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Enhancement of Power Quality using Power Electronics Transformer based DVR

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***Abstract:** In this paper a three phases four wire dynamic voltage restorer (DVR) with bidirectional power electronic transformer structure is proposed to inject required compensating series voltage to the electronic power system in such a way that continuous sinusoidal voltage is seen at load side ever at heavy fault occurrences at utility side .the proposed structure is composed of three-phase four leg inverter, three single-phase high frequency transformer , three cycloconverters and high frequency harmonic filter that are connected to the utility. Three dimensional space vector modulation (3DSVM) methods are used for pulse generation. Fourth added wire enables the DVR to compensate unbalance voltage disturbance that are custom power problems in electrical utility. The performance of the structure and applied switching scheme are verified under both balanced and applied switching scheme are verified under both balanced and unbalanced disturbances via simulation study in MATLAB software.*

***Keywords:** PET, DVR; 3DSVM; Power quality;*

I. INTRODUCTION

Power quality (PQ) problems have obtained increasing attentions as they can affect lots of sensitive end-users including industrial and commercial electrical consumers. Studies indicate that voltage sags, transients, and momentary interruptions constitute 92% of all the PQ problems occurring in the distribution power system. In fact, voltage sags have always been a huge threat to the industry, and even 0.25s voltage sag is long enough to interrupt a manufacture process resulting in enormous financial losses. Voltage sags are generally classified according to its depth and duration time. Typical sag can be a drop to between 10% and 90% of the rated RMS voltage and has the duration time of 0.5 cycles to 1 min. According to the data presented in majority of the sags recorded are of depth no less than 50% but deeper sags with long duration time obviously cannot be ignored as they are more intolerable than shallow and short-duration sags to the sensitive electrical consumers.

Many customer power devices have been proposed to mitigate such voltage sags for sensitive loads. The most studied voltage regulator topologies can generally categorized into two groups: the inverter-based regulator and direct ac–ac converters. In several ac–ac converter-based regulators are introduced. Series-connected devices (SD) are voltage-source inverter-based regulators and an SD compensate for voltage sags by injecting a missing voltage in series with the grid. There are lots of SD topologies, and key features related to the evaluation of a certain SD topology are the cost, complexity, and compensation ability. Dynamic voltage restorer (DVR) is a commonly used SD and has been widely studied. Consumer's equipment need pure balanced sinusoidal voltage with constant root mean square (RMS) value to have their satisfying operation.

Based on the aforementioned discussions, this paper proposes a PET based three-phase four-wire DVR to inject required compensating series voltage to the power system in such a way that continuous sinusoidal voltage is seen at load side ever at heavy fault occurrences at utility side. The proposed structure is composed of a three-phase four-leg inverter, three single-phase high frequency transformers and a three-phase high frequency harmonic filter that are connected to the utility.

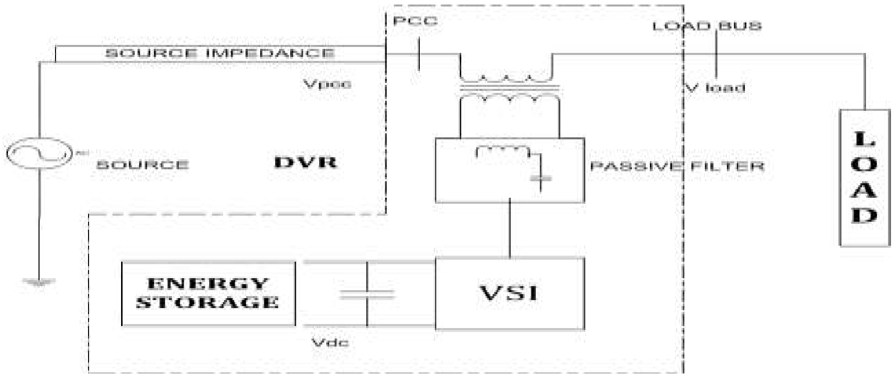


Fig.1 Basic Structure of A DVR

II. METHODOLOGY

In this paper a three phases four wire dynamic voltage restorer (DVR) with bidirectional power electronic transformer structure is proposed to inject required compensating series voltage to the electronic power system in such a way that continuous sinusoidal voltage is seen at load side ever at heavy fault occurrences at utility side .the proposed structure is composed of three-phase four leg inverter, three single-phase high frequency transformer , three cyclo converters and high frequency harmonic filter that are connected to the utility. Three dimensional space vector modulation (3DSVM) methods are used for pulse generation. Fourth added wire enables the DVR to compensate unbalance voltage disturbance that are custom power problems in electrical utility. The performance of the structure and applied switching scheme are verified under both balanced and applied switching scheme are verified under both balanced and unbalanced disturbances via simulation study in MATLAB software. Dynamic voltage restorer (DVR) can provide the lucrative solution to mitigate voltage sag by establishing the appropriate voltage quality level, necessary. It is recently being used as the active solution for mitigation of power quality problems.

