CHAPTER 2

LITERATURE SURVEY

2.1 INTRODUCTION

Brushless Direct Current motors are one among the motor types that are gaining popularity rapidly. BLDC motors are employed in industries such as Appliances, Automotive, Aerospace, Consumer, Medical, Industrial Automation Equipment and Instrumentation. As the name indicates, BLDC motors do not make use of brushes for commutation rather they are electronically commutated. BLDC motors have several merits over brushed DC motors and induction motors such as better speed versus torque characteristics, good dynamic response, greater efficiency, longer operating life, noiseless operation and higher speed ranges.

In the past decade, the research and growth on BLDC motor drives have been concentrated on the design of the motor topology and optimization along with the motor control strategies. This chapter explores the converter operations. Many modular converter topologies on the basis of a switched-capacitor cell concept, a soft-switched scheme are presented which was brought into use for reducing the switching loss and electromagnetic interference.

This chapter also investigates about a lot of work has been done in the field of control of a brushless dc motor speed using various controllers. And there is a lot of scope because majority of the scholars have worked on
the speed control of a BLDC motor. Latency diagram for various existing converter and controller topologies is shown in the figure 2.1.

**Figure 2.1** Latency diagram for various existing converter and controller topologies
2.2 CONVERTERS ON LOAD SIDE VARIATIONS OF BLDC MOTOR

Belim et al (2013) proposed an approach for the improvement of the power quality of BLDC motor drive in the energy saving during energy conversion. The ac-dc conversion of electric power is generally needed for BLDC motor drive, however it results in several current harmonics and leads to the poor power factor at input ac mains. The author made a study on a buck dc-dc converter as a single-stage Power Factor Correction converter for a Permanent Magnet Brushless DC Motor that is fed through a Diode Bridge Rectifier (DBR) from single-phase AC mains. The buck converter shows conformity to international power quality standards with improved performance of PMBLDC Motor drive such as reduction of AC main current harmonics nearer to unity power factor 1 and reduction of speed and torque ripples. A three-phase voltage source inverter is utilized as an electronic commutator for the operation of the PMBLDC Motor. The proposed PMBLDC Motor drive is designed, modelled and its performance is assessed in PSIM. The results obtained are produced for demonstrating an enhanced power quality (PQ) at AC mains of the PMBLDC Motor drive system.

Shi et al (2010) presented a novel circuit topology and a dc link voltage control approach for maintaining incoming and outgoing phase currents which keep varying at the same rate during commutation. A dc-dc Single-Ended Primary Inductor Converter and a switch selection circuit are applied before the inverter. The chosen commutation voltage is possible through the SEPIC converter. The processing part of the dc link voltage control approach is done by the switch selection circuit for the division of two procedures, tuning the SEPIC converter and regulation of speed. The reason behind commutation ripple is analyzed and the means for obtaining the desired dc link voltage is commenced in detail. Finally, the simulation and
experimental results reveal that in comparison with the dc-dc converter, the proposed technique accomplishes the needed voltage much early and limits the commutation torque ripple with more resourcefulness at both high and low speeds.

Alaeinovin et al (2012) introduced a Brushless dc motors that is controlled by Hall-effect sensors that find their use in multiple applications in which the Hall sensors should be placed 120 electrical degrees apart. This is complex to be accomplished in practical specifically in low-precision motors which results in unsymmetrical operation of the inverter/motor phases. For reducing this occurrence, a technique for the filtering the Hall-sensor signals has been introduced in the recent times. This note is an extension of the previous work and presents a very well-organized digital implementation of filters that can be easily integrated into varied brushless dc motor-drive systems for returning to their operation in steady state and transients.

