CHAPTER 2
LITERATURE SURVEY

2.1 INTRODUCTION

This chapter outlines the major research works reported so far in the multilevel inverter topologies and modulation techniques. Performance analysis of various multilevel inverters reported in the literature is given in section 2.2. Modulation techniques applicable for different multilevel inverters are presented in section 2.3. Inferences from existing works are summarized in section 2.4.

2.2 REVIEW ON MULTILEVEL INVERTER TOPOLOGIES

Multilevel inverter technology has been developed recently as a very significant alternative in the area of medium and high power applications. Jose Rodriguez et al (2002) discussed the most important topologies like diode clamped inverter, flying capacitor inverter, cascaded multi-cell with separate DC sources and emerging topologies like asymmetric hybrid cells and soft-switched multilevel inverters. The most relevant control and modulation methods developed for this family of converters like multilevel sinusoidal pulse width modulation, multilevel selective harmonic elimination and space vector modulation were also discussed. Special attention was devoted to the latest and more relevant applications of these converters such as conveyor belts, laminators and unified power flow controllers. Finally, the peripherally developing areas such as high-voltage
high power devices, optical sensors and other opportunities for future development were addressed.

Leon Tolbert et al (2002) presented transformerless multilevel inverters for the applications of high power Hybrid Electric Vehicle (HEV). Multilevel inverters could generate nearly sinusoidal voltages with fundamental frequency switching. It did not have electromagnetic interference or common-mode voltage problem. These features made an HEV more accessible and safer. Cascaded multilevel inverter used several levels of DC voltage sources, which will be available from batteries, ultra-capacitors, or fuel cells. So, it was fit for large automotive hybrid electric drives. Simulation and experimental results showed how to operate this inverter in order to maintain equal charging and discharging operations from the DC sources in hybrid electric vehicles.

Zhong Du et al (2006) proposed a cascaded multilevel inverter which is implemented using only a single DC power source and capacitors. Typical cascaded multilevel inverter required n number of DC sources for 2n+1 levels. The proposed scheme employed the use of a single DC power source without transformers and the remaining n−1 DC sources being capacitors. In this proposed scheme, the DC voltage level of the capacitors was maintained and also a fundamental switching frequency pattern was utilized to produce a nearly sinusoidal output voltage. The switching angles were chosen to eliminate harmonics in the output voltage waveform.

Rajesh Gupta et al (2007) proposed a Distributed Static Compensator (DSTATCOM), based on cascaded transformer multilevel inverter. The proposed scheme needed a common DC storage capacitor. Two level ramp comparison current control method was extended for the multilevel inverter using phase shifted multi-carrier Pulse Width Modulation (PWM) Technique. In this method, equal switching stress and equal power
handling for all the cascaded units can be achieved. The net switching frequency increased with decrease in ripple magnitude, causing the feed forward gain to increase leading to a higher bandwidth of the control loop. An expression for the feed forward gain had been derived which showed that the use of proportional plus resonant controller with proposed multilevel modulation makes the tracking characteristics to get improved at fundamental frequency. A seven level inverter based DSTATCOM was proposed for application to the three phase medium voltage distribution system and results were proved by Power System Computer Aided Design (PSCAD)/ Electromagnetic Transients Including DC (EMTDC) simulation.

Jose Rodriguez et al (2007) described a technology review of voltage source converter topologies for medium voltage industrial drives. They had discussed many inverter topologies like diode clamped, cascaded H-bridge and flying capacitor converters. Operating principle of each topology with relevant modulation methods was employed. It concluded that the selection of topology and modulation method were closely related to a particular application and also gave solution to the problems like voltage level, dynamic performance, reliability, costs and the other technical specifications.

Dietmar Krug et al (2007) compared the component count and the expense of active and passive components of the different multilevel inverter topologies for 2.3 kV, 2.39 MVA industrial medium voltage drives. Diode clamped multilevel inverter is one of the competitive topology for large variety of low and medium switching frequency (≤ 1000Hz) applications. The high capacitance values and stored energies of the flying capacitors limit the use of the flying capacitor multilevel inverter to high switching frequency (≥ 1200Hz) applications. Cascaded H-bridge multilevel inverter is an attractive topology for various medium voltage drives because it required
lowest installed switch power and stored energy of the LC sine filter. Insulated Gate Bipolar Transistor (IGBT) was recommended for industrial medium voltage drives.

