THREE LEVEL ACTIVE NEUTRAL POINT CLAMPED INVERTER WITH SINUSOIDAL PWM CONTROL

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Abstract

Multilevel inverter (MLI) plays very important role in medium and high power applications. This paper contributes the recent trend in inverter that is Three Level Active Neutral Point Clamped Inverter with their architecture, operation and control schemes with total harmonic distortion (THD). The control method used in this work is based on sinusoidal PWM. This type of model further can be used to design inverters by students from electrical and electronic engineering specializations. The simulation results are presented to verify the performance of the proposed control scheme and ANPC

Index Terms: Multilevel Inverter (MLI), Active Neutral Point Clamped (ANPC), Sinusoidal Pulse Width Modulation (SPWM), Phase Disposition (PD), Total Harmonic Distortion (THD)

I. INTRODUCTION

An inverter converts DC input voltage into AC output voltage of variable magnitude and frequency. With consideration of disadvantages like requirement of high rating semiconductor switches for higher level, poor power quality, expensive filtering circuit etc. Multi level Inverter technology has introduced. The inverter with voltage levels three and more are referred as Multi Level Inverter.

There are limited number of topologies that provide multilevel voltages and suitable for medium and high voltage applications. The most know topologies are the neutral point clamped (NPC), the flying capacitor (FC) and the cascaded H-bridge multilevel inverters [2].

The classic multilevel inverter has been undergone with several issues when level has been increased. The NPC-MLI gets complicated as number of diodes increased with increase in voltage levels more than five. Similarly FC-MLI becomes costly and bulky with increasing numbers of capacitors with increase in voltage levels. Cascaded-MLI requires different voltage sources with increase in voltage levels [3].

II. OPERATING PRINCIPLE OF ANPC

A. Active Neutral Point Clamped MLI

Active Neutral Point Clamped Topology is suitable for medium and high power applications. It is a combination of Neutral Point Clamped MLI and Flying Capacitor MLI [3]. This is achieved by replacing clamping diodes by semiconductor switches, controlling voltage balancing across capacitors with proper selection of switching states and the classical DC offset injection for controlling neutral point voltage. Architecture of 3-level ANPC MIL inverter is as shown in Figure-I

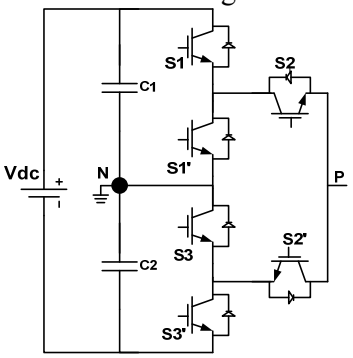

Figure I: Architecture of 3-Level ANPC MLI

B. Operating Principle

The 3-level ANPC MLI is as shown in Figure 1. A single leg / phase of 3-level ANPC inverter is made of six bidirectional switches; each switch composed of IGBT and anti-parallel diode. Switches are grouped in three commutation cell (S1, S1'), (S2, S2') and (S3, S3') as a complementary switch pair. Thus if one the switch from complementary switch pair it turned on, the other of the same pair must be in off condition. Two switches are always turned on at the same time.

Table-I shows the switching sequence of the proposed 5-level ANPC inverter in Figure 3.2. State "1" means switch is ON, and state "0" means switch is OFF.

Table I: Switching Sequence for 3-Level ANPC MLI

S/W	S1	S2	S3	S1'	S2'	S3'	O/P
V1	1	1	1	0	0	0	Vdc/2
V2	0	1	0	1	0	0	0
V3	0	1	0	1	0	1	0
V4	0	0	1	0	1	0	0
V5	1	0	1	0	1	0	0
V6	0	0	0	1	1	1	-Vdc/2

III. CONTROL TECHNIQUE FOR 3-LEVEL ANPC MLI

Pulse width modulation technique is used for inverter output voltage control and if we switch device in particular fashion harmonics can be eliminated [4]. In Pulse Width Modulation Technique the switching signal [6] is generated by comparing fundamental reference signal with carrier wave of required switching frequency. The frequency of reference signal determines the frequency of fundamental output wave and its amplitude controls the modulation index.

There are various PWM scheme available for controlling multi-level inverter such as,

- Sinusoidal Pulse Width Modulation (SPWM)
- Third Harmonic Injection Pulse Width Modulation (THI-PWM)
- Space Vector Pulse Width Modulation (SVPWM)
- Selective Harmonic Elimination Pulse Width Modulation (SHE-PWM)

Among all Sinusoidal Pulse Width Modulation technique is selected for control of ANPC MLI which is further classified as Phase Disposition, Phase Opposite Disposition and Alternate Phase Opposite Disposition SPWM.