Yaonan et al (2011) presented a highly-organized and reliable control technique for the position-sensorless Electric Vehicle through the means of a brushless dc motor. The back electromotive force detection method is taken in the beginning and improved for implementing sensorless control of the motor. The representations of the equivalent circuits of the control system are provided and the derivation of the mathematical models beneath normal driving and energy regeneration are done. By the combination of the advantages of non singular terminal sliding mode with the high-order sliding-mode methodology, a Hybrid Terminal Sliding-Mode (HTSM) control scheme for EV is brought forward to assure the system performance along with reliable stability.

Segundo-Ramirez et al (2009) presented two Voltage-Source Converter model on the basis of Fourier series and hyperbolic tangent function. Due to their being highly beneficial, power electronics technology is
considered to be one among the tools for achieving congestion management by appropriately using the unused potential of transmission system. The main purpose of Flexible AC Transmission System (FACTS) technology in transmission system and a broad classification of these as shunt compensator, a series compensator and a shunt/series compensator have also been shown. Even though VSC’s utilized a multi-pulse configuration that make the harmonics cancellation in the secondary windings of coupling transformer and therefore it becomes a huge disadvantage.

Zhao et al (2014) introduced an Optimal Load Control issue in power transmission networks. The goal of OLC is the minimization of a measure of disutility of participation in load control that is subject to the balance between total generation and load end-to-end of the network. Afterwards an equivalent problem of OLC that is evolved by taking its dual problem and then distributed primal-dual algorithm is designed for solving that equivalent problem. The algorithm is compiled by both the dynamics of the power network and frequency-based load control mechanism. In this mechanism, loads are controlled by the inversed marginal disutility function of locally measured frequency. In addition, voltage and reactive power regulation should be taken into consideration along with frequency and real power regulation. The integration of two such issues will be used for developing a more practical and complex model which is interesting for investigation. Also it look into the distribution systems located under the transmission-level buses and study the effect of load control when considering the distribution-level model together with the transmission-level model.

Vilathgamuwa & Choi (2002) analyzed the performance of a Dynamic Voltage Restorer in the improvement of the quality of power supply. It is established that the already available open-loop control technique which is utilized in the DVR for the regulation of load voltage can give rise to
poorly damped response because of the existence of the switching harmonic filter in the restorer. Damping is proven to improve if the proposed multiloop controller is utilized. Moreover, the new control scheme allows a closer tracking of the reference load voltage under various load conditions. On the contrary, for the control of DVR, the open loop feed-forward strategy is observed to be practical which usually leads to poor damping of the output harmonic filter.

Phan & Lee (2012) explored the control of a wind power conversion system based on a stand-alone Doubly Fed Induction Generator with unbalanced and nonlinear loads. In the presence of these load conditions, the quality of stator voltage and current waveforms of the DFIG is greatly impacted because of the negative and distorted components, thus limiting the performance of other normal loads that are connected to the DFIG. To deal with this problem, the control strategy is elaborately developed in both Rotor-Side Converter and Load-Side Converter of the DFIG. The LSC is utilized as an active power filter for compensating for the unbalanced and distorted stator currents wherein the RSC is evolved for fully eliminating unbalanced and harmonic voltages at the point of common coupling. The proposed compensation technique is in accordance with the current controllers in either the RSC or the LSC which use a proportionate integral plus a resonant controller. These current controllers are controlled in the positive synchronous reference frame such that the rotor current and stator current are regulated directly without sequential components decomposition. Such a system also leads to lower converter costs and lower power losses in comparison with a system that is based on a fully fed synchronous generator with full-rated converter.

Liu & Lai (2007) introduced a fuel cell power system that comprises of a single-phase dc-ac inverter that tends drawing an ac ripple
current at twice the output frequency. Such a ripple current may reduce the fuel cell life span and make worse the fuel efficiency caused because of the hysteresis effect. The impact most obvious is that it tries reducing the fuel cell output capacity due to the fuel cell controller tripping under instantaneous over-current condition. This paper analyses the path of the ripple current propagation and its liberalized ac model is obtained. The equivalent circuit model of reduction ripple current with passive energy storage component are modelled and validated with experiments. A modern active control technique is then presented such as to integrate a current control loop in the dc-dc converter for reduction in ripple. The newly introduced active ripple reduction technique has been validated with the help of computer simulation and hardware experiment with a proton exchange membrane type fuel cell making use of a multiphase dc-dc converter in addition with a full-bridge dc-ac inverter. Still large capacitor or reactor is necessary as an energy buffer.

