International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

IJIEMR Transactions, online available on 8th Sept2017. Link :http://www.ijiemr.org/downloads.php?vol=Volume-6&issue=ISSUE-8

Title: **MODERATE VOLTAGE DYNAMIC VOLTAGE RESTORER (DVR) BASED ON FIFTEEN LEVEL MLI CONVERTER FOR POWER QUALITY IMPROVEMENT**

Volume 06, Issue 08, Pages: 38– 47.

Paper Authors

Ms. MINDA PUJITHA,Mr.P.ANKINEEDU PRASAD

Vikas Group of Institutions,A.P, India.

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

MODERATE VOLTAGE DYNAMIC VOLTAGE RESTORER (DVR) BASED ON FIFTEEN LEVEL MLI CONVERTER FOR POWER QUALITY IMPROVEMENT

[1]Ms. MINDA PUJITHA, [2]Mr. P. ANKINEEDU PRASAD
[1]M.Tech(EPS) Student Scholar,Dept of Electrical & Electronics Engineering,Vikas Group of Institutions, A.P, India.
[2]Associate Professor, Head of the department,Dept of Electrical & Electronics Engineering,Vikas Group of Institutions,A.P, India.
[1] pujithaeee@gmail.com, [2]ankineedupadamata@gmail.com

Abstract- In the present electric power grids, power quality issues are recognized as a crucial concerns and a frequently occurring problem possessing significant costly consequence such as sensitive load tripping and production loss. Consequently, demand for high power quality and voltage stability becomes a pressing issue. Dynamic voltage restorer (DVR), as a custom power device, is one of the most effective solutions for "restoring" the quality of voltage at its load-side terminals when the quality of voltage at its source-side terminals is disturbed. In this paper, a new DVR topology based on double flying capacitor multicell (DFCM) converter for medium-voltage application has been proposed. The advantage of the proposed DVR is that it does not need any line-frequency step-up isolation transformer, which is bulky and costly, to be connected to medium-voltage power grid. Cascaded Asymmetrical Multilevel Converter based DVR is used for harmonics control is presented. The 15 level Asymmetrical Cascaded H Bridge MLI gives better output voltage compared to the Voltage Source Inverter. The common mode voltage is reduced by increasing the levels due to this losses will be reduced and efficiency of total system will get increased. Dynamic Voltage Restorer provides a cost effective solution for protection of sensitive loads from voltage sags currents, although the applied voltage being sinusoidal. MATLAB/SIMULINK tool is used for evaluating the performance of the proposed control scheme.

Key Words: Double Flying Capacitor Multicell Converter; Dynamic Voltage Restorer; Multilevel Power Converters; Power Quality; Voltage Sag; MLI.

I. INTRODUCTION

An increasing demand for high quality, reliable electrical power and increasing number of distorting loads may leads to an increased awareness of power quality both by customers and utilities. The most common power quality problems today are voltage sags, harmonic distortion [1]. Voltage sag is a short time (10ms to 1 minute) event during which a reduction in rms voltage magnitude occurs. It is often set only by two parameters: depth/magnitude and duration [2-3]. The voltage sag magnitude is ranged from 10% to 90% of nominal voltage and width duration from half a cycle to 1 minute. Voltage sag is caused by a fault in the

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

utility system, a fault with in the customer's facility or a large increase of the load current, like starting a motor or transformer energizing [4]. Voltage sag is one of the most occurring power quality problems. Harmonic currents cause harmonic distortion, low power factor, noise, vibration [5]. The development of power electronic devices such as custom power devices has introduced an emerging branch of technology providing the power system with new control capabilities. There are different ways to improve power quality problems. Among these, DVR is one of the most effective devices [6]. The DVR compensates the unbalance in supply voltage of different phases. The DVR supplies the active power with the help of DC energy storage and required reactive power is generated internally without any means of DC storage. The DVR can compensate voltage at both transmission and distribution sides [7-9]. Usually a DVR is installed on a critical load feeder. During the normal operating condition (without sag condition) DVR operates in a low loss standby mode [10]. During this condition the DVR is said to be in steady state. When a disturbance occurs (abnormal condition) and supply voltage deviates from the nominal value, DVR supplies voltage for compensation of sag and is said to be in transient state [11]. In recent years, industry has begun to demand higher power equipment, which now reaches the megawatt level. Controlled AC drives in the megawatt range are usually connected to the medium-voltage network [12]. Today, it is hard to connect a single power semiconductor switch directly to medium voltage grids. For these reasons, a new family of multilevel inverters has emerged as the solution for working with higher voltage levels [13]. Multilevel inverters include an array of power semiconductors and capacitor voltage sources, the output of which generate voltages with stepped waveforms. In this paper it is proposed to employ a custom power device with multilevel inverter topology using multicarrier modulation technique to mitigate the power quality problem [14]. This paper compares several alternative carrier disposition PWM strategies for a multilevel inverter, which are simulated in MATLAB/Simulink.