For 3-level active neutral point clamped inverter two triangular carrier signals are needed. The carriers should have same frequency and same peak to peak amplitude. At every instant each carrier is compared with modulating signal. Each comparison switches the switch ON, is modulating signal is greater than triangular carrier signal assigned to that switch.

SPWM Control signal for 3-Level ANPC is presented in Figure II.

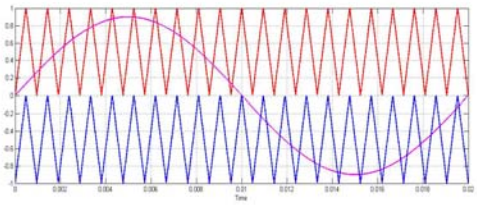

Figure II: SPWM Scheme for 3-Level ANPC

Complementary switch pair presents in the each phase are (S1, S1'), (S2, S2') and (S3, S3') and Gating signals S1', S2' & S3' are generated by inverting S1, S2, & S3. Carrier-1genrated pulses are given to cell-1 and carrier-2 generated pulses cell-2. Voltage levels obtained as follows:

1. The converter is switched to +Vdc/2 when the sine wave is greater than upper carrier wave.
2. The converter is switched to -Vdc/2 when the sine wave is less than lower carrier wave.
3. The converter voltage is switched to zero when sine wave is lower than upper carrier wave but higher than the lower carrier wave

IV. SIMULATION RESULTS

The Active Neutral Point Clamped 3-level inverter is modeled in MATLAB simulink using power system block set. Switching signals for ANPC MLI are developed using sinusoidal PWM techniques discussed previously. Simulations are performed for different modulation indices ranging from 0.6 to 1. The corresponding %THD measured are using FFT block. The Figure-I shows MATLAB simulink model for active neutral point clamped 3-level inverter. It consists of 6 IGBT switches, and 2

DC link capacitors connected with single DC source. The Figure-III shows waveform of overall voltage output of 3-level ANPC MLI and Figure-IV shows waveform of output voltage along with carrier and fundamental wave for 3 level ANPC MLI. THD value of 3-level ANPC inverter with SPWM technique without filters is as show in Figure-V.

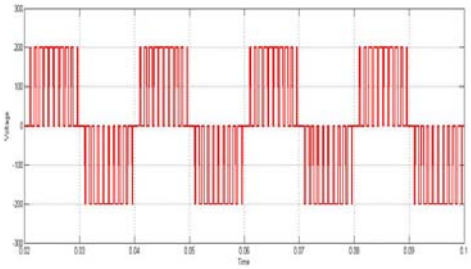

Figure III: Phase Voltage Waveform of 3-Lvel ANPC MLI

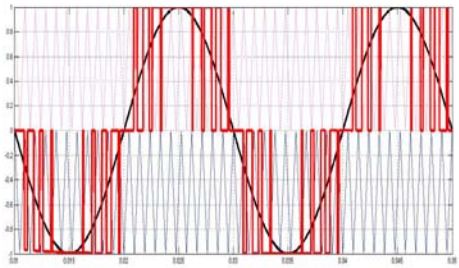

Figure IV: Output with carrier and fundamental waveform

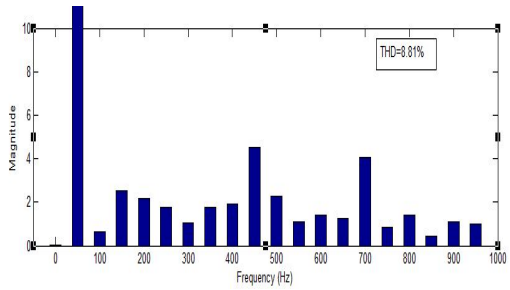

Figure V: THD value of SPWM scheme for ANPC

V. CONCLUSION

The 3-level Active Neutral Point Clamped inverter is presented in this paper with THD analysis. The various techniques like Phase Disposition (PD), Phase Opposite Disposition (POD), and Alternate Phase Opposite Disposition (APOD) PWM schemes are used for proposed converter with sinusoidal pulse width modulation. It is observed that, the Phase Disposition sinusoidal PWM scheme has less harmonic content in the output voltage compared with other schemes. As an extension of this work, this topology with PD SPWM scheme will be good choice for implementation for three phase 3-level ANPC inverter.

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