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Genetic Algorithm approach for Sensor less Vector Control of Induction Motor

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Abstract

This paper deals with control to sensor less vector control of induction motor using Genetic algorithm approach. This study discusses a method to control the speed of three phase induction motor based on sensor less control using Genetic Algorithm approach. With this method it is expected to produce accurate steady state speed response for the motor parameters. The analysis is done with conventional PI using pole placement method and GA based PI controller. An optimal simulink model has been designed in order to achieve the speed control of three phase induction motor based on sensor less control method.

Keywords: Genetic algorithm, sensor less vector control, induction motor, PI Controller.

I. INTRODUCTION

A GENETIC ALGORITHMS

- The theory of genetic algorithms is based on theory of natural evolution in the origin of species. Over several generations, biological organisms evolve based on the principle of natural selection “survival of the fittest. Genetic algorithms are based on the principle of genetics and evolution. GA was discovered as a useful tool for search and optimization problems Genes are the basic “instructions” for building a Generic Algorithms. A chromosome is a sequence of genes. Genes may describe a possible solution to a problem, without actually being the solution.The fitness of an individual in a genetic algorithm is the value of an objective function. A population is a collection of individuals. The two important aspects of population used in Genetic Algorithms are:i) Initial population generationii) Population size..Encoding is a process of representing individual genes.The breeding process is the heart of the GA. It is in this process, the search process creates new and hopefully fitter individuals.The breeding cycle consists of three steps:a. Selecting parents.b. Crossing the parents to create new individuals (offspring or children).c. Replacing old individuals in the population with the new ones Selection is the process of choosing two parents from the population for crossing. It is also called as Reproduction. The various selection methods are Roulette wheel selection, Random selection, Rank selection, Tournament selection, Boltzmann selection. The most widely used is Roulette wheel selection.In this method a string is selected from the mating pool with a probability proportional to the fitness. i^{th} string in the population is selected with a probability proportional to Fi. Where Fi is the fitness of the string. Probability for selecting the i^{th} string is where n is the population size. The Roulette wheel mechanism is expected to make copies of i^{th} string of the mating pool.***Crossover (Recombination)***Crossover is the process of taking two parent solutions and producing from them a child.Reproduction makes clones of good strings but does not create new ones. Crossover operator is applied to the mating pool with the hope that it creates a better offspringCrossover is a recombination operator that proceeds in three steps:i) The reproduction operator selects at random a pair of two individual strings for the mating.ii) A cross site is selected at random along the string length.iii) Finally, the position values are swapped between the two strings following the cross site. Crossover probability is a parameter to describe how often crossover will be performed. The probability varies from 0 to 1.It is the ratio of the number of pairs to be crossed to some fixed population. Mutation prevents the algorithm to be trapped in a local minimum.If crossover is supposed to exploit the current solution to find better ones, mutation is supposed to help for the exploration of the whole search space. GA uses the mutation rates varying from 0.001 to 0.5

B Induction Motor

- Induction motor is the work horse in industry due to its rigid construction & can work under all conditions of environment. But due to the factor that flux & torque cannot be controlled individually as the stator current is a combination of both it is not popular like D.C. Motor. But with the development of power electronics & Vector control concept the three phase stator current can be resolved into two phase components by orthogonal transformation by using Clarke's transformation& to rotor reference frame by parks transformation. To do this the position of flux vector is important. This position of flux vector can be found by direct & indirect methods where direct method employs sensors incorporated in stator which adds to cost, size & induction of harmonics. Hence in indirect control this flux vector can be found by machine parameters & modeling equations governing its performance. Hence sensor less vector control has gained importance. Basically there are various methods of indirect vector control of which Kalman filter, MRAS, sliding mode observer are in major use in earlier days, and hence these methods are prone to numerical & steady errors due to large calculations involved. Hence with the development of software's like Matlab/Simulink, & computer methods like fuzzy logic, neural networks the complications have been resolved.

