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THD Analysis of 3-Phase 2-Level and 3-Phase 3-Level Neutral Point Clamped Inverter

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Abstract:
Multi-level inverter has capability to handled low and medium power with less total harmonic distortion (THD), reduced switching losses. Diode Clamped Multi-Level Inverter (DCMLI) has a capability to increase the output voltage and performance with low switching losses, reduced voltage stress and total harmonic distortion. Diode Clamped Multi-Level Inverter (DCMLI) is also called the Neutral Point Clamped (NPC) Inverter. The main feature of NPC inverter includes reduced dv/dt and THD in the AC output voltages in comparison to the two–level inverter. Simulation result of 3-phase 3-level Neutral point clamped (NPC) inverter can be obtained by MATLAB SIMULINK software multi-level inverter using SPWM technique.

Keywords: PWM, SPWM, NPC Inverter, Harmonic Reduction.

I. INTRODUTOIN

Power conversion investigation attracted particularly in Medium voltage/ High power ranges [1,2]. During the three last decades, advancements in the power electronics fields have led innovation converter topologies, called Multi-level inverter [3,4]. In fact, to classical two-level converter, multi-level converter attractive solution since they support higher operation voltage, reduced common mode voltage, minimize output current and voltage distortion, andoptimize output filter size and cost. The quality of output voltage waveform depends on the number of inverter voltage levels i.e., as the number of output level increases, the waveform become lower THD and more sinusoidal [5].

II. RELEVANCE

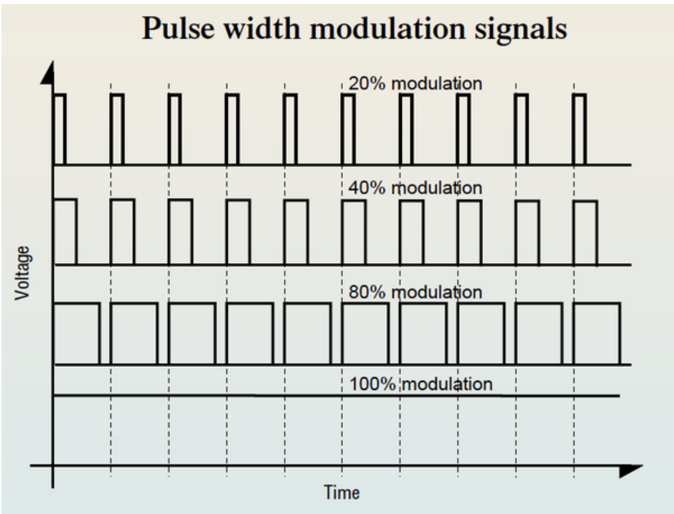
An inverter is circuit which converts a DC power into an AC power at desired output voltage and frequency. The output voltage could be fixed at a fixed or variable frequency. The conversion can be achieved by controlling turn-on and turn-off devices (e.g., BJTs, MOSFET, IGBBTs, GTOs and Thyristors) depends on the application. Convention Two-level pulse width modulation (PWM) inverter generates high dv/dt, high frequency common mode voltage and introduce harmonics which is very harmful is electrical drives application. It damages motor bearings, conducted electromagnetic interferences, and malfunctioning of electrical equipment. Hence, we demonstrate the 3-phase 3-level NPC inverter which is better than the two-level inverter. Pulse with modulation techniques have been the subject of intensive research during the last few decades towards the betterment of electrical power flow control to various application. Now-days there is a growing interest in development of microcontroller based PWM system compared to other conventional one like dedicated analog and digital control. The stand-alone mode working features of microcontroller simplifies with hardware with reduced component, improves performance, enhance reliability of system, offers less again than analog device etc. thus the flexibility in control with cost effectiveness is one of the major advantage of any microcontroller based on dedicated module. PWM methods reduce the harmonics by shifting the frequency spectrum to the vicinity of high frequency band of carrier signal. In normal Sinusoidal PWM scheme, the control signal generates by comparing a sinusoidal reference signal and a triangular carrier.

