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Harmonic Elimination in Multilevel Inverter for Induction Motors using Modified Human Opinion Dynamics

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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.

The real issues are the harmonics generated by the inverters which affects the induction machine performance. Several inverters like Voltage Series Inverters, PWM fed Inverters, Multilevel inverters etc. exist in literature. For these reasons a novel multilevel inverter design based on an improved Modified Human Opinion Dynamics 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.

KEYWORDS: Modified Human Opinion Dynamics, Induction Motor, Multi-level Inverter, Harmonic elimination

I.INTRODUCTION

In recent years the control of high-performance induction motor drives for general industry applications and production automation has received widespreadresearch interests. Induction machine modelinghas 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 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 most cases, AC motors are preferred to DC motors, in particular, an induction motor due to its low cost, low maintenance, lower weight, higher efficiency, improved ruggedness and reliability. All these features make the use of induction motors a mandatory in many areas of industrial applications. The advancement in Power electronics and semiconductor technology has triggered the development of high power and high speed semiconductor devices in order to achieve a smooth, continuous and low total harmonics distortion (THD). Multilevel inverter technology have become more attractive for their use in high voltage and high power applications. In Multilevel inverters the desired output voltage is achieved by Suitable low combination of multiple low dc voltage sources used at the input side. As the number of dc sources increases the output voltage will be pure closer to sinusoidal waveform. Multilevel inverters have drawn tremendous interest in the field of high-voltage high-power applications such as laminators, Mills, conveyors, compressors, large induction motor drives, UPS systems, and static vary compensation level by connecting different dc sources of lower. There are several methods used for harmonic elimination in multilevel inverter. If the switching losses in an inverter are not a concern (i.e., switching on the order of a few kHz is acceptable), then the sine-triangle PWM method and its variants are very effective for controlling the inverter output voltage.

This paper proposes a novel Multi-level inverter fed induction motor using Modified Human Opinion Dynamics based Optimisation for improved performance. The real issues are the harmonics generated by the inverters which affects the induction machine performance. 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

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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 four configurations of multilevel inverter design based on harmonic elimination and reduction in design 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 were compared among themselves in terms of voltage and THD. All the simulations were performed in MATLAB software and the results are found to be quite encouraging.

This paper aims at designing of a multilevel inverter based on an Improved Modified Human Opinion Dynamics [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, [2] 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, [3] 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:

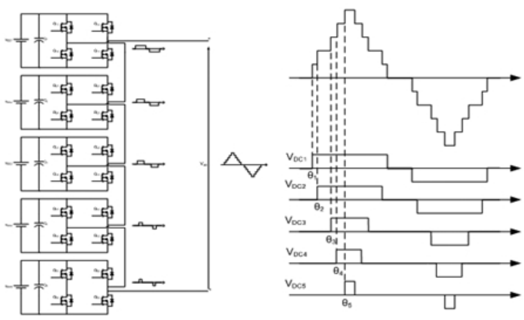

Figure 1: General Design of Multilevel Inverter

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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.Many models have been proposed for representing harmonic sources as well as linear components. Various network harmonic solution algorithms have also been published. In the following sections, we briefly summarize the well-accepted methods for harmonic modelling and simulations. Other chapters in this tutorial will expand upon these ideas and illustrate how to set up studies in typical situations. The most commonly used index for measuring the harmonic content of a waveform is the total harmonic distortion (THD). It is a measure of the effective value of a waveform and may be applied to either voltage or current. Total harmonic distortion is the contribution of all the harmonic frequency currents to the fundamental. Just as waveforms can be added to produce distorted waves, distorted waves may be decomposed into fundamental and harmonic components.

$$THD_i = \frac{\sqrt{\sum_{h=2}^{\infty} I_h^2}}{I_1}$$

The THD is a measure of the effective value of the harmonic components of a distorted waveform. This index can be calculated for either voltage or current. The following equation gives THD for current.

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 Modified Human Opinion Dynamics 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 Modified Human Opinion Dynamics

Modelling human behaviour has been an interesting area of research for quite a time now and a lot of theories have been put forward to emulate the real life dynamics into a mathematical model. HOD is one such recent area which has been recently claimed to solve complex optimization problem. Although roots of this approach lies in Social Impact Theory Optimisation (SITO), they are found to have limited utility in high dimensionality problems and are based on discrete opinion formation. HOD model is utilized to develop an optimizer referred as Continuous Opinion Dynamics Optimizer (CODO). The model is based on the opinion formation mechanism of a group of individuals during a discussion and has four primitive fundamentals- social arrangements, point view area, social impact and restore order. Social structure forms the platform for different individuals to interact with each other where each individual are placed on the nodes of the social graph. A cellular automata model is employed with a modified form of Moore's neighbourhood where all the individuals are included as neighbours of each other rather than immediate orthogonal members as in Van Neuman topology or all immediate eight neighbours as in simplistic Moore's topology. Opinion space is different from the social space and refers to a hyperspace, where the opinions of each individual affects each other and is modified under a certain update rule. An important difference of HOD based optimization from PSO is that, in opinion space, collision is possible, i.e. two individuals can have same opinion at a time while two insects cannot have the same position in the swarm at a time. Opinions are considered to be continuous here to suit our problem of optimization where optimizing parameters can have any value within a finite range. Opinions are influenced

