PERFORMANCE OF GENETIC ALGORITHM BASED MULTI-TIERED INVERTER FED SLIPRING INDUCTION MOTOR DRIVE

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Abstract- **The paper deals about the analysis and performance of a slip-ring induction motor which is driven by a Multi-tiered inverter and thus too the switching angles of the multi-tiered inverter for very low Total Harmonic Distortion (THD) is achieved by Genetic algorithm approach. Here the analysis of the Slip-ring induction motor is achieved in terms of Total Harmonic Distortion, Speed of the rotor and the performance in terms of efficiency. The output voltage, speed is analyzed by Matlab simulation, and the total THD is analyzed by FFT spectrum.**

Keywords: **THD, Slip-ring Induction motor, Multi-tiered Inverter.**

I. INTRODUCTION

In the universe maximum industrial and commercial applications requires most powerful motors such as uniquely an Induction motor. At the same time the speed control of the motor is one of the most important parameter considerations in application point of view.

The improvement and advancement in the technology of power electronic devices field, semi conductor technology has triggered the development of high power and high speed semiconductor devices in order to achieve a smooth, continuous and stepless variation in induction motor speed. Applications of solid state converters/inverters for adjustable speed induction motor drives are useful in a large spectrum of industrial systems.

In the conventional Multilevel inverters the harmonic content and the switching losses are the major problems to get the by-directional output. The content of the harmonics in the output voltage due to this the winding of the rotor gets heated up, by that the power loss gets increases, and also the motor gets suffer from severe torque fluctuations at low speeds which causes the motor in cogging at the shaft. It will also cause undesired motor heating and electromagnetic interference. In order to obey these effects the large size filters to be used and by this the size and cost of the controlling system gets increases.

The Multi-tiered inverter is considered to be the one of the best promising alternative method and cost effective solution for applications where it requires high voltage and high power. They occupied best place in the modern industries. Multilevel structure allows toraise the power handling capability of the system in a powerful and systematic way. The advancements in the field of power electronics and microelectronics made it possible to reduce the magnitude of harmonics with multilevel inverters, in which the number of levels of the inverters are increased rather than increasing the size of the filters. The performance of multilevel inverters enhances as the number of levels of the inverter increases.

II. MULTI-TIERED INVERTERS

Presently industry has begun to demand higher power rating converters with reasonably good efficiency, reduced EMI and less distorted output waveforms. Multilevel voltage source inverter's unique structure allows them to reach high voltage and high currents. Multilevel inverters will significantly reduce the magnitude of harmonics and increases the output voltage and power without the use of step-up transformer. A multilevel inverter consists of a series of H-bridge inverter units connected to three phase induction motor. The general function of this multilevel inverter is to synthesize a desired voltage from several DC sources. The AC terminal voltages of each bridge are connected in series. Unlike the diode clamp or flying-capacitors inverter, the cascaded inverter does not require any voltage clamping diodes or voltage balancing capacitors. This configuration is useful for constant frequency applications such as active front-end rectifiers, active power filters, and reactive power compensation.

Choosing appropriate conducting angles for the H-bridges can eliminate a specific harmonic in the output waveform (Rashid, 2004). The required conduction angles can be calculated by analyzing the output phase voltage of cascade inverter assuming that four H-bridges have been used, the output voltage V_{ao} can be given as

$$V_{ao} = V_{a1} + V_{a2} + V_{a3} + V_{a4} + V_{a5} \ldots$$

Since the wave is symmetrical along the x-axis, both Fourier coefficient A_0 and A_n are zero. Just the analysis of B_n is required. It is given as

$$B_n = \{[4V_{dc}]/n\pi\}[\sum \text{Cos}(n\alpha_1)]$$

J = Number of DC sources.

N = Odd harmonic order.

Therefore, to choose the conducting angle of each H-bridge precisely, it is necessary to select the harmonics with certain amplitude and order, which needs to be eliminated. To eliminate 5th, 7th, and 11th harmonics and to provide the peak fundamental of the phase voltage equal to 80 percent of its maximum value, it needs to solve the following equation with modulation index M=0.8 $\text{Cos}(5_{\alpha1}) + \text{Cos}(5_{\alpha2}) + \text{Cos}(5_{\alpha3}) + \text{Cos}(5_{\alpha4}) = 0$ $\text{Cos}(7_{\alpha1}) + \text{Cos}(7_{\alpha2}) + \text{Cos}(7_{\alpha3}) + \text{Cos}(7_{\alpha4}) = 0$ $\text{Cos}(11_{\alpha1}) + \text{Cos}(11_{\alpha2}) + \text{Cos}(11_{\alpha3}) + \text{Cos}(11_{\alpha4}) = 0$

$$\text{Cos}(\alpha_1) + \text{Cos}(\alpha_2) + \text{Cos}(\alpha_3) + \text{Cos}(\alpha_4) = 0.8*4$$

In order to get the triggering pulses for the cascaded multilevel inverter an approach used is genetic algorithm. The conventional methods are also to be used to generate the pulses to the switching devices used in the multilevel inverter. But in this case it is concluding that the harmonic distortion is very less as compared to conventional methods. This is due to biological process and here reducing the effects of harmonics by concentrating the major harmonic orders as fifth and seventh harmonics.