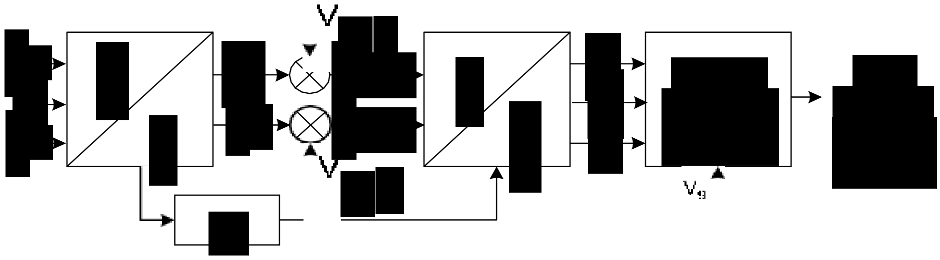


Fig. 2. Control block diagram of DVR

Three dimensional space vector modulations (3DSVM) is applied to the proposed DVR to generate switching pulses for power switches. Fourth added wire enables the DVR to compensate unbalance voltage sag and swell that are custom power quality problems in electrical utility. The aim of this paper is to propose a new approach solution to provide voltage quality for sensitive loads under balanced and unbalanced disturbance. This can be done by a three-phase four-leg converter based on 3DSVM. This technique has some advantages such as higher amplitude modulation indexes if compared with convectional SPWM techniques [12]. The proposed DVR is shown in Fig. 1. The purpose of control scheme is to maintain the load voltage at a desired value. In order to control the three-phase four-wire inverter, 3DSVM method is used that has some advantages such as more efficiency, high DC link voltage utilization, lower output voltage THD, less switching and conduction losses, wide linear modulation range, more output voltage magnitude and its simple digital implementation [l2]. The block diagram of the control system used is shown in Fig. 2.

III. SIMULATION & RESULTS

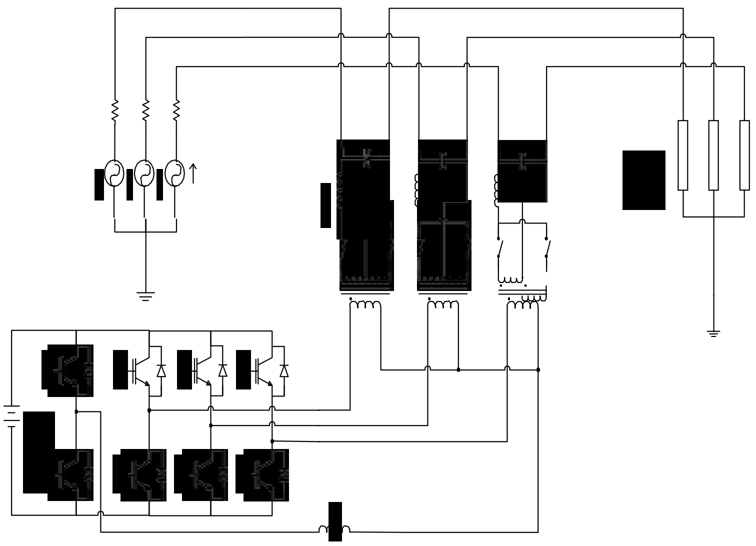


Fig. 3. Three-Phase Four-Wire DVR

In this section, the proposed system in Fig.l is simulated in MATLAB. System parameters are given Table 1. It should be noted that the series transformers are operating at switching frequency and in linear region. Fig. 8 shows the simulation results under balance voltage sag condition. In this case, 50% voltage sag has been considered for each phases. Utility voltage, injected voltage and load voltage are shown, respectively. It is clear that the load voltage is restored to the nominal condition (before sag occurrence) after a time lower than a half cycle. It shows the simulation results under unbalance voltage sag condition with the values of 60%, 50% and 40% on phases a, b, and c, respectively. As can be seen, under such conditions, this structure injects unbalance voltage in such a way that the load voltage remains balanced and sinusoidal and doesn't sense the voltage sag.

