Improvement of Power Factor and Reduction of Harmonics in Three-Phase Induction Motor by PWM Techniques: A Comprehensive Literature Survey

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Abstract
In this paper presents a literature survey on improvement of power factor and reduction of harmonics in three phase induction motor by Pulse Width Modulation (PWM) techniques. Also presents the current status of the improvement of power factor and reduction of harmonics in three phase induction motor by PWM techniques. Authors strongly believe that this survey article will be very much useful to the researchers for finding out the relevant references in the field of improvement of power factor and reduction of harmonics in three phase induction motor by PWM techniques.

Keywords: *Power fator, Harmonics, PWM Technique,three phase induction Motor*

1 INTRODUCTION

Variable frequency AC drives are increasingly used for various applications in industry and traction. Due to the improvement of fast-switching semiconductor power devices, voltage source inverters (VSI) with PWM control, find particularly growing interest. Control methods that generate the necessary PWM technique has been discuses extensively in the literature. Two basic concepts may be distinguished for small and medium-size drives the current controlled PWM has proved to be advantageous. For big drives employing inverters with low switching frequency, PWM voltage control is more advantageous.

A new technique for high-frequency conversion has been proposed to reduce the component stress of voltage and current and the switching losses in the traditional PWM converter. The PWM inverter driving the machine is then required to excite the machine with these current commands. Various techniques have been devised by many researchers for controlling the output current of a PWM voltage-fed inverter. A current control technique has also been devised for three-phase PWM ac/dc converters. Switching frequency should be increased by decreasing switching losses to achieve higher power density and faster transient response in well known PWM dc–dc converters. A new active snubber cell is proposed to contrive a new family of PWM converters. This snubber cell provides perfectly zero voltage transition (ZVT) turn on and zero voltage transition (ZCT) turn off together for the main switch of a converter. A new three-phase, three-level dc to dc phase shifted PWM converter is proposed for high power and high input voltage applications. Output voltage is controlled by incorporating phase shift PWM. PWM VSI is widely utilized in ac motor drive applications and at a smaller quantity in controlled rectifier. Presents an improved PWM current control technique for torque ripple minimization in the low speed mode of operation. The control circuit of the active power filter using quadseries voltage-source PWM converters consists of three parts, namely, the current control circuit of the PWM converters, the calculation circuit for the compensating current references and the control circuit for the dc capacitor voltage.

PWM control of dc drive systems is considered as a challenge to the conventional phase controlled systems. Forced commutated converters with PWM control has been developed and offer considerable performance improvements over phase-controlled converters for the same armature inductance. The main topology used in high power dc–dc conversion is the zero voltage switching (ZVS) PWM full bridge converters with phase-shift control.

A simple and reliable PWM ac controller which requires only four force-commutated switches and a three-phase diode bridge is proposed for the implementation of the three-phase compensator. A new soft-switched ac/dc PWM converter structure is presented. It is useful for current-fed inverters and PWM rectifiers. Typical applications are magnet power supplies, high-power ac motor drives, and active power filters with magnetic energy storage. The PWM current-source rectifier (CSR) is a preferred choice for providing a dc current source for dc loads or current source fed drives, due to its high input power factor and low line current harmonics. An inductor–capacitor (LC) filter is normally required at the input of a PWM CSR, to assist in the switching devices commutation as well as filtering switching harmonics.

The PWM converter is a potential challenge to the venerable thyristor Graetz bridge at the rectifier end of the variable-speed ac drive system. The objective of this literature is to report on the successful integration of two identical experimental current-controlled PWM power modulators to form the redfiedinverter pair in the frequency changer for variable-speed ac drive systems. A PWM control technique for ac choppers is proposed that has the advantages of enabling linear control of the fundamental component of the output voltage and complete elimination of its harmonics. The proposed PWM method is investigated by digital simulation. Several characteristics such as the changes of PWM switching points, the harmonics and rms values of voltage and current, distortion factor, and fundamental power factor are evaluated.

2 PWM TECHNIQUES

The PWM dc-to-ac inverter has been widely used in many applications such as uninterruptible power systems (UPS), motor drives, induction heating, etc., due to its circuit simplicity and rugged control scheme. In the proposed ZVS dc link technique, the switch voltage is clamped to the dc link voltage and PWM technique can be used to control the inverter output voltage. The PWM technique is modified to obtain optimum system performance and to achieve ZVS at different power factor loads.

PWM technique that uses a digital circuit to create a variable analog signal. PWM is a simple concept open and close a switch at uniform, repeatable intervals. Analog circuits that vary the voltage tend to drift, and it costs more to produce ones that do not than it does to make digital PWM circuits. Output voltage from an inverter can also be adjusted by exercising a control within the inverter itself. The most efficient method of doing this is by PWM control used within an inverter. In this method, a fixed dc input voltage is given to the inverter and a controlled ac output voltage is obtained by adjusting the on and off periods of the inverter components. This is the most popular method of controlling the output voltage and this method is termed as PWM Control.

The advantages possessed by PWM techniques are as under

- The output voltage control with this method can be obtained without any additional components.
- With the method, lower order harmonics can be eliminated or minimized along with its output voltage control. As higher order harmonics can be filtered easily, the filtering requirements are minimized.

The main disadvantage of this PWM technique is that

- SCRs are expensive as they must possess low turn-on and turn-off times.

