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A Novel of Tuned GA and Tuned PSO Neuro Fuzzy Logic Controller Based Speed Control of Brushless DC Motor

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Abstract : This paper presents a comparative study of Generic Algorithm (GA) and Particle Swarm Optimization (PSO) technique for determining the optimal parameters of (PID) Neuro Fuzzy controller for speed control of a brushless DC motor (BLDC) where the (BLDC) motor is modeled in simulink in MATLAB. The planned technique was a lot of economical in up the step response characteristics similarly as reducing the stedy-state error, rise time, subsidence time and most overshoot.
Keywords : Brushless DC motor, Neuro Fuzzy PID controller, Matlab, Particle Swarm Optimization, Generic Algorithm

1. Introduction

Typical electrical machine drives involve torsion, current, position, or speed control. In permanent-magnet machines, of these states square measure directly or indirectly smitten by the position of the rotor. To get the rotor-position info of a permanent-magnet machine, associate degree auxiliary instrument like optical encoder, resolver, or Hall-effect sensors may be used. PI controller with its 3 terms practicality covering treatment for transient and steady-state response offers the best and gets best answer to several globe control issues [4]. In spite of the straightforward structure, optimally standardization gains of PI controllers area unit quite tough. Recently, the procedure intelligence has projected bacterial foraging (BF) technique and Particle Swarm Optimization (PSO) technique for constant purpose. Direct Current (DC) motor was chosen for the speed control applications attributable to the control simplicity on the intrinsic decoupling between the flux and therefore the torsion. Because the name implies, there area unit physical limitations to hurry and life time due to brush wear. However, BLDC are created to beat this downside. Since there aren't any carbon brushes to wear out, a BLDC motor will offer considerably bigger life being currently solely restricted by bearing wear. This advantage create BLDC motor becomes well-liked within the industry (e.g. vacuum cleaners, laundry machines) or in trade (e.g. conveyor tapes and drilling machines at production lines) however this motor could be a non-linear system thus, want additional complicated speed controller than the DC motor. By this reason, the Gaussian fuzzy logic controller and Particle Swarm optimization (PSO) technique are developed to boost the performance of variable speed for BLDC motor since the system of this motor is non-linear system.

The asynchronous electrical motors square measure typically the foremost acceptable alternative owing to their strong construction, high output power, and comparatively easy control [1]. In addition, the quantitative relation of force delivered to the scale of the motor is higher, creating it helpful in applications wherever house and weight square measure vital factors [2]. The applications BLDC motor square measure wide employed in several industries as growth because the quickly developments in power electronic technology, producing technology for top performance magnetic materials and fashionable control theory for motor drives

[3]. Modern intelligent motion applications demand correct speed and position control owing to the favorable electrical and mechanical properties of BLDC motor. To implement the digital control of 3 part BLDC motor. To style a neuro formal logic control for speed management of BLDC motor. to create the BLDC to rotate within the constant speed to boost the system potency by sensing the inner hall signals of the BLDC motor The BLDC motor has some benefits compare to others form of motors. However, the nonlinearity of this motor drive characteristics cause it's tough to handle victimization typical proportional-integral-differential (PID) controller. so as to beat this main downside, formal logic controller with a mathematician membership perform is developed. The mathematical model of BLDC motor is derived. The controller is meant to tracks variations of speed references and stabilizes the output speed throughout load variations. The effectiveness of the planned technique is verified by develop simulation model in Matlab Simulink software package. The simulation results show that the planned Neuro formal logic controller (FLC) manufacture important improvement control performance compare to the Particle Swarm optimization (PSO) controller for each condition dominant speed reference variations and cargo disturbance variations.

2. Anatomy of a BLDC

Figure 1 may be a simplified illustration of BLDC motor construction. A brushless motor is built with a static magnet rotor and wire wound stator oil poles. Voltage is regenerate to energy by the magnetic engaging forces between the static magnet. A remarkable property of brushless DC motors is that they're going to operate synchronously to a particular extent. This suggests that for a given load, applied voltage, and commutation rate the motor can maintain open loop lock with the commutation rate as long as these three variables do not deviate from the perfect by a major quantity. The perfect is decided by the motor voltage and force constants. Think about that once the commutation rate is simply too slow for an applied voltage, the BEMF are too low leading to a lot of motor current.