II. PRE-SAG COMPENSATION METHOD

The basic concept of DVR is shown in Figure.1. A commonly used method for compensating voltage sags is restoring the load voltage to the level and condition before the sag [2]. Therefore, the amplitude and the phase of the voltage before the sag have to be exactly restored [2]. The phasor diagram of the pre-sag compensation strategy is shown in Figure.2. In this figure, dashed quantities ($Vg'\ rid$, $Vload'$, $Vdvr'$ and $Iload'$) indicate variables after the sag. The phasors prior to the sag are represented by $Vgrid$, $Vload$ and $Iload$. Moreover, angle of φ is phase angle difference between the load voltage and load current phasors and angle of δ is phase jump of grid voltage during the voltage sag. All of the load and grid voltage phasors are line-to-neutral voltages. For this strategy, the PLL is synchronized with the load voltage. As soon as a failure occurs, the PLL will be locked and so, the phase angle can be restored.

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

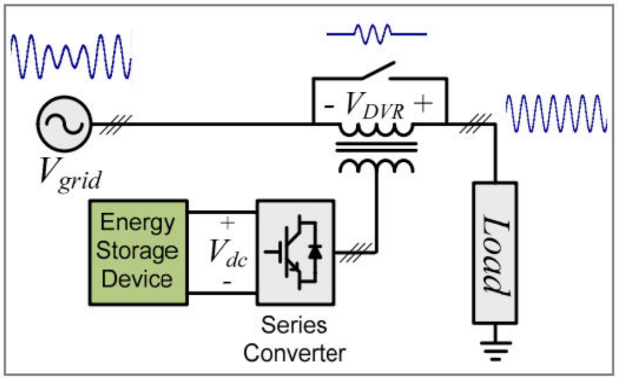


Fig.1. General topology of DVR

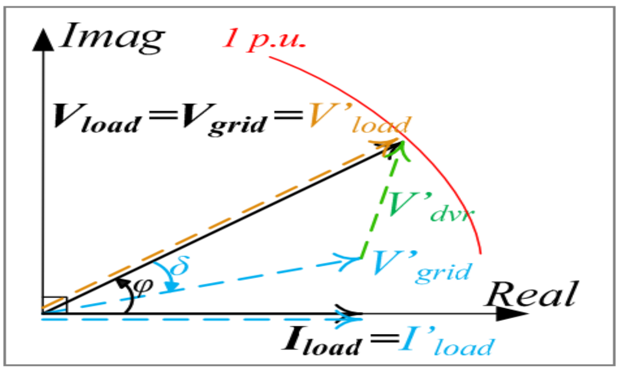


Fig.2. Phasor diagram of pre-sag compensation strategy

The magnitude of DVR injected series voltage in this compensation method is not minimal and it depends on both amount of voltage drop and phase jump during the voltage sag because the phase jump of the grid voltage has also to be compensated by the DVR. Consequently, DVR has to be designed for the highest possible voltage sag compensation. Furthermore, voltage rating of dc link in DVR controlled with this method needs to be larger than one controlled with in-phase compensation method. Moreover, this compensation strategy leads to the lowest distortions at the load-side because both phase angle and magnitude of the voltage at the load-side are restored during the sag. Thus, the sensitive load doesn't sense any voltage disturbance. This method is so reliable and proper to protect sensitive loads without having any possible transient and circulating currents. Moreover, even if the phase jumps of the grid voltage in each phase are not the same, DVR controlled with pre-sag compensation method can eliminate the voltage disturbance completely. This strategy is able to compensate any kind of voltage sags including balanced or unbalanced voltage sags with or without any phase-variations in each phase of grid voltages.

Regarding the amount of power exchanged between DVR and power grid, pre-sag compensation method injects both active and reactive power depends on magnitude of injected voltage, grid voltage phase jump and phase angle difference between load voltage and load current phasors. The reason for injecting active power is that the injected voltage phasor is not certainly perpendicular to the load current phasor in this method as like as in-phase compensation method. Consequently, it needs the active power to be supplied at dc link side otherwise this method can't compensate deep voltage sags for a long time. Thus, without supporting the active power at the dc link, dc link voltage will drop during the compensation and as a result, the maximum producible voltage of DVR will decrease and the modulation index of series converter will increase continuously and therefore, over-modulation may occur.The power rating of DVR controlled by pre-sag compensation method and the amount of the exchanged active power between DVR and power grid are as follows:

$$S_{DVR} = \sum_{k=a,b,c} \left[V'_{grid,k} \cdot I_{load} \right] \quad (1)$$

$$P_{DVR} = P_{load} - P_{grid} = \begin{bmatrix} 3 \cdot V_{load} \cdot I_{load} \cdot \cos(\phi) \\ - \sum_{k=a,b,c} \left[V'_{grid,k} \cdot I_{load} \cdot \cos(\phi - \delta_k) \right] \end{bmatrix} \quad (2)$$

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

Where, δk is the phase jump in phase k. The magnitude of injected voltage is:

$$V'_{DVR,k} = \sqrt{2} \cdot \sqrt{\left(V_{load}\right)^2 + \left(V'_{grid,k}\right)^2 - 2 \cdot V_{load} \cdot V'_{grid,k} \cdot \cos\left(\delta_k\right)} \quad (3)$$

and the phase angle of injected voltage phasor is:

$$\angle V'_{DVR,k} = \arctan\left(\frac{V_{load} \cdot \sin(\varphi) - V'_{grid,k} \cdot \sin(\varphi - \delta_k)}{V_{load} \cdot \cos(\varphi) - V'_{grid,k} \cdot \cos(\varphi - \delta_k)}\right) \quad (4)$$