Dong et al (2000) did the evaluation of the efficiency of load side soft-switching inverters for the case of electric vehicle drive applications. Five types of load side soft-switching inverters are taken for study which includes the Auxiliary Resonant Commutated Pole Inverter, the zero-current-transition inverter, the Zero-Voltage-Transition inverter with Coupled Inductors, the ZVT inverter with a single switch, and the ZVT inverter with a Single Inductor. Loss categorization techniques are evolved utilizing simplified device model for the purpose of revealing the mechanism of improvement in efficiency. It is observed that the ZVTSI and the ZVTSS has poor efficiency with regard to performance when compared to the hard-switching inverter due to the additional turn-off of main switches and the nonzero-current-switching for the auxiliary devices. The ARCP, the ZCT inverter and the ZVTCI provide considerable energy savings. Also the variable timing soft-switching control can help in increasing the efficiency further in ZVT inverters. Still the losses are not entirely eliminated, but a
portion of the losses can be switched to external capacitors and turn-on losses can also exist in the switches because of the discharge of the snubber capacitors.

Gamage et al (2003) proposed a phase shifted PWM controlled full bridge-type series load resonant high-frequency inverter making use of the IGBT power modules which is for inventive induction heating applications like hot water producer, steamer and super heated steamer. The bridge arm side passive capacitor snubber and AC load side active edge resonant snubber-assisted series load resonant soft switching inverter with a phase shifted PWM scheme is assessed and studies are made based on the simulation and results from experiments. It is established from a practical point of view that a novel multi resonant inverter topology which includes the enhanced inverter changes can help in expanding soft switching area even under low power setting ranges which is more appropriate for induction heated dual packs fluid heater.

Fathy et al (2006) introduced a new ZVT-PWM high frequency inverter. The ZVT operation is accomplished in the whole load range by making use of a simple auxiliary reverse blocking switch in parallel with series resonant capacitor. Dual duty cycle is applied for providing a wide range of output power regulation which is crucial in several high frequency inverter applications. On the contrary, passive techniques do not possess controlled switches in the auxiliary commutation circuit. Consequently load-characterization system is necessary for ensuring proper converter operation.

Wei et al (2013) presented an enhanced control of rotor side and load side converters with iterative control for compensating the harmonic components in the stator voltage and current of the doubly-fed induction generator on being connected with non-linear loads. The non-linear loads lead
to distortion in stator voltage and current with further degradation in power quality and electromagnetic torque pulsations of DFIGs. The distorted stator voltage and current are covered by the newly introduced hybrid control scheme with Repetitive Control (RC) based PI controller. The harmonic components of variable orders and negative sequence component of the stator voltage can be eliminated by making use of a single PIRC whereas many of the other alternate harmonic compensators need individual controllers for damping these components. The PIRC is employed in rotor side converter for stator voltage compensation and in Line Side Converter for stator current compensation correspondingly.

Goel et al (2010) studied a novel Autonomous Wind Energy Conversion System (AWECS) which employs parallel operated Permanent Magnet Synchronous Generators that is driven by variable speed wind turbines and feeding three-phase four-wire local loads. The system proposed uses Voltage Source Converters based on three Pulse Width Modulated Insulated Gate Bipolar Transistors (IGBTs) with a battery energy storage system (BESS) at their dc link. The system makes use of two isolated machine side converters one for every PMSG for Maximum Power Tracking by means of their rotor speed control. Still a common dc bus, battery bank and common load side converter are utilized for Voltage and Frequency Control (VFC) at the load terminals. The proposed electro-mechanical system which uses PMSGs, MPT controllers, Voltage and Frequency Controllers (VFC) are designed and the simulation is done in MATLAB making use of Simulink and Sim Power System (SPS) set toolboxes. The performance of the proposed AWEC system is shown to exhibit its ability of MPT, controlling load voltage magnitude and frequency, harmonic elimination and load balancing.