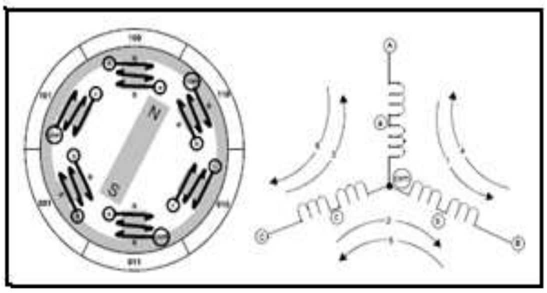

Figure-1. BLDC motor construction

The motor can react by fast to future section position then cut down looking ahead to future commutation. Within the extreme case the motor can snap to every position sort of a stepper motor till future commutation happens. Since the motor is ready to accelerate quicker than the commutation rate, rates abundant slower than the perfect will be tolerated while not losing lock however at the expense of excessive current.

Currently think about what happens once commutation is too quick. When commutation happens early the BEMF has not reached peak leading to additional motor current and a larger rate of acceleration to future section however it'll arrive there too late.

The motor tries to stay up with the commutation however at the expense of excessive current. If the commutation arrives therefore early that the motor cannot accelerate quick enough to catch consequent commutation, lock is lost and also the motor spins down. This happens short not terribly far away from the perfect rate. The abrupt loss of lock seems like a separation within the motor response that makes control system control troublesome.

An alternate to control system control is to regulate the commutation rate till self lockup open loop control is achieved. This is often the tactic we are going to use in our application. Once the load on a motor is constant over its in operation vary then the response curve of motor speed relative to applied voltage is linear.

If the provision voltage is well regulated, additionally to a relentless force load, then the motor will be operated open loop over its entire speed vary.

3. Neuro Fuzzy Pid Controller

We think about a multi-input, single-output dynamic system whose states at any instant is outlined by "n" variables X1, X2,...,Xn. The management action that derives the system to a desired state is represented by a accepted idea of "if-then" rules, wherever input variables are first reworked into their several linguistic variables, conjointly known as fuzzification shown in figure 2. Then, conjunction of those rules, known as inferencing method, determines the linguistic worth for the output. This linguistic worth of the output conjointly known as fuzzified output is then regenerate to a crisp worth by victimization defuzzification theme. All rules during this design are evaluated in parallel to get the ultimate output fuzzy set that is then defuzzified to urge the crisp output worth. The conjunction of fuzzified inputs is sometimes done by either min or product operation (we use product operation) and for generating the output grievous bodily harm or total operation is mostly used. For defuzzification, we've used simplified reasoning technique, conjointly referred to as changed center of space technique. For simplicity, triangular fuzzy sets are going to be used for each input and output. the complete operating and analysis of fuzzy controller relies on the subsequent constraints on fuzzification, defuzzification and also the knowledge domain of associate FLC, that provides a linear approximation of most FLC implementations.

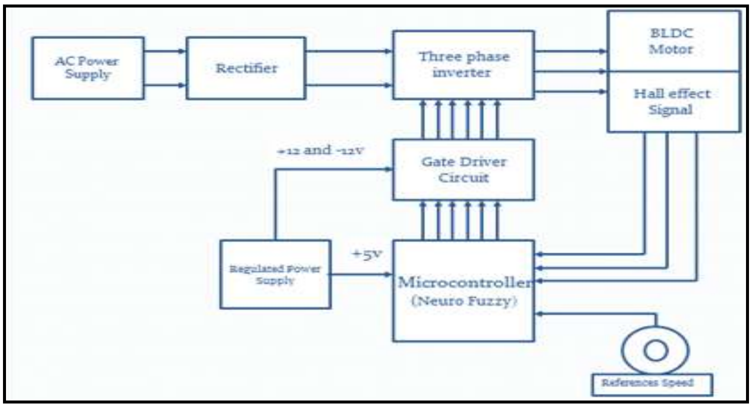

Fig. 2 Proposed Block Diagram

Constraint 1: The fuzzification process uses the triangular membership function.

Constraint 2: The breadth of a fuzzy set extends to the height price of every adjacent fuzzy set and the other way around. The total of the membership values over the interval between two adjacent sets are going to be one. Therefore, the total of all membership values over the universe of discourse at any instant for an impression variable can perpetually be up to one. This constraint is usually said as fuzzy partitioning.

Constraint 3: The defuzzification methodology used is that the changed center of space methodology. This methodology is comparable to getting a weighted average of all potential output values.