III. PROPOSED DVR BASED ON DFCM CONVERTER

Fig.3 illustrates general scheme of proposed DVR which is based on DFCM converter. The main advantage of the proposed DVR is that it has the capability of direct connection to medium-voltage power grid without any step-up line-frequency transformer which is bulky and heavy. This advantage is obtained thanks to utilization of DFCM converter as a core inverter of DVR to inject series

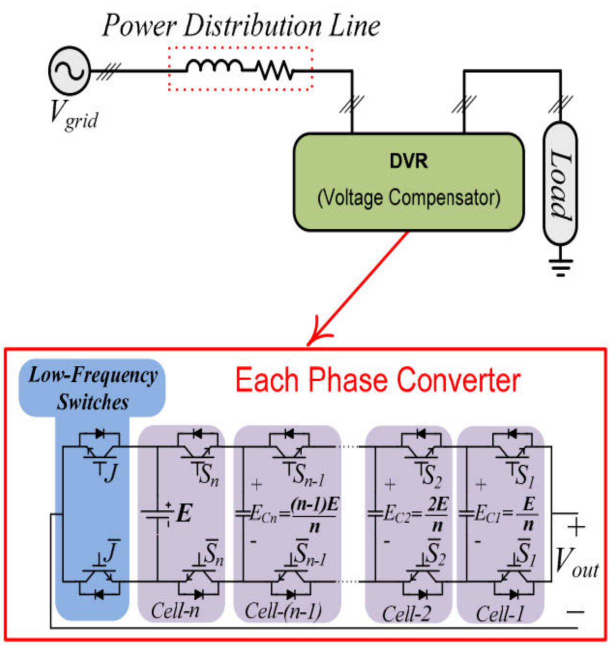


Fig.3 Proposed DVR based on DFCM converter for medium-voltage applications

IV. DVR REFERENCE VOLTAGE DETERMINATION

The control system of DVR has two main parts; the first one is voltage sag detection part and the second part of DVR control system is determining the reference of DVR series injected voltage. The approach to determine reference signal of DVR series injected voltage is based on the type of energy storage device and its ability to support active power. One of the methods for compensating voltage sags is restoring the load voltage to the level and condition before the sag, called pre-sag method. Therefore, the amplitude and the phase angle of the voltage before the sag have to be exactly restored. For this strategy, the PLL is synchronized with grid voltage and its phase angle is backed up and stored in memory continuously. As soon as a voltage sag is detected, the PLL will be locked to the phase angle stored in the memory and so, the phase angle can be restored. The magnitude of DVR injected series voltage in the pre-sag compensation method depends on both amount of voltage drop and phase jump during the voltage sag; because the phase jump of the grid voltage has also to be compensated by the DVR. In the synchronous reference frame (SRF)-based method, the first step of voltages to compensate voltage disturbances. Generally, FC voltages in FC-based converters are more diverse whenever the number of cells is high and so it is not more practical to have high number of cells. To negate this disadvantage, a topology called DFCM converter has been proposed wherein the number of FCs and power switches is half of those in the conventional topology of an FCM converter for generating the same stepped output voltage.

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

Determining the reference of DVR series injected voltage is to measure the line-to-neutral grid voltages and transfer them from *abc* coordinate system to SRF as follows:

$$\begin{bmatrix} V_{grid,d} \\ V_{grid,q} \\ V_{grid,0} \end{bmatrix} = \frac{2}{3}\begin{bmatrix} \cos(\omega t) & \cos(\omega t-120) & \cos(\omega t+120) \\ \sin(\omega t) & \sin(\omega t-120) & \sin(\omega t+120) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \cdot \begin{bmatrix} V_{grid,a} \\ V_{grid,b} \\ V_{grid,c} \end{bmatrix} \quad (5)$$

Where, $V_{grid,a}$, $V_{grid,b}$, $V_{grid,c}$, are the measured line-to neutral grid voltages of phases a, b and c, respectively and $V_{grid,d}$, $V_{grid,q}$, $V_{grid,0}$ are the d-component, q-component and zero-component of grid voltages in the SRF, respectively. The phase angle of phase a voltage in pre-sag state (no-fault condition) is stored as the reference angle as follows:

$$\theta^{ref} = \arctan\left(\frac{V_{grid,d}\big|_{dc}}{V_{grid,q}\big|_{dc}}\right) \quad (6)$$

Where, $V_{grid,d}|_{dc}$ and $V_{grid,q}|_{dc}$ are dc values of d- and q-components of grid voltages in SRF, respectively. After a voltage sag is detected using the proper detection method, the reference fundamental amplitude of line-to-neutral grid voltages (V_{g1}^{ref}) and the obtained reference angle (θ^{ref}) are used to determine the values of reference grid voltages in the SRF as follows:

$$V_{grid,d}^{ref} = V_{g1}^{ref} \cdot \sin\left(\theta^{ref}\right) \quad (7)$$

$$V_{grid,q}^{ref} = V_{g1}^{ref} \cdot \cos\left(\theta^{ref}\right) \quad (8)$$

