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Modeling And Simulation Of Multilevel Inverter Based Dynamic Voltage Restorer For Voltage Sag Compensation

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ABSTRACT

The dynamic voltage restorer, with its excellent dynamic capabilities, when installed between the supply and a critical load feeder, can compensate for voltage sags, restoring line voltage to its nominal value within few milliseconds and hence avoiding any power disruption to the load. This paper presents the modeling and simulation of multilevel inverter based dynamic voltage restorer as a voltage sag mitigation device in electrical power distribution networks. The proposed method relies on the adjusting the DC voltage input of the multilevel inverter using a DC/DC converter according to voltage sag. The modeling and 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.

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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 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. Voltage sag/sell 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 (Choi, S.S., *et al*., 2000). Dynamic Voltage Restorer, which consists of a set of series and shunt converters connected back-to-back, three series transformers, and a dc

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capacitor installed on the common dc link (Jimichi, T., *et al*., 2005). 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 (Loh, P.C., *et al*., 2004). 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 (Gajanayake, C.J., *et al*., 2005; Peng, F.Z., 2003) and (Torabzad, S., *et al*., 2010).

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 (Sira-Ramirez, H and R. Ortega, 1995). 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 (Sng, E.K.K., *et al*., 2004). Installation of the world's first Dynamic Voltage Restorer (DVR) on a major US. 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 (Woodley, N.H., *et al*., 1999). Modeling and simulation of DVR is presented (Usha Rani, P. and S. Rama Reddy, 2009). The modeling and simulation of ZSI based DVR is presented (Usha Rani, P. and S. Rama Reddy, 2011) and (Usha Rani, P. and S. Rama Reddy, 2011). The modeling and simulation of Interline DVR is presented (Usha Rani, P. and S. Rama Reddy, 2011) and (Usha Rani, P., 2014). The digital simulation of Interline DVR using space vector pulse width modulation technique is presented (Usha Rani, P., 2014). 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.

Dynamic Voltage Restorer:

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.

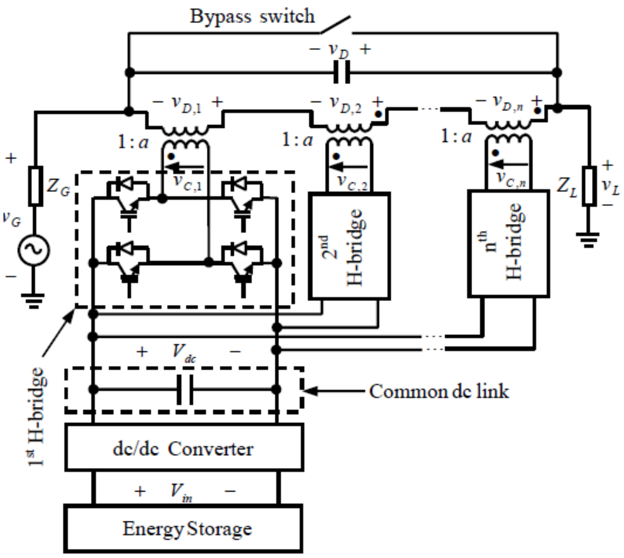

Fig. 1: Block Diagram of MLI based DVR Circuit

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Voltage Sag 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.