II. Modeling of Induction Motor

A. Dynamic Modeling of induction motors

This section presentsthe dynamic model of the induction motor as shown in the below fig.1, it is derived by transforming the three-phase quantities into two phases direct and quadrature axes quantities. The equivalence between the three-phase and two-phase machine models is derived from the concept of power invariance [16].

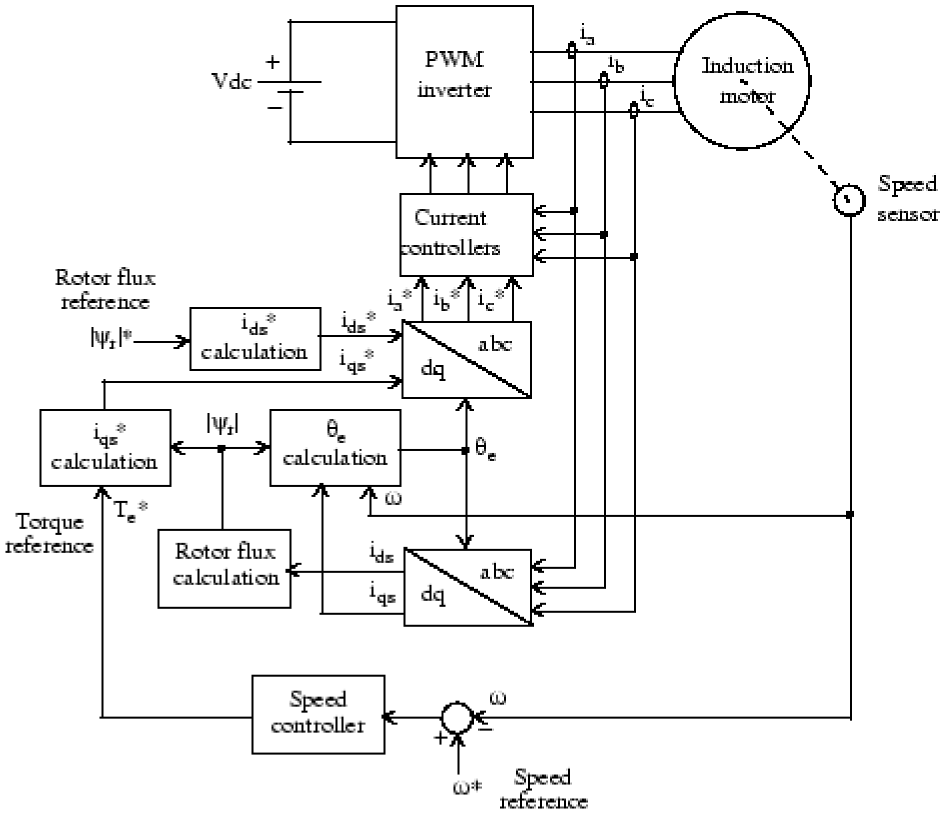

Fig.1.Block diagram of the dynamic model of the induction motor

Electromagnetic Torque:

$$T_e = \frac{3}{2}\frac{P}{2}L_m\left(i_{qs}\,i_{dr} - i_{ds}\,i_{qr}\right) \qquad (1)$$

The dynamic equations of the induction motor in synchronous reference frames can be represented by using flux linkages as variables. This involves the reduction of number of variables in dynamic equations, which greatly facilitates their solution. The flux-linkages representation is used in motor drives to highlight the process of the decoupling of the flux and torque channels in the induction machine. The stator and rotor flux linkages in synchronous reference frame are shown in equations (2)-(7)

$$\lambda_{qs} = L_s i_{qs} + L_m i_{qr} \quad (2)$$
$$\lambda_{ds} = L_s i_{ds} + L_m i_{dr} \quad (3)$$
$$\lambda_{qr} = L_r i_{qr} + L_m i_{qs} \quad (4)$$
$$\lambda_{dr} = L_r i_{dr} + L_m i_{ds} \quad (5)$$
$$\lambda_{qm} = L_m(i_{qs} + i_{qr}) \quad (6)$$
$$\lambda_{dm} = L_m(i_{ds} + i_{dr}) \quad (7)$$

