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Power Quality Improvement Using 3 Phase Cascaded H-Bridge Multi Level Inverter Under Unbalanced Voltage Conditions

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Abstract :
A Multilevel Inverter(MLI) is a power electronic device built to synthesize a desired A.C voltage from several levels of DC voltages. Generally unbalanced voltages will occur at supply side these can be eliminated by using Multi level Inverter. In this paper a closed loop Control system is designed using PI controller in order to maintain load voltage constant for under voltage and Over voltage conditions and MATLAB simulations have been carried out.
Keywords:- Cascaded H-Bridge Multi Level Inverter(CHMLI),Power Quality Issues.

I.INTRODUCTION

Multilevel inverters have gained more attention in high power applications because it has got many advantages [1-4]. It can realize high voltage and high power output by using semiconductor switches without the use of transformer and dynamic voltage balance circuits. When the number of output levels increases, harmonic content in the output voltage and current as well as electromagnetic interference decreases.
The basic concept of a multilevel inverter is to achieve high power by using a series of power semiconductor switches with several lower dc voltage sources to perform the power conversion by synthesizing a staircase voltage waveform [1,5]. To obtain a low distortion output voltage nearly sinusoidal, a triggering signal should be generated to control the switching frequency of each power semiconductor switch .In this paper the triggering signals to multi level inverter (MLI) are designed by using the Sine Pulse Width Modulation (SPWM) technique. A three phase cascaded H-bridge Multi (five) Level Inverter has been taken. Fig.1 shows a three-phase five-level cascaded Multi Level Inverter. It requires a total of six D.C voltage sources.

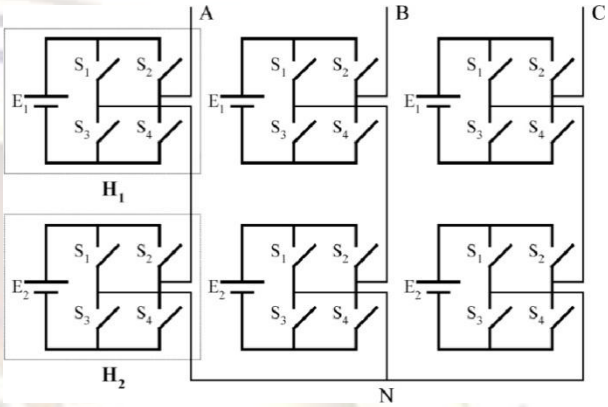


Fig.1 Conventional three phase 5 level cascaded MLI

This paper investigates an approach where the reference signal is modulated by the carrier wave resulting in multiple SPWM signals. These signals are then used to drive the „on" / „off" switches for each level of the inverter.

II.CONTROL TECHNIQUES FOR MULTILEVEL INVERTER

There are different control techniques available for a CHB MLI [13, 15]. Among all those techniques, PWM control technique which produces less total harmonic distortion (THD) values is most preferable. In PWM technique, modulated signal can be of pure sinusoidal, third harmonic injected signals and dead band signals. The carrier signal is a triangular wave. For generating Triggering pulses to MLI, pure sinusoidal wave as modulating signal and multi carrier signal which is of triangular in shape have been considered [10, 14, 15]. For a m-level MLI, (m-1) carrier signals are required.

