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Performance Analysis of Three Phase Three Level NPC Inverter

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Abstract - Multi-level inverters have been utilized widely in many applications, especially in renewable energy aspects. This is because of the associations in high power, medium switch voltage and lower output total harmonics distortion. Multilevel inverters are the best solution for high power dc-to-ac conversion applications. The quality of the multilevel waveform is improved by increasing the number of levels. But, if number of level increases, a large number of power semiconductor devices and gate driver circuits are also increased. So, it will increases system complexity and cost and tends to reduce the system reliability and efficiency. For a high-resolution waveform, therefore, practical considerations necessitate reduction in the number of switches and gate driver circuits. In this paper, the three level inverter is constructed using MOSFETS and PIC microcontroller. The effectiveness of the proposed methodology is investigated by hardware implementation of the system.

Keywords —NPC Inverter, Three level Inverter.

I. INTRODUCTION

With the rapid growth of renewable power generation, conversion of DC to usable AC becomes most prominent technology to capitalize on abundant renewable energy available across the globe. As the scale of renewable power generation also reaches in the range of mega watt (MW), to connect a single switch for power conversion becomes a cumbersome task. To overcome these hindrances, a family of multilevel inverters came into picture as solution to power conversion of DC to AC at higher voltage levels.The Three Level Neutral Point Clamped Inverter is now becoming popular technology for medium voltage, high power applications such as variable speed drives, power compensation, rolling mills and renewable energy applications [5]. The reason behind the increasing popularity of multilevel inverter is the better quality of output voltage which involves the reduced harmonic distortion, lesser voltage stress across switches and nearly sinusoidal output waveform generation. Due to the world energy crisis and environmental problems caused by conventional power generation, renewable energy sources such as photovoltaic (PV) and wind generation systems are becoming more promising alternatives to replace conventional generation units for electricity generation. The continuously growing amount of renewable sources starts compromising the stability of electrical grids [2]. Advanced power electronic systems are needed to utilize and develop renewable energy sources. In three-phase applications, two types of power electronic configurations are commonly used to transfer power from the renewable energy resource to the grid: single-stage and double-stage conversion. In the double-stage conversion for a PV system, the first stage is usually a dc/dc converter and the second stage is a dc/ac inverter. The function of the dc/dc converter is to facilitate the maximum power point tracking (MPPT) of the PV array and to produce the appropriate dc voltage for the dc/ac inverter [1]. The function of the inverter is to generate three-phase sinusoidal voltages or currents to transfer the power to the grid in a grid-connected solar PV system or to the load in a stand-alone system. Inverters are very important power electronics equipment in PV systems. Their major role is to convert DC power into AC power.

II. STRUCTURE OF THE THREE LEVEL INVERTER

Three level inverter topology, often referred to as Neutral Point Clamped (NPC) inverter. Three level inverters are widely used in several application motor drives, STATCOM, HVDC, pulse width modulation (PWM) rectifiers, active power filters (APFs), and renewable energy applications[1]. The three level inverter offers several advantages over the more common two level inverter. As compared to two level inverters, three level inverters have smaller output voltage steps. In addition, the cleaner output waveform provides an effective switching frequency twice that of the actual switching frequency. Most often the NPC inverter is used for higher voltage inverters. Multilevel inverter topologies are experiencing increased application in the industrial environment, particularly in high-power drive systems. The main advantages of these inverters are improving quality of voltage waveforms and an increase in the dc-link voltage [3].

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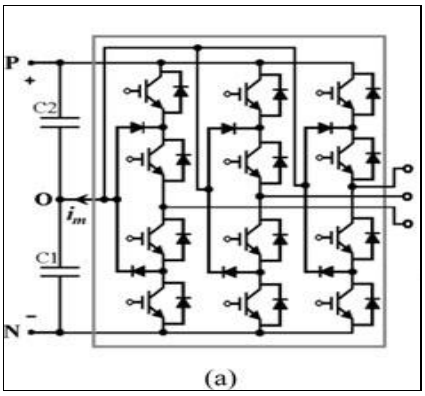