B. **State Space model of induction motor**

The space phasor model of the induction motors can be presented in state space equations from previous equation, so it can be expressed in the synchronously rotating *d-q* reference frame as shown in equations (8) to (16).

$$\dot{X} = AX + Bu \quad (8)$$
$$X = [i_{ds} i_{qs} \lambda_{dr} \lambda_{qr}]^T \quad (9)$$
$$u = [V_{ds} V_{qs}]^T \quad (10)$$

$$A == \begin{pmatrix} a_1 & w_e & a_2 & \frac{L_m w_r}{\sigma L_s L_r} \\ -w_e & a_1 & \frac{L_m w_r}{\sigma L_s L_r} & a_2 \\ \frac{L_m R_r}{L_r} & 0 & \frac{-R_r}{L_r} & w_e - w_r \\ 0 & \frac{L_m R_r}{L_r} & -w_e + w_r & \frac{-R_r}{L_r} \end{pmatrix} \quad (11)$$

$$B = \begin{pmatrix} a_3 & 0 \\ 0 & a_3 \\ 0 & 0 \\ 0 & 0 \end{pmatrix} \quad (12)$$

III. Sensor less vector control techniques

A. **Sensor less vector control techniques by using Conventional method.**

The conventional method of tuning PI controller for sensor less vector control

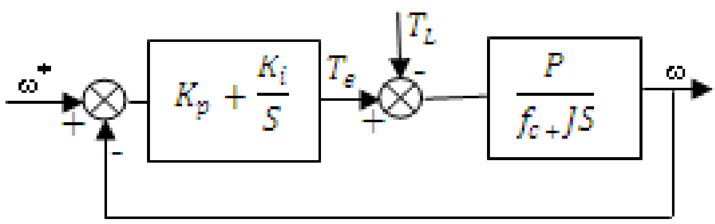

Fig.2 Dynamic model of conventional PI based induction motor

The above figure shows the block diagram of conventional PI controller which incorporates the machine parameters & enables to model induction motor. To obtain the initial values of PI controller parameters the load torque is assumed to be zero in order to obtain closed loop transfer function.

The characteristic equation of the above transfer function is as follows

$$P(S) = S^2 + \frac{(f_c + K_p P)}{J} S + \frac{K_i P}{J} S = O \quad (17)$$

$$K_i = \frac{2J\rho^2}{P} \quad (18)$$

$$K_p = \frac{(2J\rho - f_c)}{P} \quad (19)$$

Where ρ is a positive value

Modelling of controller for genetic algorithm approach.

In the proposed method the dynamic model of induction motor in terms of k_p, K_i, P, J, f_c is considered.

The characteristics equation is framed and by using pole assignment method the values of k_p, K_i are found in terms of motor parameters.

This is considered as initial values for genetic algorithm approach.

For the genetic algorithm approach the objective function is the error function which is the fitness function given by

$$Fitness = e^2(t)dt = [\omega^*(t) - \omega(t)]^2\, dt \quad (20)$$

Where ω^*= speed reference

ω= real speed of induction motor

Block diagram of sensorless vector control of induction motor using genetic algorithm approach.

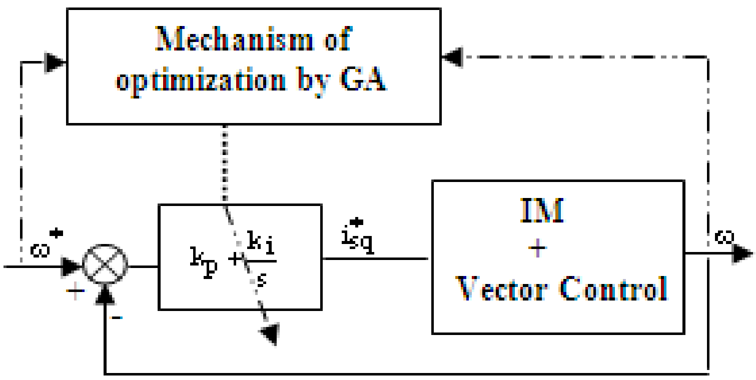

Fig.3 block diagram of proposed genetic algorithm controller

The above block diagram shows the mechanism of genetic algorithm controller which gives optimal values of control parameters.

