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SIMULATION MODELLING BASED CONTROL OF AN INTERLEAVED BOOST CONVERTER FED INDUCTION MOTOR USING PSO ALGORITHM

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Abstract: In this proposed system the interleaved boost converter (IBC) and the induction motor is controlled by using particle swarm optimization (PSO) algorithm. This topology increases the efficiency of the IM drive and reduces the current stresses of the switching devices. Ripple cancellation network used in the boost converter cancels the ripple components in the output which is produced due to the switching of the devices. The PSO algorithm is an iterative method of accelerating the particle towards its best point to control the quality of the speed with the use of this method Total harmonic Distortion (THD) value of the converter is reduced and the efficiency is increased. The performance of the proposed system and drive efficiency is verified by simulation results.

Keywords: Interleaved Boost Converter (IBC), Particle Swarm Optimization (PSO), and Ripple Cancellation Network (RCN), induction Motor.

I.INTRODUCTION

Induction motors play a vital role in the industrial sector especially in the field of electric drives and control. Without proper controlling of the speed, it is impossible to achieve the desired task for a specific application[9]-[22]. AC motors, particularly the squirrel-cage induction motors (SCIM), enjoy several inherent advantages like simplicity, reliability, low cost and virtually maintenance-free electrical drives [1]. However, for high dynamic performance industrial applications, their control remains a challenging problem because they exhibit significant nonlinearities and many of the parameters, mainly the rotor resistance, vary with the operating conditions. Induction motors are widely used in various industries as prime work-horses to produce rotational motions and forces. Generally, variable-speed drives for induction motors require both wide operating range of speed and fast torque response, regardless of load variations.

The classical control is used in majority of the electrical motor drives. Conventional control makes use of the mathematical model for the controlling of the system [2]. When there are system parametric variations or environmental disturbance, behavior of system is not satisfactory and deviates from the desired performance Field orientation control (FOC) or vector control of an induction machine achieves decoupled torque and flux dynamics leading to independent control of the torque and flux as for a separately excited DC motor. FOC methods are attractive, but suffer from one major disadvantage that they are sensitive to motor parametric variations such as the rotor time constant and an incorrect flux measurement or estimation at low speeds. Moreover, the design and tuning of conventional controller increases the implementation cost and adds additional complexity in the control system and thus, may reduce the reliability of the control system. Hence, the fuzzy based techniques are used to overcome this kind of problems. Efficient torque control of induction motor drives in combination with resonant DC-link input filters can lead to a type of stability problem that is known as negative impedance instability.

To overcome this proposed a solution to the above problem by using the concept of particle swarm optimization algorithm which is an iterative method. The optimization technique accelerates the particle towards its best point to control the speed of the motor [3].

Interleaved boost converter (IBC) has proposed for photovoltaic generation, electric vehicles, and power factor correction due to its high power density and fast dynamic response. The input current ripple of the conventional boost converter is inversely proportional to its input inductor value which means that a large inductor value will result in low input current ripple; however, a large inductor value increases the total weight of the converter. On the other hand, since small inductor values increase the loss of the capacitor, a capacitor with low equivalent series resistance (ESR) must be used Interleaved parallel structure has been applied in many

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high power density applications in order to minimize the input current ripple, reduce the passive component size, improve the transient response, and increases the power level [4]. The frequency-doubling characteristic of the interleaved structure can significantly reduce the output capacitor value and the input current ripple of the converter, but the quality of input power supply will still be deteriorated by the input current ripple, especially in large current applications. The coupled-inductor IBC proposed has used a coupled inductor to achieve the input current ripple cancellation, and their applications. However, the leakage inductance of the coupled inductor increases the current stress of the output diodes, introducing extra electromagnetic interference (EMI) problems. A soft-switching circuit is an attractive solution to avoid the major drawbacks of the coupled inductor; however, the control strategy of this circuit is too complex and not cost-effective [5].
To overcome the above mentioned problem the interleaved converter with ripple cancellation network [6] is used.

II.IMPLEMENTATION OF PROPOSED SYSTEM

The proposed system consists of a photovoltaic module, interleaved boost converter, an induction motor and PSO controller.