Fig 1: Three level NPC Inverter basic structure

Fig.1 shows a typical three phase, three-level neutral-point-clamped (NPC) inverter circuit topology. The three-phase three-level structure NPC inverter consists of three symmetrical arms, each one is composed of four switches in series, floating diodes (two per arm) ensure the application of different voltage levels at the output of each arm[6].Each leg has four IGBTs connected in series. The converter has two capacitors in the dc side to produce the three-level ac-side phase voltages. The bus voltage is split in two by the connection of equal series connected bus capacitors. Each leg is completed by the addition of two clamp diodes. This topology traditionally has been used for medium voltage drives both in industrial and other applications. Normally, the capacitor voltages are assumed to be balanced, since it has been reported that unbalance capacitor voltages can affect the ac side voltages and can produce unexpected behaviour on system parameters such as even-harmonic injection and power ripple.

NPC three level Inverter has following advantages:

- It provides a cost effective approach.
- High quality output voltage and current waveforms.
- High efficiency design due to decreased switching losses.
- Lower output filter requirement, lower EMI level and lower output harmonics level of the output waveform than a conventional two level inverter [7].
- Reduced output filter component size and cost as compared to a two level inverter.
- The field of application of NPC inverters is permanently growing due to their compactness, efficiency, and good performance [4].

III. SPWM TECHNIQUE

SPWM is the most popular technique. In SPWM a digital waveform is generated and the duty cycle is modulated such that the average voltage of the waveform is corresponds to a pure sine wave. SPWM moves the voltage harmonic components to the higher frequencies. The SPWM technique treats each modulating voltage as a separate signal and compared to the common carrier triangular waveform.

The working principle of SPWM includes the following points:

- The frequency of triangular wave is the frequency of PWM.
- Frequency of control voltage controls the fundamental frequency.
- The peak value of control voltage controls the amplitude.

Principle of Sinusoidal Pulse Width Modulation (SPWM):

Generation of the desired output voltage is achieved by comparing the desired reference waveform (modulating signal) with a high-frequency triangular 'carrier' wave as depicted schematically in Fig.2 [8]. Depending on whether the signal voltage is larger or smaller than the carrier waveform, either the positive or negative dc bus voltage is applied at the output. Note that over the period of one triangle wave, the average voltage applied to the load is proportional to the amplitude of the signal (assumed constant) during this period. The resulting chopped square waveform contains a replica of the desired waveform in its low frequency components, with the higher frequency components being at frequencies close to the carrier frequency. Notice that the root mean square value of the ac voltage waveform is still equal to the dc bus voltage, and hence the total harmonic distortion is not affected by the PWM process. The harmonic components are merely shifted into the higher frequency range and are automatically filtered due to inductances in the ac system. When the modulating signal is a sinusoid of amplitude Am, and the amplitude of the triangular carrier is Ac, the ratio m=Am/Ac is known as the modulation index. Note that controlling the modulation index controls the amplitude of the applied output voltage. With a sufficiently high carrier frequency (see Fig. 3 drawn for fc/fm = 21 and t = L/R = T/3; T = period of fundamental), the high frequency components do not propagate significantly in the ac network (or load) due the presence of the inductive elements. However, a higher carrier frequency does result in a larger number of switching per cycle and hence in an increased power loss. Typically switching frequencies in the 2-15 kHz range are considered adequate for power systems applications [10].

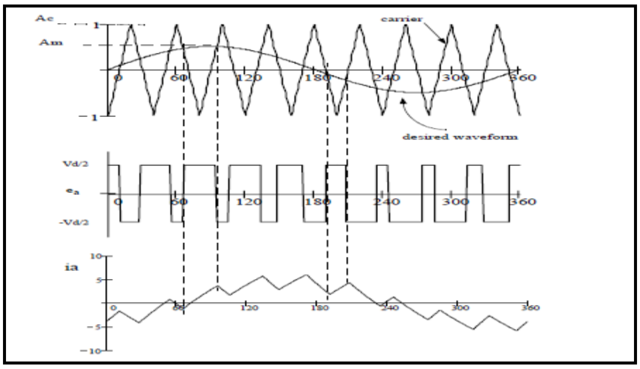

Fig 2: Sinusoidal pulse width modulation

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IV. Block Diagram of the Proposed System