Table 1 PI Controller values for conventional method.

Variable	kp	ki
Values	0.588	11.91

Table 2 PI Controller parameters using genetic algorithm approach

Variable	kp	ki
Values	0.9232	7.8216

Table 3 GA parameters

GA property	value
Population size	60
Maximum number of generations	100
Cross over probability	0.8
Mutation probability	0.1
Tolerance	10e-6

Table 4 : Parameters of Induction motor

HP=5	Power rating of motor
V=440v	Voltage applied
F=50HZ	Frequency
N=1500RPM	Speed in RPM
P=4	No of poles
$R_s = 0.406\Omega$	Stator Resistance
$R_r = 0.478\ \Omega$	Rotor Resistance
$L_{ls} = 2.13mH$	Stator Leakage Resistance
$L_{lr} = 2.13mH$	Rotor Leakage Resistance
$L_m = 49.4mH$	Mutual Inductance

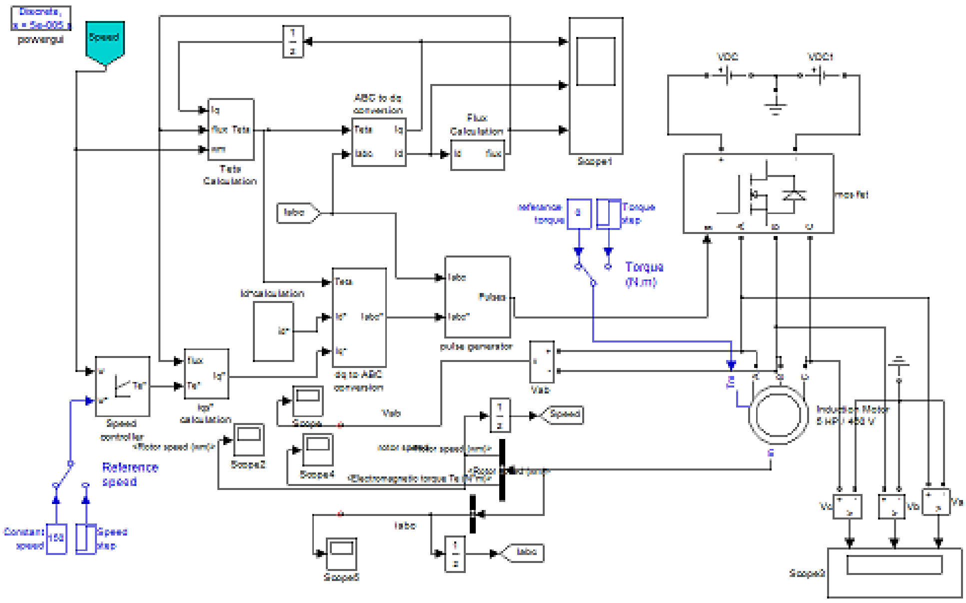

Figure 4 proposed block diagram of sensorless vector controlled induction motor

The above block diagram shows the proposed sensor less control method for the proposed induction whose parameters are mentioned below.In this proposed method the PI Controller parameters obtained from conventional pole place method and that obtained from genetic algorithm tuned PI Controller parameters are used and the analysis for steady state response for various parameters obtained are as shown below in the table 5.

Results and analysis:

Table 5 COMPARATIVE ANALYSIS OF VARIOUS PARAMETERS

property	Conventional PI	GA Tuned PI	REFERANCE INPUT
Peak amplitude	174	160	150
% over shoot	16.5	6.65	0
Settling time	0.157	0.201	0.144
Rise time	0.0228	0.02	0.0808

Wave forms:

Case A: Sensor less vector control techniques by using PI Controller:.