Noroozi & Farhangi (2014) made the analysis of the stability of voltage and frequency in doubly fed induction generator for a variable speed
wind turbine in stand-alone mode of operation. Significant equations that govern the stand-alone structure have been taken into discussion and then the analysis of the control loops of Rotor Side Converter and Load Side Converter are analyzed and designed. Two methods of direct and indirect stator voltage control techniques are also introduced and the comparison made and owing to benefits of direct voltage control technique has been utilized. During the system changes, voltage and frequency of the stator is stabilized and regulated with a constant value by making use of vector control method and choosing the stator flux rotating frame.

Hussein et al (2013) proposed a simple control strategy for the working of a variable speed stand-alone wind turbine with a Permanent Magnet Synchronous Generator. The PMSG is connected to a three phase resistive load with the help of a switch mode rectifier and a voltage source inverter. Control of the generator side converter is utilized for achieving maximum power extraction from the wind power available. Control of the DC-DC bidirectional buck-boost converter which is connected between batteries bank and DC-link voltage is helpful for maintaining the DC-link voltage at a steady value. It is also utilized for making the batteries bank store the surplus of wind energy and then renders this energy to the load when shortage of wind power occurs. The load side voltage source inverter makes use of a relatively complex vector control scheme for controlling the output load voltage with respect to amplitude and frequency.

Jamil et al (2014) presents a brushless dc motor drive which is utilized as the load of a photovoltaic system with a maximum power point tracking (MPPT) controller. To achieve a fast and stable response for the real power control, the intelligent controller consists of Incremental Conductance for maximum power point tracking where the output signal is used to control the interleaved boost converters to achieve the MPP. A brushless DC motor
drive system that incorporates a motor controller with proportional integral speed control loop using MATLAB/Simulink is used to build the dynamic model and simulate the system.

In Chen et al (2010) was described a cascade high step-up dc–dc converter based on quadratic boost converter with coupled inductor in the second boost converter. A study of a topology based on two for-switch bridges around a LC circuit that does not utilize iron core transformers applied in megawatt level power transfers.

2.3 INVESTIGATION ON HIGH GAIN INTERLEAVED CONVERTER TOPOLOGIES

A novel ZCS-PWM boost rectifier has been presented in Wang (2004). This circuit is used to achieve nine transition states in the power conversion and PFC. The rectifier has been built with state-space average model. The ZCS usage in the rectifier provides high efficiency. A two-inductor interleaved power-factor corrected boost converter exhibiting voltage doubler characteristics when the duty cycle is greater than 0.5. This voltage doubler characteristic of the converter is suitable for universal-line (90-264 VRMS). Since the proposed PFC boost rectifier operates as voltage doubler at low-line, its efficiency is improved compared to the conventional boost converter. A new technique of interleaved boost converter with coupled inductors and switched capacitors was proposed in Qian & Lehman (2008). This technique is added to the output stage so that higher step-up voltage gain and lower voltage stress is obtained when compared to conventional interleaved boost converter. The load-current can be equally shared by each phase without any additional current sharing module. The switching losses can be reduced by the ZVT soft switching performance. An active clamped circuit adopted also helps in the reduction of switching losses and the leakage energy of the coupled inductor is recycled. A new dual interleaved active-
clamp forward topology has been proposed in Wang et al (2008). Series and parallel connection of two interleaved forward circuits on the primary and secondary side respectively. This proposed method provides a new solution to reduce the voltage stress and number of components. An interleaved boost converter with soft switching technique and modelling of PV topology with MPPT controller was proposed in Marimuthu et al (2012). This interleaved boost converter has been used to increase the output power in high power applications. This interleaved boost converter required low current rating of switching device since the current in each phase is distributed. An interleaving boost converter with PV and passive snubber for battery charging applications were studied. The snubber helps to reduce the voltage stresses at turn-off transition and to obtain maximum power; P&O method is used. An interleaved boost converter which is magnetically coupled to a voltage doubler circuit providing a voltage gain higher than that of conventional boost converter was discussed in Gustavo et al (2010). This converter has low voltage stress across the switch, voltage balancing between output capacitors, low input-current ripple and high switching frequency.

