Power Quality Improvement By Using CHB Inverter Based DVR

Bharti Vaidya[1], Prasant Debre[2], Akshay Kadu[3]

[1] Student, Dept. of Elect. Engg., Rajiv Gandhi College of Engineering & Research, Nagpur, India
[2,3] Associate Professor, Dept. of Elect. Engg., Rajiv Gandhi College of Engineering & Research, Nagpur, India

---

Abstract - *Power quality is one of the major concerns in the power system. Power quality problem occurred due to non-linear load in distribution network and its severe impact on sensitive loads. To overcome this problem, the DVR is a modern and important custom power device for compensation of voltage sags in power distribution system, which is efficient and effective power electronics device. The DVR is a series connection device which injects an appropriate voltage to restore a voltage waveform and ensure constant load voltage. This paper presents the design and analysis of a DVR which employing 7-level cascade H-bridge inverter. The CHB based inverter enables the DVR to connect directly to the distribution network which eliminates the series injection transformer. The modeling and performance of DVR is analyzed using MATLAB software*.

Key Words: **Dynamic Voltage Restorer (DVR), Power Quality (PQ), Cascade H-Bridge Inverter (CHB)** etc.

1. INTRODUCTION

Modern power system is complex power network, where hundreds of generating loads and thousands of loads interconnected through networks. The main concern is to provide a quality of power to the costumer [8]. In distribution system have numerous nonlinear loads, which affect the quality of power supply. The effect of power quality is on sensitive load which are connected on power system. The power quality problem occurred due to voltage sag, voltage swell, flicker, interruption, voltage imbalance and harmonics imbalance.Power quality is described as the variation of voltage, current and frequency in a power system [4]. Power quality problems have major concern of the industrial and commercial electrical consumers due to enormous losses. Among all of the power quality problem voltage sag is most severe disturbances. It occurred due to load switching, motor starting, faults, non-linear load; lightning etc. to overcome this problem modern custom power device is introduced recently. In 1995 the concept of custom power device is first explained by Hingorani [1]. These are compensating power electronics devices connected in shunt or series or in combination of both. The widely known custom power devices are DSTATCOM, DVR and UPQC. One of those devices is the Dynamic Voltage Restorer (DVR), which is one of the most efficient and modern custom power device used in distribution network. A DVR is a series connected solid state device that injects voltage into the system to regulate load side voltage. It is normally installed in a distribution system between the supply and a critical load feeder. Its primary function is to rapidly boost up the load side voltage in the event of voltage sag [4]. To achieve this functionality reference voltage is generated which is similar in magnitude and phase angle to that of supply waveform. Therefore by comparing reference and actual voltage waveform any abnormality can be detected. This paper divided in five section II part deals basic structure of DVR Section III describes multilevel cascaded H-Bridge Inverter. Section IV discusses various compensation methods for voltage quality improvement. Section V shows circuit configuration with analysis of result last section deals with conclusion of this work

2. DVR STRUCTURE

The general configuration of DVR consists of:

1. An injection transformer
2. A harmonic filter
3. A voltage source converter
4. Storage device
5. DC charging device
6. Control and protection system
7.

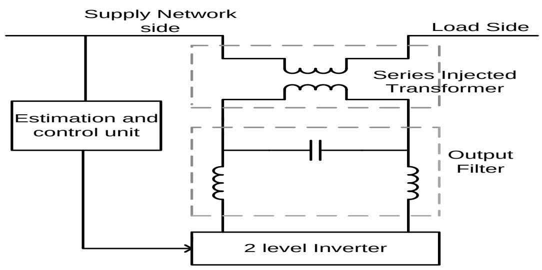


Figure 1: Conventional DVR structure

When sag is occurred in the system, the DVR is required to inject active power into the distribution line during the period of compensation[14]. Hence the capacity of the energy storage unit can become a limiting factor in the process of long duration sag. The power may pass through this transformer during compensation. A power source which provides this level of power, the transformer would be a bulky element which adds losses in the system[9]. Due to this disadvantage of the conventional DVR new CHB-based DVR is utilized in this paper.

