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Speed Control of Induction Machines Using GA Based PID Controller

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Abstract: The control over the speed of three phase induction motor provides a challenge for all the industries. This paper explains the speed control of induction motor using Proportional Integral Derivative controller based on Genetic Algorithm. Proportional Integral Derivative controller combines the characteristics of Proportional Integral and Proportional Derivative controller thus giving optimum overshoot, quick settling time and reducing the steady state error. Genetic Algorithm is a part of evolutionary computing, a subordinate of artificial intelligence, whose principle depends on Darwin's theory of evolution – the survival of the fittest. It mimics the principle of natural selection and natural genetics to construct the optimization procedure. The method of determining the gain parameters of PID controller using GA whose output is used to control the voltage applied to the induction motor thereby controlling its speed is presented in this paper. The results are simulated in MATLAB environment and are compared with the conventional tuning method of PID controller.

Key words: Genetic Algorithm · PID Controller · Sinusoidal Pulse Width Modulation · Roulette Wheel Selection

INTRODUCTION

Induction machines have seen considerable development in the recent years widening the scope of application in various industries. In addition, the immense progress in the field of power electronics and micro computing has led to the control of induction machines according to its application. The control and estimation of ac drives are more complex than that of dc drives. This complexity increases when performance requirement increases. The speed of the induction motor can be controlled with the help of conventional PID controller [1]. PID controllers are widely used in different industries for control of different plants and have a reasonable performance. Hence, modern evolutionary algorithms are used to tune the gain parameters of PID. Genetic Algorithm is a stochastic search technique based on the mechanism of natural selection and natural genetics. This paper emphasizes the use of Genetic Algorithm to compute the gain parameters of PID controller that is, K_p, K_i, K_d which stands for Proportional, Integral and Derivative gains respectively and to compare the performance of the three phase induction motor using GA-PID controller with the conventional method.

Genetic Algorithm: Genetic Algorithm is a computerized search and optimization algorithm based on the concept of natural genetics and natural selection. It uses the process that nature uses for developing the fittest individual - selection, crossover, mutation and accepting. These are known as genetic operators on the basis of which the best individual of a population are selected to produce the next generation of individuals with improved characteristics as compared to that of the previous generation. The individuals of the population are represented in the form of chromosomes either in binary form represented in the form of bits consisting of '0's and '1's or can be real coded depending upon the application. The representation in binary form is easier to operate on considering the crossover and mutation operators. The space consisting of all possible feasible solutions is called search space. Every point in the search space consists of a feasible solution.

A fitness function describes the quantities on which the manipulation of data takes place. It can be either a minimization function or maximization function. For example, the difference between the desired speed and the actual speed of the machine should be less. Here, the fitness function, which may be the error value of speed,

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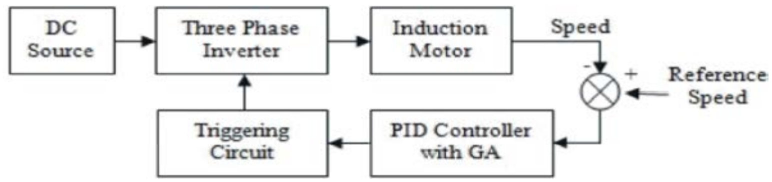