A. Block Diagram of Proposed System

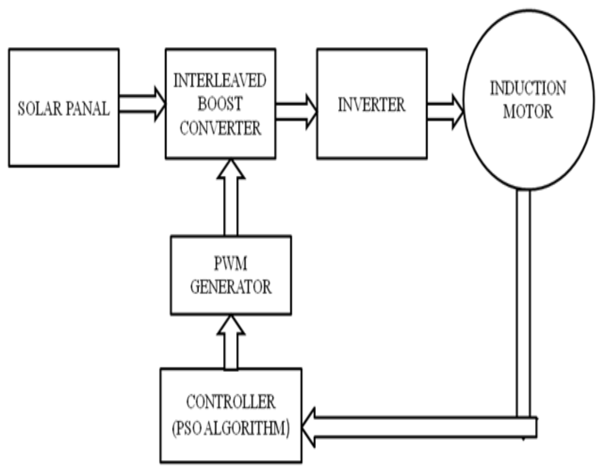

Fig.1.Block Diagram of Proposed System

The DC supply is given to the interleaved boost converter from the solar panel. The output voltage from the panel is stepped up to required value by the boost converter. The output from the IBC is given to the inverter which converts the direct current to alternating current and it is given to the induction motor. The actual speed of the motor is calculated by using speed sensor and it is given to the PSO controller which precisely and accurately follows command speed and also provides variable speed operation. The output of the controller is given to the PWM generator from which the gate signals are given to gate terminals of the switching devices in voltage source inverter.

B. Interleaved Boost Converter

Interleaved boost converter mainly used for renewable energy sources has a number of boost converters connected in parallel which have the same frequency and phase shift. These IBC`s are distinguished from the conventional boost converters by critical operation mode, discontinuous conduction mode (DCM) and continuous conduction mode (CCM) so that the devices are turned on when the current through the boost rectifier is zero. In the critical conduction mode the design becomes tedious as the critical point varies with load. In the DCM, the difficulties of the reverse recovery effects are taken care but it leads to high input current and conduction losses and it is not best suited for high power applications. CCM has lower input peak current, less conduction losses and can be used for high power applications. By dividing the output current into ‘n’ paths higher efficiency is achieved and eventually reducing the copper losses and the inductor losses

C. Induction Motor

In this study, the mathematical model of the system consists of space vector PWM voltage source inverter, induction motor, direct flux and the torque control. An induction motor model to predict the voltage required achieving a desired output torque is given in[16]. Fig.1.shows the power circuit of the 3-phase induction motor and Fig. shows the equivalent circuit used for obtaining the mathematical model of the IM.

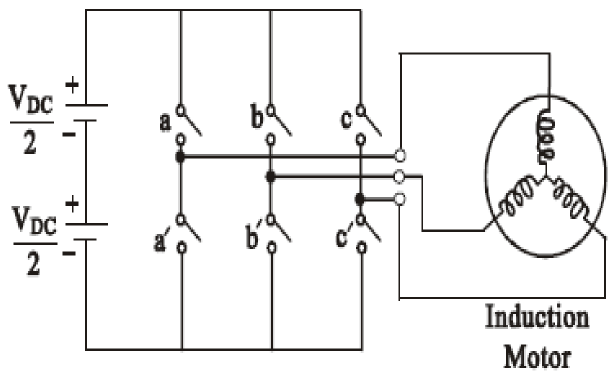

Fig.2. Power circuit connection diagram for the IM

An induction motor model is then used to predict the voltage required to drive the flux, torque and the speed to the demanded values. This calculated voltage is then synthesized using the space vector modulation. The stator and rotor voltage equations are given by

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$$v_{sd} = R_s i_{sd} + \frac{d}{dt}\lambda_{sd} - \omega_d \lambda_{sq}$$
(1)

$$v_{sq} = R_s i_{sq} + \frac{d}{dt}\lambda_{sq} - \omega_d \lambda_{sd}$$
(2)

$$v_{rd} = R_r i_{rd} + \frac{d}{dt}\lambda_{rq} - \omega_{dA} \lambda_{rq}$$
(3)

$$v_{rq} = R_r i_{rq} + \frac{d}{dt}\lambda_{rq} - \omega_{dA} \lambda_{rd}$$
(4)

Torque Equation in terms of inductance is,

$$T_{em} = \frac{3}{2}\left(\frac{P}{2}\right) L_m \left(i_{sq} i_{rd} - i_{sd} i_{rq}\right)$$
(5)

Instantaneous Torque Equation by Electromechanical interaction is,

$$T_{em} = \frac{3}{2}\left(\frac{P}{2}\right) \left(\lambda_{rq} i_{rd} - \lambda_{rd} i_{rq}\right)$$
(6)

D. Proposed Circuit

Solar panel is used as a input power supply the output from the panel is boosted using interleaved boost converter. The boosted voltage is depending on the value of inductors &capacitors of the converter.