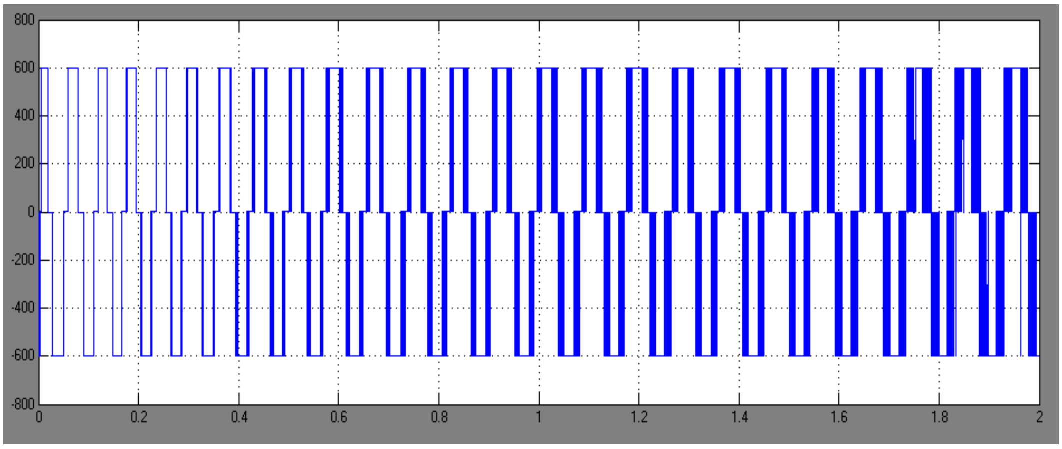

Fig.4. The voltage wave form using conventional PI controller

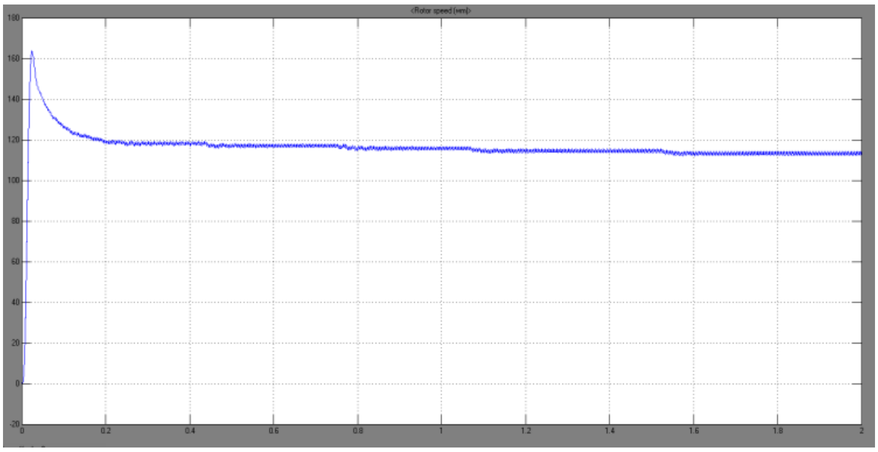

Fig.5. The speed wave form using PI controller

Analysis of Genetic algorithm based PI Controller

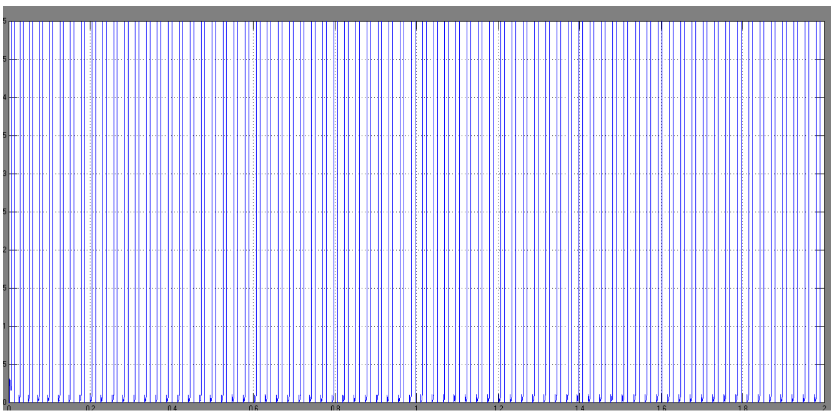

Fig 6 The voltage wave form using with genetic algorithm based PI controller.