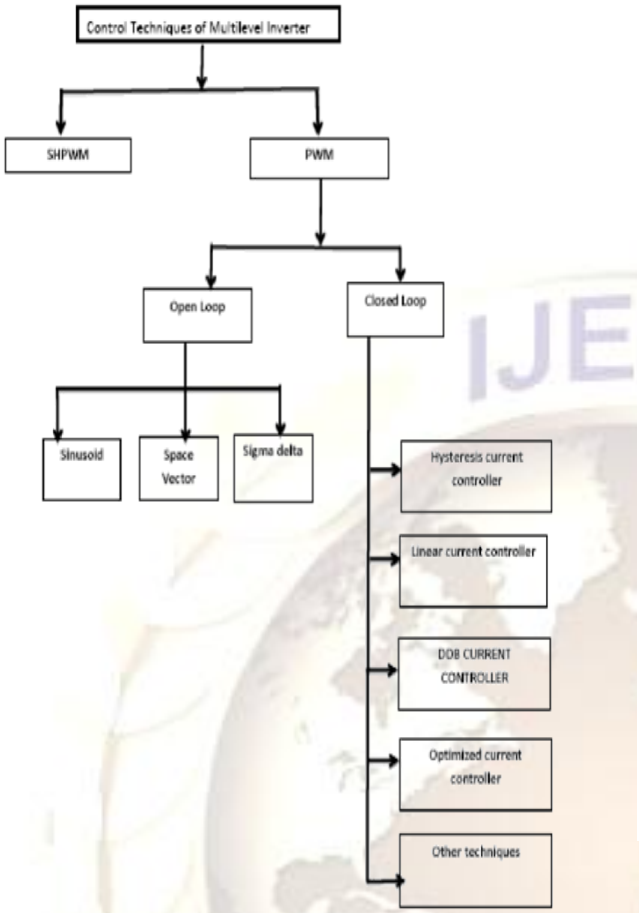


Fig.2 Control techniques for a cascaded H-bridge MLI

Sinusoidal PWM

For generation of triggering pulses to the MLI, carrier signals are constructed for different modulation indices like APOD, POD, PD, PS and Hybrid control techniques. Output phase voltage has been measured using all the techniques. THD analysis for the PS control techniques in Bipolar mode of operation have been presented in this paper. Multilevel sinusoidal PWM can be classified as shown in Fig.3 [14-19].

Multi carrier PWM techniques have sinusoidal signal as reference wave and triangular as carrier signals [6-7].

Amplitude Modulation $M_a=A_m/((m-1)*A_c)$.

Frequency modulation $M_f=F_C/F_r$

Here A_m =Amplitude of modulating wave (sin wave) A_c=Amplitude of carrier wave (triangular wave)

F_c =Carrier Frequency, F_r=Reference Frequency

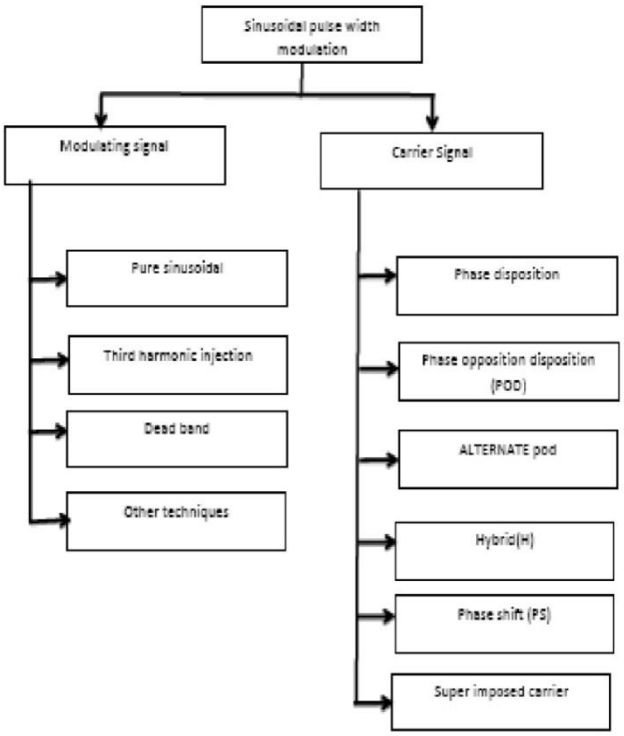


Fig.3 Classification of Sinusoidal PWM

Modes of Operation

For generating triggering pulses in Bipolar mode, four carrier signals of triangular in nature and one sine wave are used. In the case of Unipolar mode of operation, two reference sine waves and two carrier signals (level-1)/2 which are triangular in nature are used to generate the pulses to MLI[6,15]. For Unipolar mode of operation the formulae has been changed to $M_a= (A_m/ ((m-1)/2*A_c)$,

$M_f= F_c /F_r$.