Interleaved boost converter (IBC) has been widely used in photovoltaic generation, electric vehicles, and power factor correction due to its high power density and fast dynamic response. Here the coupled inductor boost with ripple cancellation network is used the boost converter with RCN has several advantages over the traditional boost converter. The RCN includes two capacitors, two coupled inductors, and two inductors, the coupled inductors of the network share the same core with the main inductors. The interleaved structure with the RCN the input current ripple without introducing extra EMI problem and deteriorating the reverse-recovery problem of the output diodes.

An inverter is an electrical device that converts direct current (DC) to alternating current (AC); the converted AC can be at any required voltage and frequency with the use of appropriate transformers, switching, and control circuits. The output of the inverter is given to the permanent magnet synchronous motor.

The controller is based on the PSO technique to reach and maintain command speeds quickly and accurately during the step increase and step decrease of command speed. The general idea Control (PSO) is to create a closed loop controller with parameters that can be updated to change the response of the system. The output of the system is compared to a desired response from a reference model. The control parameters are update based on this error. The goal is for the parameters to converge to ideal values that cause the plant response to match the response of the reference model.

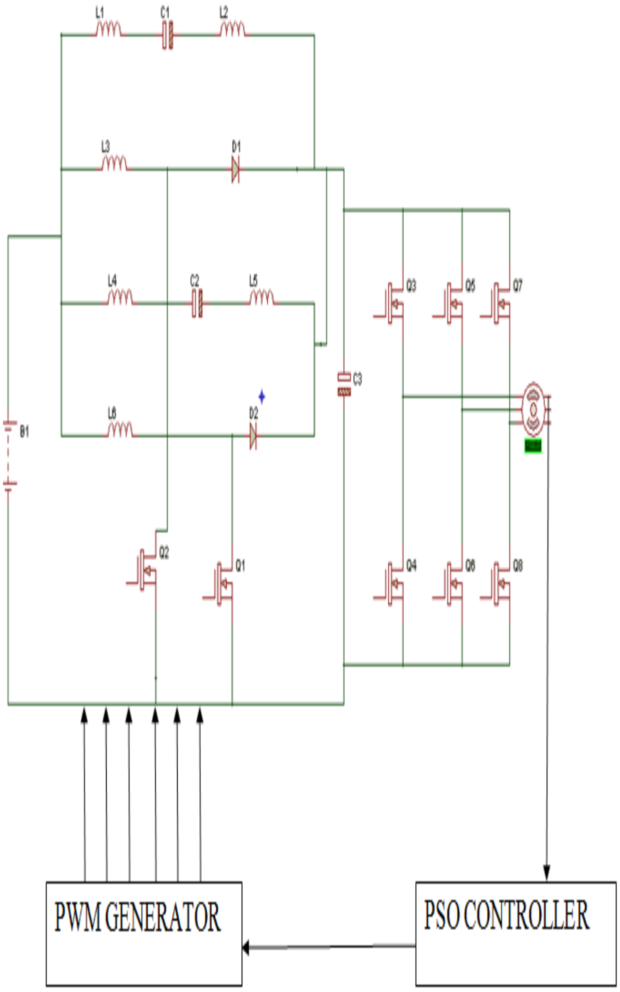

Fig.3. Circuit Diagram of Proposed System

III.PARTICLE SWARM OPTIMIZATION TECHNIQUE

A. Basics of PSO Algorithm

Natural creatures sometimes behave as a swarm. One of the main streams of artificial life researches is to examine how natural creatures behave as a swarm and reconfigure the swarm models inside a computer. Swarm behavior can be modeled with a few simple rules. School of fishes and swarm of birds can be modeled with such simple models.

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According to the research results for a flock of birds, birds find food by flocking (not by each individual). The observation leads the assumption that all information is shared inside flocking. PSO is basically developed through simulation of bird flocking in two-dimension space). The position of each agent is represented by XY axis position and also the velocity is expressed by vx (the velocity of X axis) and vy (the velocity of Y axis). Modification of the agent position is realized by the position and velocity information. Bird flocking optimizes a certain objective function. Each agent knows its best value so far (pbest) and its XY position. This information represents the personal experiences o each agent. Moreover, each agent knows the best value so for in the group (gbest) among (pbests). Namely, each agent tries to modify its position using the following information: the current positions (x, y), the current velocities (vx, vy), the distance between the current position and pbest, the distance between the current position and gbest. This modification can be represented by the concept of velocity.