III. PROBLEM STATEMENT-

After studying 2 level inverters we came across the problem that output of the inverter contains greater harmonic distortion and voltage stress across the switches is high. To overcome this problem, we implement 3-phase 3-level inverter.

IV. PLUSE WIDTH MODULATION-

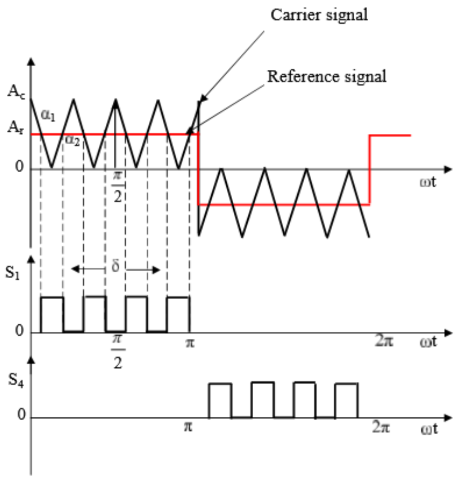
Pulse Width Modulation method is a fixed dc input voltage is given to the inverters and a controlled ac output voltage is obtained by adjusting the on and off periods of the inverter components. This is the most popular method of controlling the output voltage and in this method, is known as pulse width modulation (PWM CONTROL).



TYPES OF PWM TECHNIQUE-

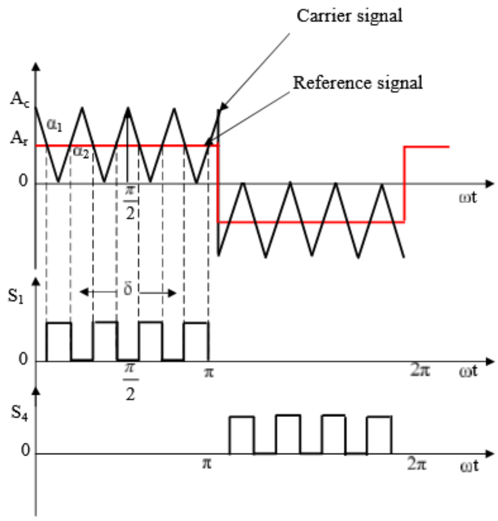
1. Single pulse width modulation (Single PWM)
2. Multiple pulse width modulation (MPWM)
3. Sinusoidal pulse width modulation (SPWM)
4. Modified Sinusoidal pulse width modulation (MSPWM)

4.1) Single pulse width modulation (Single PWM)



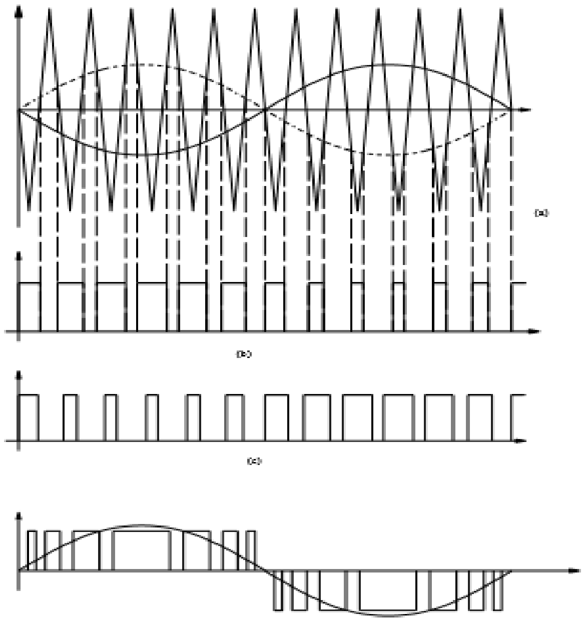
In single pulse width modulation control technique only one pulse will be there for every half cycle. The width of the single pulse can be adjusted to control the output voltage of the inverter. By comparing rectangular reference signal of amplitude (Ar), and a triangular carrier wave (Ac), the gating signals can be generated as shown in Figure. This generated gating signal is used to control the output of single phase full bridge inverter. The fundamental frequency of the output voltage is determined by the frequency of the reference signal. For this technique, the amplitude modulation index (M) can be defined as, $M = Ar/Ac$whereas the instantaneous output voltage of the inverter can be given as $Vo = Vs(S1 - S4)$