The different PWM techniques are as under:

PWM techniques are characterized by constant amplitude pulses. The width of these pulses is however modulated to obtain inverter output voltage control and to reduce its harmonic content. Because of advances in solid state power devices and microprocessors, switching power converters are used in industrial application to convert and deliver their required energy to the motor or load. The energy that a switching power converter delivers to a motor is controlled by PWM signals applied to the gates of the power transistors. PWM signals are pulse trains with fixed frequency and magnitude and variable pulse width. There is one pulse of fixed magnitude in every PWM period. However, the width of the pulses changes from pulse to pulse according to a modulating signal. When a PWM signal is applied to the gate of a power transistor, it causes the turn on and turns off intervals of the transistor to change from one PWM period to another PWM period according to the same modulating signal. The frequency of a PWM signal must be much higher than that of the modulating signal, the fundamental frequency, such that the energy delivered to the motor and its load depends mostly on the modulating signal [4].

The advantage of PWM based switching power converter over linear power amplifier is:

- Lower power dissipation
- Easy to implement and control
- No temperature variation- and aging-caused drifting or degradation in linearity
- Compatible with today's digital micro-processors

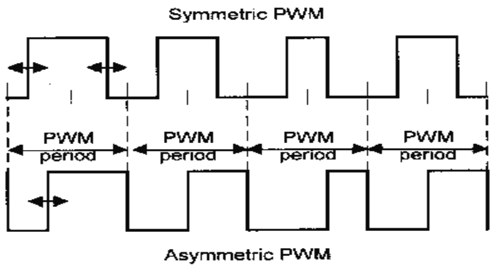

Fig. 1. Symmetric and asymmetric PWM signals.

Fig. 1. shows two types of PWM signals, symmetric and asymmetric. The pulses of a symmetric PWM signal are always symmetric with respect to the center of each PWM period. The pulses of an asymmetric PWM signal always have the same side aligned with one end of each PWM period. It has been shown that symmetric PWM signals generate less harmonic in the output currents and voltages. This literature is considers three popular PWM techniques for the mostly used three phase Voltage Source power inverter applications. Brief description of each PWM method is

presented followed by discussion of implementation issues. Experimental data are shown for each method and a comparison is made based on our implementation.

- Single-pulse modulation
- Multiple pulse modulations
- Sinusoidal pulse width modulation (Carrier based PWM Technique*)*

3 A LITERATURES SURVEY REGARDING WITH PWM TECHNIQUES APPLIED TO THREE PHASE INDUCTION MOTOR FOR IMPROVEMENT OF REDUCTION OF HARMINICS, POWER FACTOR, SWITCHING FREQUENCY AND OTHERS PERFORMACE PARAMETERS.

3.1 Reduction of Harmonics

3.1.1 Voltage Harmonics

J. Hamman, *et al.* [1], presented in this literature the harmonics generated by natural sampled PWM are investigated experimentally and by means of theoretical models for the outputs obtained with triangular and saw-tooth carrier signals. These equations are valid for synchronous and asynchronous operation. It is shown that triangular carriers generate fewer harmonic than sawtooth carriers and that in synchronous operation with single-phase modulation the carrier-to-output frequency ratio may be any integer value in this literature. K. Taniguchi, *et al.* [2], suggested a new sinusoidal PWM inverter suitable for use with power metal oxide semiconductor field effect transistors (MOSFETs) is described. The output waveforms in the proposed PWM inverter are investigated both theoretically and experimentally. A modulating signal for the three-phase PWM inverter is obtained by adding the harmonic components of integer multiples of 3 to the three phase sine waves. By using the new modulating signal, the amplitude of the fundamental component is increased about 15 percent more than that of a conventional sine wave inverter and the commutation number of the inverter is decreased to two-thirds of a conventional one presented in this literature. K. Thorborg, *et al.* [3], addressed an optimized staircase PWM is presented. The staircase is not a sampled representation of a sine wave and the number of steps and the frequency ratio are selected for a desired output voltage quality. A criterion for evaluating the quality of the output voltage, the weighted relative harmonic content, is presented has been in this literature. M. B. De Rossiter Correa, *et al.* [4], introduced a general PWM method for control of four-switch three-phase inverters is presented. The proposed vector PWM offers a simple method to select three or four vectors that effectively synthesize the desired output voltage, even in presence of voltage oscillations across the two dc-link capacitors. The method utilizes the so called space vector modulation, and includes its scalar version. Different vector combinations are compared in this literature. L. A. C. Lopes, *et al.* [5], used in this literature the conventional structures used for phase shifters employ quadrature voltage injection controlled by means of on-load tap changers that require considerable maintenance. Line-commutated thyristor structures have been proposed to replace tap changers, but problems related to filter requirements or the number of switches has limited their utilization. A. M. Hava, *et al.* [6], presented in this literature provides analytical and graphical methods for the study, performance evaluation, and design of the modern carrier based PWM, which are widely employed in PWM VSI drives presented in this literature. Y. Sozer, *et al.* [7], suggested a new inverter output filter topology for PWM motor drives. It is shown that the proposed filter effectively reduces high frequency harmonics which can cause serious damage to the motor bearings and insulation. The proposed filter is comprised of a conventional resistance, inductance, and capacitance (RLC) network cascaded with an LC trap filter. The LC trap, tuned to the inverter switching frequency, is very effective in reducing the switching harmonics. By using this new proposed topology the need for high damping resistance and low RLC cut-off frequency is eliminated presented in this literature. C. Iannello, *et al.* [8], addressed small-signal and transient analysis of a full bridge zero-current-switched (FB-ZCS) PWM converter designed for high voltage, high power applications using an average model. The development shows the model follows directly from the converter's steady-state analysis and is produced by inspection of the converter's instantaneous waveforms. M. S. A. Dahidah, *et al.* [9], introduced generalized formulation for selective harmonic elimination pulse-width modulation (SHE-PWM) control suitable for high-voltage high-power cascaded multilevel voltage source converters (VSC) with both equal and non equal dc sources used in constant frequency utility applications. C. M. De Oliveira Stein, *et al.* [10], used a universal auxiliary commutation cell for PWM inverters termed zero current and zero voltage transition (ZCZVT) commutation cell. It provides zero current and zero voltage commutation, simultaneously, during main power devices turn-on and turn-off, with controlled *di*/*dt*, and *dv*/*dt* presented in this literature. B. P. McGrath, *et al.* [11], presented in this literature is known that the optimal carrier based approach for modulating a multilevel converter is to use a phase disposition (PD) carrier arrangement with a common mode offset added to the reference waveforms to centre the implicitly selected space vectors. However, this strategy does not fully utilize all available voltage levels at lower modulation depths, with an odd level system only using odd voltage levels and an even level system only using even voltage levels as the modulation depth varies. Recent work has suggested that this is not the harmonically optimal approach at reduced modulation depths. Jung-Ik Ha, *et al.* [12], suggested a voltage injection method for reconstructing phase currents from current signals measured on single current–shunt circuits with cost-effective and high performance configurations in the PWM inverters that are used for digital appliances. This method involves the injection of voltage signals at the carrier frequency for reconstructing the phase currents in PWM inverters using a single current sensor in the dc-link in this literature. John E. Makaran, *et al.* [13], addressed empirical approach to gate charge control of a MOSFET used in low-side drive applications such as found in dc motor drives during turn-OFF, using PWM based on ideal expressions of MOSFET behavior during turn-OFF. Without gate charge control, ringing and overshoot caused by *dv/dt* effects during the turn-OFF can result in an increase in electromagnetic interference as well as an increased power dissipation.