In the particle swarm optimization algorithm, particle swarm consists of "n" particles, and the position of each particle stands for the potential solution in D-dimensional space. The particles change its condition according to the following three principles:

(1) To keep its inertia

(2) To change the condition according to its most optimist position

(3) To change the condition according to the swarm's most optimist position.

$$v_i{}^{k+1} = wv_i{}^k + c_1r_1 \times (pbest_i - s_i{}^k) + c_2r_2 \times (gbest - s_i{}^k) \quad \textbf{(7)}$$

where, v_i^k : velocity of agent i at iteration k,
w: weighting function,
c_j : weighting factor,
s_i^k : current position of agent i at iteration k,
$pbest_i$: pbest of agent i,
gbest: gbest of the group.

The following weighting function is usually utilized in

$$w = w_{max} - \frac{w_{max} - w_{min}}{iter_{max}} \times iter \quad (8)$$

where Wmax= initial weight,

Wmin = final weight,

maxIter = maximum iteration number,

iter = current iteration number.

$$s_i{}^{k+1} = s_i{}^k + v_i{}^{k+1} \quad \textbf{(9)}$$

The position of each particle in the swarm is affected both by the most optimist position during its movement (Individual experience) and the position of the most optimist particle in its surrounding (near experience). When the whole particle swarm is surrounding the particle, the most optimist position of the surrounding is equal to the one of the whole most optimist particle; this algorithm is called the whole PSO. If the narrow surrounding is used in the algorithm, this algorithm is called the partial PSO. Each particle can be shown by its current speed and position, the most optimist position of each individual and the most optimist position of the surrounding. In the partial PSO, the speed and position of each particle change according the following equation *pbest* represents the d-dimension quantity of the individual "i" at its most optimist position at its "k" times. *gbest* is the d-dimension quantity of the swarm at its most optimist position.

In order to avoid particle being far away from the searching space, the speed of the particle created at its each direction is confined between -vdmax, and vdmax. If the number of vdmax is too big, the solution is far from the best, if the number of vdmax is too small, the solution will be the local optimism; c1 and c2 represent the speeding figure, regulating the length when flying to the most particle of the whole swarm and to the most optimist individual particle. If the figure is too small, the particle is probably far away from the target field, if the figure is too big, the particle will maybe fly to the target field suddenly or fly beyond the target field. The proper figures for c1 and c2 can control the speed of the particle's flying and the solution will not be the partial optimism.

Usually, c1 is equal to c2 and they are equal to 2; r1 and r2 represent random fiction, and 0-1 is a random number. In local PSO, instead of persuading the optimist particle of the swarm, each particle will pursuit the optimist particle in its surrounding to regulate its speed and position. Formally, the formula for the speed and the position of the particle is completely identical to the one in the whole PSO.

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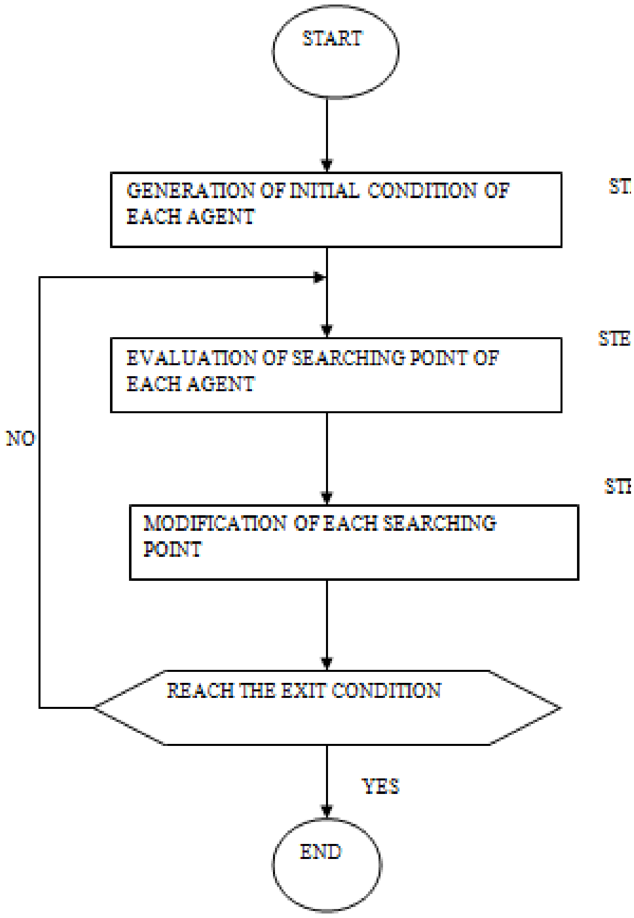

