CHAPTER 1

INTRODUCTION

Multilevel inverters (MLI) have very important development for medium voltage and high power application due to their ability to synthesize waveforms with better harmonic spectrum. Multilevel inverters refer to the inverters with output which have more than two voltage levels possible with respect to pole. The feature of having an output voltage level that is higher than those of the power semiconductor switching devices' ratings puts the MLIs in high power inverters class. The application of MLIs has been extended to the medium power range due the advantages of reduced distortion, dv/dt stress and common mode voltage [1]–[3].

1.1 OVERVIEW

The cascaded H-bridge inverter (CHB) is a MLI topology with a modular structure. The main drawback of a CHB inverter is the need for a large number of isolated dc supplies [4]-[6]. To ease this problem hybrid multilevel inverters created by cascading smaller dissimilar inverter circuits are suggested [7].

Hybrid inverters have different approaches to achieve the goal of multilevel output such as: Employing different power switches like GTO and IGBT in cascade thus operating at low and high frequency[8] or modifying the series connection of cascade connected MLI[9] or obtaining multilevel output with combination of inverter and converter[10],[11] or replacing the dc supply of the lower voltage stages with capacitors and controlling the inverter to receive zero average power from the capacitor-fed stages [12], [13] or replacing the highest voltage cascaded stages with a singly-supplied inverter such as a basic 2-level, six-switch inverter [14] or a multilevel neutral point clamped stage [15] or supplying various hybrid inverter stages using the same dc source and isolating the outputs using a multi primaries transformer [16], [17] but this option is not suitable when a wide frequency range including very low frequency is needed and also by applying half bridge inverter cascaded with H bridge inverter[18] with single DC source or separate DC sources.

Multicarrier pulse width modulation (PWM) inverters have been developed to overcome shortcomings in solid-state switching device ratings, so that large motors can be controlled by high-power adjustable-frequency drives. Multilevel inverters can operate at both fundamental switching frequency and high frequency switching.

The different PWM schemes of multilevel inverters are classified into two types the multi carrier Sub- Harmonic pulse width modulation (MC-SH PWM) and the multi carrier switching frequency optimal pulse width modulation (MC-SFO PWM), Sub Harmonic PWM (SHPWM), Phase Shift PWM (PSPWM), Variable Frequency PWM

(VFPWM) and Carrier Overlapping PWM (COPWM) techniques employed for various modulation indices using spectrum of the output voltage. Other performance measures from above modulation techniques such as crest factor, form factor etc. and the use of inverter state redundancies to perform additional application specific control tasks.

For all above modulation techniques, the switching devices of the main power stage switch once per cycle for different modulation indices. This is suitable for the high power semiconductor devices. Stress on the devices is reduced and total harmonic distortion (THD) is also reduced.

The multicarrier PWM method uses several triangular carrier signals, keeping only one modulating sinusoidal signal. For an n level inverter n-1 carriers are employed [19] – [20]. The carriers have the same frequency and same peak to peak amplitude but are disposed so that the bands they occupy are contiguous. The zero reference is placed in the middle of the carrier set. The modulating signal is a sinusoid of frequency 50 Hz. At every instant each carrier is compared with the modulating signal. Each comparison gives high level or low level output if the modulating signal is greater or smaller than the triangular carrier respectively. The results are added to give the voltage level, which is required at the output terminal of the inverter.

Different multicarrier PWM methods include Phase Disposition (PD) Method [21], Alternative Phase Opposition Disposition (APOD) Method, Phase Opposition Disposition (POD) Method, Phase Shifted (PS) Method [22] and Hybrid Modulation Technique [23]-[26]. Different modulation techniques for hybrid multilevel inverter are studied in simulations and results are compared.

Other modulation techniques are also studied such as Multicarrier Sub Harmonic Pulse Width Modulation (MC-SH PWM)[27], Multi Carrier Switching Frequency Optimal PWM (MC-SFO PWM)[28], Phase Shifted Carrier Switching Frequency Optimal Pulse Width Modulation (PSC-SFO PWM)[29] and HLCCAPOPWM control technique [30].

The research will have an impact such that THD, stress on the devices are reduced. This project aims at developing a multilevel inverter using various pulse width modulation. It will be possible to implement the developed pulse width modulation techniques for linear range of modulation.

