shape, and phase shift. These are important voltage attributes as they can affect the performance of the load equipment. Voltage restoration involves energy injection into the distribution systems and this determines the capacity of the energy storage device required in the restoration scheme

Fig. 1 shows the proposed DVR. It consists of an energy storage, a dc/dc converter, a multilevel inverter and the injection transformers. The capacitor *C* is used as a filter. The main aim in the proposed topology is to adjust the dc link voltage according to the amount of voltage sag. The dc output voltage of the energy storage (*Vin*) is given to a DC/DC converter as its input voltage. The dc/dc converter offers a variable dc link voltage (*Vdc*) so that it can be adjusted considering the amount of voltage sag. A new method for application of a multilevel inverter in the DVR structure is proposed in this paper. The proposed method relies on the adjusting the dc voltage input of the multilevel inverter using a dc/dc converter according to the voltage sag. As a result, for a wide range of voltage sag, the proposed DVR generates all of the possible voltage levels which is not possible in the existing methodologies. Cascaded seven level inverter is used.

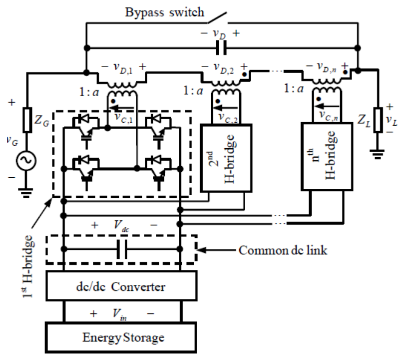

Fig. 1: Block Diagram of MLI based DVR Circuit.

Voltage Compensation in DVR System:

The simulation circuit of MLI based DVR is shown in Fig.2. The subsystem 4 consists of boost converter and multilevel inverter pulse generator which is shown in Fig.3. Initially the system was subjected to voltage sag at t=400ms and remains up to t=700ms with the total voltage sag duration of 300ms, in a run time of 1000ms.

The cascaded seven level MLI switching pulses, output voltages and FFT analysis of MLI output voltage are shown in Fig.4,5 & 7. The response of MLI based DVR for voltage sag compensation is shown in Fig.6. Uncompensated voltage, an injected voltage (seven level cascaded MLI) and the compensated voltages are shown in Fig.6.

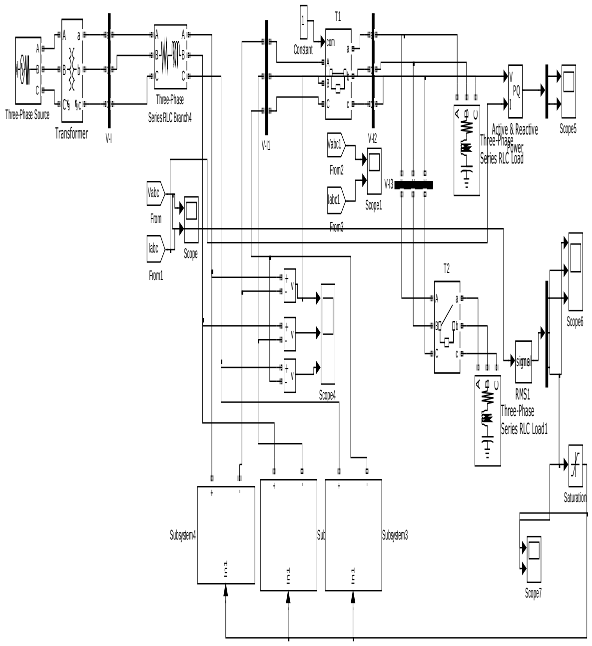

Fig. 2: MLI based DVR simulated circuit.

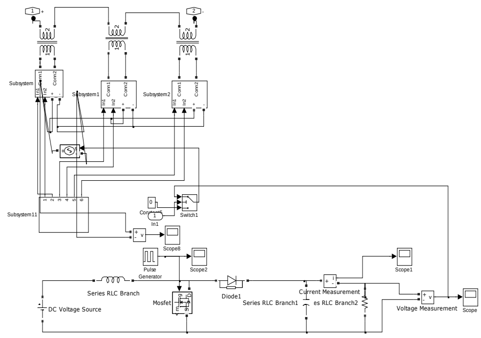

Fig. 3: Subsystem4 of MLI based DVR.

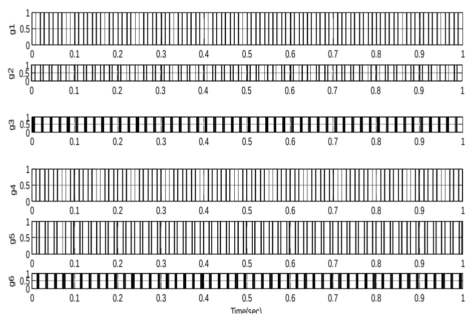

Fig. 4: Switching pulses.

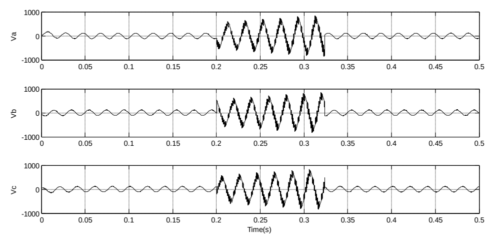

Fig. 5: Output voltage of MLI.

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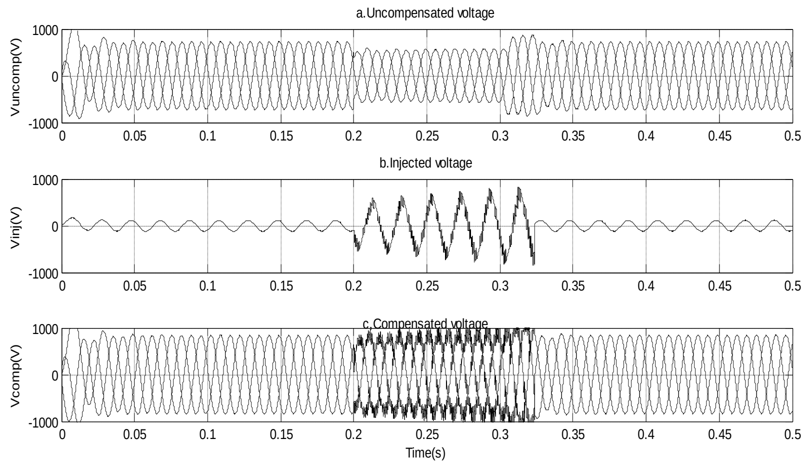

Fig. 6: Response of MLI based DVR.

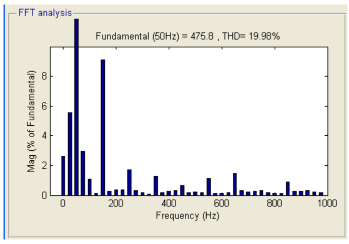

Fig. 7: FFT analysis of MLI output voltage.

Conclusion:

The modeling and simulation results of Multi Level inverter based Dynamic Voltage Restorer using DC/DC converter is proposed and the simulation is done using MATLAB software. The three-phase cascaded seven level MLI topology that produces a significant reduction in the number of power devices required to implement multilevel output. The studied inverter topology offer strong advantages such as improved output waveforms. The simulation results indicate that the implemented control strategy compensates for voltage sag with high accuracy. The results show that the control technique is simple and efficient method for voltage sag compensation.

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