Fig.4. General Flowchart for PSO

The general flow chart of PSO can be described as follows:

Step 1: Generation of initial condition of each agent Initial searching points and velocities of each agent are usually generated randomly within the allowable range. The current searching point is set to pbest for each agent. The best-evaluated value of pbest is set to gbest and the agent number with the best value is stored.

Step 2: Evaluation of searching point of each agent. The objective function value is calculated for each agent. If the value is better than the current pbest of the agent, the pbest value is replaced by the current value. If the best value of pbest is better than the current gbest, gbest is replaced by the best value and the agent number with the best value is stored.

Step 3: Modification of each searching point. The current searching point of each agent is changed.

Step 4: Checking the exit condition such as maximum number of iteration.

A. Advantages

Advantages of the basic particle swarm optimization algorithm:

(1)PSO is based on the intelligence. It can be applied into both scientific research and engineering use.

(2)PSO have no overlapping and mutation calculation. The search can be carried out by the speed of the particle. During the development of several generations, only the most optimist particle can transmit information onto the other particles, and the speed of the researching is very fast.

(3)The calculation in PSO is very simple. Compared with the other developing calculations, it occupies the bigger Optimization ability and it can be completed easily.

(4) PSO adopts the real number code, and it is decided directly by the solution. The number of the dimension is equal to the constant of the solution.

IV. SIMULATION DIAGRAM & RESULTS

The proposed PSO based controller has been applied to the speed control of induction motor by an interleaved boost converter and verified with the conventional schemes. An ideal scenario is simulated with results confirming the correctness of the design. All simulations were performed using the Mat lab Simulink toolbox 2011. Fig.5. Shows the simulation circuit diagram of the proposed system which is simulated by using Mat lab Simulink 2011.

Fig 6 shows the input supply voltage to the converter is 200V

Fig.7. shows output voltage which is boosted up to 400V by the interleaved boost converter

