ANALYSIS AND SIMULATION OF NINE LEVEL ASYMMETRICAL MULTILEVEL INVERTER USING PIC MICROCONTROLLER

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ABSTRACT

Asymmetric Cascaded Multilevel Inverter (ACMLI) was widely studied. Various control strategies have been investigated however, most of the reported control strategies not discussed how to determinate voltage levels, firing angle, switching- state and other parameters control design. It focuses on asymmetrical topologies where the cell input voltages are of different values. These hybrid topologies might be interesting for several applications. One of the main benefits is the high resolution that can be obtained with a small number of cells. Another benefit is the higher energetic efficiency of the inverter alone. Nevertheless, the need of DC-DC converters to supply the cells of reversible multilevel converters increases the cost and losses of such inverters. It limits their application field. This paper is implemented using a PIC Microcontroller so that better resolution is achieved in the control of multilevel inverter output voltage magnitude and it is verified experimentally.

IndexTerms: Multilevel inverter, THD, MATLAB/SIMULINK (keywords)

1. INTRODUCTION

An inverter takes DC power (battery or solar, for e.g.) and converts it in to AC power for running electronic equipment and appliances. Numerous industrial applications have begun to require higher power apparatus in recent years. Some medium voltage motor drives and utility applications require medium voltage and megawatt power level. For a medium voltage grid, it is troublesome to connect only one power semiconductor switch directly. As a result, a multilevel power converter structure has been introduced as an alternative in high power and medium voltage situations.

A multilevel converter not only achieves high power ratings, but also enables the use of renewable energy sources. Renewable energy sources such as photovoltaic, wind, and fuel cells can be easily interfaced to a multilevel converter system for a high power application. The concept of a multilevel converter to achieve higher power is to use a series of power semiconductor switches with several lower voltage dc sources to perform the power conversion by synthesizing a staircase voltage waveform. Capacitors, batteries, and renewable energy voltage sources can be used as the multiple dc voltage sources. A multilevel converter has several advantages over a conventional two-level converter that uses high switching frequency pulse width modulation (PWM). The attractive features of a multilevel converter can be briefly summarized as follows.

In the recent years digital control techniques are becoming the most widespread resolution in modern power electronics applications. The microprocessors, DSP processor and application specific integrated circuits (ASIC) are responsible for better performance of the power converters Yet the design of digitally controlled power electronics is affected by several problems, such as sampling rate, software portability, re-usability, peripheral devices and register settings specific for each microprocessor. These problems can be mitigated by PIC microcontroller. In the following chapters we are going to discuss about the literature survey done why we are going for design of multilevel inverter and their implementation in software simulation using Simulink model in Mat LAB software package. Then the same is implemented in hardware using PIC microcontroller. And the test results are obtained.

2. LITERATURE SURVEY

Soft-switching techniques have gained popularity in recent times because they offer many advantages over hard-switched PWM inverters such as higher efficiency, higher power density and better performances. The resonant topologies employing soft-switching are classified based on the location of resonant network in the inverter with respect to load and dc link. This is an exhaustive study of various resonant link inverter topologies that appeared in the literature in recent times. This critical literature review brings out merits, demerits, and limitations besides giving the basic operating principles of various topologies.

Family of multilevel inverters has emerged as the solution for working with higher voltage levels [1]–[3].

Multilevel inverters include an array of power semiconductors and capacitor voltage sources, the output of which generate voltages with stepped waveforms. The commutation of the switches permits the addition of the capacitor voltages, which reach high voltage at the output, while the power semiconductors must withstand only reduced voltages. Fig. 1 shows a schematic diagram of one phase leg of inverters with different numbers of levels, for which the action of the power semiconductors is represented by an ideal switch with several positions.