III. GENETIC ALGORITHM (GA)

Genetic algorithm is a computational model that solves optimization problems by imitating genetic processes and the theory of evolution. It imitates biological evolution by using genetic operators like reproduction, crossover, mutation etc. Optimization in GA means maximization. In cases where minimization is required, the negative or the inverse of the function to be optimized is used. Fig 1: 11 Level H-Bridge Inverter

Fig 2: Output wave form of 11 Level H-Bridge Inverter

To minimize a function *f(y1, y2, ….yk),* using GA, first, each *yi* is coded as a binary string of length *m*. In this paper, a binary string is preferred, e.g.

y1=[011001010101…..0101110]

y2=[111100101001…..0101001]

………….

yk=[10000010101…..0101110]

The set of { *y1, y2, ….yk* } is called a *chromosome* and *yi* are called *genes*. The algorithm works as follows:

A. Initialize population:

Set a population size, N, i.e. the number of chromosomes in a population(P). Then initialize the chromosome values randomly. If known, the range of the genes should be considered for initialization. The narrower the range, the faster GA converges.

B. Evaluation each chromosome:

Use a cost function specific to the problem at hand to evaluate the fitness value (FV) of each chromosome, =1(1,2,….)

To get the total fitness value add all the FVs. Divide each FV by the total FV and find the weight/probability of selection, pi, for each chromosome. The integer part of the product, piN gives the number of descendents (offspring) from each chromosome. At the end, there should be N descendent chromosomes. If the number of descendents calculated is less then N, the rest of the descendents are found randomly considering the reproduction probabilities, pi of each chromosome.

C. Crossover Operation:

A floating number (between 0 and 1) for each chromosome is assigned randomly. If this number is smaller than a pre-selected crossover probability, this chromosome goes into crossover. The chromosomes undergoing crossover are paired randomly. In this case assume x1 and x2 are paired. The crossing point is randomly selected, assume 3 in this case.

Then, before crossover,

y1=[011001010101…..0101110]

y2=[111100101001…..0101001]

and after crossover,

y1=[011001010101…..0101001]

y2=[111100101001…..0101110]

D. Mutation Operation:

A floating number (between 0 and 1) for each bit is assigned randomly. If this number is smaller than a pre-selected mutation probability, this bit mutates. Assume that the 2nd and 4th bits of y1 and 2nd, 3rd and 5th bits of y2 need to be mutated.

Then, before mutation and after crossover,

y1=[001101010101…..0101001]

y2=[100110101001…..0101110]

Finally, the new population is ready for another cycle of genetic algorithm. The algorithm runs a certain number of times as required by the user. At the end, the chromosome with the maximum FV is the answer.

IV. FORMULATING THE PROBLEM

GA algorithm procedure is same for any application. There are only a few parameters to be set for GA to work. The steps for formulating a problem and applying GA are as follows:

1- Select binary or floating point strings.

2- Find the number of variables specific to the problem; this number will be the number of genes in a chromosome. In this application, the number of variables is the number of controllable switching angles, which is the number of H-bridges in a cascaded multilevel inverter.

A 11-level inverter requires five H-bridges; thus, each chromosome for this application will have three switching angles, i.e. {α1, α 2, α 3,α4,α5}.

3- Set a population size and initialize the population. In this application a population size of 20 is selected. Higher population might increase the rate of convergence but also increases the execution time. The selection of optimum sized population requires some experience in GA. The population in this paper has 20 chromosomes, each containing three switching angles. The population is initialized with random angles between 0 and 90 degrees taking into consideration the quarter-wave symmetry of the output voltage waveform.

4- The most important item for the GA to evaluate the fitness of each chromosome is the cost function. The objective of this study is to minimize some harmonics; therefore the cost function has to be related to these harmonics. As an example assume that the 5th and 7th harmonics at the output of a 11-level inverter have to be minimized. Then, the cost function, f can be selected as the sum of these two harmonics normalized to the fundamental,

$$(\alpha1,\alpha2,\alpha3,\alpha4,\alpha5) = |_5| + |_7| \; |_1|$$

where αi are the switching angles and Vn are the nth order voltage harmonics.