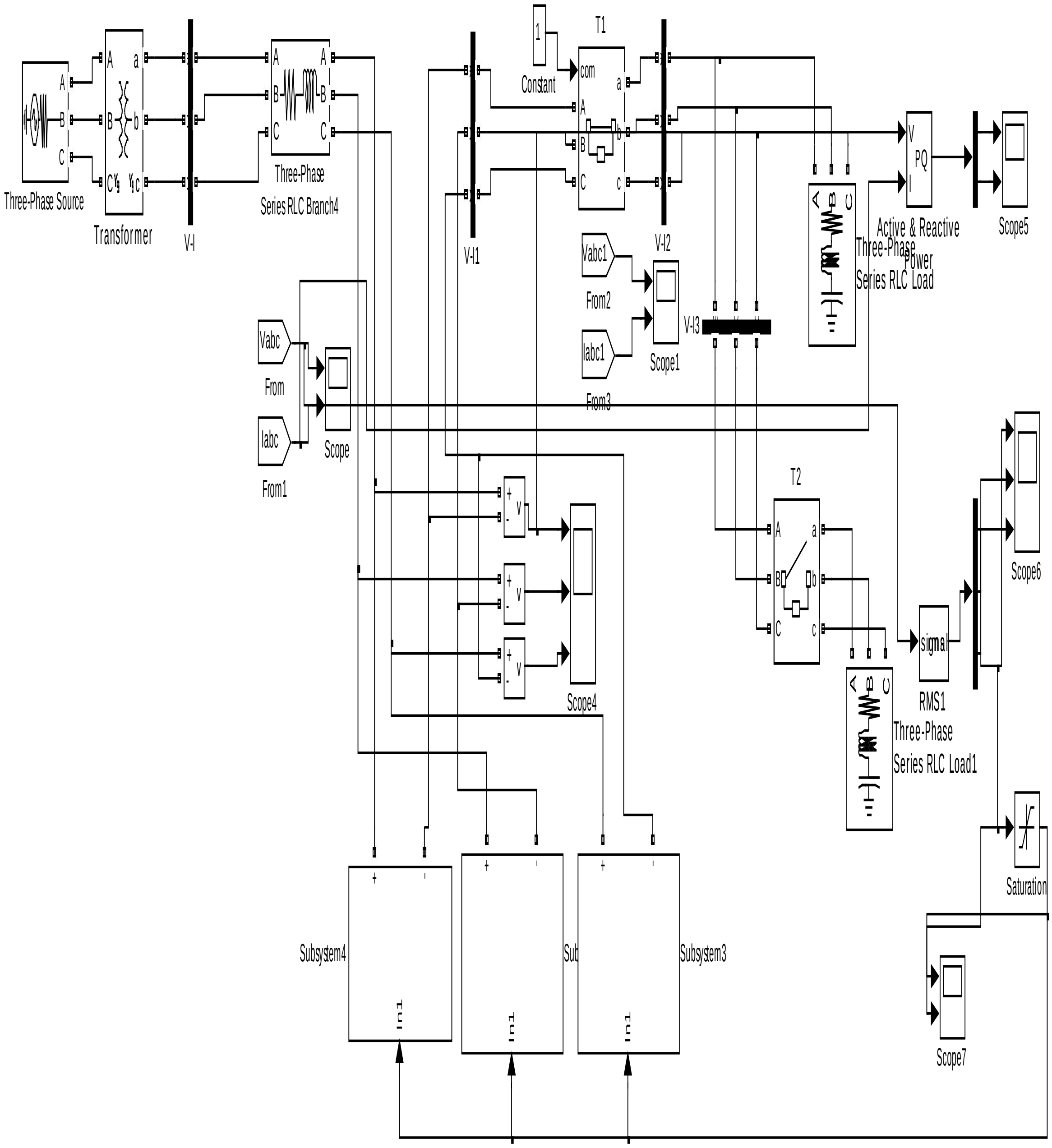

Fig. 2: simulation circuit of MLI based DVR

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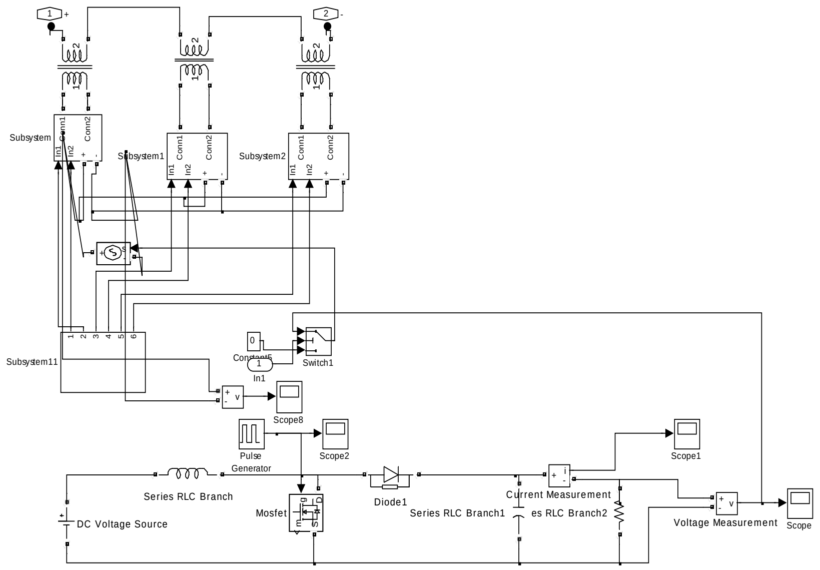