4.2) MULTIPLE PULSE WIDTH MODULATION (MPWM)-



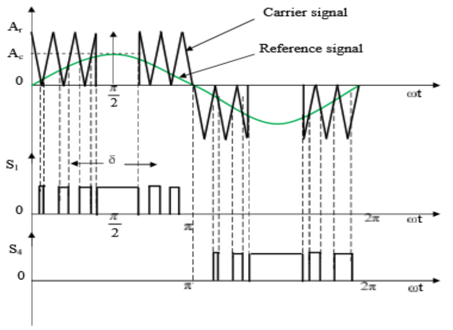
The main drawback of single PWM technique is high harmonic content. To reduce the harmonic content, the multiple PWM technique is used, in which several pulses are given in each half cycle of output voltage. The generation of gating signal is achieved by comparing the reference signal of the amplitude (Ar) with a triangular carrier wave (Ac) as shown Figure The output frequency (fo) is determined by the frequency of the reference signal. The output voltage can be controlled by modulation index. The number of pulses (p) per half cycle is calculated by the carrier frequency (fc). Number of pulses per half cycle is found by, $p = \frac{fc}{fo} = \frac{Mf}{2}$. Where $Mf = \frac{fc}{fo}$, called the frequency modulation ratio. The instantaneous output voltage of the inverter can be given as $Vo = Vs(S1 - S4)$

4.3) SINUSOIDAL PULSE WIDTH MODULATION (SPWM)-



The generation of a sinusoidal PWM signal, which finds more applications in industries the gating signal can be generated by comparing a sinusoidal reference signal with a triangular carrier wave and the width of each pulse varied proportionally to the amplitude of a sine wave evaluated at the centre of the same pulse. The output frequency (fo) of the invertercan be found by using the frequency of the reference signal (fr). The rms output voltage (Vo) can be controlled by modulation index M and in turn modulation index is controlled by peak amplitude (Ar). The voltage can be calculated by $Vo = Vs(S_1 - S_4)$, The number of pulses per half cycle depends on the carrier frequency. The gating signal can be produced by using the unidirectional triangular carrier wave. The width of the single pulse can be adjusted in order to control the output voltage of the inverter. By comparing rectangular reference signal of amplitude (Ar) and a triangular carrier wave (Ac). This generated gating signal is used to control the output of single phase full bridge inverter. The fundamental frequency of the output voltage is determined by the frequency of the reference signal. For this technique, the amplitude modulation index (M) can be defined as $M = \frac{Ac}{Ar}$ whereas the instantaneous output voltage of the inverter can be given as $Vo = Vs(S_1 - S_4)$, In this, Vc is the peak value of the triangular carrier wave and Vr is the reference, or modulating signal. For realizing SPWM, a high frequency triangular carrier wave is compared with a sinusoidal reference of the desired frequency. The intersection of sinusoidal reference and triangular waves determines the switching instants and commutation of the modulated pulse. Operating with constant frequency of carrier signal concentrates on voltage harmonics around switching frequency (which is of double the carrier frequency) and multiples of switching frequency. Carrier based modulation for more than two level inverters require more carrier signals. For NL -level inverter, minimum (NL -1) carrier signals are needed.