There are several types of multilevel inverters but the one considered in this work is the hybrid cascade multilevel inverter (HCMLI). HCMLI has many distinct features particularly in terms of its structure which is simple and modular.

Most multilevel inverters have an arrangement of switches and capacitor voltage sources. By a proper control of the switching devices, these can generate stepped output voltages with low harmonic distortions. These multilevel inverters are widely used in manufacturing factories and acquired public recognition as one of the new power inverter fields because they can overcome the disadvantages of traditional pulse width-modulation (PWM) inverters. The selected hybrid cascaded multilevel inverter includes a standard 3-leg inverter (one leg for each phase) and H-bridge in series with each inverter leg. It can use only a single DC power source to supply a standard 3-leg inverter along with three full H-bridges supplied by capacitors. But in this work separate four DC sources are used instead of capacitors because capacitors were not easily available. In case capacitor were used, balancing of capacitor is main task. Multilevel carrier based PWM method is used to produce a five level phase voltage. Control for this hybrid MLI is obtained using DSP 28335. Control signals are generated using MATLAB/SIMULINK (2013) in discrete model, code is generated using CCS 3.3/ CCS 5.1, which is loaded in EPB28335 using Emulator xds510USB.

The features and discussions of research carried out in the thesis includes:

- Survey of different modulation techniques, power circuits and limitations of existing topologies of Hybrid multilevel inverter (HMLI) with control circuitry.
- Comparison of different modulation techniques applied to different hybrid multilevel inverter topologies on the basis of THD using MATLAB simulation
- MATLAB simulations for selected HMLI (single phase and three phase) with different modulation techniques.
- Effect of amplitude modulation index (referred as modulation index in this work) and frequency modulation index on Total harmonic distortion (THD) for HMLI using MATLAB simulations.
- Design and development of power circuit for HMLI.
- Realization of hardware circuit using MOSFET/IGBT.
- Control signal realization using EPB28335 with CCS3.3 and emulator xds510usb
- Designing and implementation of interfacing card.
- Implementation of selected HMLI for low and high power output (single phase and three phase) with different modulation techniques using EPB28335.
- Testing of hardware circuit and comparison with simulated results.

1.2 ROADMAP

The thesis is organized as follows:

Chapter 1 This chapter provides an overview and the context for the remainder of the thesis. It also introduces the present trends in Multilevel inverter. It presents the significance and scope of work to be carried out in the thesis.

Chapter 2 This chapter gives comparative study of multilevel inverters and evolution of hybrid multilevel inverter. Hybrid multilevel inverters are classified on basis of power devices used, power supplies used and configuration of power devices. Other classification is based on modulation technique applied

Chapter 3 This chapter introduces different modulation techniques that can be applied to multilevel inverter. More focus is on multicarrier based modulation techniques. Discussion is related with modulation index which is based on modulation index and frequency modulation index.

Chapter 4 In this chapter MATLAB simulations carried out for different cascaded multilevel inverters and hybrid multilevel inverters are discussed to finalize the topology of this project. Important factors to be considered are total harmonic distortion, number of power supplies and number of power devices. Also output levels are decided initially.

Chapter 5 In this chapter MATLAB simulations are carried out for single phase and three phase with different modulation techniques and results are discussed for selected topology.

Chapter 6 In this chapter controlling of power switches is discussed. The processor used for controlling switching pattern of power circuit is TMS28335 with code composer studio and emulator. Control signals are obtained using MATLAB SIMULINK with Code Composer Studio and Emulator. All these interfaces are discussed in detail. This chapter describes steps involved in generation and application of control signals to power circuit.

Chapter 7 Design of the power circuit of hybrid multilevel inverter for five level output is described in this chapter. Design is for single phase and three phase circuits. Circuit is designed for low as well as high power rating. This chapter also describes regulated power supply design.

Chapter 8 In this chapter results obtained from hardware are given and compared with simulation results.

Chapter 9 Conclusion and further possible expansion with respect to output power and load applied are discussed in this chapter. Also applications could be open loop or closed loop as per requirement.

Chapter 10 Thesis ends with Bibliography which includes the list of references used in each chapter.