For each chromosome, a multilevel output voltage waveform Fig-2 is created using the switching angles in the chromosome and the required harmonic magnitudes are calculated using FFT techniques.

The fitness value for each chromosome is evaluated as,

$$(\alpha1,\alpha2,\alpha3,\alpha4,\alpha5) = |_5| + |_7| \; |_1|$$

The switching angle set producing the max FV is the best solution of the first iteration.

5- GA is usually set to run for a certain number of iterations (200 in this case) to find an answer. After the first iteration, FV's are used to determine new offspring as explained in Section II. These go through crossover and mutation operations and a new population is created which goes through the same cycle starting from FV evaluation. Sometimes, GA can converge to a solution much before 200 iterations are completed. To save time, in this paper, the iterations have been stopped when the cost function goes below 1 in which case the sum of the 5th and the 7th harmonics is negligible compared to the fundamental. As seen in Fig. 1, GA resulted in cost functions even smaller than 0.4.

V. RESULTS

Figure-1 shows the solution of firing angles for the switches in the multi-tiered inverter in terms of cost function and overall modulation index. Based on the result obtained in figure-1, the corresponding FFT analysis is shown in figure-2. It clearly shows that the total harmonic distortion is to be 5.85% it is considerable percentage as compared to conventional methods. Fig-3 shows that the per phase equivalent simulation model of 11-level multi-tiered inverter. Fig-4 shows the gate/triggering pulses to the devices used in multi-tiered inverter. Based on these angles the output voltage obtained from the multi-tiered inverter is shown in the figure-5. Fig-6 gives the simulation circuit for an eleven level multi-tiered inverter fed slip ring induction motor drive.