3.1.2 Current Harmonics

A. M. Hava, *et al.* [14], introduced the over-modulation region voltage gain characteristics and waveform qualities of carrier-based PWM methods are investigated. Through detailed analytical study, voltage-gain characteristics are extracted independent of carrier frequency. The influence of blanking time and minimum pulsewidth (MPW) control on the inverter gain characteristics are studied and shown to be significant presented in this literature. I. Husain, *et al.* [15], used in this literature higher torque ripple is one of the few drawbacks of switched reluctance motor (SRM) drives which otherwise possess excellent characteristics for applications in many commercial drives. D. S. Oliveira, *et al.* [16], presented in this literature proposes the use of a three-phase version of the hybridge rectifier in the three-phase zero-voltage switch (ZVS) dc/dc converter with asymmetrical duty cycle. The use of this new rectifier improves the efficiency of the converter because only three diodes are responsible for the conduction losses in the secondary side. F. Peng, *et al.* [17], suggested an active power filter using quad-series voltage-source PWM converters to suppress ac harmonics by injecting compensating currents to the ac system is described. The calculation circuit for the compensating current references, the compensation characteristics, and the capability of the dc capacitor are discussed theoretically and experimentally in this literature. Sadeq A. Hamed, *et al.* [18], addressed PWM control of dc drive systems is considered as a challenge to the conventional phase controlled systems. This is a reality that is expected to be practically reinforced by the increasing availability and power capability of controlled-on and controlled-off power switching devices, such as gate turn-off thyristors (GTO's), insulated gate bipolar transistors (IGBT's), and MOS-controlled thyristors (MCT's) in this literature. M. Ohshima, *et al.* [19], introduced the error-tracking mode (ETM) in this literature, constantly sampled PWM technique for a voltage source power conversion system (PCS) interconnecting with a utility network to regulate its ac current waveform. It guarantees theoretically the ac actual current to be settled within an arbitrary target allowable error. Generated current harmonics can be restricted by a relatively small filter in this literature. G. Narayanan, *et al.* [20], used in this two synchronized bus-clamping PWM strategies based on the space vector approach are proposed for high-power induction motor drives. The two strategies together can produce PWM waveforms with any odd pulse number, preserving the waveform symmetries. The proposed strategies operate up to the six-step mode, maintaining the proportionality between the reference magnitude and the fundamental voltage generated throughout. These two strategies lead to lesser harmonic distortion as well as lesser peak current over the conventional space vector strategy (CSVS) in the high speed ranges of constant *V/F* drives. D. S. Oliveira Jr., *et al.* [21], this is presents the theoretical analysis of the three-phase zero voltage switching pulsewidth modulation dc–dc converter associated with a double Wye connected rectifier, delta primary, using a special switching scheme in order to maintain equilibrium among the currents through the output filters in this literature. R. Ghosh, *et al.* [22], presented in this literature the analysis, design, and control of a four-wire rectifier system using split-capacitor topology. The proposed controller does not require any complex transformation or input voltage sensing. A detailed analysis of the distortions in the line and the neutral currents is presented. D. Kimhi, *et al.* [23], suggested a SPICE simulation model of current mode PWM converters, operating in the continuous mode, is described and tested against analytical expressions and experimental data for buck and boost converters. The simulation model in this literature is also used to compare an earlier average model to a recently suggested modification and to examine the effect of the gain factor in the current feedback path. S. Kim, *et al.* [24], addressed in this literature a matrix converter interfaces with three-phase ac voltage source, which creates three different virtual dc-link voltages. In this paper, a new PWM method for the matrix converter is proposed to generally use these three virtual dc-link voltages. By using the two higher line-to-line voltages as the virtual dc-link voltages, the proposed method can create the identical switching sequences to those created by the conventional space vector pulse width modulation (SVPWM) method. H. Akagi, *et al.* [25], introduced a transformerless hybrid active filter integrated into a medium-voltage motor drive for energy savings. This hybrid filter is intended for line harmonic-current mitigation of the three-phase diode rectifier used as the front end of the motor drive. It is based on direct connection of a passive filter tuned to the seventh-harmonic frequency in series with an active filter using a three-level PWM converter in this literature. K. Marouani, *et al.* [26], used a new SVPWM technique for the control of a six-phase VSI-fed dual stator induction machines (DSIM). A DSIM is an induction machine which has two sets of three-phase stator windings spatially shifted by 30 electrical degrees and fed by two three-phase VSIs. J. H. Seo, *et al.* [27], presented in this literature a new simplified SVPWM method for three-level inverter is proposed. This method is based on the simplification of the space–vector diagram of a three-level inverter into that of a two-level inverter. If simplified by the proposed method, all the remaining procedures necessary for the three-level SVPWM are done like conventional two-level inverter and the execution time is greatly reduced. L. A. C. Lopes, *et al.* [28], suggested a variable reactance type series compensator with PWM capability. On a per-phase basis, it can be represented by a bidirectional force commutated switch in parallel with a combination of a capacitor in series with another bidirectional force-commutated switch. The equivalent reactance of the capacitor circuit can be continuously varied, with no risk of short-circuiting the capacitor or interrupting the line current. M. P. Kaimierkowski, *et al.* [29], addressed in two literatures simple control strategies for current-controlled, PWM transistor inverters are presented. Both methods are based on the three-level hysteresis comparators which select appropriate inverter output voltage vectors via switching electrically programmable read-only memory (EPROM) table in this literature. K. M. Rahman, *et al.* [30], introduced literature hysteresis current controllers having fixed bands are used in inverters of high-performance ac drives. The switching frequency of such controllers varies over the fundamental period of the modulating signal. The maximum switching frequency (MSF) of these controllers is high. To limit the MSF within the limit of inverter switches, fixed carrier lockouts are usually incorporated. The incorporation of carrier lockouts causes current distortion, and load currents do not confine within the predetermined band in this literature. A. Z. Albanna, *et al.* [31], used in this literature derives a closed-form analytical approximation of the output harmonic spectrum of a single-phase two level inverter under the action of hysteresis current control. The analytical approach consists of first describing the error current as a triangular signal of variable duty cycle and frequency, and subsequently, deriving the Fourier transform of the complex envelope of the modulated triangular signal. M. Salo, *et al.* [32], presented in this literature three-phase current-type PWM rectifiers are becoming increasingly popular as the front-end converter unit in power electronic systems due to tighter electromagnetic compatibility (EMC) regulations. In this literature the control of the current source PWM rectifier in the synchronously rotating reference frame is discussed. J. A. Pomilio, *et al.* [33], suggested a new soft-switched ac/dc PWM converter structure is presented. It is useful for current fed inverters and PWM rectifiers. Typical applications are magnet power supplies, high-power ac motor drives, and active power filters with magnetic energy storage. Soft switching is provided at the expense of a limited increase of the circuit complexity as compared to usual hard-switching solutions in this literature. J. Chen, and P. Tang, *et al.* [34], addressed in this is proposes a sliding mode current control scheme for PWM brushless dc motor drives. An improved “equivalent control” method is used in this scheme. A simple algorithm is proposed that differs from the original equivalent control method, which requires extensive calculation to estimate the load parameters. Y. Wei Li, *et al.* [35], introduced an inductor–capacitor (LC) filter is normally required at the input of a PWM current source rectifier (CSR), to assist in the commutation of switching devices and to mitigate line current harmonics. To dampen the LC resonance introduced by the input filter, an effective damping method is proposed in this literature by using a hybrid combination of a virtual harmonic resistive damper and a three-step control signal compensator.