Kumar & Prabhakaran (2014) presented a PFC interleaved converter-based VSI-fed BLDC motor drive targeting low-power applications. A new method of speed control has been utilized by controlling the voltage at dc bus and operating the VSI at fundamental frequency for the electronic commutation of the BLDC motor for reducing the switching losses in VSI. The front-end interleaved converter has been operated in DICM for achieving an inherent power factor correction at ac mains. A satisfactory performance has been achieved for speed control and supply voltage variation with power quality indices within the acceptable limits of IEC 61000-3-2. Moreover voltage and current stresses on the PFC switch have been evaluated for determining the practical application of the proposed scheme. Finally an experimental prototype of the proposed drive has been develop to validate the
performance of the proposed BLDC motor drive under speed control with improved power quality at ac mains. The proposed scheme has shown satisfactory performance and it is recommended solution applicable to low-power BLDC motor drives.

In Wuhua et al (2007), the authors described a high step-up ZVT interleaved boost converter applied to grid-connected PV power system. This interleaved boost converter use an active-clamp circuit as the first power processing stage which can boost a low voltage from a PV array up to the high-dc bus. A topology using the boost converter output terminal and fly back converter output terminal serially connected to increase the output voltage gain with the coupled inductor was presented in Tseng & Liang (2004). The proposed converters use diodes and coupled windings instead of active switches to realize functions similar to those of active clamps, perform better than their active-clamp counterparts. The topology introduced in Henn et al (2010) consists of an interleaved boost converter where the inductor current ripple and the current stress through the main switches are reduced. Besides reduction of volume, size, and weight is expected because the inductors are designed for twice the switching frequency.

The converter presented in Gules et al (2003) uses voltage multiplier cells that allow high voltage step-up with reduced stress regarding the semiconductor elements. The interleaved configuration allows the very reduction of the input inductors and the output capacitors at the cost of high component count as additional multiplier cells are included. A similar topology based on the three-state commutation cell was proposed in Tofoli et al (2012), where the current sharing problem of the interleaved converter can be eliminated.

Summarizing the aforementioned topologies employ such techniques, the use of high frequency transformers, coupled inductors
associated with voltage multiplier cells or switched capacitors. Although the development of novel topologies with wide conversion ratio and high efficiency is necessary, their interconnection with photovoltaic panels, battery banks and the inverters dc link has a great interest for both industry and academy.

2.4 PI, FUZZY AND HYBRID CONTROLLER IN BLDC MOTOR

Sowjanya & Tarakalyani (2013) intended to compare the two Controllers namely Proportional-Integral controller and Sliding Mode Controller for the speed control of a permanent magnet brushless DC motor. It is the simple strategy required to achieve good performance in speed or position control applications. This paper addresses the controlling speed of BLDC motor which remains among the vital issues. A BLDC motor is generally controlled by Proportional plus Integral controller. PI controller is simple but sensitive to parameter variations and external disturbance. Due to this reasons, Sliding Mode Control is proposed in this paper. This control technique works against parameters variations and external disturbances and also its ability in controlling linear and nonlinear systems. It is observed that SMC provides important advantages over the traditional PI controller like limiting the overshoot in speed, thus the starting current overshoot can be reduced.