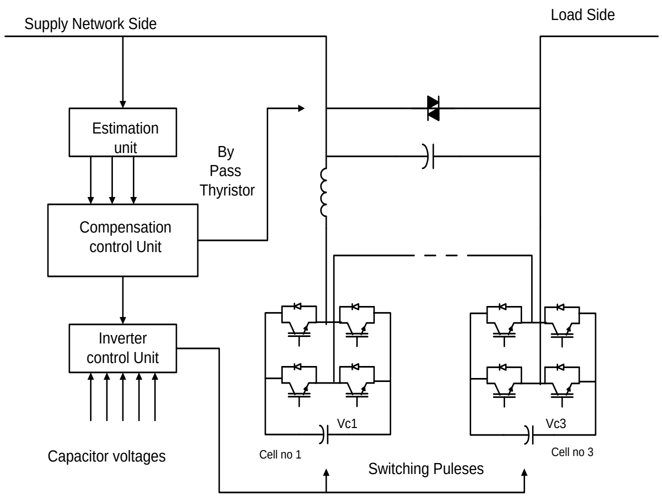


Figure 2: CHB based DVR structure

Figure 2 illustrates structure of the DVR that is utilized in this paper. This DVR employs a multilevel CHB inverter which generates voltage waveforms with small dv/dt and low THD. Due to this series connection H-bridge inverter, it can be easily extended for different voltage and power levels.

1. SEVEN LEVEL CHB INVERTER

The usual two or three levels inverter does not significantly eliminate the unnecessary harmonics in the output waveform. Therefore, we are using multilevel inverter. In this technique, the number of phase voltage levels at the converter terminals is 2N+1, where N is the dc link voltages or number of cells. In this arrangement, every cell has a separate dc link capacitor and the voltage through the capacitor may vary among the cells. So, every power circuit needs only a single dc voltage source. The quantity of dc link capacitors depends on the number of phase voltage levels .Every cell of H-Bridge can have positive, negative or zero voltage. Cascaded H-bridge multilevel inverters usually have IGBT switches [15]. Such switches have low block voltage and high switching frequency.

Every single DC source is linked with a single H-bridge converter & AC terminal voltages of various level converters are joined in series and generate three different voltage outputs, $+V_{dc}$, $-V_{dc}$ and zero. The output of AC voltage waveform is the summation of all converter outputs.

Now a day multilevel inverter get more popular in high power application specially in variable speed drives and interconnecting renewable source of energy with grid. Here seven level Inverter is used to interconnect DVR with grid.

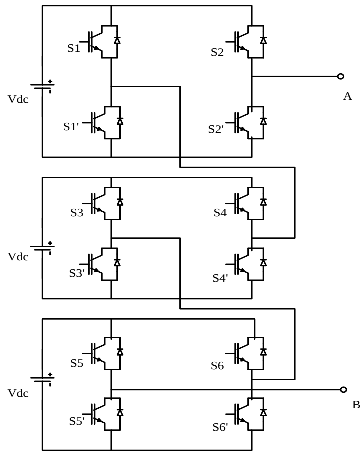


Figure 3: 7 Level CHB Inverter

2. COMPENSATION METHOD

DVR is used during compensation is depends on several limiting factors such as: DVR power rating, condition of load and type of voltage sags. Compensation is achieved via real and reactive power injection in the system [8]. The compensation is possible in three different ways:

A. Pre-sag compensation
B. In-phase compensation
C. Energy optimization

4.1 Pre-sag compensation

In this method, the non-linear loads which need both voltage magnitude as well as phase angle to be compensated. This method is the simplest way of compensation which inject smallest amount of voltage, while it require the largest amount of active power. The DVR supplies the difference between the pre-sag and the sag voltage, thus restore the voltage magnitude and phase angle to that of the pre-sag value. Drawback of this method is that it requires higher capacity energy storage device.