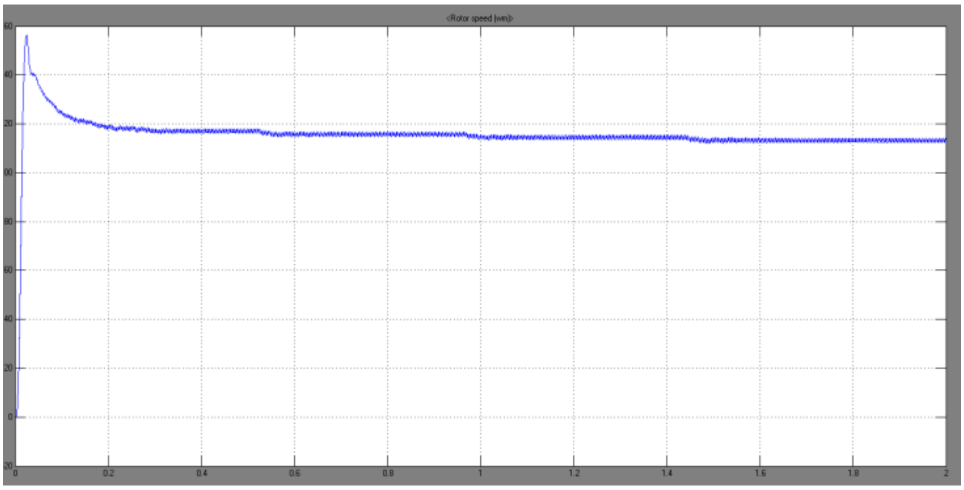

Fig 7 Speed response of sensorless vector control induction motor with genetic algorithm based PI controller

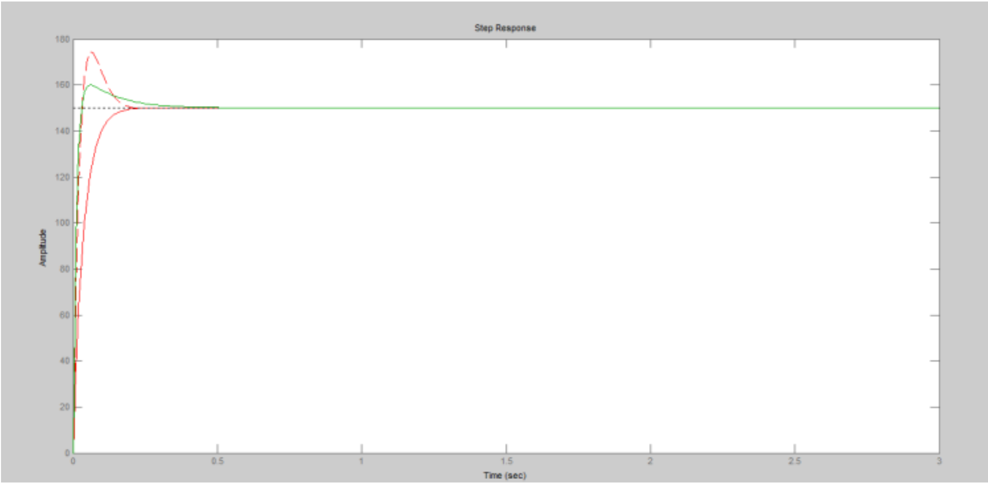

Fig 8 The wave form showing the comparative analysis of speed response with conventional method & genetic algorithm method.

Conclusion

The above analysis from figure 4 to figure 6 shows the senseless vector control of induction motor using PI controller employing conventional pole placement method & proposed genetic algorithm method. The results show that using proposed method the speed over shoot is reduced from 174 radians/sec to 160 radians/second which indicates 10 % decrease in over shoot.The settling time is changed from 0.157secs to 0.201 sec and rise time is changed from 0.0228 sec to 0.02 sec Hence from the speed response studies it is found that steady state error is reduced & improved response is obtained.

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