Phase shifted carrier control technique (PS)

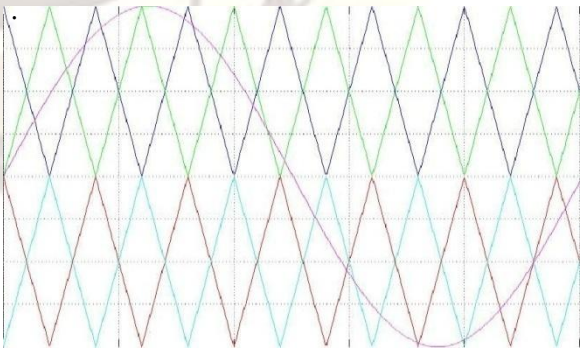


Fig.4 Carrier arrangement for Bipolar mode in PS technique

For a five level MLI, in PS technique the carrier signals which are phase shifted by 90 degrees (360/4) and the reference signal is of sinusoidal is taken and shown in Fig.4.

III. POWER QUALITY

Power Quality is the concept of powering and grounding sensitive equipment in a matter that is suitable to the operation of that equipment according to IEEE Std 1100.

Power quality is mainly concerned with deviations of the voltage from its ideal waveform (voltage quality) and deviations of the current from its ideal waveform (current quality).Power quality phenomena can be divided into two types, they are 1)Variations 2)Events.

Voltage and Current variations are relatively small deviations of voltage or current characteristics around their nominal or ideal values. The two basic examples are voltage magnitude and frequency.

Events are phenomena which only happen every once in a while. An interruption of the supply voltage [IEEE Std.1159] is the best-known example.

impedance, fault distance, system characteristics (grounded or ungrounded) and fault resistance. The duration of the sag depends on the time taken by the circuit protection to clear the fault. High speed tripping is desired to limit the duration of sags.

Over Voltage

Just like with under voltage, overvoltage events are given different names based on their duration. Over voltages of very short duration, and high magnitude, are called "Transient Over Voltages", "Voltage Spikes," or sometimes "Voltage Surges." Over Voltages with a duration between about 1 cycle and 1 minute. The latter event is more correctly called "Voltage Swell" or temporary power frequency overvoltage. "Longer" duration over voltages are simply referred to as "Over Voltages." Long and Short over voltages originate from,

lightning strokes, switching operations, sudden load reduction, single phase short circuits, and nonlinearities. A resonance between the nonlinear magnetizing reactance of a transformer and a capacitance (either in the form of a capacitor bank or the capacitance of an underground cable) can lead to a large overvoltage of long duration. This phenomenon is called Ferro resonance, and it can lead to serious damage to power system equipment.

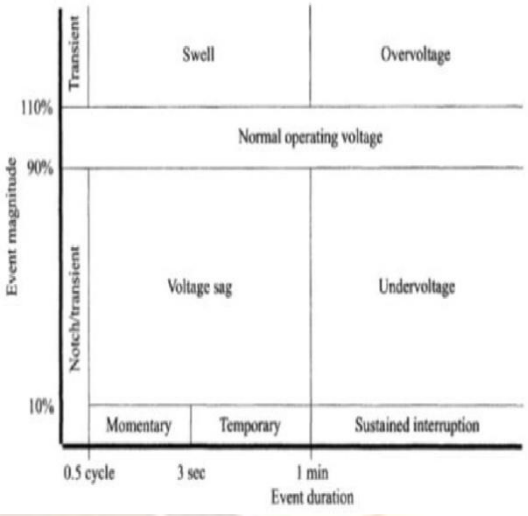


Fig.5 Voltage magnitude events as used in IEEE Std.l 159-1995

Under Voltage

Under voltages of various duration are known under different names. Short duration under voltages are called "voltage sags" or "voltage dips". Long duration under voltage is normally simply referred to as "under voltage". Voltage sag is a reduction in the supply voltage magnitude followed by a voltage recovery after a short period of time. When a voltage magnitude reduction of finite duration can actually be called a voltage sag.

For the IEEE voltage drop is only a sag if the during sag voltage is between 10% and 90% of the nominal voltage. Voltage sags are mostly caused by short circuit faults in the system and by starting of large motors.