3.1.3 Voltage and Current Harmonics

S. C. Rizzo, *et al.* [36], used in this PWM current-source inverter (CSI) used in ac-drive applications can be implemented with symmetric gate turn-off thyristors (GTO’s). One of the major difficulties in the optimization of the GTO switch and the snubber components of the inverter is the variation in different switching conditions encountered during normal operation in this literature. T. Kawabata, *et al.* [37], presented in this literature a new method of the microprocessor control of three phase sinusoidal voltage PWM inverters is proposed. First, the discretized state equations of the inverter main circuit on the *d-q* frame have been derived. S. Fukuda, *et al.* [38], suggested in this literature sinusoidal PWM technique suitable for single-chip microprocessor-based control is described. The proposed scheme can be considered as a digital alternative of the conventional sub-harmonic method in the sense that on-line real time PWM control is possible and synchronization between carrier wave and signal wave is unnecessary in this literature. D. Lee, and D. Lim, *et al.* [39], addressed in this a control technique of three-phase PWM rectifiers eliminating both the ac input voltage and current sensors is proposed. The phase angle and the magnitude of the source voltage are estimated by controlling the deviation between the rectifier current and its model current to be zero. The input currents can be reconstructed from switching states of the PWM rectifier and the measured dc link currents. E. Kim, *et al.* [40], introduced an improved soft-switching topology of a full-bridge pulse width modulation (FBPWM) dc/dc converter is described. The new topology employs an energy recovery snubber to minimize a circulating current flowing through the transformer and switching devices. L. A. C. Lopes, *et al.* [41], used in this PWM phase shifters allow the smooth control of power flow in a transmission line. In this literature analyzes a PWM quadrature booster phase shifter based on a multimodule ac controller structure to attain high voltage levels and improve the harmonic spectrum in this literature. Y. Birbir, *et al.* [42], presented in this literature, firstly a sinusoidal pulsewidth modulation (SPWM) inverter feeding five different chorded three-phase induction motors were tested for low-order odd harmonic voltage component and efficiency at different loads. E. Van Dijk, *et al.* [43], suggested in this PWM-switch modeling method is a simple method for modeling PWM dc-dc converters operating in the continuous conduction mode. The main advantage of this proposed method is its versatility and simple implementation compared to other methods in this literature. Lizhi Zhu, *et al.* [44], introduced a soft-commutating method and control scheme for an isolated boost full bridge converter is proposed in this literature to implement dual operation of the well-known soft-switching full bridge dc/dc buck converter for bidirectional high power applications. Osman Kukrer, *et al.* [45], addressed the discrete-time current control of three-phase voltage-fed PWM inverters are discussed, with emphasis on important practical aspects. The inverter feeds a balanced three-phase bad of R-L impedances in series with back-emfs. The inverter-load system is modeled by using space vectors in this literature. Y. Shrivastava, *et al.* [46], used in this literature is presents a generalized theory which covers both two-level and three-level random pulsewidth modulation (RPWM) techniques. Various three-level RPWM techniques with low switching frequency are presented and compared with two-level techniques. Three-level RPWM schemes have less discrete harmonics and continuous noise than two-level RPWM techniques in this literature. J. Cho, *et al.* [47], presented in this literature zero voltage and zero current switching (ZVZCS) full bridge PWM converter is proposed to improve the demerits of the previously presented ZVZCS-FB-PWM converters, such as, use of lossy components or additional active switches. D. Sharon, *et al.* [48], suggested in this switched link PWM current source converters are presented. These converters supply a controlled dc current to the load with a concurrent elimination of selected harmonics in the ac mains. The new topologies permit minimal constraints to be formulated resulting in significantly more efficient PWM patterns than hitherto reported in the literature. J. Kim, and S. Sul, *et al.* [49], addressed a voltage modulation method based on a triangular carrier wave for the three-phase four-leg voltage source converter is described. The four-leg converter can produce three output voltages independently with one additional leg in this literature. Y. Jang, *et al.* [50], introduced in a full-bridge converter which employs a coupled inductor to achieve zero-voltage switching of the primary switches in the entire line and load range is described. Because the coupled inductor does not appear as a series inductance in the load current path, it does not cause a loss of duty cycle or severe voltage ringing across the output rectifier. H. Bodur, *et al.