4.5) MODIFIED SINUSOIDAL PULSE WIDTH MODULATION-



When considering sinusoidal PWM waveform, the pulse width does not change significantly with the variation of modulation index. The reason is due to the characteristics of the sine wave. Hence this sinusoidal PWM technique is modified so that the carrier signal is applied during the first and last 600 intervals per half cycle as shown in Figure. The fundamental component is increased and its harmonic characteristics are improved. The main advantages of this technique is increased fundamental component, improved harmonic characteristics, reduced number of switching power devices and decreased switching losses.

V. SIMULINK MODEL-

Simulation of NPC inverter using sinusoidal pulse width modulation was carried out with help of “MATLAB”. From simulation we can observed the improvement in the line voltage and reduced the THD

5.1) MATLAB SIMULATION MODEL USING SPWM-

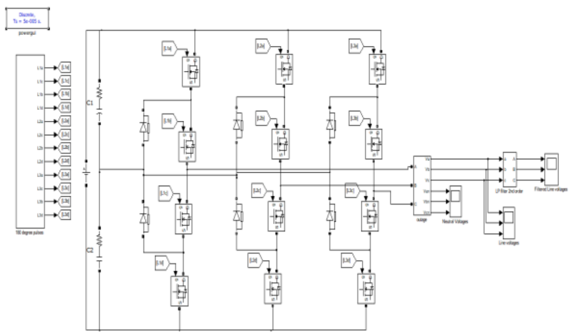
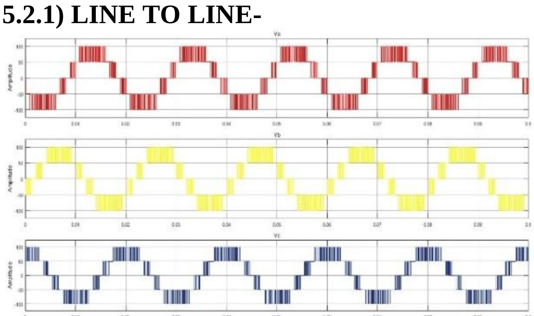


Figure.1. Simulation Model of 3-Phse 3-Level Neutral Point Clapped Inverter

Above fig. shows the Simulink model of the NPC inverter in the MATLAB. In this model for generation of SPWM pluses the technique was used comparing sinusoidal control voltage with a triangular waveform which select from the switching frequency.

5.2) WAVEFORM OF THE MODEL-

5.2.1) LINE TO LINE-



5.2.2) FILTERED LINE VOLTAGE-

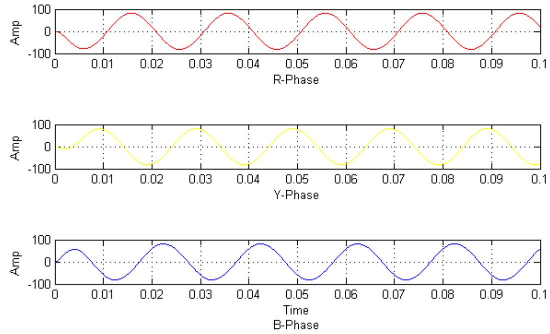


Figure.1.shows the filtered output waveform of the NPC inverter.

VI.HARMONIC RESULT AND ANALSIS-

Harmonic is multiple of the fundamental frequency and it can be voltage and current in an electric power system are a result of non-linear electric loads. Harmonic frequencies in the power grid are a frequent cause of power quality problems.

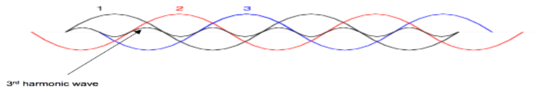


Figure.6.1. 3rd harmonic wave.

The harmonic calculation can be carried by the following formula

$$\mathrm{THD_V} = \frac{\sqrt{V_2^2 + V_3^2 + V_4^2 + \cdots + V_n^2}}{V_1} * 100\% = \frac{\sqrt{\sum_{k=2}^{n} V_k^2}}{V_1} * 100\%$$

$$THD_I = \frac{\sqrt{I_2^2 + I_3^2 + I_4^2 + \cdots + I_n^2}}{I_1} * 100\% = \frac{\sqrt{\sum_{k=2}^{n} I_k^2}}{I_1} * 100\%$$

For analysis of the harmonic we build two-level three phase inverter. The MATLAB model of two level three phase inverter is shown in figure.

