Pulse Width Modulation (PWM) Inverter for Control Applications

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Abstract - Industrial automation point of view inverter plays a very important role in developing drives. The PWM is widely used for motion control with two level voltage source inverters to obtain a quality output voltage or a current waveform with minimum amount of ripple content that they require for high switching frequency along with various pulse width modulation (PWM) strategies. These two level inverters have drawn tremendous inverters for high voltage and high power applications. This paper has proposed for design and implementation of sinusoidal pulse width Modulation i.e SPWM and multilevel technique to decrease the harmonics. The design and development of multilevel techniques will carried out in Matlab / Simulink environment.

Keywords – PWM, SPWM, Ripple, Neural Network Switching frequency, THD.

I. INTRODUCTION

From few years, Multilevel inverters has been attracting attention as power converters of choice in applications and also in the field of high voltage, high power applications. Now modern power electronics based devices have put great effect on the development of new power applications and industrial solutions. But at the time, these advances have increased the harmonic problems in line currents which makes distortion in voltage waveforms. Diode power rectifiers, thyristors converters and static VAR compensators (SVCs) are the examples of power electronics applications. The series connections of several high bridges allows working with much higher voltages and steepled voltage waveforms to eliminate voltage stress in associated equipment, such as transformers. Besides on a very low switching frequency the bridges of each converter works which allows working with low speed semiconductors and low switching frequency losses.

The multilevel inverters do a job of power conversion in multilevel voltages steps to obtain low switching losses of improved power quality, better electromagnetic compatibility and high Voltage capability. Because of these advantages multilevel inverters have been gaining Considerable popularity in recent years.

II. MULTILEVEL INVERTERS

A. Topology of multilevel inverters –

Multilevel inverters has been attracting increasing attention in the past few years as Power converters of choice in many applications. They have significant advantages over Conventional one because of capability to reduce the undesirable harmonics in order to improve the performance and efficiency. Multilevel inverters topologies are classified into three categories diode clamped inverters, flying capacitor inverters and cascaded inverters. In diode clamped inverters clamping diode per phase, DC bus capacitors, power semiconductor Switches are presented. In flying capacitors, balancing capacitors per phase are presented. In Cascaded inverters DC bus capacitors, power semiconductor switches are presented.
In the inverter design the PWM generation is plays the important role therefor few multi-carriers technique have been developed which helps in reduction of distortion in multilevel inverters. Basically multilevel inverter is to synthesize a desired AC voltage from several levels of DC voltages. Hence multilevel are perfect choice for connecting either in series or in parallel on AC grid with renewable energy sources like photovoltaic, fuel cells, and energy storage devices like capacitors or batteries.

B. Difference between multilevel inverter topologies –

Number of semiconductor devices used per phase lag. Number of balancing capacitors used per phase lag. Number of DC bus capacitors used. Amplitude of fundamental and dominant components. Total Harmonic Distortion (THD) of output voltage. Cascaded inverters requires the least number of components to achieve the same number of voltage levels in compared with diode clamped and flying capacitors inverters. The implementation cost of flying capacitor multilevel inverter and cascaded multilevel inverter are almost same but it is lower than that of Diode clamped multilevel inverters. It is found from above three inverters that the cascaded multilevel inverter topology is most promising one. Cascaded inverters used to compounding of voltage levels for reducing harmonic distortion which avoids single isolated voltage sources and constructed with low rating power devices.

C. Advantages of multilevel inverter –

Main advantage of multilevel inverters structures is to overcome shortcomings in solid state switching devices ratings, so that they can be best to applied to a higher voltages electrical systems. The multilevel voltage source inverters unique structure allows them to reach high voltages with low harmonics without use of transformers. It limits the problems of large voltage transient naturally which is occurs due to the deflections of cables, which can damage the motor winding cause other problems. To decrease the THD value. Again multilevel converter are useful to control frequency voltage output and real & reactive power flow at dc/ac interface which provides notable opportunities in the control of distributed power systems.

III. CONVENTIONAL CONTROL OF MULTILEVEL INVERTER

A. Five level cascaded H-Bridge Multilevel inverter

The converter consist of two series connected H-bridge cells which are fed by independent voltage sources. The output of the H-bridge cells are connected in series such that the synthesized voltage waveform is the sum of all individual cell outputs.
The output voltage is given by, 
\[ V = V_a + V_b \]

where \( V_a \) = output of first cell, \( V_b \) = output of second cell. Therefore five levels of output voltage i.e. \( 2v, v, 0, -v, -2v \). The main advantage of cascaded H-bridge inverter is that it requires least number of components, modularized circuit and soft switching can be employed. But main disadvantage is that when voltage level increases the number of switches increases and also the sources this in effect increases the cost and weight. This inverter is operated with \( V_{dc} = 2v \). The pulse pattern for the circuit is generated by using the sinusoidal pulse width modulation. The output responses of model which are voltage and current waveforms and their THD spectrums are shown fig 4, 5, 6 and 7 respectively.

**IV. ARTIFICIAL NEURAL NETWORK CONTROL OF MULTILEVEL INVERTER**

In above fig consist of five level H-bridge inverters. IGBT power electronic devices use as switching components and five separated DC sources with equal amplitude. Input signals that entrance to NN have to normalize and output signal that exit from NN have to deormalized. Neurons and amount layers in each layer determined by optimization, where the optimum conditions occurs if the NN system has little amount of neurons, but have lowest error rate.
The implementation of feed forward neural network based SPWM is interesting. In Artificial Neural networks consists of an interconnected group of artificial neurons and process information using a connectionist approach to computation. In most cases an ANN is an adaptive system that changes its structure based on external or internal information that flows through the network during learning phase. Neural network are nonlinear statically data modeling tools. A neural network is an interconnected group of nodes, akin to the vast network in human brain.

The neural network used has one input neuron. The feed forward neural network accepts reference signal as input. And the neural network has five output neurons which gives pulses as output the pulses when are generated are given to CHMLI.

The five level CHMLI using NN control circuit diagram as shown in above fig. The NN controller trained by their inputs. This neural network produces output pulse signals which is given to CHMLI. The performance of training process in graph format is given in fig below.

![Performance of training process](image)

**Figure 4. Performance of training process**

![Output voltage waveform of five level CHMLI using NN controller](image)

**Figure 5. Output voltage waveform of five level CHMLI using NN controller**
Figure 6. Output current waveform of five level CHMLI using NN controller

Figure 7. THD spectrum of voltage waveform of five level CHMLI using NN controller
Figure 8. **THD spectrum of current wave form of five level CHMLI using NN control**

THD of CHMLI using NN control is further more decreased than conventional five level PWM inverter. From the comparison table it can conclude that neural network based multilevel has better performance than conventional multilevel inverter.

| Sr No | Five level Multilevel Inverter | Voltage THD in % | Current THD in % |
|-------|--------------------------------|------------------|------------------|
| 1     | Conventional CHMLI            | 9.67             | 3.17             |
| 2     | CHMLI using NN control        | 8.23             | 2.89             |

**IV. CONCLUSION**

Artificial neural network technique has been developed and used to realize the proposed technique. We observed that the multilevel inverter uses neural network has better performance than conventional one. From results it is observed as level increases THD is decreased. Five level cascaded multilevel inverter which is using neural network controller results in 8.23% for voltage THD and 2.89% for current THD and we found that Neural based multilevel inverter has given better performance compared to conventional multilevel inverter.

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