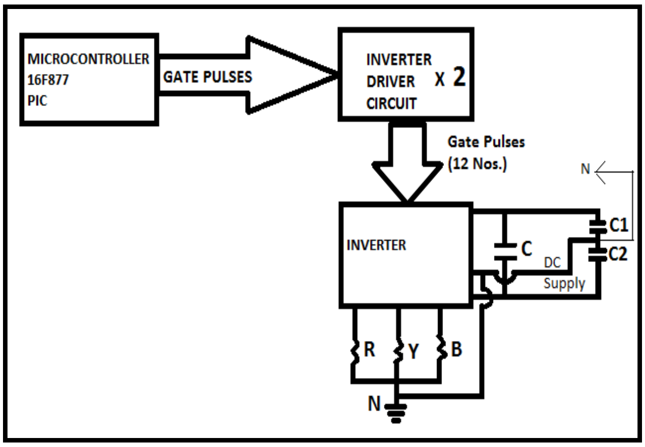

Fig 3: Block diagram of the proposed system

The elements of the proposed system are as follows:

- DC supply
- Microcontroller:

The main component of this inverter is a microcontroller as it is used to generate control signals. The theory of encoding a sine wave with a PWM signal is relatively simple. A sine wave is needed for the reference that will dictate the output, and a triangle wave of higher frequency is needed to sample the reference and actuate the switches. This microcontroller is specially developed for the generation of sinusoidal PWM (SPWM).The generation of PWM signal is as shown in fig.7. PIC16F877A is used in this system as a microcontroller.

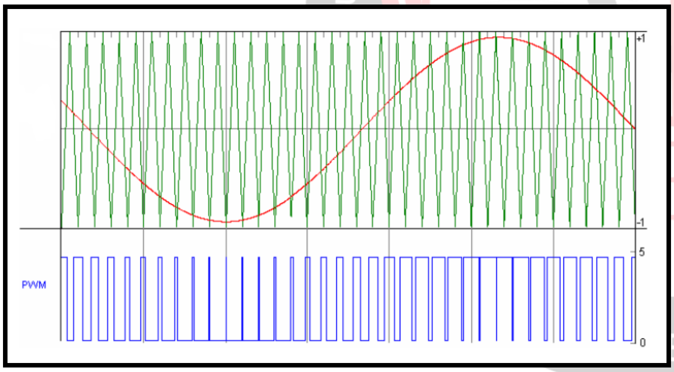

Fig 4: PWM generation

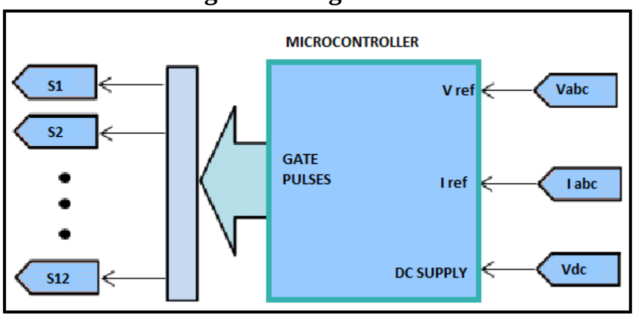

Fig 5 : Microcontroller block diagram

- Features of PIC16F877A are as follows:

Key Features	PIC16F877A
Operating Frequency	DC – 20 MHz
Resets (and Delays)	POR, BOR (PWRT, OST)
Flash Program Memory (14-bit words)	8K
Data Memory (bytes)	368
EEPROM Data Memory (bytes)	256
Interrupts	15
I/O Ports	Ports A, B, C, D, E
Timers	3
Capture/Compare/PWM modules	2
Serial Communications	MSSP, USART
Parallel Communications	PSP
10-bit Analog-to-Digital Module	8 input channels
Analog Comparators	2
Instruction Set	35 Instructions
Packages	40-pin PDIP 44-pin PLCC 44-pin TQFP 44-pin QFN

- Pin diagram of PIC16F877A:

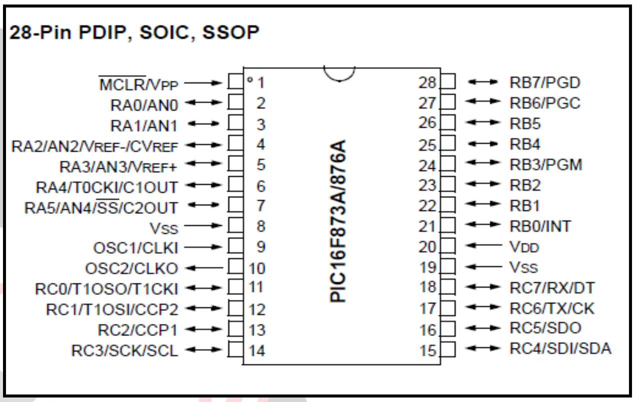

Fig 6 : PIN diagram PIC16F877A

- Generating control signals:

The microcontroller is tasked with generating 12 control signals that are used as inputs to the driver circuit. Driver circuit generate 12 gate pulses that are given to 12 MOSFETS. By using the gate pulses, MOSFETS will get turned ON or OFF.

- Inverter gate driver circuit:

For driving the high side MOSFET, the microcontroller cannot be directly interfaced to its gate terminal. There must be a gate driver circuit for switching the high side MOSFETs contrary to the low-side MOSFETs which can be directly operated without need of any external circuitry. Gate driver circuit is used to amplify current signals from microcontroller.

- Power MOSFETS:

Power MOSFETS are used as switches in this system. Power MOSFETS have a much higher switching frequency capability than IGBTs, and can be switched at frequencies higher than 200 kHz. They do not have as much capability for high voltage and high current applications, and tend to be used at voltages lower than 250V and less than 500W. MOSFETs do not have current tail power losses, which makes them more efficient than IGBTs. Unlike IGBTs, MOSFETs have body diode. MOSFETs are ideal for low voltage, high frequency applications (<250V, >200 kHz) [9].

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V. HARDWARE SETUP AND EXPERIMENTAL RESULTS

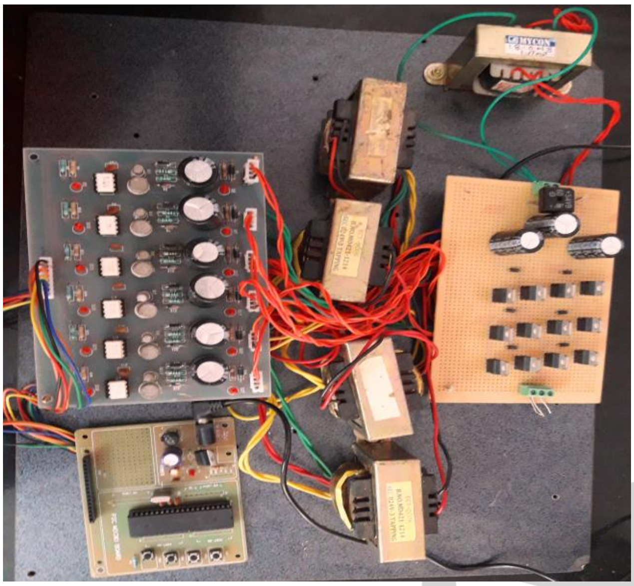

Fig 7 : Hardware of three phase three level Inverter

Hardware implementation has been carried out to test effectiveness of proposed.

Hardware results are as follows:

- Inverter output phase voltage waveform(ean,ebn,ecn):

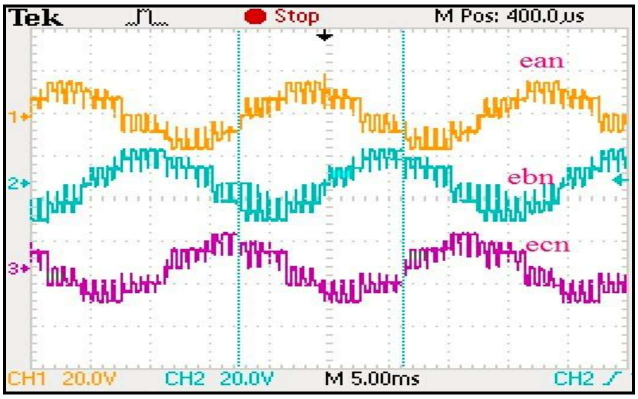

Fig 8 : Inverter output phase voltage waveform

- Gate pulses generated by microcontroller to trigger MOSFETS:

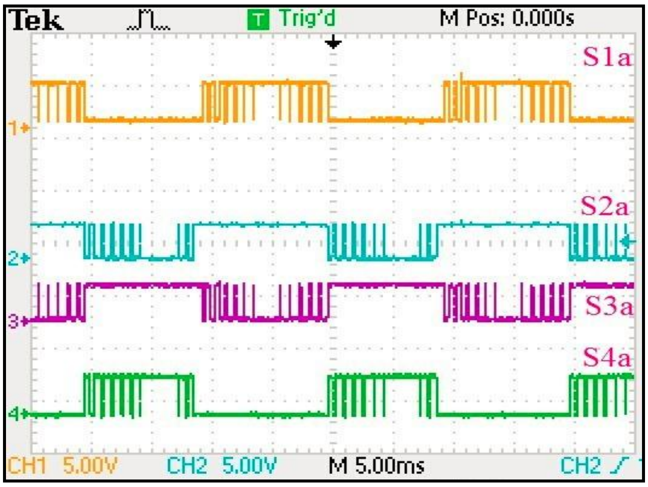

Fig 9 : Gate pulses

VI. CONCLUSION

A topology of three phase, three level NPC inverter has been presented. With the use of microcontroller PIC16F877A, desired results are obtained. The objective of the circuit was to invert power from DC sources into AC power. Output waveform frequency was found to be satisfactory at 50 HZ. Sine pulse with modulation circuit is much simplified by the use PIC16F877A microcontroller. The use of three-level inverter reduces the harmonic components of the output voltage. The result demonstrates that the proposed system is able to develop correct AC waveform as required. The results from experiments using a prototype built in the lab have validated the proposed topology.

REFERENCES

[1] Hamid R. Teymour et al.," Solar PV and battery storage integration using a new configuration of a three-level NPC inverter with advanced control strategy", *IEEE transaction on energy conversion*, Jan 2014.

[2] Michael Bragard, Student Member, IEEE et.al "The Balance of Renewable Sources and User Demands in Grids: Power Electronics for Modular Battery Energy Storage Systems": *IEEE transaction on power electronics*, Vol.25,No.12, Dec 2010.

[3] Arkadiusz Lewicki et al." Space-vector pulse width modulation for three-level NPC Converter with the neutral point voltage control", *IEEE transaction on Industrial Electronics*, Vol. 58, No. 11, November 2011.

[4] Jose Rodriguez et al."A Survey on Neutral-Point-Clamped Inverters", *IEEE transaction on Industrial Electronics*, Vol. 57, No. 7, July 2010.

[5] Xinchun Lin et al. "A New Control Strategy to Balance Neutral Point Voltage in Three-Level NPC Inverter", *8th International Conference on Power Electronics*, 2011.

[6] Habib Dallagi et al. "Study, Analysis and Simulation of Three Phase Three-Level, Five-Level and Seven-Level Neutral-Point-Clamped Inverters by PSIM", *15th international conference on Sciences and Techniques of Automatic control & computer engineering - STA'2014, Hammamet, Tunisia*, December , 2014.

[7] Necmi Altin et al. "Three-Phase Three-Level Inverter Based Shunt Active Power Filter", *16th International Power Electronics and Motion Control Conference and Exposition, Antalya*, Sept 2014.

[8] Vadhiraj S et al. "Generic SPWM Technique for Multilevel Inverter", *Electrical and Electronics Engineering Department REVA Institute of Technology & Management, Bangalore-560064*, IEEE 2013.

[9] Chitra Natesan et al. "IGBT and MOSFET: A comparative study of power electronics inverter topology in distributed generation", International conference on circuit, power and computing technology, IEEE, 2015

[10] K.V.V.S.R.Chowdary et al. "Performance Analysis of Transformer Operated by Sinusoidal Pulse Width Modulation Inverter", *School of Electrical Engineering, KIIT University, Bhubaneswar, India.*

 DOI : 10.18231/2454-9150.2018.0123