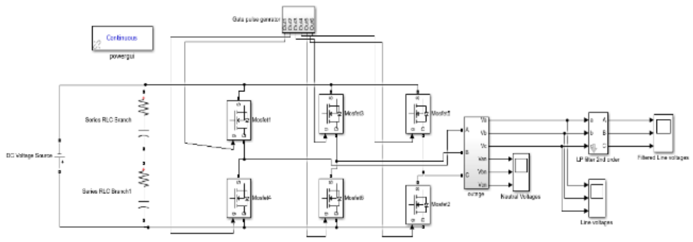


Figure.6.2.MATLAB model of two level three phase inverter.

The output waveform of two level tree phase inverter are show in fig.

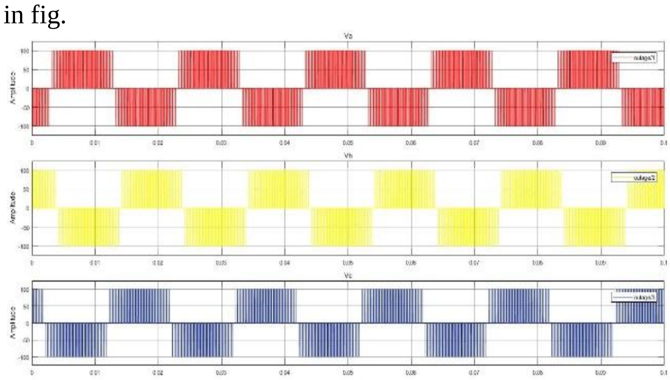


Figure.6.3. Output Waveform of the two level three phase inverter without filter.

Comparison of harmonic in two level three phase and of 3-phase 3-level NPC inverter.

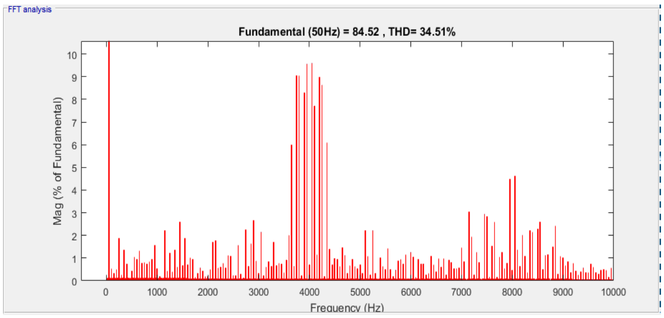


Figure.6.4. THD in Line Voltage of 3-phase 3-level inverter.

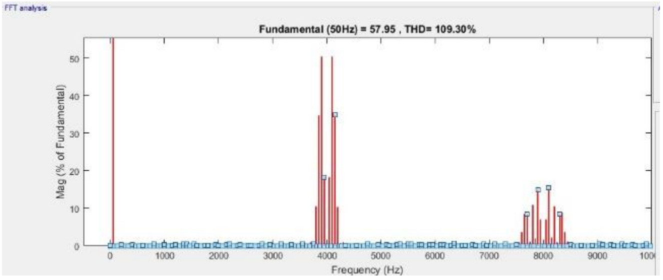


Figure.6.5.THD in Line Voltage of 3-phase 2-level inverter.

VII. THD IN INVERTERS-

3-phase 2-level Inverter	3-phase 3-level Neutral Point clapped Inverter
109.30%	**34.51%**

VIII. CONCLUSION-

In normal inverters odd harmonics are present which causes distortion of the output waveform. By using the **"THREE LEVEL DIODE CLAMPED INVERTER"** we can eliminate some number of harmonics hence increasing the efficiency of the inverter.

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