4.2 In-phase compensation

The compensated voltage is in phase with the sagged voltage, therefore this technique minimize the voltage injected by the DVR. The control system will then generate a reference sinusoidal signal which is in-phase with the source voltage and its magnitude is equal to depth of voltage sag. This voltage is fed to the inverter and the compensating voltage is generated which added to the source voltage and restore the load voltage. It is recommended for the linear loads.

4.3 Energy optimization

This method usually requires a large injection voltage. The load will experience active power drop and phase jump: but active power is not required, no need of active energy source. This method is employed for protection of high power loads.

3. SYSTEM CONFIGURATION & SIMULATION

Converter type	Medium voltage connection	Energy storage	Switching frequency	Voltage balance	Unbalanced compensation	Size of line filter	Harmonic mitigation
2 level	Transformer	Batteries	High	-	No	Medium	No
2 level	Transformer	Batteries	High	-	No	Medium	Yes
Direct matrix	Transformer	Grid	High	-	No	Medium	No
AC-AC, buck, boost	Transformer	Grid	High	-	No	Medium	No
2 level, AC-AC	Transformer	Grid	High	-	No	Medium	No
CHB	Direct	Batteries	Low	-	Yes	Small	Yes
CHB, DC-DC	Direct	Batteries	Low	-	No	Small	No
CHB	Direct	Capacitors	Low	No	Yes	Small	No
CHB (current study)	Direct	Capacitors	Low	Yes	Yes	Small	Yes

RESULT

A 3Ø 7 level CHB based DVR for compensating voltage sag is as shown in fig [4]. The compensator is connected in series through a DIAC & LC filter at the PCC (Point of coupling).

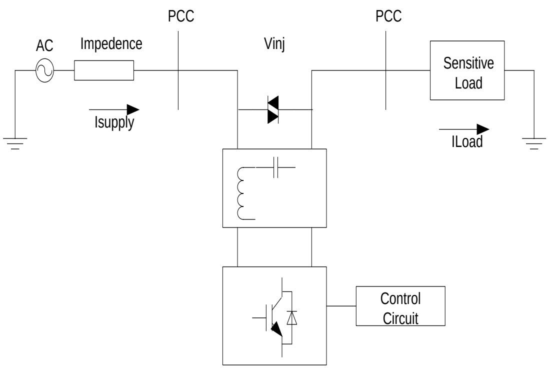


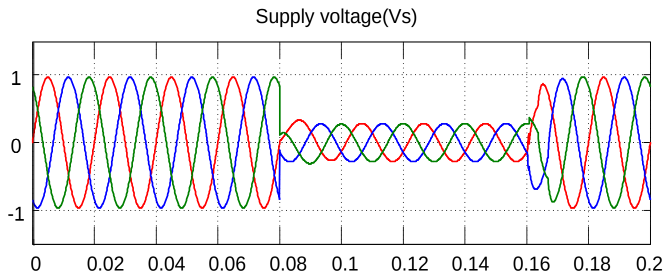
Figure 4: System Diagram

The system parameters used for the simulation study are shown in table 1.

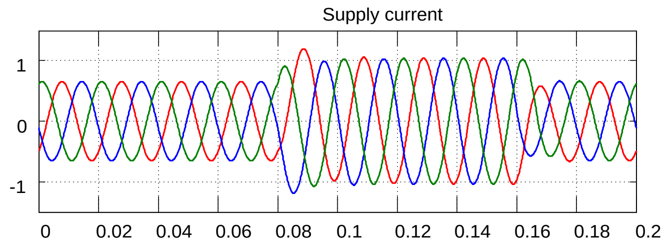
TABLE II SYSTEM PARAMETERS

SystemParameters	Values(Rating)
Sy stem voltage	480 V rms/phase 50 Hz AC Supply
Line Parameters	R=0.2Ω , L=1e-3H
Line Filter Capacitor	90μF
Line Filter Inductor	1.1Mh
CHB Inverter	V_{dc}=300V No. of H Bridge cells per phase= 3
PI controller gains	K_p=-100 , K_i=0

