Harmonic Elimination in Multilevel Inverter for Induction Motors using Particle Swarm Optimization

Manoj Kumar, **Mamta Singh**

Abstract— **Harmonics measurement of an industrial unit is done to asset the power quality aspects in a typical factory. . Several inverters like Voltage Series Inverters, PWM fed Inverters, Multilevel inverters etc. exist in literature. Among all these, multilevel inverters have been very popular of late due to its several advantages. But there is a challenge of optimal design of the inverter and optimal selection of pulse width of each level so as to get minimal Total Harmonic Distortion.**

For these reasons a novel multilevel inverter design based on an improved Particle Swarm Optimization is proposed in this thesis for obtaining the optimal width of the pulse of each level so as to get minimal Total Harmonic distortion. The results has been compared to that of the existing techniques and found to be quite better than the existing ones.

Index Terms— **Particle Swarm Optimization, Induction Motor, Multi-level Inverter, Harmonic elimination**

I. INTRODUCTION

In many industrial applications, usually, DC motors were the work horses for the regulating Speed Drives [2] (ASDs) because of their excellent speed and torque response. But, they have inherent disadvantage of commutator and mechanical brushes, which go through wear and tear with the passage of time. Generally [10], AC motors are preferred to DC motors, in particular, an induction motor because to its low cost, low maintenance, lower weight, low maintenance, higher efficiency, improved ruggedness and reliability. All these features make the use of induction motors a mandatory in many areas of industrial applications. The improvement in Power electronics [11] and semi-conductor technology has triggered the growth of high power and high speed semiconductor devices in order to get a smooth, continuous and step less variation in motor speed. Applications of solid state converters/inverters for adjustable speed induction motor drive are well-known in electromechanical systems for a large spectrum of industrial systems. Comparison of basic and high frequency carrier based techniques for NPC inverters is given by Feng, 2000. Influence of number of stator windings on the characteristics of motor is given by Golubev, 2000. Modified CSI based induction motor drive is given by Gopukumar, 1984. Multilevel inverter modulation schemes to eliminate common mode voltage is given by Zhang, 2000. Modulation schemes for six phase induction motor are given by Mohapatra, 2002. Improved reliability in solid state ac drives is given by Thomas, 1980. Multilevel converters [13] for large electric drives are given by Peng, 1999. Active harmonic elimination for multilevel inverters is given by Tolbert, 2006. The inverters are either Current Source Inverter (CSIs) or Voltage [7] Source Inverters (VSIs). Current source inverters are widely used for the implementation of fully generative induction machine variable speed drives. An important and attractive feature of CSI is its good fault protection capability and the inherent regeneration capability.

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This paper aims at designing of a multilevel inverter based on an Improved Particle Swarm Optimization [14] technique for reduction of harmonics in induction motor control. The remainder of this paper is as follows. Section 2 deals with the various literatures which are present in this field and related fields. It discusses the amount of work which are currently being carried out in the scientific community. Section 3 proposes our problem statement and gives a mathematical shape to it so that various algorithms could be applied on it. Section 4 introduces our methodology and discusses the implementation of our proposed algorithm. Section 5 shows the results of our approach and finally Section 6 concludes the report with a discussion on the future scopes of this method.

II. LITERATURE SURVEY

In this paper, [1] author proposed the control of high-performance induction motor drives for general industry applications and production automation has received widespread research interests. Induction machine modeling has continuously attracted the attention of researchers not only because such machines are made and used in largest numbers but also due to their varied modes of operation both under steady and dynamic states. Traditionally, DC motors were the work horses for the [3] Adjustable Speed Drives (ASDs) due to their excellent speed and torque response. But, they have the inherent disadvantage of commutator and mechanical brushes, which undergo wear and tear with the passage of time.

In this paper, [4] author proposed the application of nonlinear loads as a result of power electronic development is growing very fast. In general view [5], the shape of network voltage can't be imagined sinusoidal and motor manufacturers have to consider non-sinusoidal conditions in their designs. The harmonics [6] of network voltage effect on operation of all electrical equipment like relays, that are the guards of power system, measurement equipment, and electric motors, that are the wheels of industries. In fact, all of these equipment have been designed to work in normal conditions, but in real networks [8] the power is non-sinusoidal that reduces the motor efficiency and their lifetime.
In this paper, [9] author proposed the multilevel converter has a several advantages, that is:

1. Common Mode Voltage:

The multilevel inverters produce common mode voltage, reducing the stress of the motor and don't damage the motor.

2. Input Current:

Multilevel inverters can draw input current with low distortion

3. Switching Frequency:

The multilevel inverter [12] can operate at both fundamental switching frequencies that are higher switching frequency and lower switching frequency. It should be noted that the lower switching frequency means lower switching loss and higher efficiency is achieved.