Ramesh et al (2011) proposed a fuzzy logic PI controller for speed control of BLDC motor is proposed. In this paper, it uses three fuzzy logics to scale speed error for the three PI controllers. The simulation results demonstrate the fuzzy logic control at different load torque. As the load torque varies, the speed of the BLDC motor remains constant. The mathematical modelling of BLDC motor is done and the speed control of the BLDC motor by using fuzzy logic speed controller and current controller is
proposed. The results have been presented and analyzed for various load conditions.

Fuzzy based gain scheduling of PI controller has been proposed, but the limits of the gains have to be determined manually. The advantages of the fuzzy and PI controllers can be combined with a hybrid fuzzy-PI controller which can be implemented as a speed controller where the PI controller is active near and at steady state conditions and the fuzzy controller is active during transient conditions. Hybrid fuzzy-PI speed controller has been in use for the control of the induction motor where the fuzzy controller is active during speed overshoot or undershoots only Zerikat & Chekroun (2007). In a Permanent Magnet Brushless DC motor with hybrid fuzzy-PI speed controller, the fuzzy logic controller is only activated under the condition of overshoot and oscillations, else the output of the fuzzy logic controller is null and hence inactive. However, the major drawback of fuzzy control is the lack of design technique. Most of the fuzzy rules are human knowledge oriented and hence rules will deviate from person to person inspite of the same performance of the system. The selection of suitable fuzzy rules, membership functions and their definitions along the universe of discourse always involve trial-and-error process Viljamaa (2000).

Many random search methods such as Genetic Algorithm (GA) have recently received much interest for achieving high efficiency and searching global optimal solution in problem space Mahony et al (2000) such as the search of optimal PI controller parameters. But optimal PI controller parameters vary based on population size, generation number, selection method, crossover and mutation probabilities. Also no solid theoretical basis is available and parameter turning is largely based on trial and error and there is no guarantee for finding optimal solutions within a finite amount of time. Fuzzy based controllers develop a control signal which yields on the selection
of the rule base which is written on the previous experiences and these rules are selected which is random in nature. As a result, the outcome of the controller is also random and optimal results may not be obtained. Selection of the proper rule base depending upon the situation can be achieved by the use of an ANFIS controller which becomes an integrated method of approach for the control purposes and yields excellent results Aware et al (2000). In the designed ANFIS scheme, neural network techniques are used to select a proper rule base which is achieved using the back propagation algorithm. The simulation results show that the ANFIS controller based soft switching inverter is designed for BLDC motor drive systems which are easy to implement in industries and it has the advantages of low switching power loss, low inductor power loss, low dc link voltage ripple, small device voltage stress, low switching noise and simple control scheme. Moreover the system provides low torque ripples, high starting torque, better transient response with negligible overshoot, smaller settling time and rise time.

Rubaai & Kotaru (1999) worked on a nonlinear neuro controller but this time it was for controlling the speed of brushless dc motors operating in a high performance drives environment. They used three-hidden-layer dynamic neural networks to control inputs and the identification parameters of the system simultaneously in real time while the system in operation. The problem of persistently spanning excitation faced with the use of an on-line neuro-controller was addressed. They verified the ability of the neuro-controller to remember previously-trained reference tracks when confronted with an input excitation that was markedly different from what it was trained and also investigated was the sensitivity of real-time neuro-controllers to system parametric changes. Simulations showed that the network needs to be trained for longer periods but eventually succeeds in capturing the dynamics of the rapid load changes in the process of fulfilling its main objective of emulating the brushless dc motor system dynamics Techniques.
Kumar et al (2006) presented a sensorless scheme for rotor position estimation of permanent magnet brushless dc motor using Artificial Neural Networks with the formulation and comprehensive analysis of vector control PMBLDC drive. They found that the developed neural network based position estimation scheme worked efficiently for both on loading and unloading condition. The sensorless scheme not only eliminates the position sensor thereby cutting the cost but also transforms the drive in to a highly efficient drive by eliminating the losses caused by the position sensor. The estimation error was found to be very minimal of the order of fraction of a percent thereby proving that the developed system was a very efficient and reliable.