Where, $V_{grid,d}^{ref}$ and $V_{grid,q}^{ref}$ are the reference d- and q components of grid voltages in the SRF, respectively. Next, the differences between the dq0 values of line-to-neutral grid voltages and the dq0 values of reference line-to-neutral grid voltages are taken into account as dq0 values of DVR reference injected voltages as follows:

$$V_{dvr,d}^{ref} = V_{grid,d}^{ref} - V_{grid,d} \quad (9)$$

$$V_{dvr,q}^{ref} = V_{grid,q}^{ref} - V_{grid,q} \quad (10)$$

$$V_{dvr,0}^{ref} = -V_{grid,0} \quad (11)$$

Where, $V_{dvr,d}^{ref}$, $V_{dvr,q}^{ref}$ and $V_{dvr,0}^{ref}$ are the reference d component, q-component and zero-component of DVR series injected voltages in the SRF, respectively. These values are transferred to abc coordinate system and then, three single-phase reference voltages of DVR are obtained as follows:

$$\begin{bmatrix} V_{dvr,a}^{ref} \\ V_{dvr,b}^{ref} \\ V_{dvr,c}^{ref} \end{bmatrix} = \begin{bmatrix} \cos(\omega t) & \sin(\omega t) & 1 \\ \cos(\omega t-120) & \sin(\omega t-120) & 1 \\ \cos(\omega t+120) & \sin(\omega t+120) & 1 \end{bmatrix} \cdot \begin{bmatrix} V_{dvr,d}^{ref} \\ V_{dvr,q}^{ref} \\ V_{dvr,0}^{ref} \end{bmatrix} \quad (12)$$

Where, $V_{dvr,a}^{ref}$, $V_{dvr,b}^{ref}$ and $V_{dvr,c}^{ref}$ are DVR reference injected voltages of phase a, b and phase c, respectively.

V. MULTILEVEL INVERTERS

There are mainly three types of MLI topologies:

1. Diode clamped multilevel inverter
2. Flying capacitor multilevel inverter
3. Cascaded H- bridge multilevel inverter

A. Diode clamped MLI:

The advantages of DCMLI are:

i. More number of levels leads to less harmonic distortion.
ii. Reactive power flow is controlled.
iii. High efficiency for fundamental switching frequency.
iv. Control method is easy.

The disadvantages of DCMLI are:

i. More number of clamping diodes.
ii. Real power flow is difficult because of imbalance capacitances.

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

iii. Different current ratings required for switches.

B. Flying capacitor MLI:

The advantages of FCMLI are:

i. Flexible switch redundancy for balancing the voltage.
ii. Lower harmonic distortion when levels are more.
iii. Both real and reactive power is controlled.

The disadvantages of FCMLI are:

i. Excess number of storage capacitors.
ii. Inverter control is complicated.
iii. Switching frequency and losses are more.

C. Cascade H-bridge MLI:

The advantages of H-bridge MLI are [5]:

i. Switching losses and device stress is less.
ii. Least number of components are required.
iii. Potential of electric shock is less.

The disadvantages of H-bridge MLI:

It is limited to certain applications because separate DC sources are required

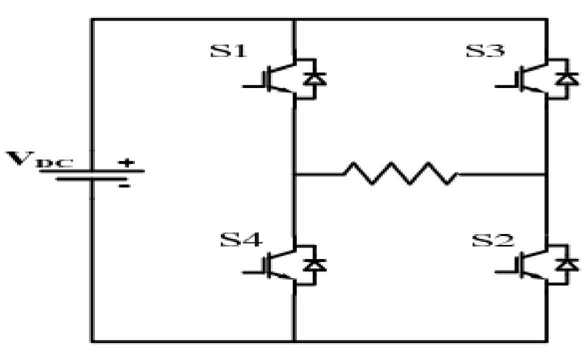


Fig.4. H-Bridge inverter

From above all discussion we can conclude that in all these topologies CHB topology is advantageous because of individual dc voltage sources which are available like batteries and fuel cells. In diode clamped MLI excess clamping diodes are required as number of levels increases clamping diodes requirement increases rapidly and it is difficult to control the power flow in flying capacitor MLI excess numbers of storage capacitors are required and it is difficult to maintain voltage balance in between capacitors. Now coming to required total number of switches for same level are more in diode clamped and flying capacitor because of clamping diodes and storage capacitors. This paper deals with different levels like three, five, seven, nine level topologies of CHB MLI and comparisons of THD of each inverter. By increasing no of levels we can reduce the total harmonic distortion for power quality improvement we have to reduce the harmonic content to meet the minimum harmonic distortion level of IEEE-519 [7].The harmonic content decreases as the number of levels increases and filtering requirement reduces. This paper presents detail enhancement of simulation results of different levels CHB inverter [6] and comparison of THD between them.