4. Reduced harmonic distortion:

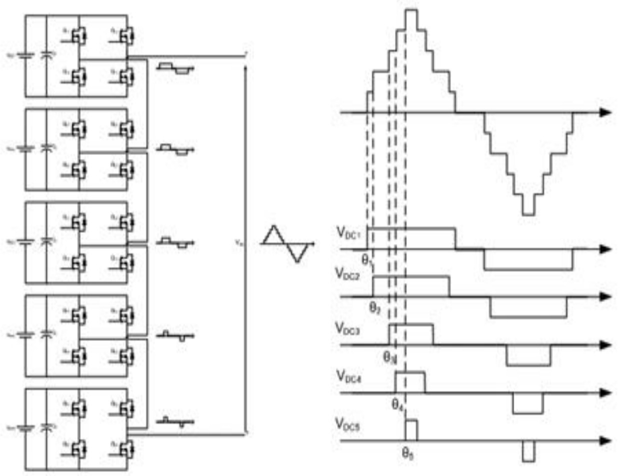

Figure 1: General Design of Multilevel Inverter

III. PROBLEM FORMULATION

This Section deals with the problem formulation of induction motor performance enhancement and the various challenges faced by the existing and proposed techniques. Evolutionary algorithms can be applied on various applications but it needs to be modified according to applications.

Harmonic Elimination method provides an efficient method to remove lower order harmonics in various configurations of inverters. The selection of the type of inverter and the topology of the inverter plays an important role in the performance. This leads to a critical design requirement in terms of pulse wave design to be fed at the gate terminals of the various power electronics switches. The problem can also be visualized as an optimization problem with the pulse widths being the tuning parameters which needs to be optimized in terms of minimal Total Harmonic Distortion of the output. As mentioned above the pulse gate design can be visualized as an optimization problem which can be solved using various optimization algorithms. The research problem which we are targeting here is the design of multilevel inverters and their optimal selection of pulse width in order to reduce the total harmonics distortion to a minimal value, thereby improving the performance of the induction machine.

IV. PROPOSED METHODOLOGY

Our proposed methodology for the problem discussed in Section 3 is mentioned. The sub problems which were formed in the previous sections has been solved by the below mentioned methodologies. The technique of Particle Swarm Optimization for multilevel inverter tuning has been applied on the induction motor model and then their performance was compared on the basis of Total Harmonic Distortion, machine performance etc.

4.1 Particle Swarm Optimization

Particle swarm optimization (PSO) is an evolutionary algorithm inspired by the food search methodology of a swarm of insects (Kennedy, 2010). The position of each insect represents a candidate solution, which is updated as the swarm of insect flies in a multi-dimensional search space. The movement of each insect is governed by the efficacy of their own previous position and that of the neighbors. Each insect can be described by two parameters- position (xi) and velocity (vi), which is updated by the following rule:

$$
\begin{aligned}
v_i(t+dt) &= w * v_i(t) + c_1 * r_1 * (pbest_i(t) - x_i(t)) \\
&\quad + c_2 * r_2(gbest(t) - x_i(t)), \\
x_i(t+dt) &= x_i(t) + v_i(t)dt.
\end{aligned}
$$

Here, pbesti is the best position obtained by ith particle and gbest is the best position obtained by any particle till current iteration. c1, c2 are known as acceleration vectors whereas r1, r2 are two random vectors uniformly distributed between '0' and '1' and w denotes inertial weight.

4.2 Tuning with PSO of Induction Motor

For better search, acceleration vectors c1 and c2 should be kept small, which however decreases the convergence rate and has to be selectively chosen varying from application to application. For a problem having large numbers of local extrema, the values of c1 and c2 should be kept low, so as to increase the chance of finding the global extrema at the cost of convergence time and vice-versa. Similarly, the inertial weight w is adjusted, depending on the amount of influence desired in a particle's previous position on its current movement. This optimization algorithm is finally said to converge, when each particle reaches the global best or the preset extremum value of the cost function.

V. SIMULATION RESULTS AND DISCUSSION

All the simulations were done in MATLAB R2013, 2.7GHz processor with 4 GB RAM. The proposed model of induction motor control was designed in Simulink as shown in Fig 2.

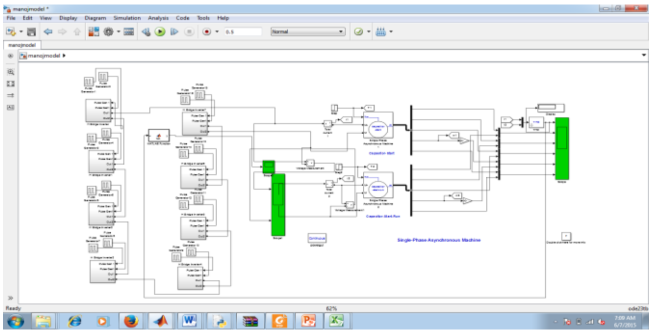

Figure 2: Complete Design of proposed model

Figure 2 shows the complete model of the multilevel inverter which is connected to induction motor, tuned by Particle Swarm optimization. The PSO is implemented using matlab s-function and is utilized for the tuning of firing angles after taking feedback from the calculated THD.