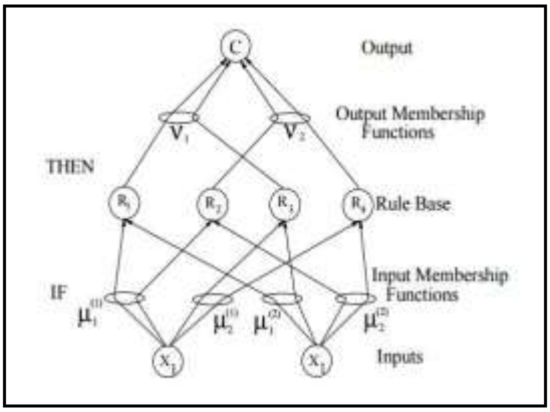

Fig. 3 Architecture of four rule fuzzy controller from neural networks point of view

A PFLC, that is described by the on top of "if - then" rules, are often simply enforced within the variety of a neural network. there's one input node, referred to as a mistake node. The input node feeds to the intermediate or hidden layer of rules, through weighted connections. These weights area unit primarily the definitions of linguistic variables or the fuzzy sets. At these shared weights, the input error is regenerate into linguistic variables and fed to the rule modules or rule layer. Every rule module processes the data accessible to its input in parallel. Rule module takes the input from input layer (error) conditioned by the fuzzy weights (fuzzification) and finds the conjunction of the inputs. The output of rule module is then fed to the output layer through weighted connections. The weights area unit definitions of output fuzzy sets and at the output defuzzification is performed that is chosen to be the "modified center of gravity" approach as shown in figure 3.

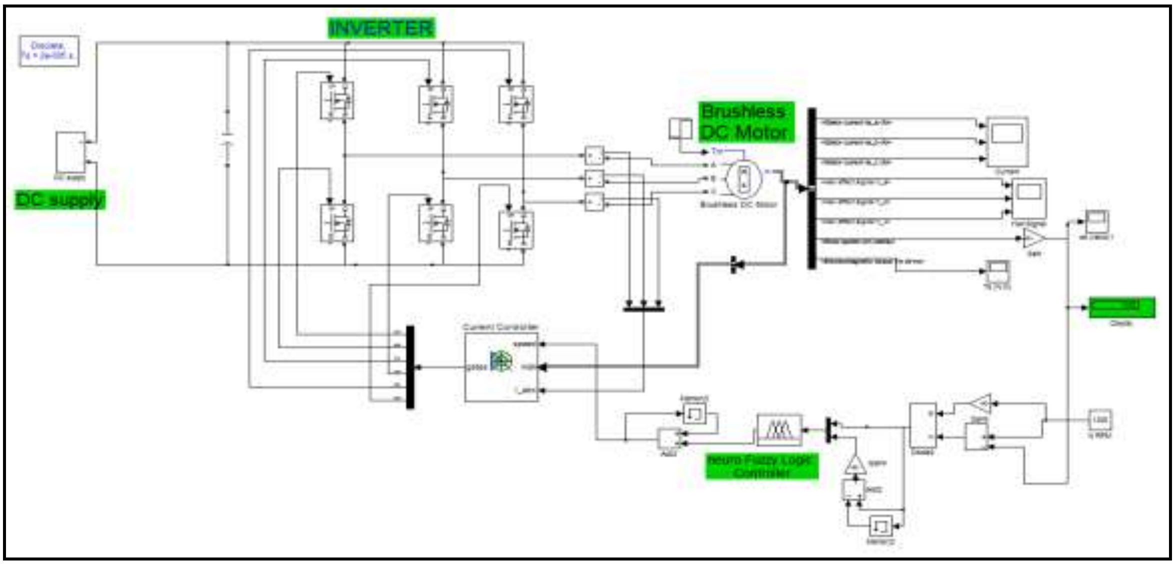

Fig. 4 Proposed Simulink Diagram

4. Computational or Optimization Techniques

Computational or improvement Techniques these are techniques that are sometimes used for knowledge modeling and improvement of a value operate, and are employed in inflammatory disease standardization. Few examples are neural networks (computational models to simulate complicated systems), genetic algorithmic program and differential evolution. The improvement techniques need a value operates they fight to reduce. There are four styles of price functions used ordinarily.

- **Integral Absolute Error**

$$IAE = \int_0^{\tau} |e(t)|$$

Computational models square measure used for self calibration or automotive vehicle calibration of PI controllers. Self calibration of PI controllers primarily sets the PI parameters and conjointly models method| by victimization some machine model and compares the outputs to ascertain if there square measure any process variations, during which case the PI parameters square measure reset to allow the specified response. The existent forms of adaptive techniques square measure classified supported the very fact that if the method dynamics square measure variable [3], then the controller ought to compensate these variations by adapting its parameters.

There square measure two forms of method dynamics variations, foreseeable and unpredictable. The foreseeable ones square measure generally caused by non linearity's and might be handled employing a gain schedule, which suggests that the controller parameters square measure found for various in operation conditions with Associate in nursing auto-tuning procedure that's used thenceforth to make a schedule. Totally different techniques are accustomed replace the gain schedule mentioned on top of.