VI. MATLAB/SIMULINK RESULTS

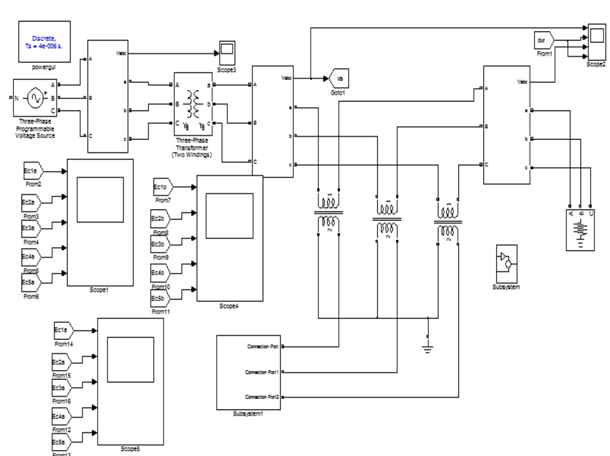


Fig.5 matlab/Simulink circuit for proposed DVR Topology

International Journal for Innovative Engineering and Management Research

A Peer Revieved Open Access International Journal

www.ijiemr.org

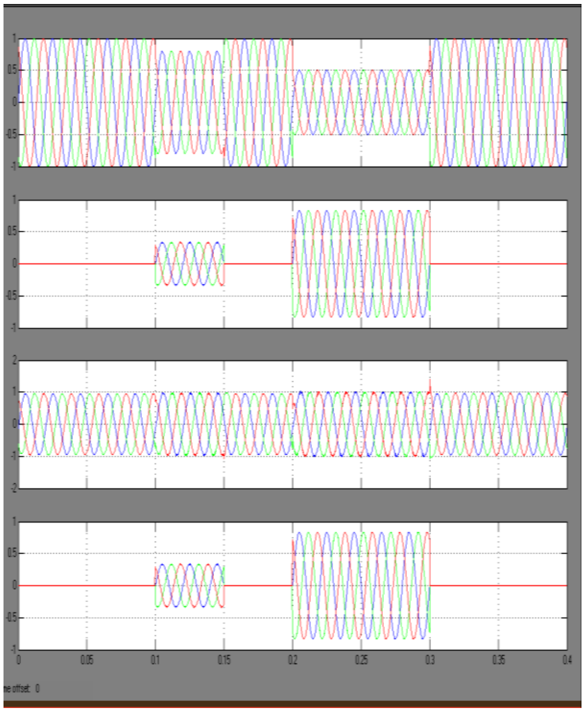
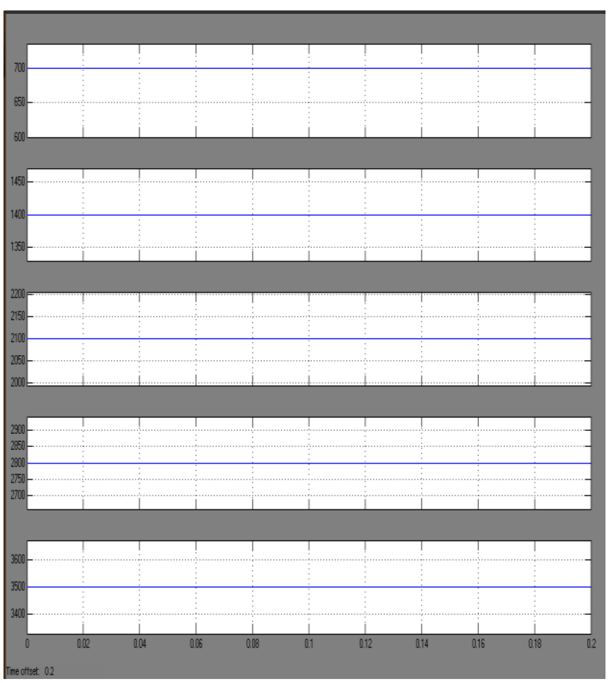
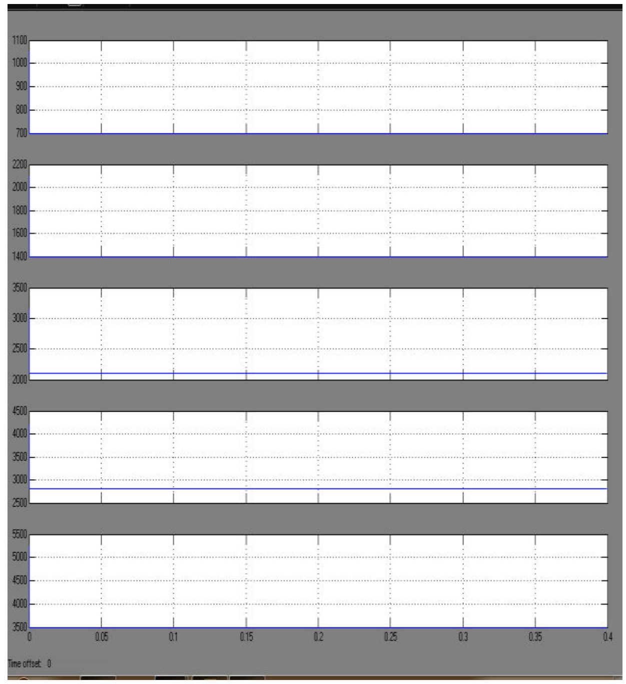


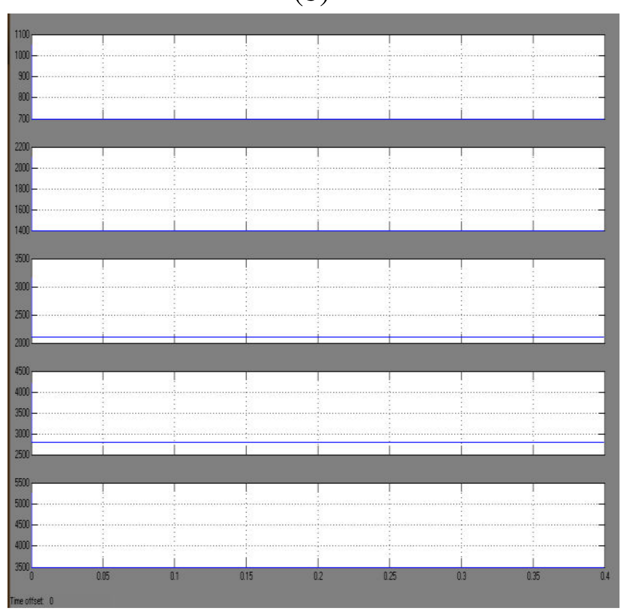
Fig.6 Simulation results of the first case study performed for voltage sag mitigation using pre-sag compensation method: (a) grid voltages; (b) DVR injected voltages; (c) sensitive load voltages; (d) DVR reference voltages in per unit.