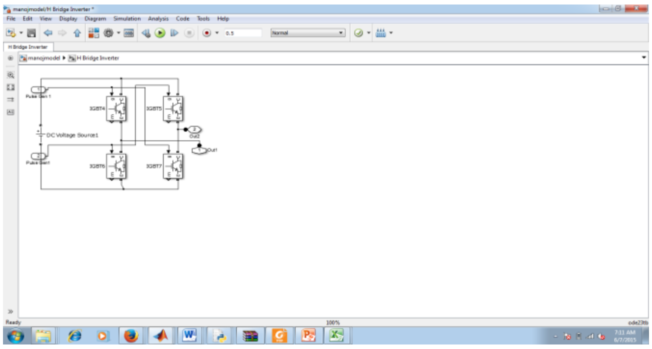

Figure 3: Individual components of H-Bridge Inverter

Figure 3 shows the individual Hbridge inverter which is implemented and cascaded using subsystem in the main model. The output of the individual inverters is kept around 20V.

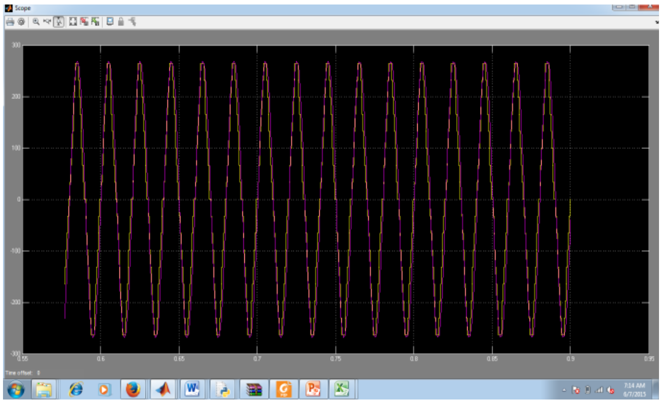

Figure 4: Output of Multilevel inverter

Figure 4 shows the motor voltage when PSO algorithm is applied and is compared to the reference sine wave. The total Harmonic distortion is found to be 21% without using PSO while it comes down to 15.6% when PSO algorithm is applied.

The THD has been taken as the optimization function for the Particle Swarm Optimization. The PSO is implemented by generating random particles in the given range and updating each particle suing the update rule of PSO. The best position of each particle is found out and called pbest and the best of all pbest is called as gbest.

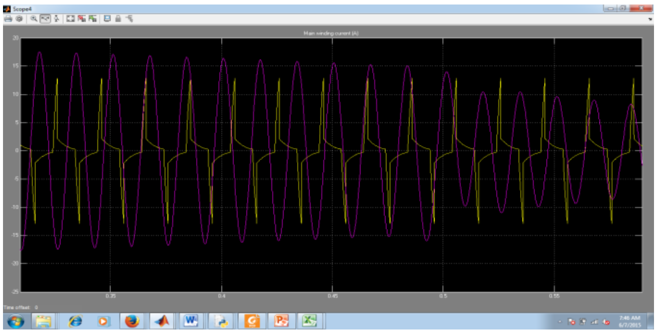

Figure 5: Motor winding currents

Figure 5 shows the graph of phase currents of the motor windings. The initial high value of the currents can be attributed to the transients occurring due to motor inrush currents.

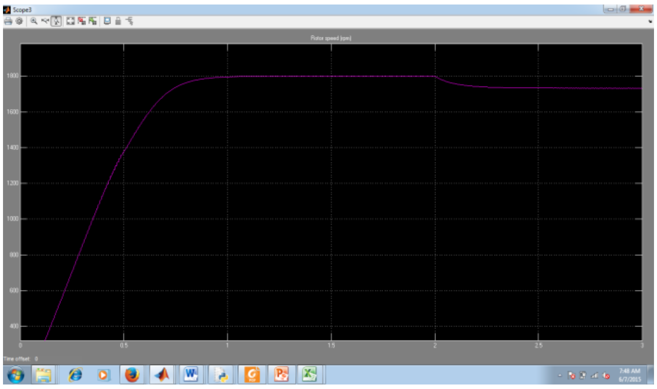

Figure 6: Plot of Rotor Speed

Figure 6 above shows the rotor speed plotted against time. As the switch is closed, the rotor starts accelerating the speed increases to the synchronous speed. But after certain time the speed is back to a stable value which is less than the synchronous speed.

VI. CONCLUSIONS AND FUTURE SCOPE

An improved PSO based harmonic elimination technique has been applied in this paper for control of induction motors and the various simulations has been performed on Simulink. The results have been shown and it is observed that the use of PSO improves the performance and also the multilevel inverters have an edge over other designs due to their design simplicity and performance. In future, other algorithms can be applied for the same problem and other configurations of inverters can be tested. Further, better objective functions can be considered and effect of other parameters can be considered in future.

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