Voltage sag is generally characterized by depth and duration. The depth of the sag depends on the system

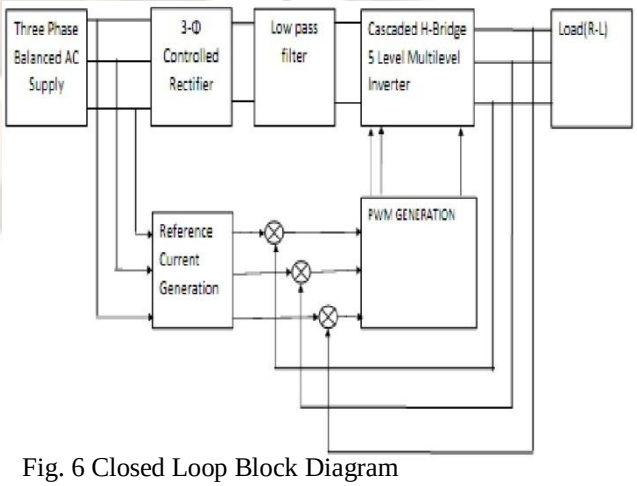


Fig. 6 Closed Loop Block Diagram

In this paper the three phase AC Voltage Supply is taken directly and is given to three phase controlled rectifier which converts AC supply to controlled pulsated DC Voltage and this is given to Low pass filter. Low pass filter is a device which converts Pulsated DC voltage to Pure DC Voltage and this pure DC Voltage is given as a input to Cascaded H-bridge 5 level Multilevel Inverter and the output of MLI is given to Load.

In closed loop Control the supply voltages and load voltages are both compared and error value is given to PI Controller. Output of PI controller is imposed on the phase shifted carrier so as to get pulses. These pulses are given to MLI for each phase. Here we are using three PI controllers for three phase MLI. The desired voltage at the load bus is maintained at 1 pu .To regulate the load-bus voltage, a PI controller is employed that contains a feedback signal derived from the voltage at the load bus, *V*.

$$Z_c = k_p e + k_i \int edt$$

K_p= Proportional constant, K_i= Integral constant, e = Error constant

Design of Filter

Here LC Filter is designed and LC Filter is the combination of two filters provides a lower ripple than is possible with either L or C alone. As it is known, in an inductor filter, ripple increases with R_L but decreases in a capacitor filter. The combination of L and C filter makes the ripple independent of R_L.

$$\text{Here } C = \frac{10}{2\times w(R_L^2 + (2wL_L)^2}$$

$$\text{VRF} = \frac{\sqrt{2}}{3}\frac{1}{(2\times w)^2 LC - 1}$$

where VRF is Voltage Ripple Factor

IV.SIMULATION STUDIES

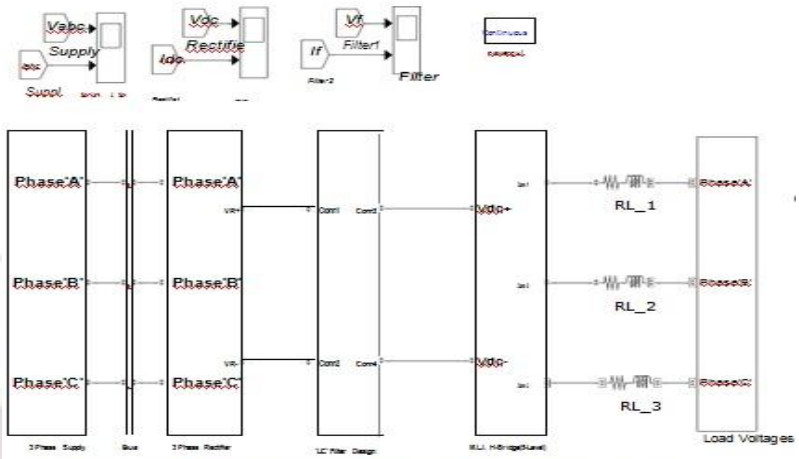
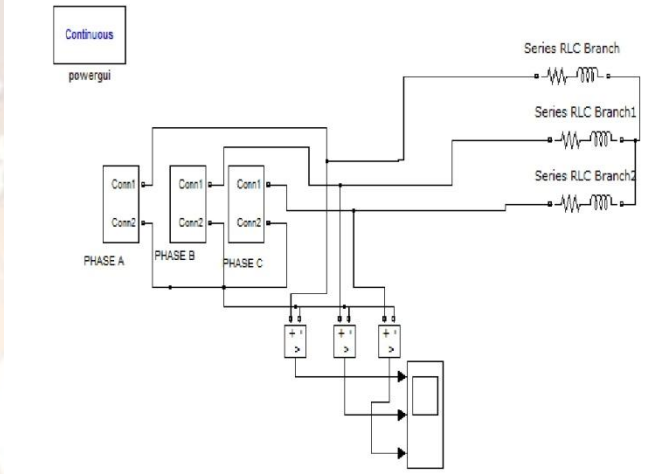