* [51], used in this literature new active snubber cell is proposed to contrive a new family of PWM converters. This snubber cell provides zero voltage transition (ZVT) turn on and zero current transition (ZCT) turn off together for the main switch of a converter. Also, the snubber cell is implemented by using only one quasi resonant circuit without an important increase in the cost and complexity of the converter. H. Xiao, *et al.* [52], presented in this current-voltage-fed bidirectional dc–dc converter, which refers to a current-fed inverter at low voltage side and a voltage-fed inverter at high voltage side, can realize zero voltage switching (ZVS) for the switches with the use of phase-shift (PS) technology. However, the current-fed switches suffer from high voltage spike and high circulating conduction loss. S. Li, *et al.* [53], suggested a presents the development of digital signal processor (DSP) based switch-mode rectifier (SMR) with robust varying-band hysteresis current-controlled pulse width modulation (HCCPWM). First, a robust fixed-frequency HCCPWM control techniques is developed. Through robust harmonic spectrum shaping, the constant frequency control performance is insensitive to the changes of system parameters and operating condition, and the low frequency harmonics possess smaller magnitudes. S. K. Mazumder, *et al.* [54], addressed in this literature demonstrate a new concept for wireless PWM control of a parallel dc–dc buck converter. It eliminates the need for multiple physical connections of gating/PWM signals among the distributed converter modules. The new proposed scheme in literature is relies on radio-frequency (RF) based communication of the PWM control signals from a master to the slave modules. D. V. Ghodk, *et al.* [55], introduced a new three-phase, three-level dc to dc phase shifted PWM converter is proposed for high power and high input voltage applications. Output voltage is controlled by incorporating phase shift PWM in this literature. H. Cha, *et al.* [56], used in this is a full-bridge dc–dc converter employing a diode rectifier in the output experiences a severe voltage overshoot and oscillation problem across the diode rectifier caused by interaction between junction capacitance of the rectifier diode and leakage inductance of the transformer. The pronounced reverse-recovery current of high-power diodes significantly contributes to these issues by increasing power loss and voltage overshoot. S. Park, *et al.* [57], attempted a single-phase five-level PWM inverter is presented to alleviate harmonic components of the output voltage and the load current. Operational principles with switching functions are analyzed. To keep the output voltage being sinusoidal and to have the high dynamic performances even in the cases of load variations and the partial magnetization in filter inductor, the deadbeat controller is designed and implemented on a prototype in this literature.

3.1.4 Voltage, Current and Noise Harmonics

K. Kim, *et al.* [58], presented in this literature is proposed a new hybrid RPWM technique in order to disperse the acoustic switching noise spectra of an induction motor drive. The proposed RPWM pulses are produced through the logical comparison of a pseudorandom binary sequence (PRBS) bits with the PWM pulses corresponding to two random triangular carriers in this literature.

3.1.5 Harmonic Distortion Factor

M. Qiu, *et al*. [59], suggested an asymmetrical pulse-width-modulated (APWM) resonant inverter topology is presented for high frequency ac power distribution systems. The inverter system is comprised of simple power and tailed analysis shows that the proposed inverter has very low total harmonic distortion, near-zero switching losses, and fast transient response. Y. Ito, et al. [60], addressed in this is describes a novel method of robust (insensitive to system parameter variations and load current changes) and fast digital control for uninterruptible power supply (UPS) with a three-phase PWM inverter. G. Fedele, et al. [61], introduced the PWM technique for single-phase bipolar switching inverters has been revisited and analyzed on the basis of the isomorphism between the implicit equation of the unknown PWM switching instants, when the input to the modulator is a sinusoidal signal of period multiple of the carrier period, and the Kepler's equation governing the trajectory of a planet around the sun in this literature. G. Narayanan, *et al.* [62], used has been in this a method to evaluate harmonic distortion due to space vector-based PWM strategies for ac drives. The proposed method is general enough to deal with division of zero vector time as well as division of active vector time within a sub-cycle. The method is based on the notion of stator flux ripple, which is a measure of line current ripple. C.