Alireza Nami et al (2011) proposed H-bridge multilevel pulse width modulation converter topology which included a series connection of a high voltage diode clamped inverter and a low voltage conventional inverter. A DC link voltage arrangement was used to get maximum number of output voltage levels with the help of adjacent switching vectors between voltage levels. By doing this, a fifteen level hybrid converter was attained with least number of power components. The output voltage THD obtained in the fifteen level hybrid inverter is 7.2%. With the help of a comparative study, it had been proved that the performance of the proposed converter was improved with low total harmonic distortion of voltage and current with elimination of the output filter. Simulation and hardware results proved that a high quality output voltage was achieved.

Banaei & Salary (2011) proposed a new multilevel inverter that operated both in symmetric and asymmetric states. This inverter generates DC voltage levels with less number of switching devices. As a result, reduction in losses, converter cost and installation area was achieved. Number of gate driver circuits were also reduced in this topology. From this topology, a nearly sinusoidal output voltage with low harmonic distortion can also be achieved. Voltage injection capabilities of the proposed converter were verified by applying this topology in Dynamic Voltage Restorer (DVR). Their operation and performance were verified by MATLAB/Simulink and experimental results.

Anup Kumar Panda & Yellasiri Suresh (2012) proposed Cascaded Multilevel Inverter (CMI) which employed a single DC source and three phase transformers. Proposed CMI has the attractive features of low
switching frequency, increased utilization rate which allowed to achieve high quality output voltages and input currents. The proposed CMI was reliable, cost effective and compact due to less number of components which were proved by prototype experiments. Voltage THD obtained in the proposed seven level inverter was 10.23%. Because of these, the proposed architecture was superior over the conventional methods. These features made the proposed converter applicable for grid-connected photovoltaic systems, wind power generator systems and Flexible Alternating Current Transmission Systems (FACTS).

Multilevel inverters had been proposed to handle high power and high voltage in the flexible power systems. They had advantages over conventional two level converters, out of which high quality of the output voltage was most important. Ebrahim Babaei et al (2012) proposed symmetric and asymmetric multilevel inverter topologies with less number of switching devices compared to other topologies. Hybrid topologies are operated in high voltage levels and their simulation results were obtained with Power System Computer Aided Design (PSCAD)/ Electromagnetic Transients Including DC (EMTDC) software and the experimental results were presented.

Banaei & Salary (2012) proposed a novel cascaded multilevel inverter, which employed two DC sources, single phase transformers and semiconductor switches. This inverter operates in both symmetric and asymmetric modes and gives more number of voltage levels. Gate driving circuits required for this inverter was less, lead to reduced circuit size and lower power consumption. Several methods available for the determination of the turns ratio had been given. Theoretical analysis was done and simulation results were verified using MATLAB/Simulink software. The output voltage THD obtained for the twenty seven level inverter was 2.91%. Experimental results were provided to verify the simulation results.
Due to the increased usage of power converters, the power quality problem became the hot research topic in the recent years. As the power level increases, the voltage level was increased accordingly to obtain better performance. The advantages of multilevel inverter topologies were low distorted output voltage waveforms, low electromagnetic interferences and limited voltage stress on the switching devices. The main disadvantage is complexity in driver circuit which can be overcome by using modern digital controllers. Venkatachalam Kumar Chinnaian et al (2013) proposed a three phase multilevel inverter with the power semiconductor switches to reduce the power quality issues in solar power conversion system. Performance parameters were analysed with the developed prototype of the three phase cascaded multilevel inverter for solar energy conversion.