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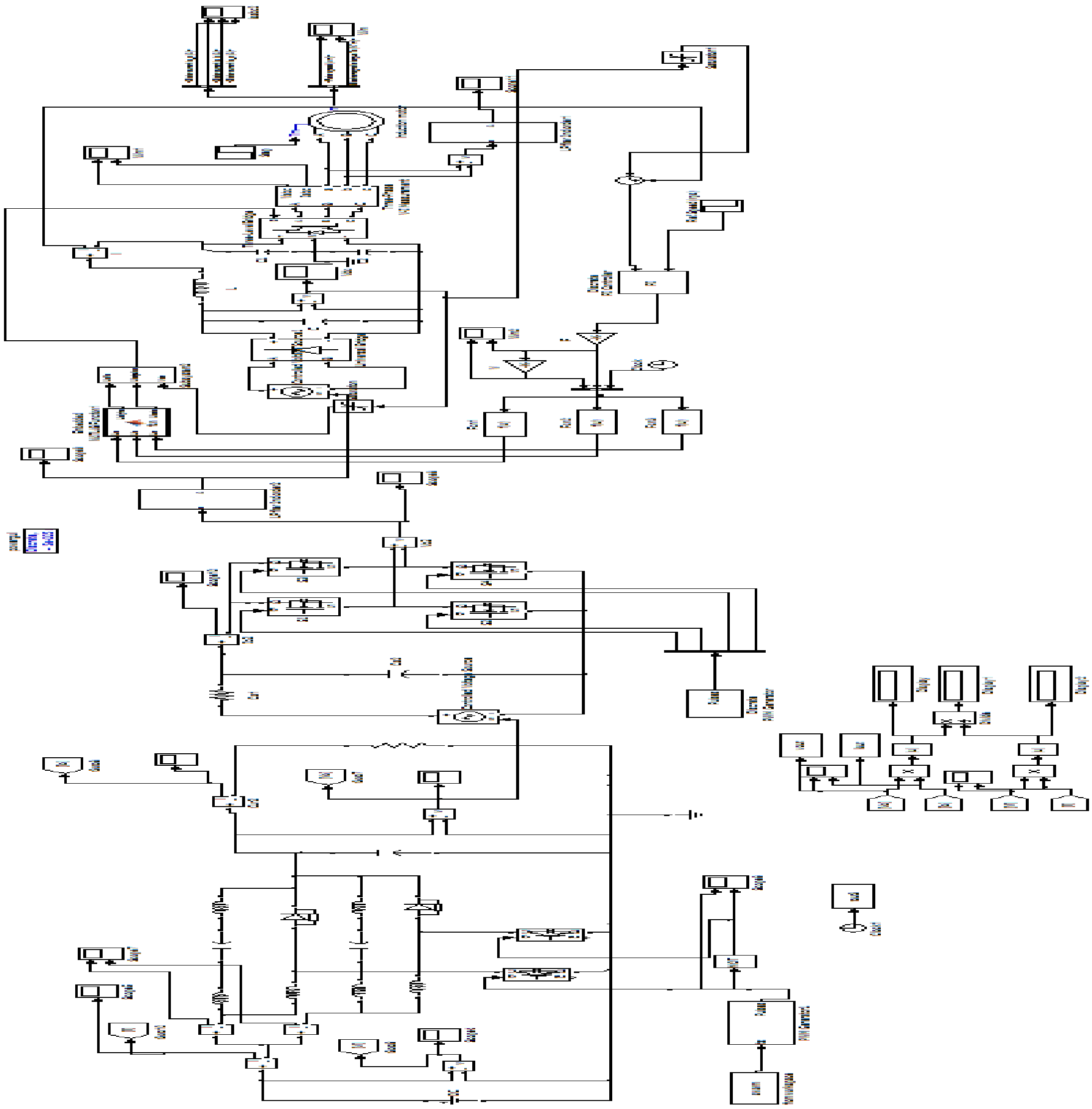

Fig 5.Simulation Circuit Diagram

A. Resultant waveforms

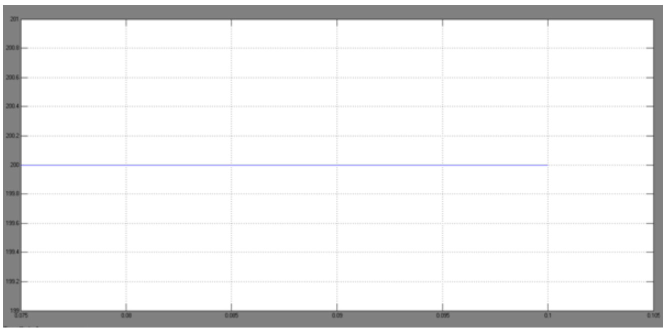

Fig.6.Input Voltage Waveform

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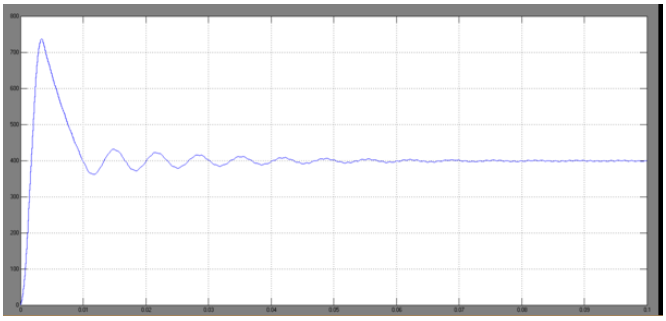