Fig. 3: subsystem4 of MLI based DVR

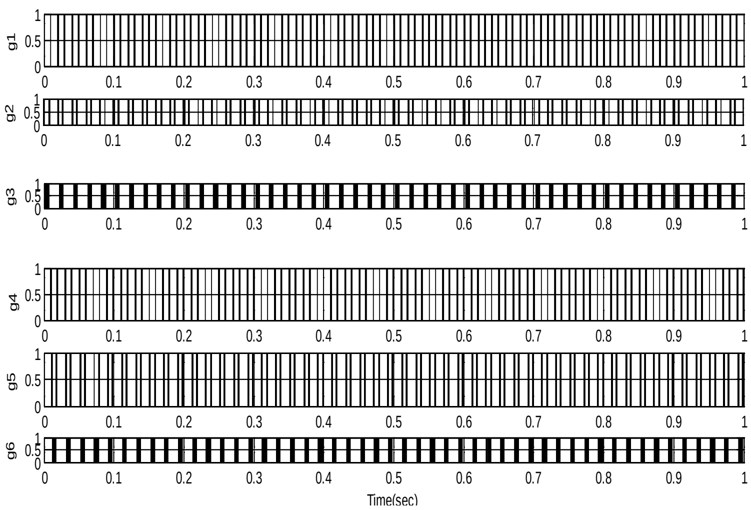

Fig. 4: switching pulses

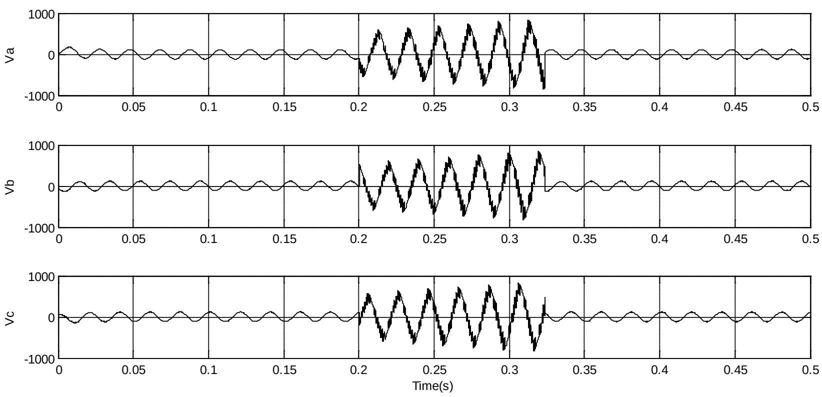

Fig. 5: MLI output voltage

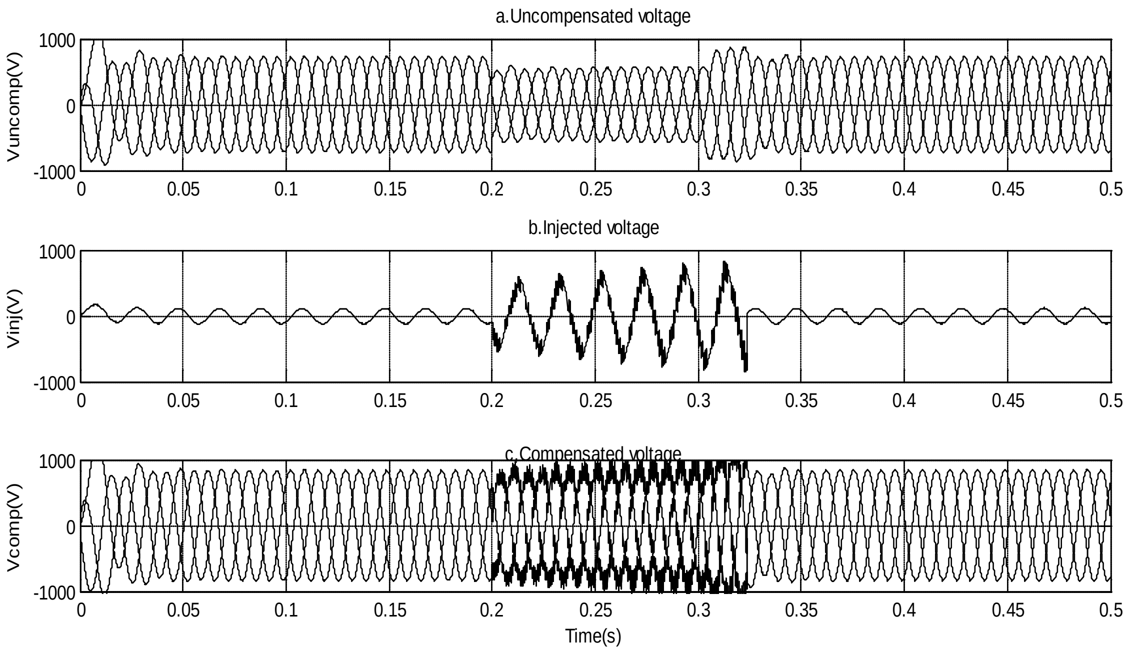

Fig. 6: Response of MLI based DVR

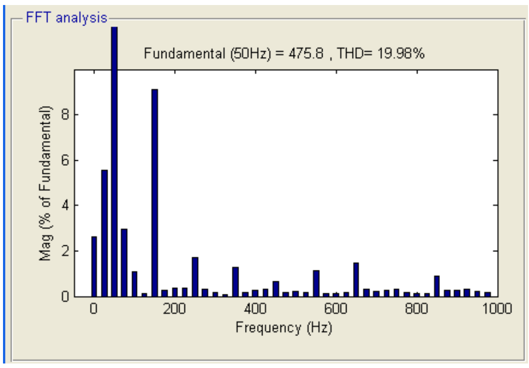

Fig. 7: FFT analysis of MLI output voltage

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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