Multilevel inverters were popular because of low voltage stress, low THD in output voltage waveform. Krishna Kumar Gupta & Shailendra Jain (2013) proposed a new multilevel inverter topology which produces additive and subtractive combinations of input DC levels at the output voltage waveform, the actual number of levels depended on the DC source arrangement. Comparison was made between proposed and classical multilevel topologies on the basis of device count and number of levels in the output voltage waveform. Also, a detailed study of the proposed topology and appropriate modulation scheme applied, had also been presented. The proposed concept was analysed through simulation and hardware.

Ebrahim Babaei et al (2013) proposed a cascaded multilevel inverter topology with less number of switching devices which also offered provisions to design a desired multilevel inverter. Optimization of the proposed cascaded multilevel inverter considering some factors such as number of semiconductor switching devices, number of output voltage levels and the voltage across each switch was given. The important reason for
improved output power quality was that the multilevel inverters generate a nearly sinusoidal output voltage. Cascaded H-Bridge (CHB) multilevel inverters can also be derived from the proposed inverter. Performance parameters related to conventional CHB inverters were analysed with thirteen level inverter by the simulation and experimental setup.

2.3 REVIEW ON MODULATION TECHNIQUES

John Chiasson et al (2003) proposed a technique which helped to find out switching angles to get the required output voltage and to cancel higher order harmonics. A complete analysis was done for seven level converter with three DC sources and it proved that, for various modulation index values, desired fundamental value was produced making the fifth and seventh harmonics zero. A full solution to the above said problem of eliminating the fifth and seventh harmonics in a seven level inverter has also been given. Resultant theory was used to solve the nonlinear transcendental equations when a solution existed and when it did not. For certain range of values, two sets of solutions were obtained by resultant theory. Also, the solution set that minimizes the $11^{th}$ and $13^{th}$ harmonics was chosen. Experimental results were compared with the theoretical results and presented.

Cascaded multilevel inverters were constructed by series connected single phase modular power bridges. Poh Chiang Loh et al (2005) presented the implementation and operation of the proposed inverters. The proposed work specified clearly about the development and control of an integrated power bridge with its own digital signal processor and also associated control circuit. The network control algorithm and signal protocol for synchronizing multiple power bridges were presented. Also, optimum harmonic cancellation and reduced common mode voltage were achieved. Performance of the
proposed system was verified through simulation and experiment on a five level prototype inverter.

An active harmonic elimination method to eliminate any number of specific higher order harmonics of multilevel converters with equal or unequal DC voltages was developed by Zhong Du et al (2006). First, resultant theory was applied to transcendental equations characterizing the harmonic content to eliminate low order harmonics and to determine switching angles for the fundamental switching frequency scheme and a unipolar switching scheme. Next, the residual higher order harmonics were computed and subtracted from the original voltage waveform to eliminate them. The simulation results showed that the method can effectively eliminate the specific harmonics and produce a nearly sine wave with a low THD. An experimental eleven level H-bridge multilevel converter with a field programmable gate array controller was employed to implement the method. The experimental results showed that the method effectively eliminates any number of specific harmonics and hence the output voltage waveform has low THD.

The issue of voltage imbalance remains a challenge for the flying capacitor multilevel inverter. The Phase Shifted Pulse Width Modulation (PS–PWM) method had a certain degree of self-balancing properties. However, the method alone is not sufficient to maintain balanced capacitor voltages in practical applications. Chunmei Feng et al (2007) proposed a closed-loop modified PS–PWM control method by incorporating a novel balancing algorithm. The algorithm took the advantage of switching redundancies to adjust the switching times of selected switching states and thus maintaining the capacitor voltages balanced without adversely affecting the system’s performance. Key techniques of the proposed control method, including selection of switching states, calculation of adjusting times for the
selected states and determination of new switching instants of the modified PS–PWM were described and analysed. The voltage and current THD obtained for five level inverter using this modulation was 13.1% and 5.3%. Simulation and experimental results were presented to confirm the feasibility of the proposed method.

Multilevel inverters can reduce the common mode voltage generated. Reduction in common mode voltage results in reduced modulation depth, high switching losses and high harmonic distortion which was proved by a space vector modulation scheme proposed by Amit Kumar Gupta & Ashwin Khambadkone (2007) for cascaded multilevel inverters. This proposed scheme had the capability of increasing the voltage range of operation by about 17% and can produce lower total harmonic distortion than the previously proposed schemes. This scheme can be easily extended to n-level inverter.