Imen & Shakeri (2007) reported an effective control method for linear motor by using feedback and learning adaptive feed forward controller. The feedback is preformed based on a Proportional-Integral-Derivative method by linear Second order model of a linear motor. The learning adaptive feed forward controller was based on neural network with one hidden layer second-order B-spline basis functions and was used for prediction the un-modelled forces and unknown relations.

Mirtalaei et al (2008) worked on sensorless operation over wide speed range. They presented a novel sensorless control method for brushless DC motors with two similar fuzzy logic based neural network observers. To determine the commutation instants, a new technique based on the sign of the back- Electromotive Force space vector components was proposed. They replaced fuzzy logic observer by two neural networks with the same performance which are easier to implement.

Vinatha et al (2008) presented the modelling of Brushless DC motor drive system along with control system for speed and current by using MATLAB / SIMULINK. The performance evaluation result shows that, such
A modelling is very useful in studying the drive system before taking up the dedicated controller design accounting the relevant dynamic parameters of the motor.

Zheng et al (2009) presented a control scheme combined with Cipher-based Message Authentication Code (CMAC) neural network and PID controller for the brushless DC motor. The mathematical model of square-wave PM BLDC motor is adopted and used to build the simulation block models. The simple fuzzy controller represents a good nonlinear controller however it cannot adapt its structure whenever the situation demands. Sometimes the fuzzy controllers with fix structures fail to stabilize the plant under wide variations in the operating conditions. These types of controllers also lack the parallelism of neural controllers. On the other hand the neural networks are very much adaptive to situations by adjusting their weights accordingly. The parallel architecture enables faster implementation of the control algorithm. However in the presence of noise and other uncertainties the performance may deteriorate. Some times in certain neural controller structures the model of the plant is required. But in case of plants whose model becomes uncertain it is difficult to use neural networks with fixed structures.

Rubaai & Kotaru et al (1999) introduced principle of a new adaptive Neuro- Fuzzy Controller (NFC) for speed control of Brushless DC motor drives. They observed that NF controller had better performance rather than PI controller. In order to overcome the disadvantages introduced by position sensors, there is a need for sensorless scheme of the drive.

Sheeba Joice et al (2011) presented a dsPIC30F4011 controller with the BLDC four quadrant operation. They simulated the results using MATLAB / Simulink and analysed the proposed control scheme. It makes the motor to change the direction from Continuous Wave (CW) to
Continuous Carrier Wave (CCW) without going to standstill position. The time taken to achieve this braking is comparatively less.

Devendra (2011) also investigated sensorless control of BLDC Motor. The performance of this method is like both Artificial Neural Networks (ANN) and Fuzzy Logic (FL). In both ANN and FL case, the input pass through the input layer by input membership function and the output could be seen in output layer. Therefore, ANFIS uses a combination of least squares estimation and back propagation for membership function parameter estimation. The validity of the proposed approach is shown through simulation. It is demonstrated in this paper that ANFIS is a very powerful approach for building a complex and nonlinear relationship between a set of input and output. Nevertheless, most of these converter topologies employ the hard-switching technique which causes high switching losses and severe electromagnetic interference.

Kandiban & Arulmozhiyal (2012) worked on the speed control of a BLDC motor using adaptive fuzzy controller. They also studied the various controllers and found that it is difficult to tune the parameters and get satisfied control characteristics by using normal conventional PID controller and comparatively Adaptive fuzzy controller is much easier or computing the modelling, control and simulation of the BLDC motor have been done using package MATLAB/SIMULINK. These three concepts prevailing over the intelligent control are used by many of the scholars and researchers in their work. Let’s through a light on the work they have done and the problem they faced while working on their area of inquiry. In the entire papers one thing was common in their area of inquiry and that is BLDCM.