A two-level inverter generates an output voltage with two values (levels) with respect to the negative terminal of the capacitor [see Fig. 1(a)], while the three-level inverter generates three voltages, and so on.
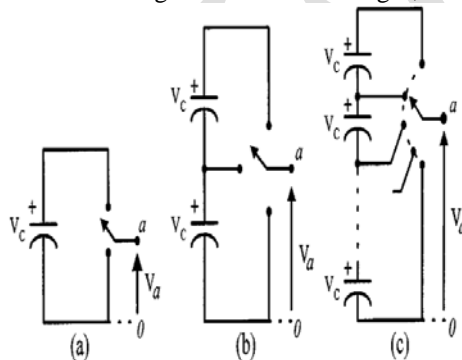

Figure. 1 One Phase Leg Of An Inverter With (A) Two Levels, (B) Three Levels, And (C) N Levels.

By increasing the number of levels in the inverter, the output voltages have more steps generating a staircase waveform, which has a reduced harmonic distortion. However, a high number of levels increases the control complexity and introduces voltage imbalance problems.

3. BLOCK DIAGRAM
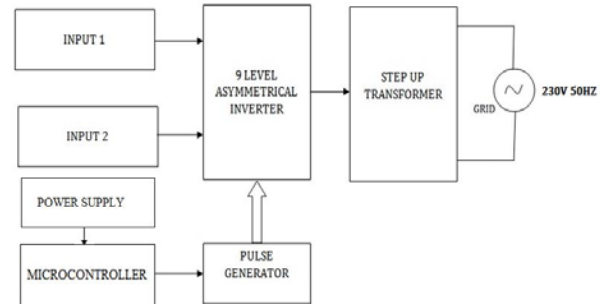
Figure 2.Block Diagram The block diagram describes the 9-level HCMLI (Hybrid cascaded multilevel inverters)

The block diagram consists of two input DC-sources, nine level asymmetrical inverter, step up transformer, pulse generator and Microcontroller. Input may be available from different renewable energy sources such as solar energy, wind turbine, fuel cell etc. Fuel cell is one of the most important sources of distributed energy because of its high efficiency, high energy density, plus high reliability and long life due to few moving parts. Let us consider two different input voltages are given to the nine level asymmetrical inverter we get an AC output. Since this low level AC output voltage is converted into high level AC output voltage that's why we are using step up transformer. This is given to the grid of the power plant..In order to maintain the output quality we use Microcontroller. The Microcontroller is used to control the pulses. This pulse is given to the pulse generator.

4. TWO LEVEL INVERTER

The inverters which produce which produce an output voltage or a current with levels either 0 or +- V are known as two level inverters. In high-power and high-voltage applications these two-level inverters however have some limitations in operating at high frequency mainly due to switching losses and constraints of device rating. This is where multilevel inverters are advantageous.

Increasing the number of voltage levels in the inverter without requiring higher rating on individual devices can increase power rating. The unique structure of

multilevel voltage source inverters' allows them to reach high voltages with low harmonics without the use of transformers or series-connected synchronized- switching devices.

The two 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 that mitigate motor issues due to long power cables between the inverter and the motor.

These issues include surge voltages and rate of voltage rise at the motor terminals and motor shaft bearing currents. In addition, the cleaner output waveform provides an effective switching frequency twice that of the actual switching frequency. Should an output filter be required, the components will be smaller and less costly than for an equivalent rated two level inverter.

5. .MULTILEVEL INVERTER

The term multilevel began with the three-level converter. Subsequently, several multilevel converter topologies have been developed. However, the elementary concept of a multilevel converter to achieve higher power is to use a series of power semiconductor switches with several lower voltage dc sources to perform the power conversion by synthesizing a staircase voltage waveform. Capacitors, batteries, and renewable energy voltage sources can be used as the multiple dc voltage sources.

The commutation of the power switches aggregate these multiple dc sources in order to achieve high voltage at the output; however, the rated voltage of the power semiconductor switches depends only upon the rating of the dc voltage sources to which they are connected. A multilevel converter has several advantages over a conventional two-level converter that uses high switching frequency pulse width modulation (PWM).

A.FEATURES OF MULTILEVEL INVERTER

➤ Staircase waveform quality: Multilevel converters not only can generate the output voltages with very low distortion, but also can reduce the dv/dt stresses; therefore electromagnetic compatibility (EMC) problems can be reduced.