Fig. 7 open loop Simulink diagram of Cascade H-Bridge 5 Level MLI



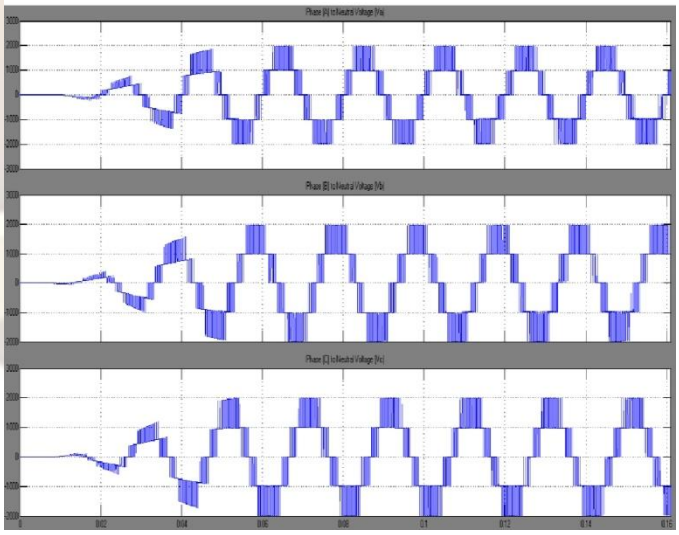


Fig 9 Output Phase Voltage Waveforms of MLI

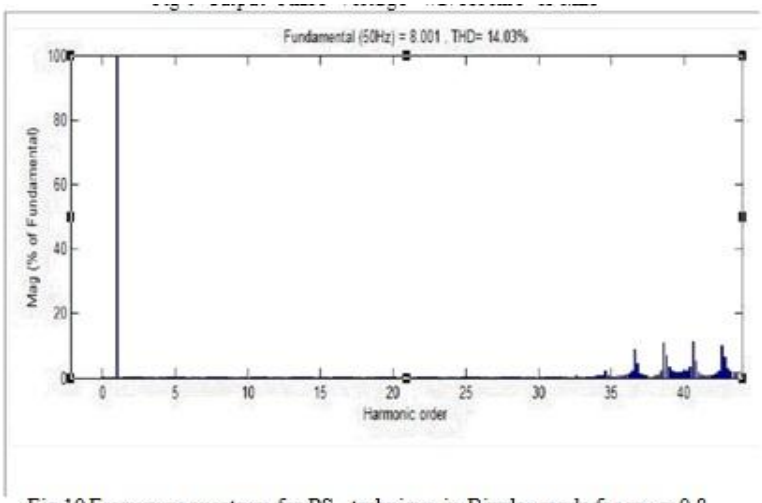


Fig.10 Frequency spectrum for PS technique in Bipolar mode for m_i = 0.8

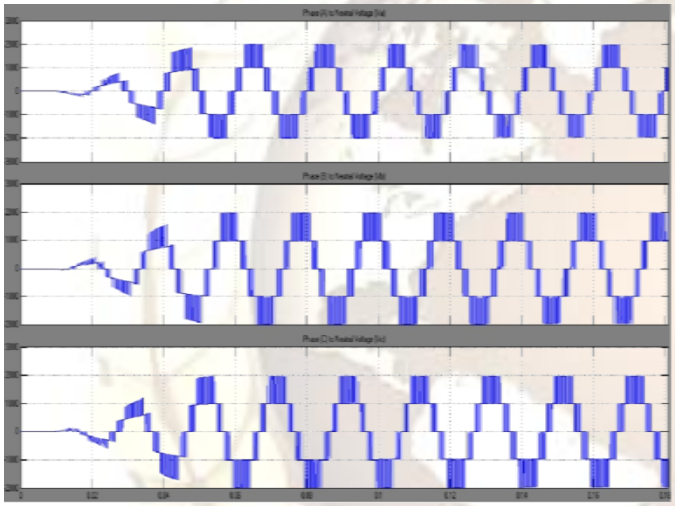


Fig.11 Open loop output voltage(2000V) waveform at rated voltage

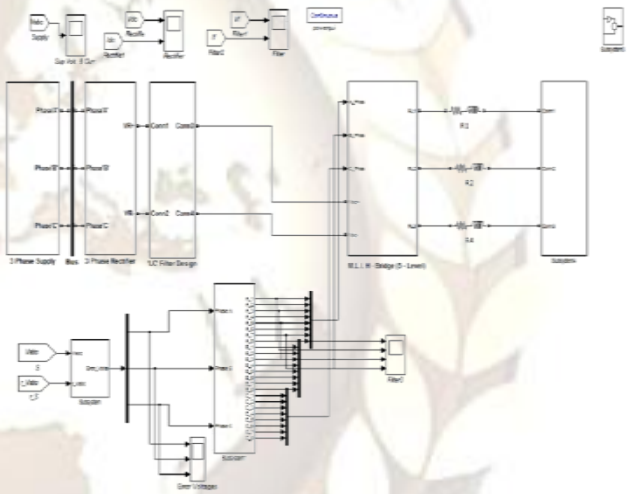


Fig.14 Closed loop Simulink diagram of Cascade H-Bridge 5 Level MLI

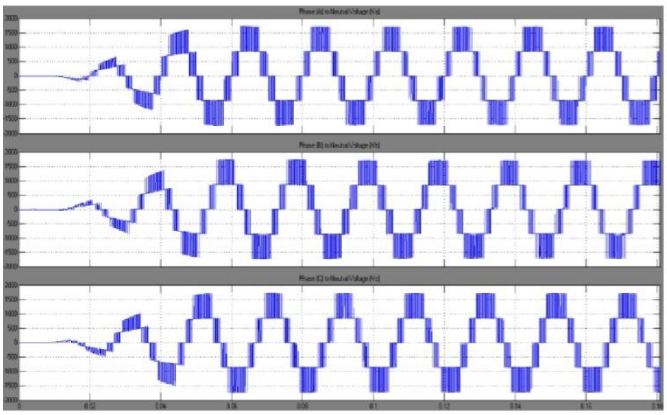


Fig. 12 Open loop Output Voltage when Under Voltage(1600V) is created

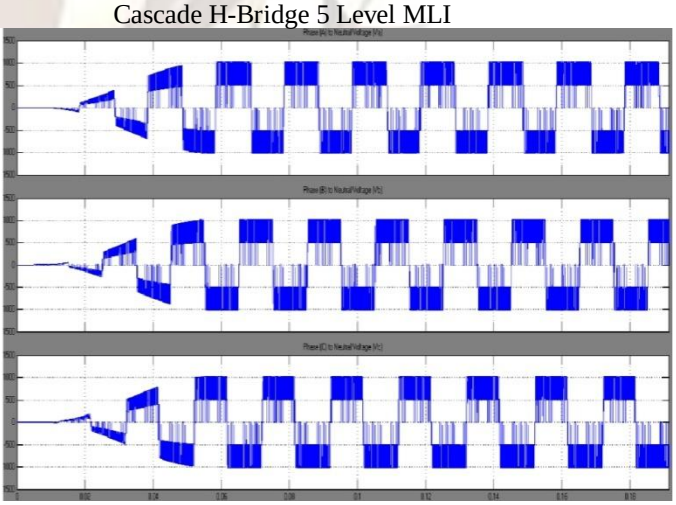