Fig. 1: Block diagram of speed control of induction motor using PID controller

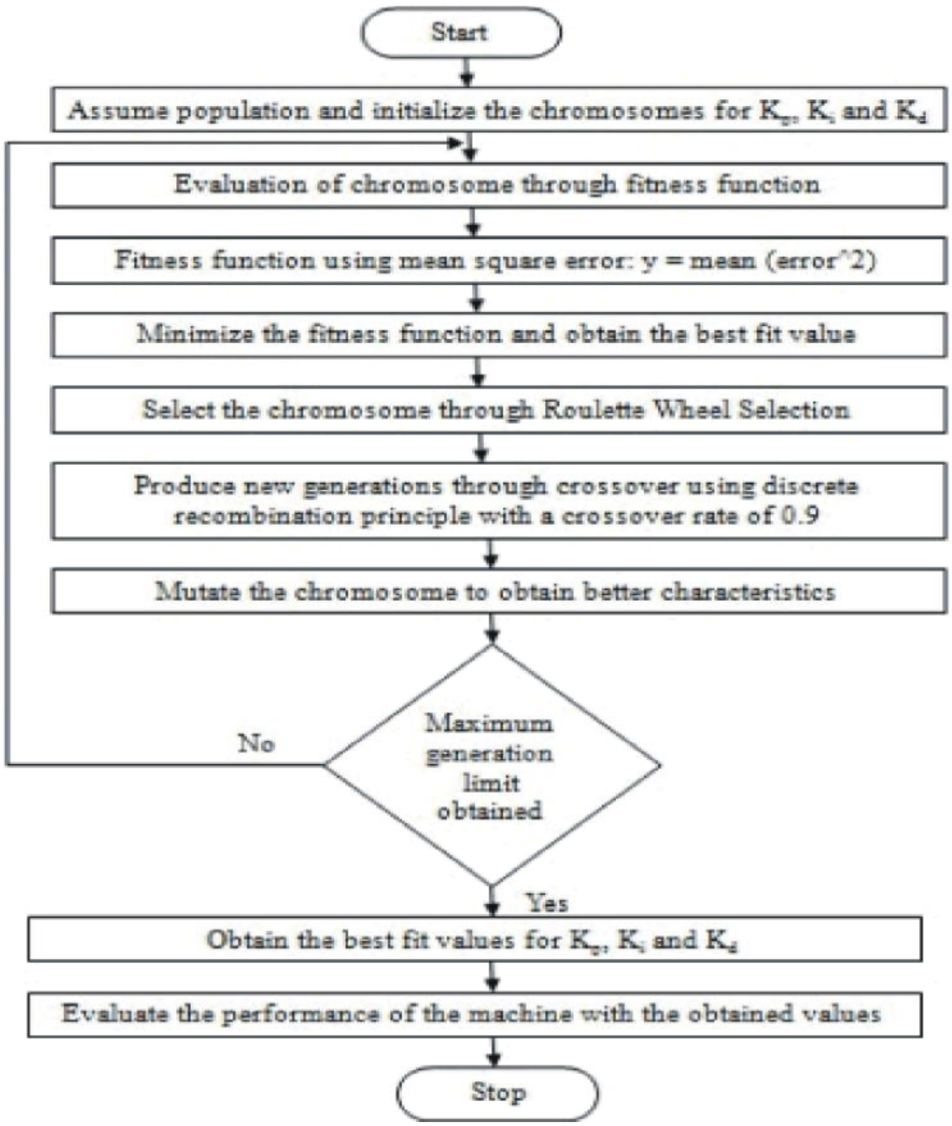

Fig. 2: Implementation of PID controller using GA

must be minimized so that the machine performance can be improved [2]. Selection is the process in which members of the population are selected according to their fitness. Fitness is determined by calculating how well each member fits an objective function. There are many methods of selection of which Roulette Wheel Selection (RWS) is considered the most simple and easiest approach. The individuals that are carried to the next generation undergo crossover and mutation [3]. Crossover is a process in which each pair of individuals mutually interchanges a randomly selected portion of bits to produce variety. There are many types of crossover namely, single point crossover where the parental chromosomes are split at a randomly determined crossover point, two point crossover where the parental chromosomes are split at two randomly determined crossover point, uniform crossover where the mixing ratio of the parents is determined by their offspring, intermediate crossover provides a weighted average of the parents and arithmetic crossover creates offspring which the weighted arithmetic mean of their parents [4]. Mutation is the next process that alters a gene in the chromosome from ‘0’ to ‘1’ and vice versa to prevent the chromosomes from losing useful information [6].

Speed Control of Induction Motor Using Pid Controller: The block diagram for the development of simulink model is shown in the Fig. 1. It consists of a three phase IGBT bridge inverter that converts the dc input voltage into ac output voltage. The gating pulses are provided through sinusoidal pulse width modulation technique. The speed of the induction motor is sensed and given as a feedback to the PID controller whose parameters are optimized through Genetic Algorithm. The output of PID controller is combined with the sinusoidal wave of required frequency that acts as a modulating signal and is compared with the triangular reference signal thus producing the gating pulses for the switching devices in the three phase inverter. By changing the modulation index, the variation of output voltage can be obtained. Thus by varying the output voltage of the inverter which acts as an input to the three phase induction motor, the speed of the motor can be efficiently controlled.