➤ Common-mode (CM) voltage: Multilevel converters produce smaller CM voltage; therefore, the

stress in the bearings of a motor connected to a multilevel motor drive can be reduced. Furthermore, CM voltage can be eliminated by using advanced modulation strategies such as that proposed in .

➤ Input current: Multilevel converters can draw input current with low distortion

B. PROPOSED SYSTEM

The proposed system has higher efficiency and accuracy than the conventional one. In proposed system we are incorporating PIC for smooth operation and better output signal. By using Spartan software the programming complexity is reduced and desire output is obtained similar to sine wave.

C. CASCADED H-BRIDGE MULTILEVEL INVERTER:

A cascaded H-bridge converter is several H bridges in series configuration; a single H-bridge is shown in Figure C.1 A single H-bridge is a three-level converter. The four switches S1, S2, S3 and S4 are controlled to generate three discrete outputs V out with levels V dc, 0 and –V dc .When S1and S4 are on, the output is V dc ; when S2 and S3 are on, the output is –V dc ; when either pair S1 and S2 or S3 and S4 are on, the output is zero.
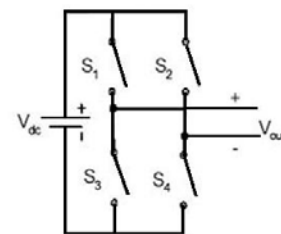
Figure.3. Single H-bridge topology

Power-electronic inverters are becoming popular for various industrial drives applications. In recent years also high-power and medium-voltage drive applications have been installed. To overcome the limited semiconductor voltage and current ratings, some kind of series and/or parallel connection will be necessary.

Due to their ability to synthesize waveforms with a better harmonic spectrum and attain higher voltages, multi-level inverters are receiving increasing attention in the past few years. The multilevel inverter was introduced as a solution to increase the converter

operating voltage above the voltage limits of classical semiconductors.

The multilevel voltage source inverter is recently applied in many industrial applications such as ac power supplies, static VAR compensators, drive systems, etc. One of the significant advantages of multilevel configuration is the harmonic reduction in the output waveform without increasing switching frequency or decreasing the inverter power output. The output voltage waveform of a multilevel inverter is composed of the number of levels of voltages, typically obtained from capacitor voltage sources.

The so-called multilevel starts from two levels. As the number of levels reach infinity, the output THD (Total Harmonic Distortion) approaches zero. The number of the achievable voltage levels, however, is limited by voltage unbalance problems, voltage clamping requirement, circuit layout, and packaging constraints.

Multilevel inverters synthesizing a large number of levels have a lot of merits such as improved output waveform, a smaller filter size, a lower EMI (Electro Magnetic Interference), and other advantages. The principle advantage of using multilevel inverters is the low harmonic distortion obtained due to the multiple voltage levels at the output and reduced stresses on the switching devices used.

Improvements in fast switching power devices have led to an increased interest in voltage source inverters (VSI) with pulse width modulation control (PWM). It is generally accepted that the performance of an inverter, with any switching strategies, can be related to the harmonic contents of its output voltage. Power electronics researchers have always studied many novel control techniques to reduce harmonics in such waveforms. Up-to-date, there are many techniques, which are applied to multilevel inverter topologies.

Pulse Width Modulation (PWM) is widely employed to control the output of static power inverters. The reason for using PWM is that they provide voltage and/or current wave shaping customized to the specific needs of the application under consideration. It is lastly performance and cost criteria, which determines the choice of a PWM method in a specific application.