Shuai Lu & Keith Corzine (2007) introduced a new control method for the cascaded multilevel inverter. It was a suitable option for high power and high performance demanding applications such as naval ship propulsion. A new control method for the topology using three level bulky and conditioning inverters which was connected in series through a three phase load is proposed. This control method avoided PWM frequency switching in the bulk inverter. The control of the conditioning inverter was based on compensating the Real and Reactive (P-Q) power difference between the inverter and the load. The new control explicitly commanded power into the conditioning inverter so that its capacitor voltage remains constant. A unique space vector analysis of hybrid inverter modulation was introduced to quantitatively determine the operating limitations. The conclusion was then generalized for all types of hybrid multilevel inverters, involving three level converter cells. The proposed control methods and analytical conclusions were verified by simulation and laboratory measurements.
A fault diagnostic system in a multilevel inverter using a neural network was developed by Surin Khomfoi & Leon Tolbert (2007). Diagnosing Multi Level Inverter Drive (MLID) system using a mathematical model was difficult because MLID systems consist of many number of switching devices. Hence, a neural network was applied to the fault diagnosis of a MLID system. The type and location of occurring faults were identified by five Multi-Layer Perceptron (MLP) networks from a measurement of inverter output voltage. The design process of neural network was described clearly. A better understanding about fault behaviours, diagnostics and detections of a multilevel inverter drive system can be accomplished by utilizing the proposed neural network fault diagnostic system. The results of this analysis were identified in percentage tabular form of faults and switch locations.

Jason et al (2007) proposed modulation based method for generating pulse waveforms with selective harmonic elimination. Harmonic elimination can be achieved by the comparison of a sine wave with modified triangular carrier. This method was used to calculate the desired waveform without solving the transcendental equations. This approach was based on a modified carrier waveform which can be calculates using concise functions requiring only depth of modulation as input. It rapidly calculated the desired switching waveforms which avoids iteration and initial estimates. Calculation time is insensitive to the switching frequency ratio. So elimination of many harmonics was straightforward. This technique was realized with low cost microcontrollers for implementation in real time. Once the carrier was computed, a conventional carrier-modulator comparison process produces switching instants in real time.

Amit Kumar Gupta & Ashwin Khambadkone (2007) proposed a simple space vector pulse width modulation algorithm for a multilevel
inverter in the over modulation range. The location of the reference vector was easily determined by the proposed scheme. This scheme also calculates ON times. This proposed scheme used a simple mapping to produce gating signals for the multilevel inverter. A five level cascaded inverter is used to demonstrate the operation of proposed scheme. This scheme can be easily extended to n-level inverter. This was also applicable to neutral point clamped topology. Experimental results were provided for five level and seven level cascaded inverters.

Five level symmetrically defined Multilevel Selective Harmonic Elimination Pulse Width Modulation (MSHE–PWM) strategy was reported by Vassilios Agelidis et al (2008). This PWM technique was mathematically expressed using Fourier based non-linear equations on a line to neutral basis. An equal number of switching transitions were produced when compared against the well-known Multicarrier Phase Shifted Sinusoidal PWM (MPS–SPWM) technique. Seventeen switching transitions for every quarter period were produced in MPS–SPWM method using four triangular carriers. Control of sixteen harmonics and the fundamental was achieved using the proposed MSHE–PWM. This proposed method offers higher converter bandwidth in the standard range of the modulation indices. Selected solutions for the switching transitions were verified experimentally in order to confirm the effectiveness of the proposed technique.

Wenxi Yao et al (2008) have described the relations of Space Vector Modulation (SVM) and carrier based PWM for multilevel inverter. The PWM generation of SVM can be achieved by carrier based PWM scheme, but the modulated wave of SVM is acquired by vectors calculations and switching states selection. There were many types of SVM modulated waves based on the selection of redundant switching states, some of which can function equivalently through proper selection of common mode
injections in the case of carrier based PWM. Selection of more switching states in space vector modulation was propitious to optimize the output voltage, balance the DC power and so on. An improved PWM scheme was proposed based on the modulation waves of three level SVM, which reserved the main advantages of SVM and can be achieved easily. Finally, a five level test circuit was built to verify this PWM scheme.