Hua, *et al.* [63], presented in this is a two-level switching algorithm of the deadbeat controlled PWM inverter is presented. Two levels, instead of three levels, are used in the pulse pattern. This technique allows the use of higher switching frequency for a given computation time delay, which results in lower total harmonic distortion at the output. Control algorithms are derived in this literature. F. Shyu, *et al.* [64], suggested in the main theme of literature is to present a new PWM technique for multilevel inverter/converter control, which provides more degrees of freedom for specifying the cost function than that for step modulation technique, for a given hardware in this literature. V. G. Agelidis, *et al.* [65], addressed in this is multiple sets of solutions for the selective harmonic elimination pulse-width modulation method for inverter control exist. These sets present an independent solution to the same problem but further investigation reveals that certain sets may offer an improved overall harmonic performance. T. Bhavsar, *et al.* [66], introduced special switching sequences can be employed in space-vector-based generation of PWM waveforms for VSI. These sequences involve switching a phase twice, switching the second phase once, and clamping the third phase in a subcycle. Advanced bus-clamping pulse width modulation (ABCPWM) techniques have been proposed recently that employ such switching sequences in this literature. B. Farid, *et al.* [67], used has been in this studies of the sets converters machine in general use in an implicit way the concept of reference frame machine and reference frame inverter. Indeed, the policies of the most traditional control consider that these two points are with the same potential. T. Brahmananda Reddy, *et al.* [68], presented in the basic direct torque control has more torque, flux and current ripples in steady state, which results in acoustical noise and incorrect speed estimations. The main objective in this literature is to present a space vector based hybrid pulsewidth modulation (HPWM) method for direct torque controlled induction motor drive to reduce the steady state ripples. The proposed HPWM method is developed based on notion of stator flux ripple, which can be used for a measure of ripple in the line current in this literature.

3.1.6 Voltage Regulation

H. Patel, *et al.* [69], suggested in this operation of a distributed-generation (DG) source, producing sinusoidal output voltage and supplying nonlinear loads is characterized by a nonsinusoidal voltage at the point of common coupling (PCC). The situation gets particularly aggravated during the islanding mode, when the grid power is not available. This deteriorates the performance of other loads connected in parallel in this literature. P. Rioual, *et al.* [70], addressed in this study concerns the modeling and control of a PWM rectifier in the case of network variations. The aim is to limit and stabilize variations of dc output voltage and line currents in such circumstances. Network variations can result in costly damage to converters and their loads but a converter such as the PWM rectifier, using cascade digital control, offers many capabilities to stabilize the system with optimized control.

3.1.7 Current Regulation

C. Iannello, *et al.* [71], introduced in this literature a detailed small-signal and transient analysis of a full bridge zero-current-switched (FB-ZCS) PWM converter designed for high voltage, high power applications using an average model. D. N. Zmood, *et al.* [72], used in this current regulators for ac inverters are commonly categorized as hysteresis, linear PI, or deadbeat predictive regulators, with a further sub-classification into stationary ABC frame and synchronous d-q frame implementations. Synchronous frame regulators are generally accepted to have a better performance than stationary frame regulators, as they operate on dc quantities and hence can eliminate steady-state errors.