Implementation of Ga to Determine the Gain of Pid Controller: The sequential steps involved in estimating the various parameters of PID are depicted in the form of a flowchart as in Fig. 2 [7]. The parameters are tuned using Genetic Algorithm with the error in voltage, obtained as an equivalent with respect to speed, as the objective function. The fitness function is based on Mean Square Error (MSE), one of the four performances indices of PID controller [5, 8].

$$MSE = \frac{1}{N}\sum_{i}^{n}(Y_1 - Y_0)^2 \quad (1)$$

where Y_1 is the reference parameter, Y_2 is the measured parameter and n is the index number.

The fitness function is minimized. The best fit values are obtained for the parameters of PID controller through the use of genetic operators to bring variety in the individuals of a population. The iteration process is carried out till the maximum generation limit is reached.

Simulation Model: The simulink model developed from the block diagram for the speed control of three phase, 400V, 5.4HP induction motor is shown in Fig. 3. The feedback signal calculates the error value in speed against a set signal and is given to the PID controller. The signal generated from the PID controller is multiplied with sinusoidal input to produce the modulating signal.

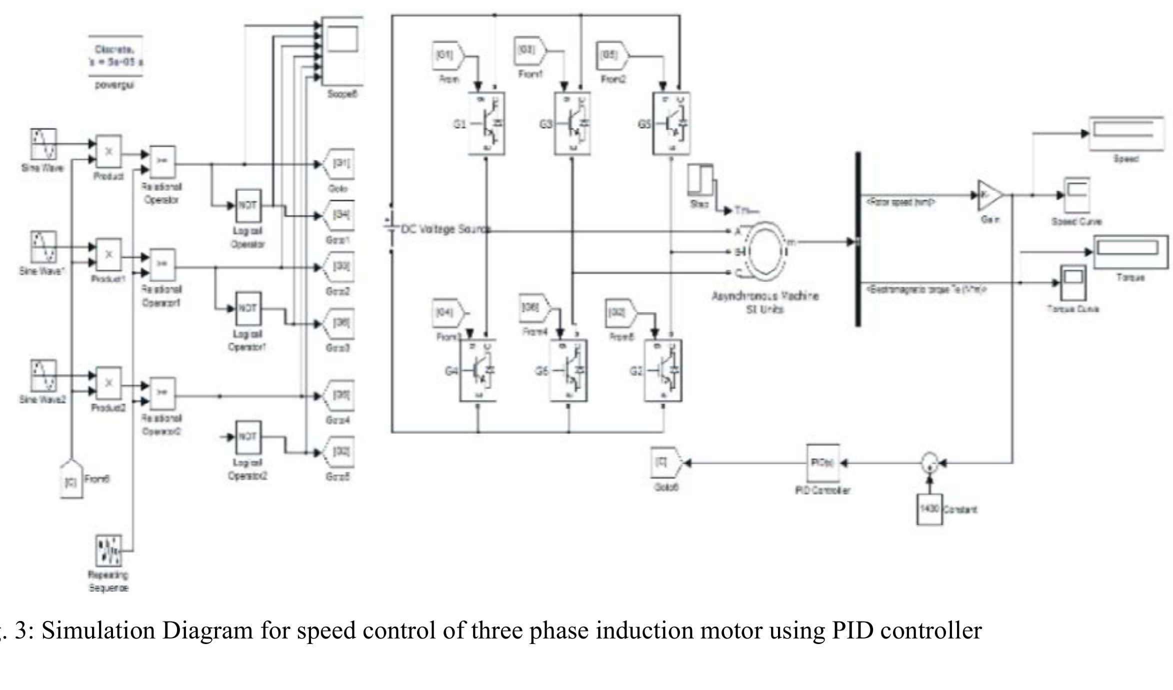

Fig. 3: Simulation Diagram for speed control of three phase induction motor using PID controller

The modulating signal is then compared with the triangular carrier signal and the gating signals for IGBT in the three phase inverter are provided. The output voltage of SPWM inverter is controlled thereby obtaining an improved speed response.

RESULTS

On simulating the closed loop model of induction motor, the speed response of GA based PID is obtained and it is inferred that the speed control using GA based PID controller is more efficient, gives smooth control and runs closer to set speed whereas Zeigler-Nichols PID tuned controller lags behind the set speed and has more transient behavior. The transient behavior in the rotor speed is more pronounced when it draws away from the rated speed. The speed response curves for various speeds for GA tuned PID controller and ZN tuned PID controller are shown in Fig. 4, Fig. 5, Fig. 6 and Fig. 7.