Multilevel inverters were controlled through modulation techniques which are conceptually based on nonlinear waveform synthesis assuming constant DC-link voltages like most power converter topologies. Load and supply dependent DC-links in real time applications consisted of low frequency ripple. These were modulated and transmitted to the load which generates undesirable low frequency voltage and current distortion. Samir Kouro et al (2008) introduced a simple but effective DC-link ripple feed forward strategy into traditional carrier-based modulation techniques. The measured DC-link ripples were used to modify the carriers or the reference signals directly in the modulation stage. Voltage THD obtained for seven level inverter using proposed Phase Shifted PWM (PSPWM) was 20%. Simulation and experimental results showed the accuracy of the proposed method in eliminating lower order harmonics.

Mohamed Dahidah & Vassilios Agelidis (2008) proposed a new variation of Selective Harmonic Elimination Pulse Width Modulation (SHE-PWM) technique which is suitable for a high power five level inverter used in constant frequency utility applications. A set of non-linear equations associated with the elimination of specific harmonics was defined based on equal number of switching transitions when compared against the Single Carrier Sinusoidal PWM (SC-SPWM) technique. The switching transitions for every quarter period were distributed between the converter levels with respect to the modulation index of SC-SPWM. Higher converter bandwidth
and higher DC bus utilization was achieved using the proposed technique for the same switching transitions. Better harmonic performance when compared to its SC-SPWM counterpart was also attained in the proposed technique. Effectiveness of the proposed technique was verified experimentally for the selected solutions of switching transitions.

Anshuman Shukla et al (2008) focused on the development of multilevel hysteresis current regulation strategies. Two strategies have been discussed and some modifications in their control tasks had been proposed to achieve more reliable and improved performance. The multiband concept was used while making the proposals. Desired and existing system conditions were taken into account for hysteresis band size considerations. The operation of a five level flying capacitor inverter which utilized the proposed technique under hysteresis current control mode was much less established. A new method for voltage balancing of flying capacitor was proposed which ensures balanced flying capacitor voltages. The desired current profile was maintained at the same time. Time-based approach was used for controlling the capacitor voltages and also appreciable voltage spectrum under wide range of load power factor conditions was achieved. The performance of the proposed technique was confirmed by both simulation and experimental investigations.

Krikor et al (2008) described the Optimized Harmonic Elimination Stepped Waveform (OHESW) technique to improve the quality of output voltage waveform of multilevel inverter fed induction motor. A new method was presented where switching angles were computed such that a desired fundamental sinusoidal voltage was produced, while at the same time certain higher order harmonics were eliminated. The proposed method also minimize the THD of the synthesized multilevel output voltage waveform. THD was investigated over a wide range of possible output voltages and a number of
voltage levels were used to synthesize the output waveform. Simulation results of a cascaded multilevel inverter under OHESW technique with five level to fifteen level were used to eliminate the third to thirteenth harmonics. The voltage THD obtained in simulation for seven level case was 11.62%. A prototype single phase cascaded seven level inverter loaded by single phase induction motor was investigated.

Zhong Du et al (2008) presented a Reduced Switching Frequency Active Harmonic Elimination Method (RAHEM) to eliminate any number of specific order harmonics of multilevel inverters. First, resultant theory approach was applied to solve transcendental equations for eliminating lower order harmonics and to determine switching angles for a low frequency switching method. Second, Newton climbing technique was applied to solve transcendental equations for eliminating higher order harmonics and to determine switching angles for a low frequency switching method. Third, the magnitudes and phases of the residual lower order harmonics were computed and subtracted from the original voltage waveform to eliminate these lower order harmonics. RAHEM has lower switching frequency in comparison with the Active Harmonic Elimination Method (AHEM). An eleven level H-bridge inverter with a field programmable gate array controller is used to validate the method experimentally. It was concluded that RAHEM can effectively eliminate all the specific harmonics and able to produce nearly sine wave output voltage with low THD.