D. ADVANTAGES

The least number of components are required comparing among all multilevel converters in order to obtained the same number of voltage levels.
Modularized circuit layout and packaging is possible as each level has the same structure, and there are no extra clamping diodes or voltage balancing capacitors. Soft switching can be used.
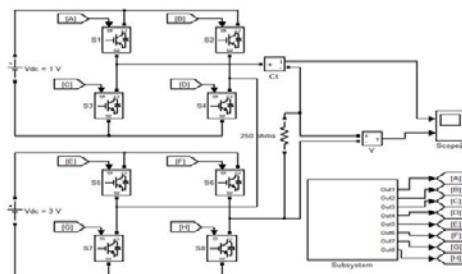
E. NEED OF ASYMMETRICAL INVERTER

☐ Different voltage sources can be used.
☐ To provide a large number of output levels without increasing the number of inverters, asymmetric multilevel inverters can be used.
☐ Increasing the number of levels provides more steps; hence , the output voltage will be of higher resolution and the reference sinusoidal output voltage can be better achieved.
☐ An asymmetrical configuration provides nearly sinusoidal voltages with very low distortion, using less switching devices.
☐   In addition, torque ripples are greatly reduced
☐ Asymmetrical multilevel inverter enables a DTC solution for high-power induction motor drives, not only due to the higher voltage capability provided by multilevel inverter

☐   But mainly due to the reduced switching losses and the improved output voltage quality, which provides sinusoidal current without output filter.

6. MATLAB SIMULATION

The simulation of the 9-level inverter is done using MatLAB in simulink model software. In this paper we used three H-Bridges connected in cascaded with three different voltages sources as input and IGBT's are used as switches and the pulse generator is used to generate timing pulses for the gate. And the output is obtained in scope.
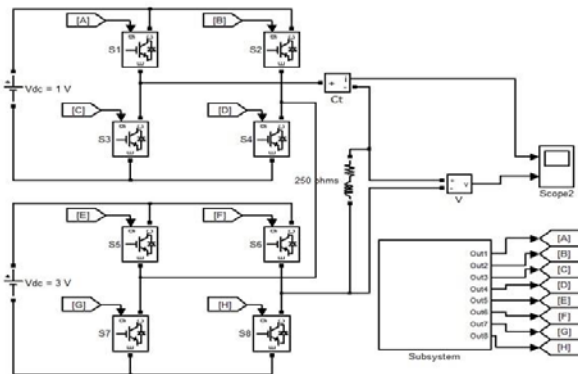
Matlab Simulation For 9 Level Inverter With R-Load

Figure.4. Simulation of 9Level Asymmetrical Inverter With R-load

The fig.5 shows the simulation of 9-level inverter using IGBT's for R-load. The pulse generator is used to produce pulse for turning on and off the IGBT. The output is viewed in the scope.

Matlab Simulation For 9 Level Inverter With Rl-Load

Fig.5 Simulation of 9Level Asymmetrical Inverter With RL-load

The fig.6,shows the simulation of 9-level inverter using IGBT's for RL-load. The pulse generator is used to produce pulse for turning on and off the IGBT. In this the inductance is connected in series with resistance. The results are obtained in scope.
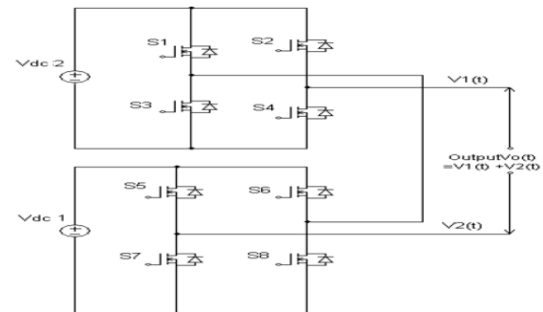
7. PIC MICROCONTROLLER 16F877A
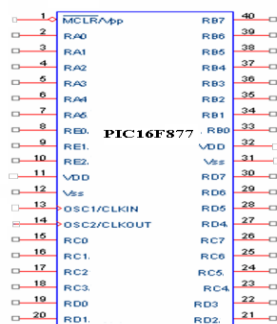
A. NEED FOR PIC

☐ Cost Effective

The peripheral Interface controller is very cost effective, that is the different model PIC's are available with proportional cost.

☐ Easily Available

The different models are easily available in the market.