TABLE I. System parameters

Parameters	Value
Line Frequency	50Hz
Switching frequency	l0000Hz
Load voltage	230vrms
dc bus voltage	80v
Series transformer turns ratio	l:4
Filter inductance and capacitance	lmh & 25µf

It shows the simulation results of the proposed DVR under harmonic polluted utility voltage. It is clear that the load voltage remains balanced and sinusoidal even when such condition is occurred for utility voltage.

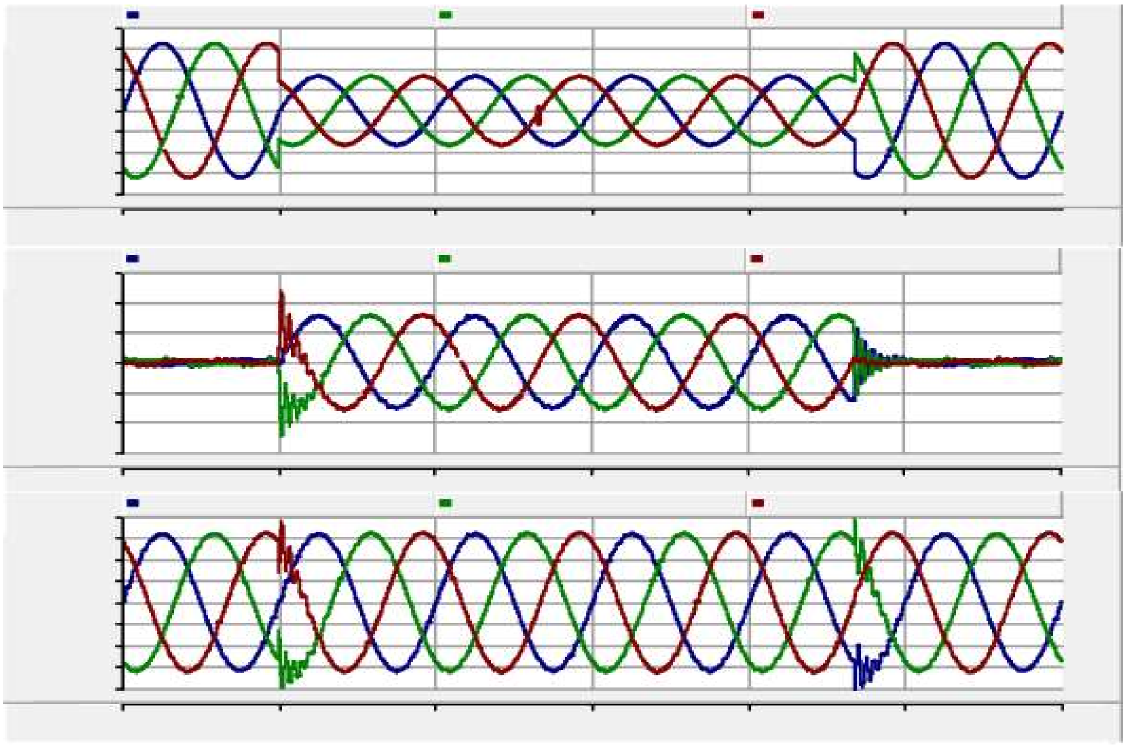


Fig.4. Simulation results under balanced sag (a) utility voltages (b) injected voltages (c) load voltages