Fig 15.Closed loop output voltage(2000V) waveform at rated voltage

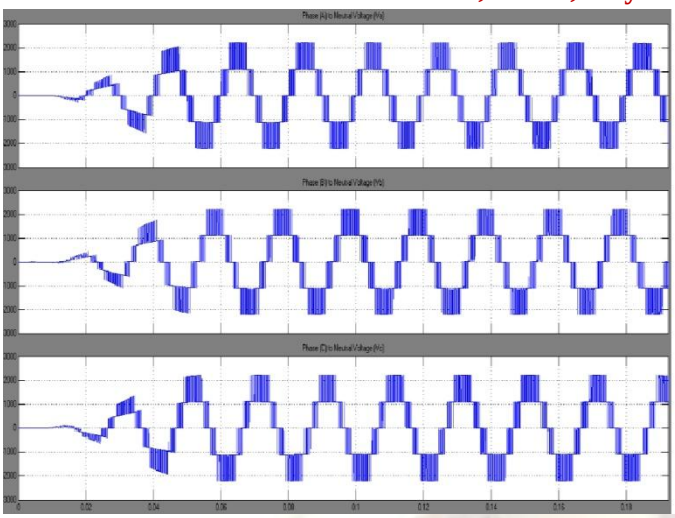


Fig. 13 Open loop Output Voltage when Over Voltage(2500V) is created

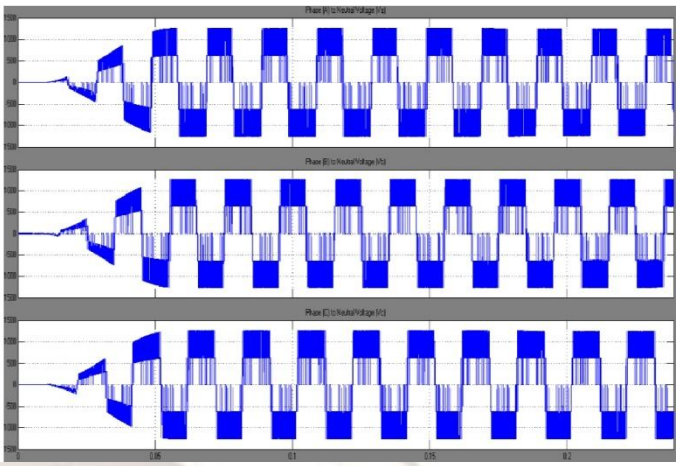


Fig. 16 Closed loop Output Voltage when Under Voltage is created

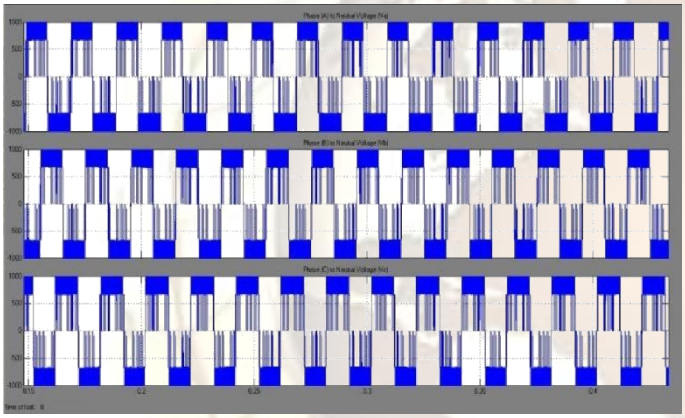


Fig. 17 Closed loop Output Voltage when Over Voltage is created

S.No	Parameter	Value
1	Amplitude Modulation Index(M_a)	0.83
2	Number Of Levels(M)	5
3	Reference Wave Amplitude(A_m)	2V
4	Frequency	50Hz
5	Carrier Wave Amplitude(A_c)	0.6V
6	Frequency Modulation Index(M_f)	20
7	Carrier Frequency(F_c)	1KHz
8	Voltage Ripple Factor(VRF)	10%(Assume)
9	Filter Capacitor (C)	1054.2µF
10	Filter Inductance(L)	13.72mH

V.CONCLUSION

In this paper three phase cascaded H-Bridge multilevel inverter is simulated and observed under various unbalanced voltage conditions like Under Voltage and Over Voltage. In the open loop system Under Voltage and Over Voltage were introduced at the Supply side, and the waveforms of those were observed under unbalanced conditions.

In the closed loop system with the help of PI Controller the load voltage is maintained constant for unbalanced voltage conditions and these can be observed from the above simulations.

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