3.2 Power Factor

B. T. Ooi, *et al.* [73], presented a two identical 3-phase, bipolar transistor, and controlled-current, pulsewidth modulation power modulators are integrated so that one functions as a rectifier and the other as an inverter in an ac drive system. The rectifier input currents maintain near 60-Hz sinusoidal waveforms with unity factor. Leading power factor option is available in this literature. O. Stihi, *et al.* [74], suggested the analysis and test results are given of an experimental single-phase controlled-current PWM rectifier which operates at unity power factor with near sinusoidal current waveform and which has power reversal capability. The twice-line-frequency ac power is identified as a source of voltage harmonics in the dc link. The harmonics enter into the voltage regulation feedback loop to distort the ac current waveform. G. Choe, *et al.* [75], addressed a new PWM control technique for ac choppers is proposed that has the advantages of enabling linear control of the fundamental component of the output voltage and complete elimination of its harmonics up to a specified order. Theoretical comparisons are made with other basic PWM techniques and the computed performance indicates the superiority of the new method. M. A. Rahman, *et al.* [76], introduced an analysis and implementation of delta modulation (DM) technique in the control of ac-dc converters are presented in this literature. The DM technique offers advantages of easy implementation, continuous converter voltage control, and a direct control on the line harmonics. J. Yanchao, *et al.* [77], used in this literature three-phase ac/dc converter without a front-end filter. Because an adjustable triangular-wave pulsewidth modulation (ATPWM) technique is adopted, not only is a front-end filter located after the three-phase rectifier is omitted, but also the size of the input ac filter and the output dc filter are reduced in this literature. V. Vlatkovic, *et al.* [78], presented in a literature three-phase, single-stage, isolated PWM rectifier is proposed, which is capable of achieving unity power factor, and low harmonic distortion of input currents, and in the same time realizing zero voltage switching for all power semiconductor devices. J. A. Pomilio, *et al.* [79], suggested a three-phase ac/dc converter based on isolated Cuk topology feeding an inductive load is presented. The main goal is to get a compact, highly stable current source to feed an electromagnet. A high power factor is achieved, at constant duty cycle and switching frequency, by discontinuous input current mode operation in this literature. R. Torrico-Bascope, *et al*. [80], addressed in this an isolated dc–dc converter based on two ZVS-PWM active-clamping forward converters connected in series and coupled by a single high-frequency transformer. The proposed converter features no switching losses from no-load to full-load operation and low conduction losses. Y. W. Li, *et al.* [81], introduced a in this literature power-factor (PF) control strategy for a high-power pulsewidth-modulated current-source rectifier–current-source inverter-fed motor drive system. The PF regulation is realized by adjusting the motor flux in the drive's field oriented control scheme. The relationship between the motor flux and the drive's input reactive power is first investigated. K. Zhou, *et al.* [82], used in a digital repetitive control (RC) strategy is proposed to achieve zero tracking error for constant- voltage constant-frequency (CVCF) PWM converters. The proposed control scheme is of "plug-in" structure: a plug-in digital repetitive controller plus a conventional controller (e.g., PD controller). The design of the plug-in repetitive learning controller is systematically developed in this literature. R. Gurunathan, *et al.* [83], presented in a zero voltage switching (ZVS) dc link, single-phase, PWM VSI is proposed. Operating principle and various operating intervals of the converter are presented and analyzed in this literature. E. F. Vidal, *et al.* [84], suggested in this a new three-phase rectifier that allows the operation as rectifier or as inverter, with the use of three conventional switching cells. This reversion of power flow can be obtained simply by the inverting two reference currents. The system is analyzed as a connection of three independent lower order subsystems, controlled by sliding regime with decentralized switching scheme. A. Xu, *et al.* [85], has been in this literature multipulse converters are suitable for high-power application with the merits of low switching frequency and perfect harmonic performance. But less controllability and poor regulation lead the restriction on its application. A bidirectional PWM converter based on multipulse structure is proposed in this literature, which has the same perfect harmonic performance with very low switching frequency. C. A. Canesin, *et al.* [86], introduced in a single-phase high-power factor PWM boost rectifier featuring soft commutation of the active switches at zero current (ZC). It incorporates the most desirable properties of conventional PWM and soft-switching resonant techniques. The input current shaping is achieved with average current mode control and continuous inductor current mode. X. Ruan, *et al* [87], used in this literature a family of modulation strategies for PWM three-level (TL) converters. The modulation strategies can be classified into two kinds according to the turn-off sequence of the two switches of the pair of switches. The concept of the leading switches and the lagging switches is introduced to realize soft-switching for PWM TL converters. The realization of soft-switching for both the leading switches and the lagging switches is proposed, based on which, soft-switching PWM TL converters can be classified into two kinds: ZVS and zero-voltage and ZVZCS, for which the suitable modulation strategies are pointed out respectively from the family of modulation strategies. J. Wu, *et al.* [88], presented in this literature a 100 kW three-phase PWM boost rectifier that serves as the front-end power source for a dc distributed power system. A zero current transition (ZCT) soft-switching technique is applied to achieve greater performance in this high-power converter. This ZCT soft-switching technique assists the turn-on as well as the turn-off of the main and auxiliary IGBT switches. An issue about the implementation of the ZCT soft-switching technique in three-phase applications is discussed in this literature. A SVM technique suitable for high power applications with high performance is identified. Experimental results demonstrate that high performance is achieved, in terms of wide control bandwidth, low total harmonic distortion (THD), unity power factor and high efficiency.

3.3 Switching Frequency

H. W. Van Der Broeck, *et al.* [89], suggested in this literature is harmonic content of current, torque pulsations, and harmonic copper losses of a three-phase induction machine fed by a two-phase PWM inverter. S. K. Mazumder, *et al.* [90], addressed in this demonstrate a new concept for wireless PWM control of a parallel dc–dc buck converter. It eliminates the need for multiple physical connections of gating/PWM signals among the distributed converter modules. K. M. Smith, Jr., *et al.* [91], introduced in this literature a new nonlinear control technique that has one-cycle response, does not need a resettable integrator in the control path, and has nearly constant switching frequency. It obtains one-cycle response by forcing the error between the switched variable and the control reference to zero each cycle, while the on and off pulses of the controller are adjusted each cycle to ensure near constant switching frequency in this literature. Y. Tzou, *et al.* [92], used in a new circuit realization of the novel SVPWM strategy. An SVPWM control integrated circuit (IC) has been developed using the state-of-the-art field-programmable gate array (FPGA) technology in this literature. I. Boonyaroonate, *et al.* [93], presented in a class E isolated dc/dc converter for regulating the output voltage at a fixed switching frequency is presented, analyzed and experimentally verified. It consists of class E series-resonant inverter, high-frequency transformer and class E low *dv/dt* PWM synchronous rectifier in this literature. D. De Souza Oliveira, *et al.* [94], suggested in this literature the application of the asymmetrical duty cycle to the three-phase dc/dc pulse-width modulation isolated converter. Thus, soft commutation is achieved for a wide load range using the leakage inductance of the transformer and the intrinsic capacitance of the switches, as no additional semiconductor devices are needed. J. K. Steinke, *et al.* [95], addressed in this literature by putting an LC filter between a PWM VSI and induction motor, standard industrial motors can be utilized also for adjustable speed drive applications in this literature. L. D. Reis Barbosa, *et al.* [96], introduced in this literature high-switching frequency associated with soft commutation techniques is a trend in switching converters in this literature. P. K. Jain, *et al.* [97], used in this literature APWM dc/dc resonant converter topologies that exhibit near-zero switching losses while operating at constant and very high frequencies in this literature. K. Satyanarayana, *et al.* [98], has been presented in this literature two RPWM algorithms for voltage source inverter fed induction motor drives with fixed switching frequency for reduced harmonic distortion and acoustical noise.