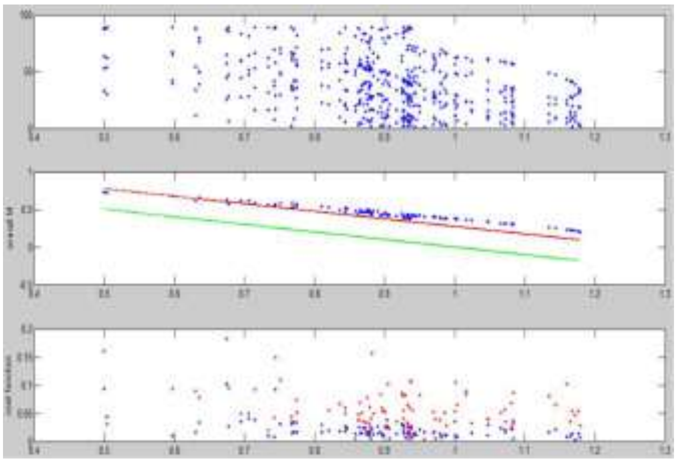

Fig. 1. Solutions for α1, α 2, α 3, α 4, α 5 and the cost function

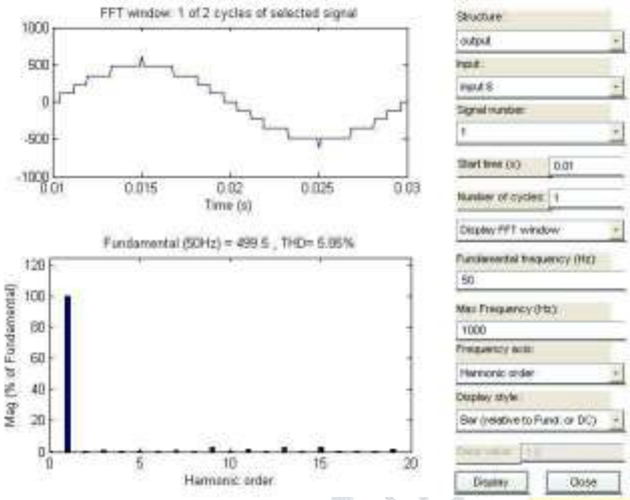

Fig.2. Normalized (with respect to the fundamental) FFT

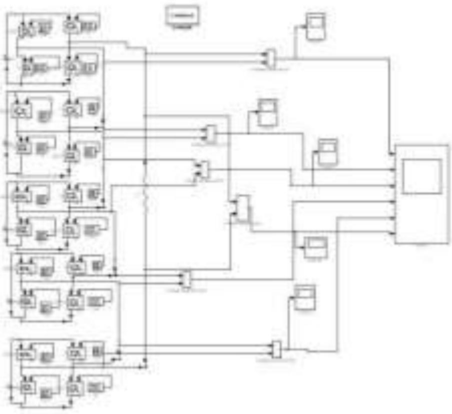

Fig.3. Per phase equivalent of Multi-tiered inverter

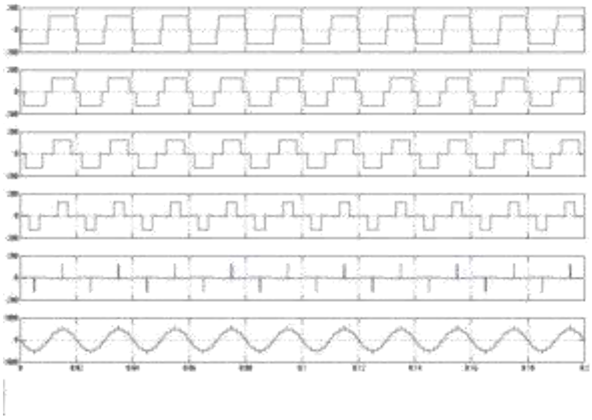

Fig.4.

Gate pulses of Multi-tiered inverter

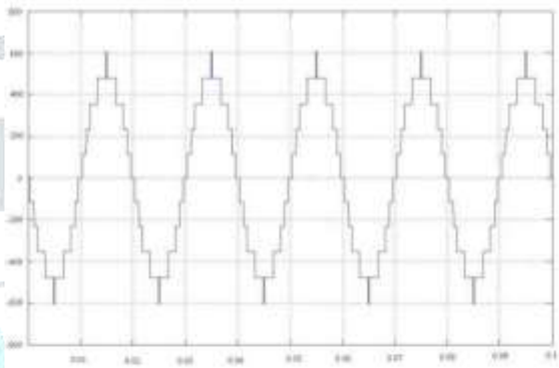

Fig. 5. Experimental output voltage waveform

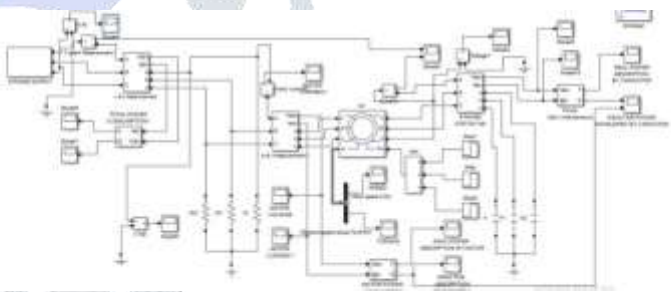

Fig. 6 Simulation model of Multi-tiered inverter fed slip-ring induction motor

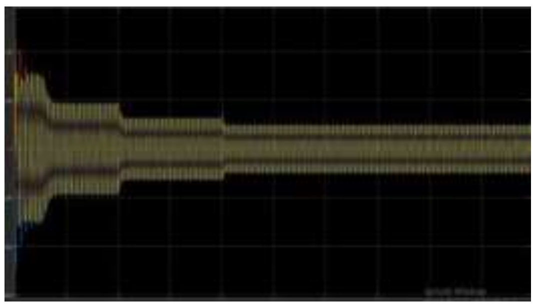

Fig 7. Input current drawn by the motor

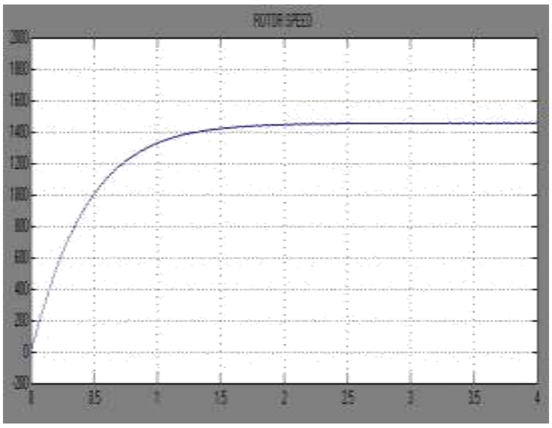

Fig 8. Rotor speed

I. CONCLUSION

Eleven-level multi-tiered inverter-fed induction motor drive is designed, modeled and simulated using the MATLAB simulation. The results of genetic algorithm, multi-tiered inverter output voltage, rotor speed and FFT spectrums are presented. The experimental values of voltage THD of 11 level inverter system are 5.85 percent. This value is within the limits of IEEE-519 standards. As the total harmonic distortion produced by the 11-level inverter system is less by this it is the most effective and efficient system. Therefore eleven level cascaded inverter with unequal DC sources is propsed in industries where adjustable speed drives are required to produce output with reduced harmonic content, this can be obtained by asymmetrical configuration.

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