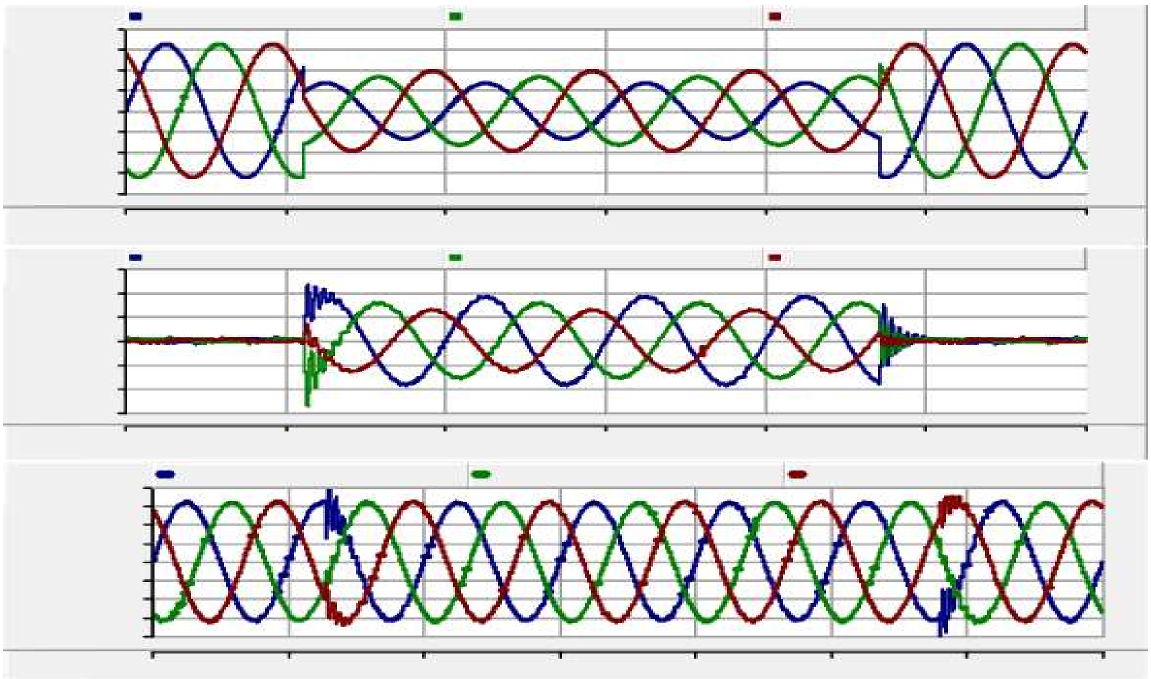
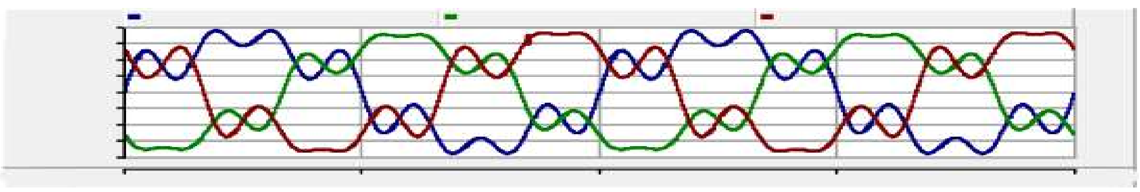


Fig.5. Simulation results under unbalanced voltage sag, (a) utility voltages (b) injected voltages (c) load voltages



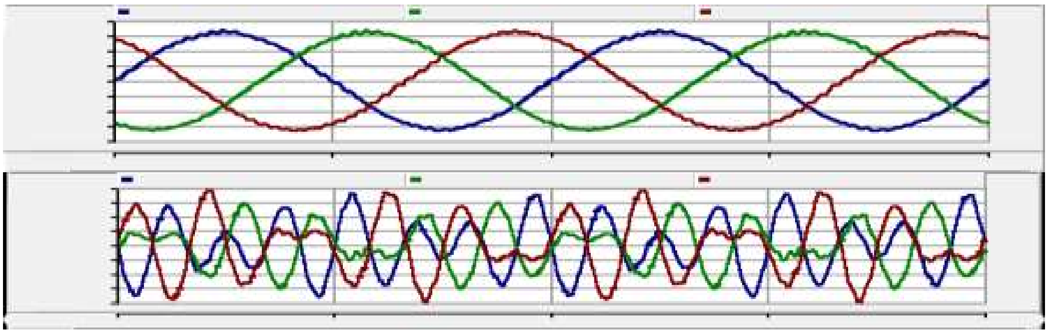


Fig.6. Simulation results under harmonic polluted utility voltage (a) utility voltages (b) injected voltages (c) load voltages

The THD values of utility voltages and load voltages compensated are given in TABLE. The THD of the load voltage is less than 3% that lays in the criterion reported in IEEE standards 519-1992.

TABLE II. THDs of utility and load voltages

	THD_a	THD_b	THD_c
Utility Voltage	%38.87	%32.02	%41.66
Load Voltage	%2.28	%1.91	%2.37

CONCLUSION

In this paper, a three-phase four-wire DVR is presented to compensate the balanced and unbalanced sag and swell voltage using three dimensional space vector modulations. The performance of DVR is validated through simulations in MATLAB and the results verify the analysis. According to the results, DVR injects appropriated series voltage during utility voltage disturbance and maintains the load voltage at desired value. Also the THD values of the load voltage are less than the standard values.

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