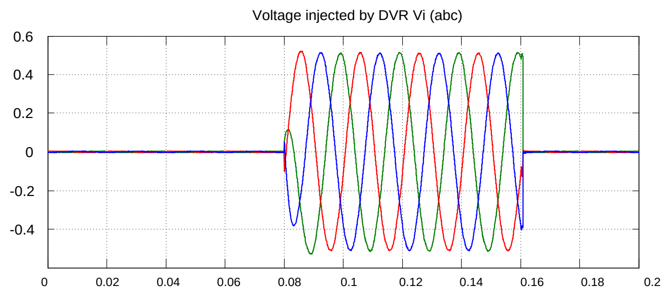
The system shown in Fig [4] is simulated in MATLAB. Table II shows the system parameters used in simulation. The system consist of source, load & in addition a CHB based DVR.



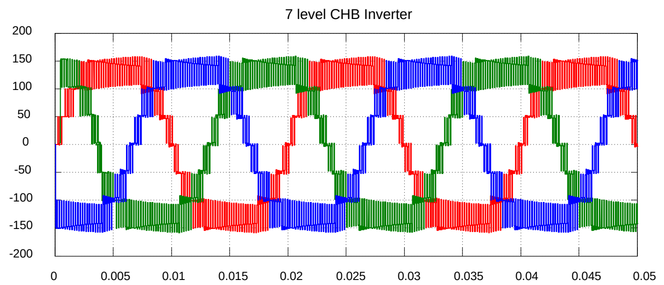
5(a)



5(b)

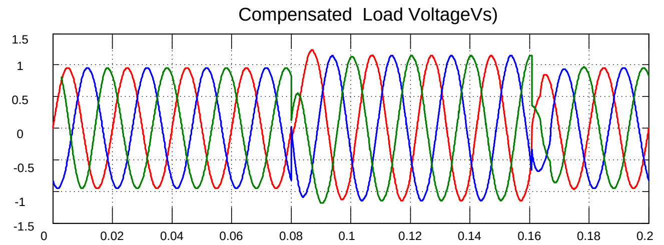


5(c)

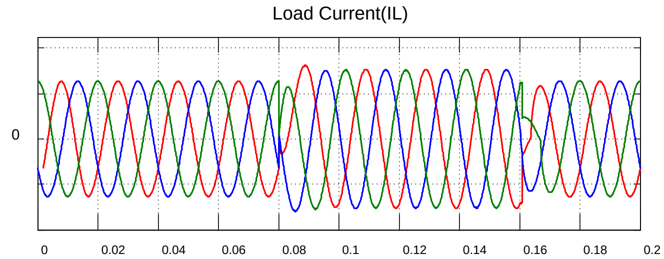


5(d)

The waveform shows transition from 0.2 sec for all the conditions the source voltages are assumed to be balanced and sinusoidal



5(e)



5(f)

The figure 4 shows the performance of uncompensated system. The supply currents are distorted and unbalance due to the presence of voltage sag shown in Figure [5]. Where figure 5[e] &5[f]shows waveforms of load currents and load voltages respectively. The source voltages & source currents are completely balanced & distortion free, even in the presence of voltage sag. Figure 5[c] shows waveform of voltage injected by DVR. Figure 5[d] shows the output voltage of 7 level CHB inverter.

4. CONCLUSION

This paper mainly focused on the compensation of voltage sag in the system for improving the quality of a distribution system .The effective implementation CHB based DVR results in a desirable output. The conventional DVR increases the extra losses in the system because of coupling transformer which is connected in series with the line. This system ensures the power quality enhancement. Detailed simulation results shown the effectiveness of DVR in a distribution network.