Govindaraju & Baskaran (2010) presented a novel hybrid carrier based space vector modulation for cascaded multilevel inverters. The properties of carrier based space vector modulation technique and the fundamental frequency switching technique were utilized in the proposed modulation method. The reduction of power loss and improved harmonic performance were also achieved using this method. The carrier based space
vector modulation algorithm was implemented with a TMS320F2407 digital signal processor. Low value of Weighted Total Harmonic Distortion (WTHD) and equal switching stress among the power devices were attained in the proposed inverter. The voltage and current THD obtained for five level inverter using proposed modulation is 21.4% and 4.03%. The feasibility of the proposed technique was verified by spectral analysis through simulation and experimentation.

Converters for Photo Voltaic (PV) systems usually has a DC/DC booster and a PWM inverter. This cascade connection of converters presents efficiency issues, interactions between its stages and problems with the maximum power point tracking. Only part of the produced electrical energy is utilized. Carlo Cecati et al (2010) proposed a single phase H-bridge multilevel converter for PV systems governed by a new integrated Fuzzy Logic Controller (FLC). Proposed system not requiring any optimal PWM switching angle generator and proportional integral controller. Most of the required signal processing was carried out by a mixed mode Field Programmable Gate Array (FPGA) controller, resulting in a fully integrated system on-chip controller. The general architecture of the system and its performance in a large spectrum of practical situations were presented and discussed. The proposed system offered improved performance over conventional two level inverters used in low and medium power applications.

Govindaraju & Baskaran (2010) proposed a hybrid carrier based space vector modulation, which was suitable for multiphase multilevel inverters. Multiphase variable voltage and variable frequency supply was obtained by the multilevel inverters through this hybrid modulation. This proposed modulation scheme took over the features of fundamental frequency modulation and carrier based space vector modulation method. Reduction in power losses and improved harmonic performance was attained by this hybrid
modulation. This hybrid modulation was best suited for implementation of cascaded multilevel inverter topologies in real time, since it has low computational complexity. Theoretical considerations were detailed using a five phase multilevel inverter. The performance of this hybrid modulation was analysed based on power loss, weighted total harmonic distortion, linearity and it was compared with standard modulation strategies. Simulation and experimental results confirmed the good performance of the proposed modulation scheme.

Faete Filho et al (2011) estimated the selective harmonic elimination problem using Artificial Neural Networks (ANNs) to generate the switching angles for eleven level full bridge cascade inverter which was supplied by five DC input sources. Each full bridge of the cascade inverter was connected to a separate 195-W solar panel. The lower order harmonics were minimized or eliminated. Non-linear equations were solved by non-deterministic method to obtain switching angle data set for the ANN training. This proposed method also provided a set of acceptable solutions in the space where solutions do not exist by analytical methods. The trained ANN was a suitable tool that brings a small generalization effect on the angles precision and it had the ability to perform in real time.

In medium and high power inverters, Optimal Pulse Width Modulation (OPWM) was often used to reduce the switching frequency, also to realize SHE technique. For both two level and multilevel inverters, most selective harmonic elimination studies were based on solving multiple variable higher order nonlinear equations. SHE technique had been often studied based on the assumption of balanced DC levels and single switching per level. Damoun Ahmadi et al (2011) presented equal area criteria based four equation method to realize OPWM for two level inverters and multilevel inverters with unbalanced DC sources. For the cases, where only a small
number of voltage levels were available, weight oriented junction point distribution was utilized to enhance the performance of the four equation method. A case study of multilevel inverter at low modulation index was presented and compared with the existing methods.

Multilevel inverters inject harmonics into the network in addition to their remarkable advantages. THD is considered as an important index to evaluate the harmonic contents of waveforms. The conventional method of line voltage THD calculation gave approximate answers, because higher order harmonics were ignored. In this proposed work, an analytical algebraic method based on formulating the line voltage THD of multilevel inverters with unequal DC sources was presented by Naeem Farokhnia et al (2011). This method was applicable to each number of switching angles and also implemented in a five level inverter with staircase waveform as a case study. The implementation process of this method can be easily repeated for various number of levels. The accuracy of the proposed method was illustrated in comparison with the approximate method. Some advantages of the extracted formulae of line voltage THD are simple and the possibility of finding optimal switching angles. Experimental results were presented to validate the theory.