Fig 7.Output Voltage Waveform

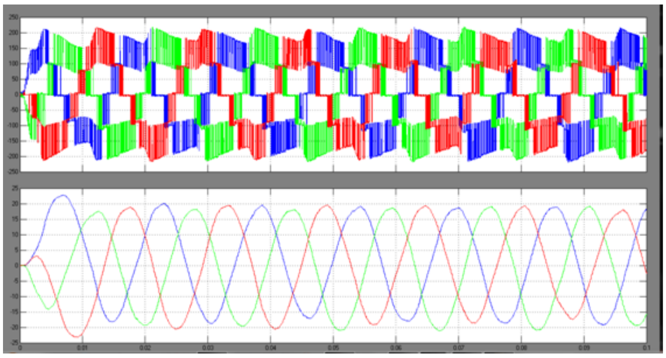

Fig 8. Motor 3 Phase Voltage and Current Waveform

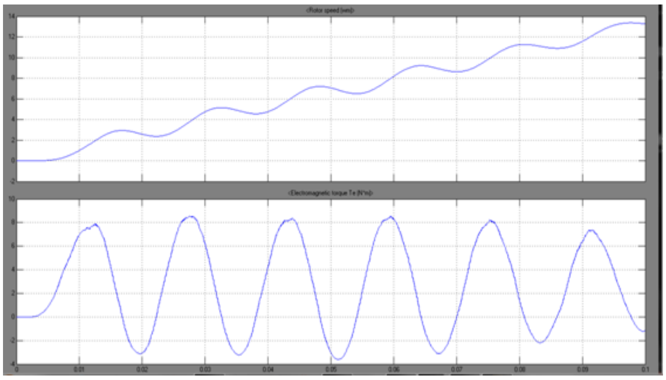

Fig 9.Motor Speed and Torque Waveform

V. CONCLUSION

An effective control technique is presented for the speed control of three phase IM drive. In this proposed work the interleaved boost converter with ripple cancellation network is used to reduce the current stress of switching devices. Particle swarm optimization algorithm based controller is used to regulate the speed of IM and also to reduce the torque ripples. The system uses iteration method. Inputs to the PSO are command speed, speed error, and change of speed error and it produces the single output from that the gate pulses are produced. The simulation result of proposed technique was carried out for three phase IM drive which is more robust than when load disturbances occurred. The simulation result shows the low current ripple, good speed regulator and high efficiency with proposed PSO controller than the conventional.

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BIOGRAPHY

Dr.Govindaraj Thangavel born in Tiruppur , India in 1964. He received the B.E. degree from Coimbatore Institute of Technology, M.E. degree from PSG College of Technology and Ph.D. from Jadavpur University, Kolkatta,India in 1987, 1993 and 2010 respectively. His Biography is included in Who's Who in Science and Engineering 2011-2012 (11th Edition). Scientific Award of Excellence 2011 from American Biographical Institute (ABI). Outstandin Scientist of the 21st century by International Biographical centre of Cambridge, England 2011.

Since July 2009 he has been Professor and Head of the Department of Electrical and Electronics Engineering, Muthayammal Engineering College affiliated to Anna University, Chennai, India. His Current research interests includes Permanent magnet machines, Axial flux Linear oscillating Motor, Advanced Embedded power electronics controllers,finite element analysis of special electrical machines,Power system Engineering and Intelligent controllers.He is a Fellow of Institution of Engineers India(FIE) and Chartered Engineer (India).Senior Member of International Association of Computer Science and Information. Technology (IACSIT). Member of International Association of Engineers(IAENG), Life Member of Indian Society for Technical Education(MISTE). Ph.D. Recognized Research Supervisor for Anna University and Satyabama University Chennai. Editorial Board Member for journals like *International Journal of Computer and Electrical Engineering*,International Journal of Engineering and Technology,International Journal of Engineering and Advanced Technology (IJEAT).International Journal Peer Reviewer for Taylor &Francis International Journal "Electrical Power Components & System"United Kingdom,Journal of Electrical and Electronics Engineering Research,Journal of Engineering and Technology Research (JETR),International Journal of the Physical Sciences,Association for the Advancement of Modelling and Simulation Techniques in Enterprises,International Journal of Engineering & Computer Science (IJECS),Scientific Research and Essays,Journal of Engineering and Computer Innovation,E3 Journal of Energy Oil and Gas Research,World Academy of Science, Engineering and Technology,Journal of Electrical and Control Engineering JECE),Applied Computational Electromagnetics Society etc.. He has published 132 research papers in International/National Conferences and Journals. Organized 40 National / International Conferences/Seminars/Workshops. Received Best paper award for ICEESPEEE 09 conference paper. Coordinator for AICTE Sponsored SDP on special Drives,2011.Coordinator for AICTE Sponsored National Seminar on Computational Intelligence Techniques in Green Energy, 2011.Chief Coordinator and Investigator for AICTE sponsored MODROBS - Modernization of Electrical Machines Laboratory. Coordinator for AICTE Sponsored International Seminar on "Power Quality Issues in Renewable Energy Sources and Hybrid Generating System", July 2013.