8. POWER CIRCUIT

Figure.6 Power Circuit

Operation of Hybrid Cascaded H- Bridge

The most common multilevel converters, DCMC, FCMC and CCMC, have symmetrical topologies that require redundant states to generate the same voltage levels. When asymmetries are allowed, it is possible to increase the number of voltage levels while reducing the number of components.

HCMLI circuit is shown in Figure 1. HCMLI consists of (n-1)/2 number of single phase H-Bridge inverters that are connected in series to generate n level of output phase voltage. A single-phase structure of a Single-phase HCMLI with 9 level of output is shown in Figure 1. The output phase voltage is equal to the summation of each H-Bridge module given by the following formula

$$V0 = Vm1 + Vm2 + ...+ Vmh$$

Where h is the number of H-Bridge modules used in the multilevel circuit.

Each module of H-Bridge has its own input voltage and consists of four switching power devices; S11, S21, S31, and S41.

HCMLI has several advantages because its circuit configuration is simple and modular. Each of its modules is identical and incorporates both input and output circuitry. Besides, HCMLI requires the least number of components compared to other types of multilevel inverter. These features provide flexibility in extending HCMLI to higher number of levels without modification on the circuit itself.

9. MATLAB SIMULATION IX.A.MATLAB SIMULATION OUTPUT WAVEFORMS OF 9 LEVEL INVERTER FOR R- LOAD
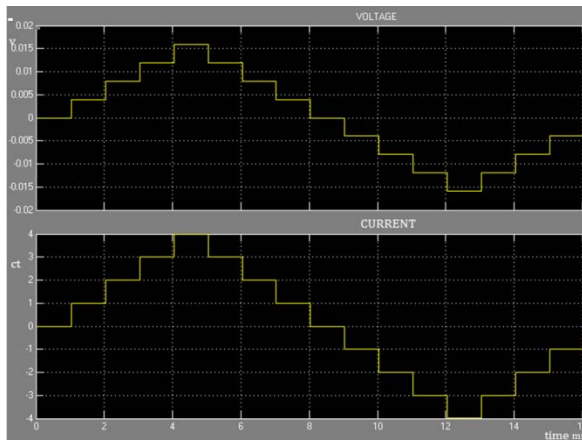
Fig.ure 7 Output Waveforms of 9 Levels Asymmetrical Inverter with RL Load

The Fig.8 Graph shows the output wave forms of 9-level inverter with RL load. In the below graph we can see the current and voltages are not phase because of inductance is added in the circuit.

Inverter Output
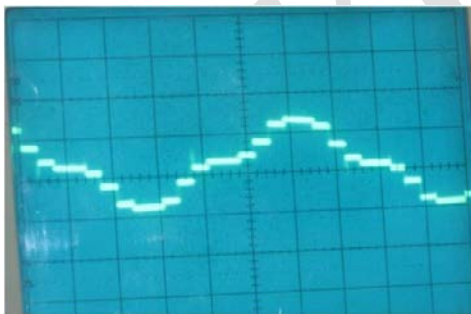
Figure.8Hardware Output in CRO

The Fig.9 shows the CRO output of the 9 level inverter in which the 9 level of outputs voltages are obtained when it is connected to resistance load.

10. CONCLUSION & FUTURE ENHANCEMENT

Multilevel inverter technology has emerged recently as a very important alternative in the area of high power medium-voltage energy control due to their low switch voltage stress and modularity. The topologies of multilevel inverter have several advantages such as lower THD, lower EMI generation, better output waveform and higher efficiency for a given quality of output waveform. Cascaded H-bridge multi level inverters (CHMLI) are a promising breed of multi level inverters which generally require several independent dc sources.

In this paper the development of PIC microcontroller as a control circuit for multilevel single phase inverter was successfully implemented. The simulation output for multilevel inverter was obtained with MATLAB and the same is implemented in hardware using PIC microcontroller and tested. The output from the 9 level inverter was obtained similar to the simulated results.

In recent years, many multi-level inverter of different topologies are proposed and analyzed in order to reduce harmonic components of the output voltage and current. If the number of level increases the complexity increases but the harmonics are reduced Speed of switches.

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