CHAPTER 11

CONCLUSIONS AND FUTURE WORK

A summary of the major contributions of this work is presented in the following sections. The significance of these contributions towards the advancement of understanding the multilevel topologies is included in this chapter. In the end, future investigations on alternate topologies, modulation strategies, and control schemes that can be carried are also discussed.

11.1 PWM Schemes in Three-Level Inverter

Novel control techniques for controlling the neutral point voltage using the carrier-based PWM technique are presented. Continuous and the discontinuous schemes are proposed in Chapter 4. Different modulation schemes are studied on three-phase three-level inverter. An analytical methodology for the determination of the expressions for the modulation signals required for continuous PWM scheme for a generalized multilevel inverter using the single carrier and multiple modulation signals was developed. The proposed scheme is generalized for higher levels of the inverter. Simulation results for the neutral current control for three-level inverter are provided. Also the methodology for deriving the expressions for modulation signals required for

carrier-based generalized discontinuous PWM schemes was developed. Detailed analysis for deriving the generalized zero sequence voltage is being laid out. A novel control scheme for controlling the neutral point voltage using the hysteresis control was developed. A prototype of three-level inverter was developed to validate the control scheme. Simulation and experimental results are provided.

11.2 Control of Three Phase Three Leg Three Level Rectifier

Control schemes for a three-phase three-leg three-level rectifier is presented to regulate the dc link voltage and to draw balanced and sinusoidal line currents. The report formulates step-by-step modeling of the converter both in the abc and qdo reference frame. Steady-state analysis has also been done. In the proposed control schemes, the line currents are controlled to be sinusoidal with unity power factor under the balanced operation. The control methodology using the natural reference frame and the control methodology using the qd analysis is laid out. Two control schemes with detailed modeling and also the control design has been provided. Simulation results show the validity of the proposed control scheme.

11.3 Control of Three Phase Two leg Three Level Rectifier

A novel control scheme for regulating the dc link voltage and to draw balanced and sinusoidal line currents using the natural reference frame controller three-phase two-leg three-level rectifier is presented. Detailed analysis of the converter with qdo modeling and steady state analysis is presented. Design of the controller and selection of the controller parameters is explained in detail. Simulation results are provided to validate the control scheme proposed.

11.4 Control of Three Phase Three Leg Three Level Rectifier under Unbalanced Conditions

A new control methodology for the control of multilevel three phase rectifiers using the natural a-b-c currents is proposed in this chapter. The natural currents are regulated using a new PI controller structure that ensures regulation without magnitude and phase angle error. The control scheme, which is applicable when the voltage sources and line impedances are balanced, or unbalanced, ensures that the output dc voltage is well regulated with a constant input power. Through simulation results, the validity of the suggested control scheme is validated. For balanced sources and line impedances, input unity power factor operation is secured in addition to a constant DC output

voltage; while for unbalances in the sources and/or in the load impedances, the input power is constant and the DC voltage regulated.

11.5 Current Regulation of a Three-Phase Unbalanced Voltage Source Inverter

A detailed analysis and design procedure of an abc reference frame current regulated three-phase voltage source inverter feeding a load with balanced/unbalanced impedances and back emfs is presented. The controller structure in this reference frame is determined with methodologies to determine their gains when the response is desired to follow the Butterworth pattern. In order to synthesize the likely unbalanced required voltages to regulate and balance the phase currents, a novel discontinuous carrier-based modulation scheme is developed which with enhanced out-input voltage gain, possible reduction in switching losses due to device clamping to the dc rails leading to better utilization of the dc voltage source aid the response of the controller. Simulation results have been shown demonstrating the quality of the regulators at the beginning of the system operation and when the back emfs change from being sinusoidal and balanced to being modulated square waves. In-spite of the non-sinusoidal nature of the back emfs, the regulated current waveforms is sinusoidal and balanced thanks to the impressed unbalanced voltages to the phases.

11.6 Contributions of This Work

- The development of systematic modeling methods for the control of the neutral point voltage of the three level inverter is the one of the major contributions.

- Generalization of the zero sequence voltage, which reduces the complexity of implementing the three-level inverter.
- Complete description of the analysis in deriving the modulation signals and the discontinuous scheme.
- The carrier based PWM scheme using single-carrier and multiple modulation signals for a generalized N-level inverter is one of the contributions.
- Development of laboratory prototype of three level diode clamped inverter.
- Developing a DSP code for generating the gating signals using the carrier-based PWM method for controlling the neutral voltage by using TMS320LF2407 DSP.
- Analysis and a detailed studied of the new structure of the controller called the natural reference frame controller.
- Control of the three-phase three-leg three-level rectifier using the natural variables to regulate the dc bus voltage and to achieve the unity power factor operation.
- Control of the three-phase two-leg three-level rectifier using the natural variables to regulate the dc bus voltage and to achieve the unity power factor operation.
- Control of the three-phase three-level unbalanced rectifier using the natural variables to regulate the dc bus voltage and to transfer constant power under unbalanced conditions and also to achieve the unity power factor condition in case of balanced operation.
- Current regulation of the three-phase unbalanced voltage source inverter using the natural reference frame controller.

11.7 Future Work

Finally, there are several interesting topics for future research work:

- The principle for discontinuous scheme proposed for the three-level diode clamped converter could be extended in generalizing the technique to N level converter.
- Analysis of the over modulation operation of the three-level inverter using the carrier-based technique.
- Extending the scheme for single-phase, five-phase and multi-phase converters.
- The research work that is been done on the multilevel inverters is under balanced load conditions, which is not the case in general, hence similar to the two-level inverter under unbalanced load conditions usage of the fourth leg to absorb the unbalance voltage and produce balanced three-phase voltage; i.e., Four-leg Three-level Three-phase inverter will be a good extension of the work.
- Some extended work on the unbalance operation of the inverter like the current regulation using the natural reference frame controller to generate balanced load currents under unbalancing load conditions.
- The carrier-based PWM scheme proposed in the present work, developing a generalized logic, which can remove the shorting of the devices for any level of the inverter.
- Exploring the applications of the inverters in areas like the active power filters, FACTS devices.

- The extension of the control scheme proposed for the unity power factor operation of the three-phase three-leg three-level rectifier and three-phase two-leg three-level rectifier such that the rectifier can be controlled to produce variable power factors so that it can operate in the leading or lagging or unity power factor mode.
- Generalizing the current regulation technique using the natural reference frame controller to multi-phase unbalanced systems.