The pre-determination of the performance of induction motor is obtained from the values obtained through the simulation. The comparison of the performance of the induction motor using the GA based PID controller and ZN technique is shown in Table 1. The torque speed characteristics of the induction motor with GA-PID controller and ZN tuned PID controller is shown as a comparison in Fig. 8.

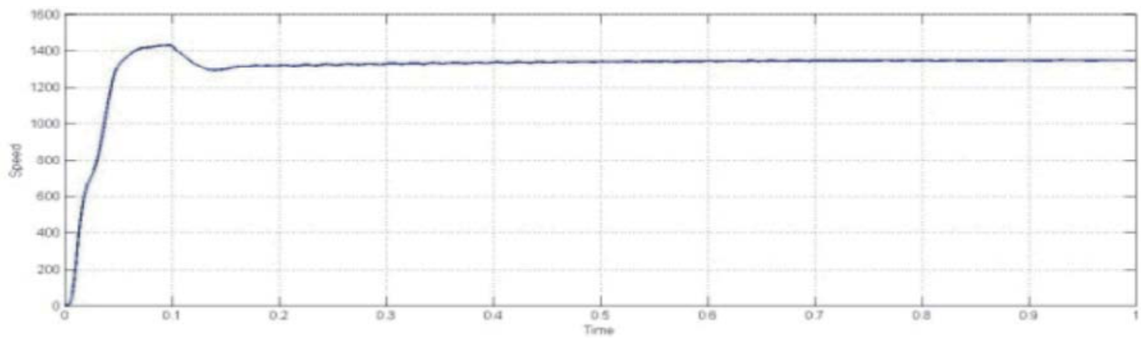

Fig. 4: Speed response of GA based PID for the speed 1350 rpm

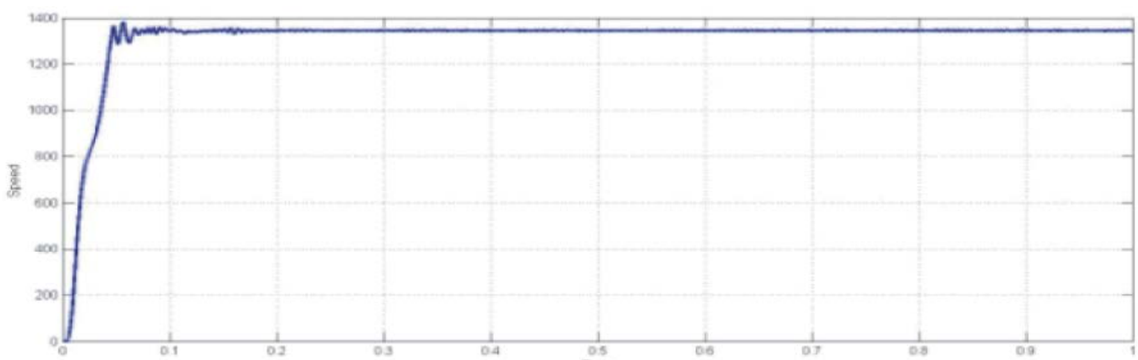

Fig. 5: Speed response of ZN based PID for the speed 1350 rpm

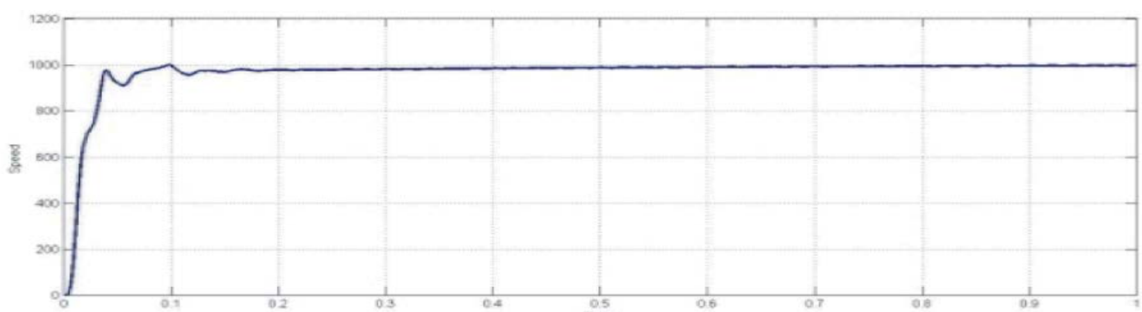

Fig. 6: Speed response of GA based PID for the speed 1000 rpm

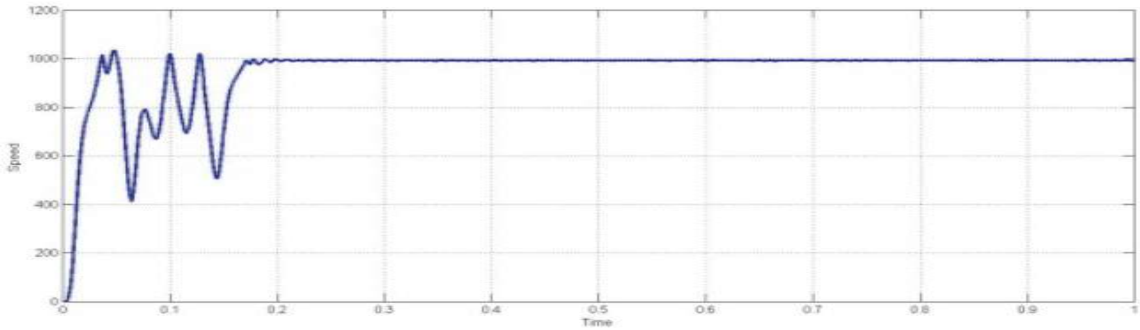

Fig.7: Speed response of ZN based PID for the speed 1000 rpm

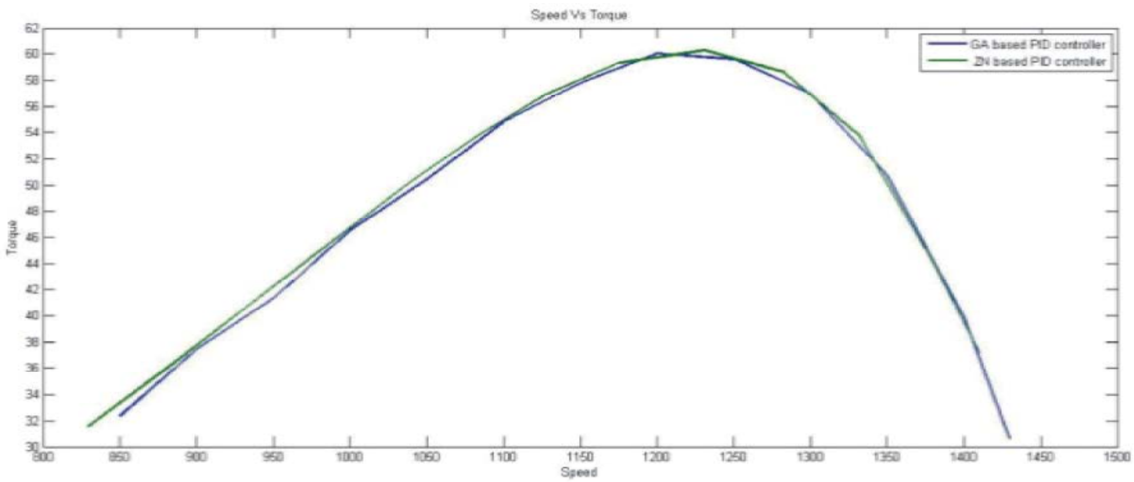

Fig. 8: Torque - Speed characteristics of GA based PID and ZN based PID

Table 1: GA based PID controller for induction motor

	GA based PID controller				ZN based PID controller			
Set Speed (rpm)	Phase Voltage (V)	Rotor Speed (rpm)	Torque (Nm)	%η	Phase Voltage (V)	Rotor Speed (rpm)	Torque (Nm)	%η
1430	230.88	1430	30.64	91.05	228.23	1410	37.22	88.64
1400	226.17	1400	39.83	87.46	223.35	1380	45.08	85.14
1350	217.85	1350	50.73	81.76	215.59	1332	53.78	79.79
1050	170.01	1050	50.52	53.75	168.00	1038	50.16	52.81
1000	161.24	1000	46.56	49.91	158.77	981	45.12	48.49
850	137.39	850	32.40	39.44	134.17	829	31.60	38.10

CONCLUSION

The conventional PID tuning using Ziegler-Nichols method gave satisfactory results. Conventional PID tuning consumes more time and has lower accuracy whereas when GA is introduced in tuning PID controller, the gain parameters optimized in lesser time. The simulation results show that GA based PID give improved speed regulation of Induction Motor, thus making Genetic Algorithm a better tool for tuning PID controllers.

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