(a)



(b)



(c)

Fig.7 Simulation results of the first case study performed for voltage sag mitigation using pre-sag compensation method: (a) flying-capacitor voltages in phase a of the DFCM converter; (b) flying-capacitor voltages in phase b of the DFCM converter; (c) flying-capacitor voltages in phase c of the DFCM converter.

International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org

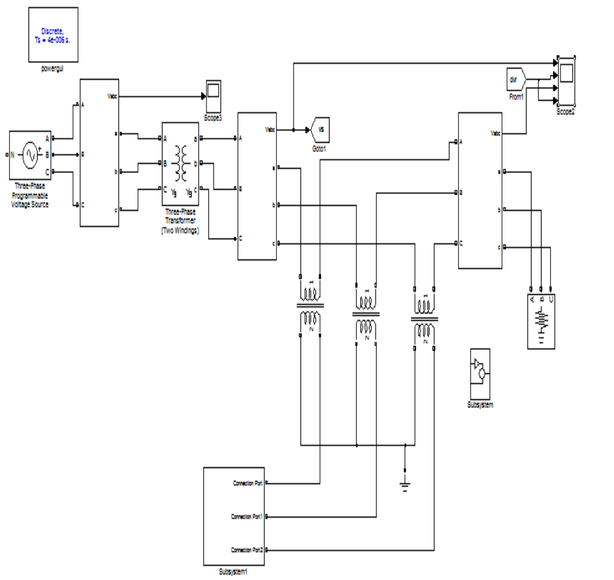


Fig.8 Matlab/Simulink circuit for DVR based on DFCM converter for medium-voltage applications.

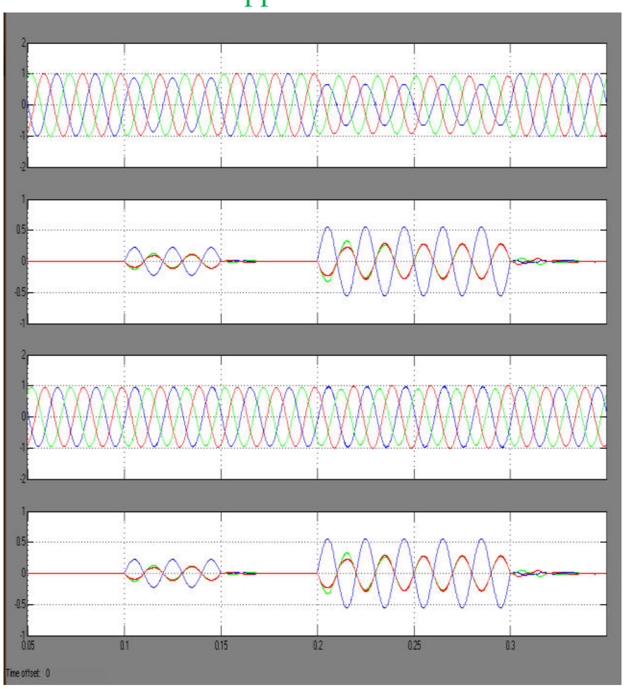


Fig.9 Simulation results of the second case study performed for voltage sag mitigation using pre-sag compensation method: (a) grid voltages; (b) DVR injected voltages; (c) sensitive load voltages; (d) DVR reference voltages in per unit