REFERENCES

[1] ArindamGhosh, and Gerard Ledwich, "Power quality enhancement using custom power devices," *Springer International Edition*, pp.241-285.

[2] N.G. Hingorani, and L. Gyugyi, "Understanding FACTS," IEEE Power Engineering Society, IEEE Press, Inc., New York, pp. 135 207.

[3] EuzeliCipriano Dos Santos Jr. ,Edison Roberto Cabral Da Silva "ADVANCED POWER ELECTRONICS CONVERTERS PWM Converters ProcessingAC Voltages" IEEE press on power engineering 2015 by The Institute of Electrical and Electronics Engineers, Inc.

[4] Shazly A. Mohammed, Aurelio G. Cerrada, Abdel-Moamen M. A, and B. Hasanin "Dynamic Voltage Restorer (DVR) System for Compensation of Voltage Sags, State-of-the-Art Review" International Journal Of Computational Engineering Research (ijceronline.com) Vol. 3 Issue. 1

[5] Juan A. Martinez, Member, IEEE, and Jacinto Martin-Arnedo "Voltage Sag Studies In Distribution Networks-Part I: System Modeling" IEEE Transcation On Power Delivery, Vol. 21, No. 3, July 2006

[6] Juan A. Martinez, Member, IEEE, and Jacinto Martin-Arnedo "Voltage Sag Studies In Distribution Networks-Part II: Voltage Sag Assessment" IEEE Transcation On Power Delivery, Vol. 21, No. 3, July 2006

[7] Juan A. Martinez, Member, IEEE, and Jacinto Martin-Arnedo "Voltage Sag Studies In Distribution Networks-Part III: Voltage Sag Index Calculation" IEEE Transcation On Power Delivery, Vol. 21, No. 3, July 2006

[8] Kapil P. Radadiya, Dr. Chirag K. Vbhakar, Sachin V. Rajani "Voltage Sag/Swell Compensation Using Dynamic Voltage Restorer (DVR)" International Journal Of Application Or Innovation In Engineering And Management (IJAIEM) 2013

[9] SoleimanGaleshi, HosseinIman-Eini "Dynamic voltage restorer employing multilevel cascaded H-bridge inverter" School of Electrical and Computer Engineering, College of Engineering, University of Tehran, Tehran 111554563

[10] Shakti Prasad Mishra, BishnupriyaBiswal, J Pretha Roselyn, D. Devaraj "Simulation & Analysis of DVR for mitigating voltage sags & swells" international Conference on DESIGN & MANUFACTURING, IconDM 2013

[11] Ahmed M. Saeed, Shaby H. E. Abdel Aleem, Ahmed M. Ibrahim, Murat E. Balci, Essam E. A. El-Zahab "Power conditioning using dynamic voltage restorers under different voltage sag types" Journal of Advanced Research(2016)7,95-103

[12] Harithainavolu "Design and analysis dynamic voltage restorer with fuzzy controller of multilevel cascaded h-bridge inverter" International Journal of Advanced Research Trends in Engineering and Technology (IJARTET) Vol. 4, Special Issue 16, April 2017

[13] M. SwathiPriya, Dr.T.Venkatesan "A Dynamic Voltage Restorer with Voltage Sag Compensation at Medium Voltage Level Using PI Control Scheme" International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering (An ISO 3297: 2007 Certified Organization) Vol. 3, Issue 2, February 2014

[14] Saranya S, Samina T "Multilevel Inverter Based Dynamic Voltage Restorer with Hysteresis Voltage Control for Power Quality Improvement" International Journal of Scientific Development and Research (IJSDR) October 2016 IJSDR | Volume 1, Issue 10

[15] AbhinayShrivastav, AamirSohail, Ravi Pandey, ShivamSachan, Naimuddin "Single Phase Seven Level Cascaded H-Bridge Multilevel Inverter" International Journal of Engineering Science and Computing, April 201