Ilhami Colak et al (2012) proposed an enhanced Sinusoidal PWM (SPWM) modulation scheme to minimize THD by eliminating the side band harmonics, not considered in regular modulation schemes. The harmonic elimination feature of SPWM was improved with the developed switching scheme. Unlike the conventional SPWM, the developed modulation scheme considered the elimination of harmonics located at the carrier frequency and at the side bands of carrier frequencies. Thus, the higher order harmonics were eliminated by the above said feature. The elimination of higher order harmonics decreases the harmonic contents in the THD spectrum. The
proposed SPWM schemes were implemented with TMS320F2812 DSP. The simulation was carried out with MATLAB/Simulink software and experimental studies were performed with the designed prototype.

Ayoub Kavousi et al (2012) presented the Bee optimization method for harmonic elimination in a cascaded multilevel inverter. The main objective in selective harmonic elimination pulse width modulation strategy was to eliminate lower order harmonics by solving nonlinear transcendental equations, by which the fundamental component was also satisfied. In this proposed work, the Bee Algorithm (BA) was applied to a cascaded seven level inverter. The algorithm worked on the food foraging behaviour of a swarm of honeybees and it performed a neighbourhood search combined in addition with a random search. The line voltage THD for seven level inverter using bee algorithm was 8.99%. The simulation was carried out with MATLAB/Simulink software and experimental studies were performed with the designed prototype for verification purposes.

2.4 INFERENCE FROM EXISTING WORKS

From the literature survey it was found that, various topologies such as diode clamped, flying capacitor and cascaded multilevel inverters had been adopted to reduce the power quality problems of conventional voltage source inverters (Jose Rodriguez et al 2002). These conventional multilevel inverters require large number of switching devices. Among the three basic topologies cascaded multilevel inverters require less components (Dietmar Krug et al 2007, Anup Kumar Panda & Yellasiri Suresh 2012). Many researchers presented the hybrid topologies to reduce the number of semiconductor switches and DC voltage sources (Zhong Du et al 2006, Alireza Nami et al 2011, Krishna Kumar Gupta & Shailendra Jain 2013).
A major effect of harmonic voltages and currents in medium and high power induction motor drive was increased heating due to iron and copper losses at the harmonic frequencies (Bell & Sung 1997). Motor efficiency and the torque developed were affected by the harmonic components. Harmonic currents in a motor can give rise to a higher audible noise emission as compared with sinusoidal excitation (Peter Hammond 1997, Mohapatra et al 2003). The quality of the output voltage can be improved by several modulation techniques such as space vector PWM (Wenxi Yao et al 2008, Amit Kumar Gupta & Ashwin Khambadkone 2007), selective harmonic elimination (John Chiasson et al 2003, Zhong Du et al 2006, Vassilios Agelidis et al 2008) and sinusoidal PWM (Chunmei Feng et al 2007, Ilhami Colak & Ersan Kabalci 2012). These modulation techniques utilized either high frequency switching or low frequency switching. Selective harmonic elimination technique had the problem in solving non-linear transcendental equations to get an optimum switching angles (Faete Filho et al 2011, Ayoub Kavousi et al 2012).

New MLI topologies are proposed which can minimize the power quality issues with less number of components. MPD-SPWM technique is proposed with the combination of high switching frequency and fundamental switching frequency for low power applications. GA optimization technique is proposed to get the precise switching angles than the existing NR method. Proposed work is mainly focused on reduction of power switches and minimization of THD.

2.5 SUMMARY

A detailed literature survey has been carried out with respect to the different types of multilevel inverter topologies and modulation techniques. To accomplish the objective of the research work, selective harmonic elimination and hybrid modulation based multilevel inverter fed induction motor has been proposed.