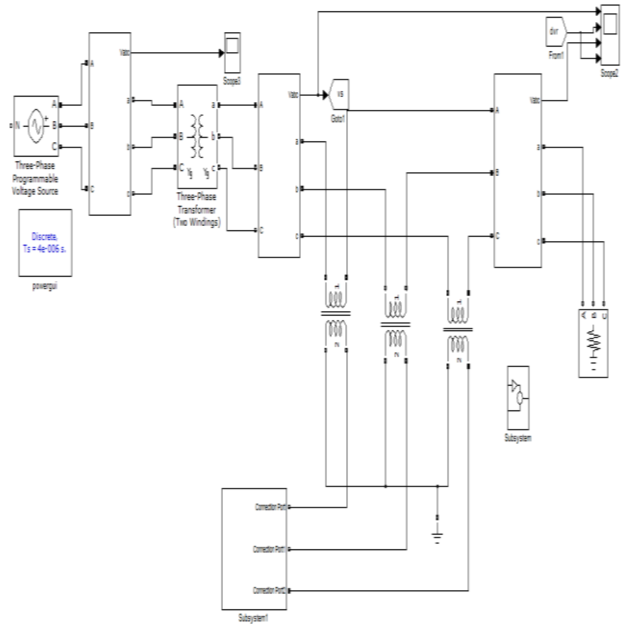
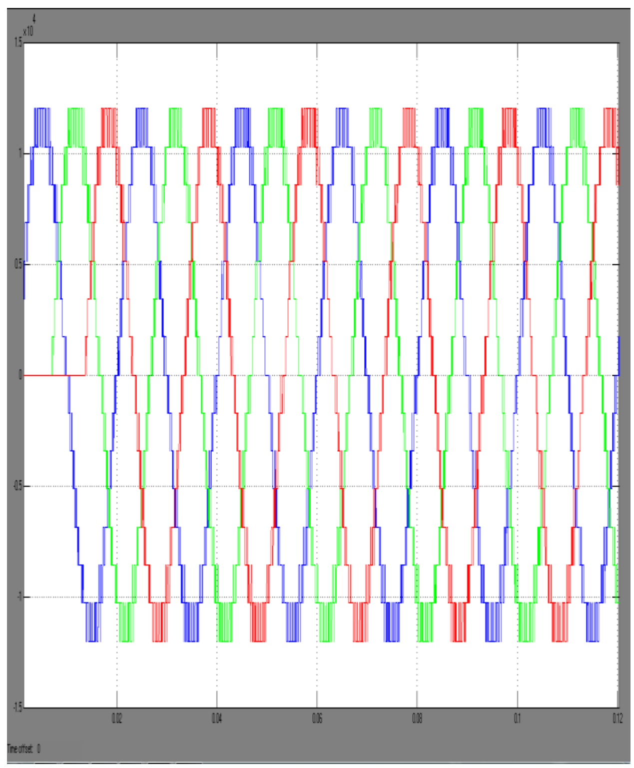
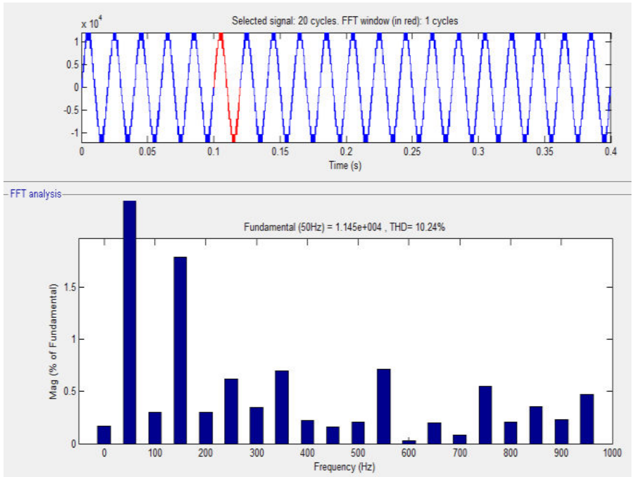


Fig.10 Matlab/Simulink circuit for DVR based on Asymmetrical H-Bridge Inverter15 level

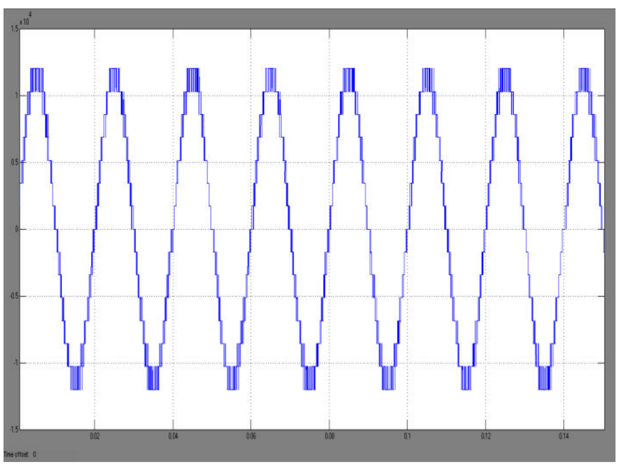


(a) Three Phase 15 level Asymmetrical CHB without filter

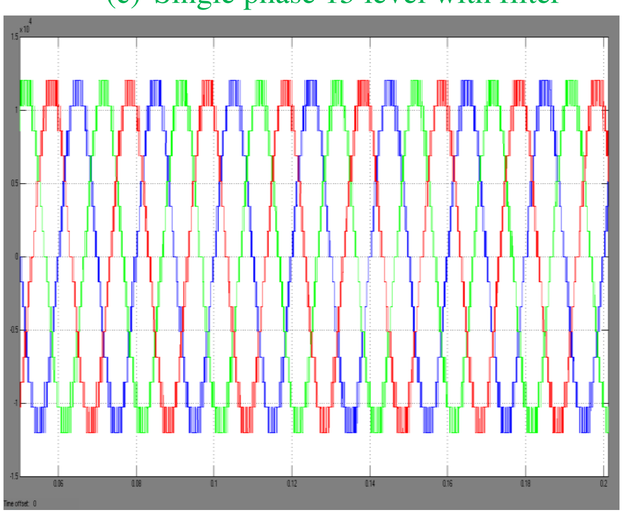
International Journal for Innovative Engineering and Management Research
A Peer Revieved Open Access International Journal
www.ijiemr.org



