ABSTRACT

Cascaded multilevel inverters synthesize a medium voltage output based on a series connection of Full Bridge Inverters (FBI) which use standard low-voltage component configurations and it is popular for many applications at high power rating due to its modular nature of modulation, control and protection requirements. The main objectives of this thesis are to propose computationally efficient Sequential Switching Hybrid Sinusoidal Modulation (SSHSM) techniques for Cascaded Multilevel Inverter (CMI), for switching loss reduction with good harmonic performance. In addition to that, the imbalances in DC-link capacitors, unequal power loss among the devices within a FBI, series connected power modules, power sharing issues are analyzed and the compensation for their effects is presented.

Hybrid modulation represents the combination of Fundamental Frequency Pulse Width Modulation (FFPWM) and Multilevel Sinusoidal Pulse Width Modulation (MSPWM), which provides the integrated solutions of minimum switching frequency and high power quality. A new series of Hybrid Alternate Phase Opposition Disposition (HAPOD), Hybrid Phase Shifted Carrier (HPSC), Hybrid Carrier Based Space Vector Modulation (HCBSVM) and Hybrid Single Carrier Sinusoidal Modulations (HSCSM) has been proposed and investigated. The modulated waves of Space Vector Modulation (SVM) are transformed in to Carrier Based SVM (CBSVM) by

adding offset voltages, for development of HCBSVM to get SVM performance with reduced switching transitions. This modulation possesses the hybrid characteristics of FFPWM and CBSVM. The proposed modulation techniques are evaluated and compared with standard MSPWM schemes.

Sequential switching hybrid modulation and base MSPWM circulation controllers, based on a simple combinational logic are proposed. A sequential switching method is used to overcome differential heating among the power devices within an inverter cell due to unequal switching losses, thereby improving inverter reliability. Also, a base MSPWM circulation scheme is embedded to get resultant SSHSM circulation among the inverter cells that effects balanced power dissipation. These control methods take the advantages of DC link capacitor voltage balancing, and equal power sharing among the series connected inverter cells throughout the voltage region.

Experimental investigations on these modulations are performed on Digital Signal Processor (DSP) - Complex Programmable Logic Device (CPLD) based digital control five-level CMI. MSPWM and its base modulation design are implemented on a low cost TMS320F2407 DSP. A Xilinx XC95108 CPLD controller realizes hybrid modulation control and base MSPWM circulation algorithms, and integrated with DSP for SSHSM pulses generation. Experimental measures on power losses and heat sink temperature rise of the power modules are done; the advantage of thermal equalization is illustrated.

The mathematical models for power devices using switching characteristics are obtained to estimate the switching and conduction losses. The switching and power loss saving due to SSHSM modulations are analyzed and quantified. Operations of these modulations in the linear and over-modulation regions are performed to show the capability of the total utilization of the inverters. The harmonic analyses of the resulting voltage and current waveforms in entire operating regions are performed, and the resultant outcome is presented. The spectrum studies on DC current ripple are also investigated, the effectiveness in reducing current ripple and equal RMS ripple value among the inverter cells are obtained.

Furthermore, the proposed modulations are generalized to a higher level inverter operation and make the superior harmonic performance. Even with an increase in the number of phases, the principle of modulations remains same that enables generation of quality inverter output, and extended to take the advantage of multiphase multilevel converters. The HCBSVM can be applied to a converter with any number of levels and phases, avoiding the use of conceptually and mathematically complex SVM strategies. In addition, the proposed SSHSM schemes are feasible for real time implementation due to its low computational complexity and direct use with existing CMI structures without any additional power circuitry.

Analyses and comparison of the new modulation schemes allow to evaluate in an objective way the contributions brought by this work. These control methods make reduced switching losses, low harmonic distortion, DC capacitor voltage balancing, and balanced power distribution and equal

loading in CMI operation. It is found that the newly proposed modulation schemes cover an area of single phase, three phase and multiphase CMI structures. The power loss reduction due to these modulations could help to improve the efficiency of the system, reduce the size of heat sink, thereby aiding design of compact and reliable power converter.