3.4 Others Performance Parameters

P. Mantovanelli, *et al.* [99], addressed a new current-fed dc-dc power converter circuit whose features are as follows: 1) two active switches gated in a complementary and asymmetrical way, connected to the same ground; 2) inherent high reliability provided by the input boost inductor; 3) isolation by a high-Frequency transformer; and 4) output filter purely capacitive in this literature. E. Toribio, *et al.* [100], has been used a study of a dc–dc Boost converter whose output voltage is controlled by naturally sampled constant-frequency PWM operating in both continuous and discontinuous mode. For certain values of the circuit parameters instability occur in this literature. R. B. Prest, *et al.* [101], used almost all PWM converters using bipolar transistors experience the problem of reverse transistor conduction. This effect is analyzed for various types of base drives. It is shown to be most serious for low-impedance direct drives in this literature. J. Sun, *et al.* [102], suggested in this literature PWM based on the elimination of low-order harmonics necessitates solving systems of nonlinear equations in this literature. S. R. Bowes, *et al.* [103], has been addressed Harmonic Elimination PWM strategies for drives, uninterruptible power supplies (UPS) and static power converters has been recently developed using modified Regular- Sampling techniques. These new PWM strategies can be generated on-line in real-time using a simple microprocessor software algorithm, without resorting to the usual time consuming offline mainframe computer harmonic elimination numerical techniques is presented in this literature. T. Wu, *et al.* [104], introduced in this literature structural approach to synthesizing soft switching PWM converters based on the concept of basic converter units (BCUs). With a proper reconfiguration, several families of passive and active soft switching PWM converters can be synthesized from buck BCU or boost BCU plus certain linear networks in this literature. N. Bianchi, *et al.* [105], has been used In high speed applications, slotless PM motors appear an attractive solution, being almost insensitive to magneto motive force harmonics and to PWM current ripple and exhibiting lower stator iron losses and rotor losses (significant with square wave current control). A. Ammous, *et al.* [106], presented in this contrary to the classical ideal averaged models, the introduced averaged model includes the nonlinear effects of the power semiconductor devices. The proposed non ideal PWM-switch model is a useful method for modeling pulse width modulated converters operating in the continuous conduction mode. R. Oruganti, *et al.* [107], addressed a new converter with two variations is proposed. A novel APWM control techniques is used to control the converter under constant switching frequency operation. The modes of operation for both variations are discussed in this literature. Y. V. Hote, *et al.* [108], introduced in this literature robust stability analysis of the closed loop pulsewidth modulated push-pull dc–dc converter with a state feedback control is presented using simple frequency-domain conditions based on the Hermite–Biehler theorem. The proposed technique for checking robust stability is efficient, since there is no need to calculate all the uncertain values of the system and hence no need to formulate and test all four Kharitonov polynomials in this literature. H. Bodur, *et al.* [109], addressed has been used new active snubber cell that overcomes most of the drawbacks of the normal “zero voltage transition- pulse width modulation” (ZVT-PWM) converter is proposed to contrive a new family of ZVT-PWM converters in this literature. J. Karpagam, *et al.* [110], suggested in this matrix converters can directly convert an ac power supply of fixed voltage into an ac voltage of variable amplitude and frequency. Matrix Converter is a single stage converter. The matrix converters can contribute to the realization of low volume, sinusoidal input current, bidirectional power flow and lack of bulky reactive elements in this literature.

4 SUMMARY

The following tables give summary of the paper as:

4.1 Reduction of Harmonics point of view:

Table 1. Reduction of Harmonics point of view

Parameters	*Total No. of Literatures Reviews out of 72 Literatures*	*% of Literatures Reviews out of 72 Literatures*
Voltage Harmonics	13	18.05
Current Harmonics	22	30.56
Voltage & Current Harmonics	22	30.56
Voltage, Current, & Noise	01	1.39
Harmonics Distortion Factor (HDF)	10	13.89
Voltage Regulation	02	2.78
Current Regulation	02	2.78

From table 1, it is concluded that the *18.05%* of total literatures are reviews based on Voltage Harmonics, *30.56*% of total literatures are reviews based on Current Harmonics, *30.56*% of total literatures are reviews on based Voltage & Current Harmonics, *1.39%* of total literatures are reviews based on Voltage, Current & Noise Harmonics, *13.89%* of total literatures are reviews on based Harmonics Distortion Factor (HDF), *2.78%* of total literatures are reviews on based Voltage Regulation, and *2.78%* of total literatures are reviews on based from Current Regulation viewpoints.

4.2 Power Factor, Switching Frequency, and Others parameters point of view

Table 2. Power Factor, Switching Frequency, and Others parameters point of view

Parameters	***Total No. of Literatures Reviews out of 38 Literatures***	***% of Literatures Reviews out of 38 Literatures***
Power Factor	16	42.10
Switching Frequency	10	26.32
Others parameters point of view	12	31.58

From table 2, it is concluded that the *42.10%* of total literatures are reviews based on Power Factor, *26.32%* of total literatures are reviews based on Switching Frequency, and the *31.58%* of total literatures are reviews carryout from other performance parameters of three phase induction motor viewpoints. Finally it is concluded that the maximum research work carryout from improvement Power Factor point of view regarding with reduction of the harmonics in three phase induction motor by using PWM Techniques.

5 CONCLUSION

This paper has been addressed a survey of several technical literature concerned with PWM techniques for harmonics reduction and power factor of three phase induction motor. A literature survey also show that the achieve significant improvements in operating parameters of the PWM technique such as reduction harmonics such as voltage, current harmonics, power factor, switching frequency, and others parameters. Authors strongly believe that this survey article will be very much useful to the researchers for finding out the relevant references as well as the previous work done in the field of reduction of harmonic and improvement of power factor of three phase induction motor by using PWM techniques. So that further research work can be carried out.

Even through, excellent advancements have been made in classical method i. e. harmonics distortion factor: they power factor based method; they suffer with the following disadvantages: In most cases, mathematical formulations have to be simplified to get the solutions because of the extremely limited capability to solve real-word large-scale PWM techniques. They are weak in handling qualitative constraints.

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