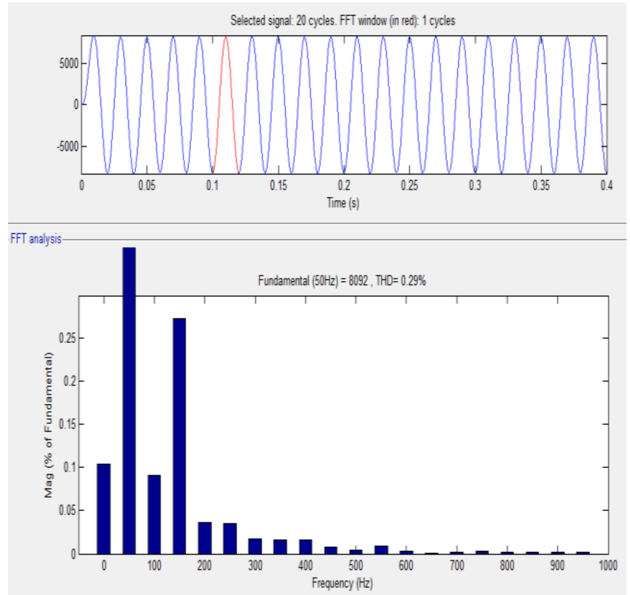
(b) THD waveform for 15 level ACHB MLI without Filter



(c) Single phase 15 level with filter



(d) Three Phase 15 level Asymmetrical CHB with filter



(e) THD waveform for 15 level ACHB MLI with Filter

Fig.11 Output waveforms and THD waveforms for Asymmetrical H-Bridge Inverter15 level

VII. CONCLUSION

In this paper, Dynamic voltage restorer (DVR) based multilevel inverter (MLI) is utilized to lessen the voltage sags, thereby improving the power quality of system. The used scheme are employed & tested for medium voltage (MV) distribution network with secondary supply system. The asymmetrical cascade H-bridge MLI based DVRs are connected step by step in the compensated feeder to evaluate their performances. The efficacy of different control techniques of asymmetrical CHB MLI has been investigated. As seen from load voltage waveform & frequency spectrum, the THD level is reduced effectively from 0.29% as in case of 15-level MLI based DVR. Simulations outcome indicate to facilitate 15-level MLI based provide better compensation to the system and also there is considerable improvement in power quality also.

REFERENCES

[1] Mayank Paliwal, Rohit Chandra Verma and Shaurya Rastogi "Voltage Sag Compensation Using Dynamic Voltage Restorer", ISSN 2231-1297, Vol. 4, No.6 (2014), pp. 645- 654.

[2] V.Priya, N.Sugandhi "DVR Using Diode Clamped Multilevel Inverter with Multicarrier Based Pulse Width Modulation Technique", International Journal of Engineering Research and Development- Vol. 9, Issue 6 (December 2013), PP. 27-33.

[3]Sanjay Haribhai Chaudhary, Mr. Gaurav gangil "Mitigation of voltage sag/swell using Dynamic voltage restorer (DVR)", IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)- Vol. 8, Issue 4 (Nov. - Dec. 2013), PP 21-38.

[4] Zulkifilie Bin Ibrahim, Md. Liton Hossain, Ismadi Bin Bugis, Jurifa Mat Lazi, Nurazlin Mohd Yaakop, " Comparative Analysis Of PWM Techniques For Three Level Diode Clamped Voltage Source Inverter ",International Journal Of Power Electronics And Drive System (IJPEDS) - Vol. 5, No. 1, July 2014, Pp. 15~23.

[5] J. Rodriguez, J. S. Lai, and F. Z. Peng, "Multilevel inverters: A survey of topologies, controls, and applications," IEEE Trans. Ind. Electron., vol. 49, no. 4, pp. 724–738, Aug. 2002.

[6] T.Ohnishi and H.Okitsu, "A novel PWM technique for three-phase inverter/converter," International Power Electronics Conference, 1983, pp.384-395.

[7] A. Nabae, I. Takahashi, and H. Akagi, "A new neutral point clamped PWM inverter," IEEE Trans. Ind. Applicat., vol. IA-17, pp. 518–523, Sept./Oct. 1981.

[8] N. Celanovic and D. Boroyevic, "A fast space vector modulation algorithm for multilevel three-phase converters," in Conf. Rec. IEEE-IAS Annu. Meeting, Phoenix, AZ, Oct. 1999, pp. 1173–1177.

[9] J. Rodríguez, P. Correa, and L. Morán, "A vector control technique for medium voltage multilevel inverters," in Proc. IEEE APEC, Anaheim, CA, Mar. 2001, pp. 173–178.

[10]P. Hammond, "A new approach to enhance power quality for medium voltage ac drives," IEEE Trans. Ind. Applicat., vol. 33, pp. 202–208, Jan./Feb. 1997.

[11]L. Tolbert and T. G. Habetler, "Novel multilevel inverter carrier-based PWM method," IEEE Trans. Ind. Applicat., vol. 35, pp. 1098–1107, Sept./Oct. 1999.

[12]B. N. Mwinyiwiwa, Z.Wolanski, and B. T. Ooi, "Microprocessor implemented SPWM for multi converters with phase-shifted triangle carriers," in Conf. Rec. IEEE-IAS Annu. Meeting, New Orleans, LA, Oct. 1997, pp. 1542–1549.

[13] V. G. Agelidis and M. Calais, "Application specific harmonic performance evaluation of multicarrier PWM techniques," in Proc. IEEE PESC'98, Fukuoka, Japan, May 1998, pp. 172–178.

[14] W. A. Hill and C. D. Harbourt, "Performance of medium voltage multilevel inverters," in Conf. Rec. IEEE-IAS Annu. Meeting, Pheonix, AZ, Oct. 1999, pp. 1186–1192.