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by the opinions of its neighbours depending on their social influence which is defined here as the ratio of social rank of any individual to the distance between them and is given by:

$$w_{ij} = \frac{SR_j(t)}{d_{ij}(t)}.$$

Here, SR is determined by the inverse of the fitness value of an individual, where fitness value is the error which needs to be minimized. Social Score is calculated in this paper instead of Social Rank using Maximum Likelihood Estimator (MLE). The modification adapted here from the works of Reshamjitet. al. are inspired from the fact that the problem at hand has to predict the value of optimal size of the DG unit which is a continuous variable and the concept of social score in place of social rank using MLE ensured that the difference in individual's fitness is well represented during the opinion update rule. Each individual's opinion is updated by the following rule given as:

$$\Delta o_i = \frac{\sum_{j=1}^{N} (o_j(t) - o_i(t)) w_{ij}(t)}{\sum_{j=1}^{N} w_{ij}(t)} + \eta_i(t),\ j \neq i,$$

Where oj(t) is the opinion of neighbours of individual i, wij is the social influence factor, and η is adaptive noise introduced to justify individualization in society after a certain consensus limit is reached. Individualization phenomena are inspired by Durkheim's theory of division of labour in society which was used by(Mäs et al., 2010)to simulate a model where individualization co-exists along with integration in society. Similar context meaning was given by (Kennedy, 2010) to explain craziness factor introduced during development of PSO. The inclusion of this term makes the optimization algorithm more robust and increases its exploration capabilities, preventing it from being trapped in local extreme while encountering complex optimization problems. η is a normally distributed random noise with mean zero and standard deviation 'σ' and is given by:

$$\sigma_i(t) = S \sum_{j=1}^{N} e^{-f_{ij}(t)},$$

Where 'f' is the difference in fitness factor between ith and jth opinion and S denotes the strength of disintegrating force. S needs to be adjusted as a compromise between individualization and integration i.e. as more number of individuals attains similar fitness, individualization increases. This increases the robustness of the algorithm at the cost of convergence rate.

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.

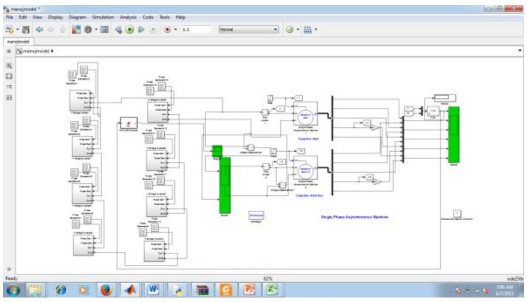

Figure 2: Complete Design of proposed model

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

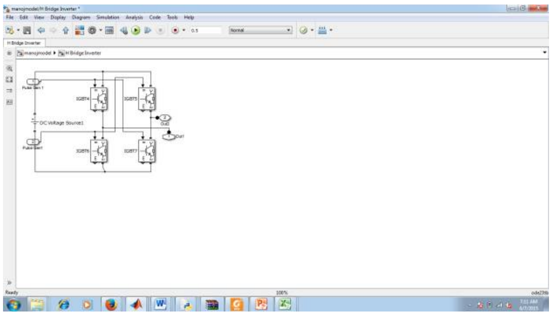

Figure 3: Individual components of H-Bridge Inverter

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 .

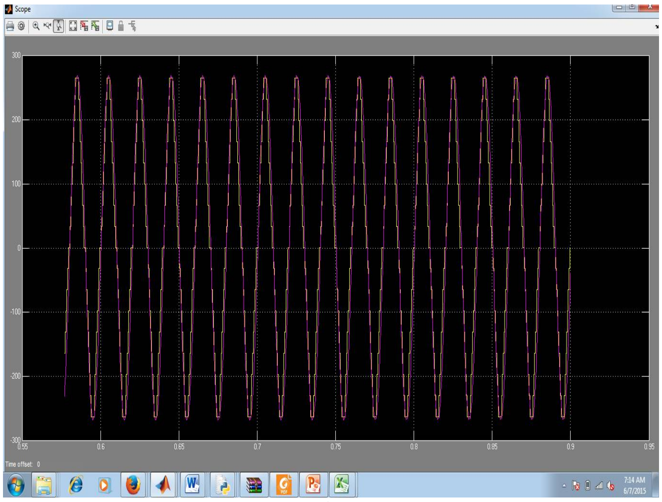

Figure 4: Output of Multilevel inverter

Figure 4 shows the motor voltage when MHOD algorithm is applied and is compared to the reference sine wave. The total Harmonic distortion is found to be 2.43% when using PSO while it comes down to 1.49% when MHOD algorithm is applied.

The THD has been taken as the optimization function for the Modified Human Opinion Dynamics. The MHOD is implemented by generating random particles in the given range and updating each particle suing the update rule of MHOD.

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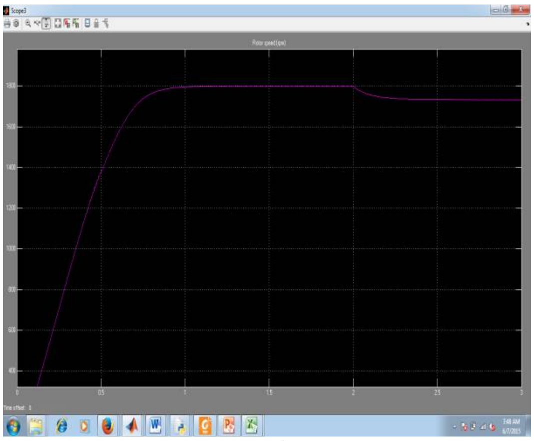

Figure 5: Plot of Rotor Speed

Figure 5 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 MHOD 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 MHOD 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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