Sreekala & Sivasubramanian (2011) proposed a fuzzy logic based soft-switching resonant pole inverter using transformer, which can generate dc link voltage notches during chopping which minimize the drawbacks of
soft switching. Hence all switches work in zero voltage switching condition. This work presented a fuzzy logic based soft-switching resonant pole inverter by transformer which can produce dc link voltage notches through chopping which reduce the drawbacks of soft switching. Hence all switches work in zero voltage switching condition. Hardware implementation of BLDC motor speed control has been achieved by PIC micro controller 16F877A.

A simple way to control in a sensorless way, a Brushless DC motor for electric vehicle applications to control this machine is generally required to count with a position sensor because the inverter phases acting at any time must be commuted depending on the rotor position. Encoders and resolvers have been used for sensing rotor position with respect to stator. These sensors however make the motor system more complicated and mechanically unreliable. In this research, a simple solution is presented to determine the commutation sequence of a BLDC motor with a sinusoidal flux distribution Tan CheeSiong et al (2011). The method is based on a two phase current sensing and the determination of the back emf. For trapezoidal flux distributions the solution may be implemented with some minor changes. The main characteristic of this type of motor fed with quasi-square-wave currents is only needs a six position sensor and one current controller for its full torque control. In contrast the sinusoidal current type, the angular position needs to be known at any moment in order to control each of the three phase currents. By the information contained in the back emf helps to find the solution, also calculating the required six commutation points. This method is only applicable while currents can be sensed, so it needs to be complemented with a starting method. The system was implemented with a fast digital signal processor (TMS320F241) which is programmed with a closed loop PI current control in order to produce a constant torque. Additionally, a fiber optic link is used between the controller and the inverter.
The speed and position estimation from Back EMF has been a problem under speed reversal response due to change of sign of speed. In this paper, an algorithm using fuzzy logic is proposed to estimate the speed and position of BLDC motor from back EMF for sensorless BLDC motor drives to improve the performance of conventional sensorless drives as explained in Boileau et al (2011). Most existing sensorless methods of the BLDC motor have low performance at speed reversal, transients or low speed range and occasionally require additional circuit. For this type of problem, the estimation of speed and position from back-EMF is suitable for high performance because the back-EMF of the BLDC motor has a trapezoidal shape. The proposed algorithm gives robust control for the reversal of the reference speed and continuously calculates the position of the rotor at transients as well as steady state. The robustness of the proposed algorithm is proved through the MATLAB simulation.

Neethu & Jisha (2012) is a comparative study on speed control of Brushless DC Motor is presented. The mathematical model of the BLDC motor is developed and it is used to examine the performance of the controllers. Initially a PI controller is developed for the speed control of the given BLDC motor. Then the controller is upgraded to PID and the performance of the BLDC motor is verified. Later a fuzzy logic based controller is developed for the speed control of the given BLDC motor. Unlike PI and PID controllers tuning is not required for the fuzzy logic based controllers. Through extensive simulations it is observed that the performance of fuzzy logic controller is better than all other controllers.

2.5 INFERERENCE FROM EXISTING WORK

The traditional high-frequency isolated converters required a transformer responsible for processing the total rated power with consequent increase of size, weight, volume and reduction of efficiency. Converters with
switched capacitors develop significant current peaks which limit the efficiency and the maximum processed power. Several modular converter topologies based on a switched-capacitor cell concept, reduce the switching loss and electromagnetic interference. Some topologies employ coupled inductors with consequently reduce the voltage stress across the switches although the input current is discontinuous and the use of an LC filter may be necessary. The research motivates to reduce the number of conversion stages to increasing the converter efficiency and simplifying the control system.

2.6 SUMMARY

This chapter briefly discuss about the various conventional approaches which has been introduced by various authors to reduce the harmonics and imprecision for power quality problems. Also, this chapter explains the various filtering techniques and their performance on the power quality issues. The existing techniques are thoroughly analyzed and inferences from the existing works are presented.