5. Particle Swarm Optimization (PSO)

Particle swarm optimization (PSO) is an optimization technique developed by Dr. Eberhart and Dr. Kennedy in 1995. This is population based optimization technique which was inspired by the social behavior of fish schooling and bird flocking. The basic algorithm of PSO is [5,6]

Step 1- At first the minimum and maximum value of the three controller parameters are being specified. This is done by selecting the population of individual which includes the searching point, its individual best value (p_{best}) and its global best value (g_{best}).

Step 2- After that the fitness value is being calculated for each individual using the evaluation function.

Step 3- Comparison of each individual is being done which is known as p_{best}. The best value from p_{best} is denoted as is g_{best}

Step 4- After that the member velocity is being modified for each individual k.

$$v_{j,g}^{(t+1)} = \omega * v_j^{(t)} + c_1^* \, rand() * \left(p_{best_{j,g}} - k_{j,g}^{(t)}\right) + c_2^* \, rand() * \left(g_{best_g} - k_{j,g}^{(t)}\right) \quad (1)$$

Where j=1,2,3………………n, g=1,2,3,……………………..n.

Where ω is known value. When g is 1 then it represents the change in velocity of controller parameter k_p.

When g is 2, then it indicates the change in parameter k_i. Similarly when g is 3 then it denotes the change in parameter k_d.

Step 5- If

$$v_{j,g}^{(t+1)} > V_g^{max} \text{, then } v_{j,g}^{(t+1)} = V_g^{max}$$

$$v_{j,g}^{(t+1)} > V_g^{min} \text{, then } v_{j,g}^{(t+1)} = V_g^{min}$$

Step 6- Modified the member of each individual k

$$k_{j,g}^{(t+1)} = k_{j,g}^{(t)} + v_{j,g}^{(t+1)},$$
$$k_g^{min} \le k_{j,g}^{(t+1)} \le k_g^{max} \quad (2)$$

Where k_g^{min} and k_g^{max} represent the minimum and maximum, respectively, of member g of the individual. When is 1,then kp parameter indicates lower and upper bound which is indicated by k_g^{min} and k_g^{max} respectively. When g is 2, then ki controller decides the which are indicated by k_g^{min} and k_g^{max} respectively. When g is 3, then the kd controller indicates the lower and upper bounds which are being indicated by k_g^{min} and k_g^{max} respectively.

Step 7- If the maximum v-0alue is reached through number of iteration then proceed to Step 8. or else proceed to Step 2.

Step 8- The latest individual which is now generated becomes the optimal controller parameter.

The Fig 4 shows that the flowchart of parameter optimizing procedure using PSO.

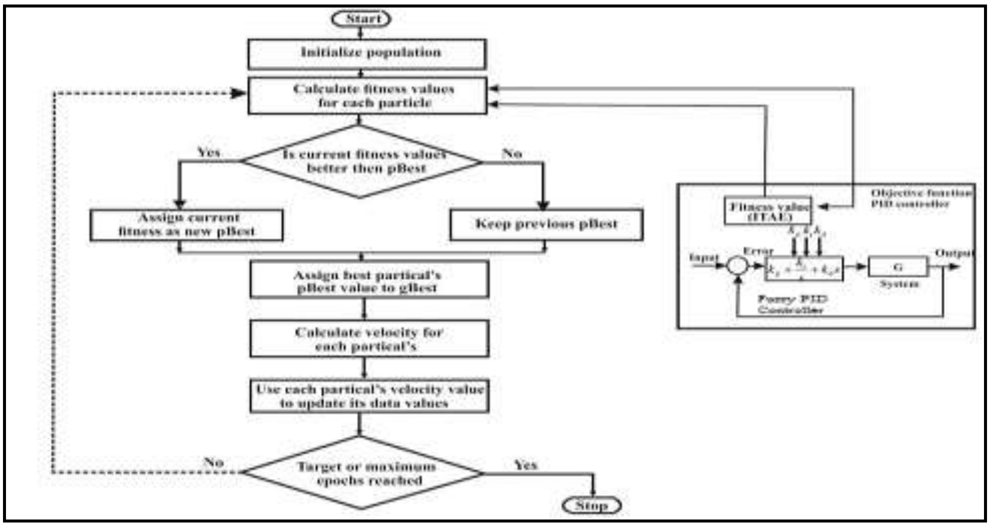

Fig. 4. Flow chart for simulation of PSO based PID controller.

6. Generic Algorithm (GA)

Genetic algorithm was first introduced by John Holland as reported. It is a heuristic optimization technique inspired by the mechanism of natural selection. The basic algorithm for GA to solve optimization problems is,

Step 1- At starting, initial population of compositions of the functions and terminals of the optimization problem is generated.

Step 2- Perform the following sub steps iteratively on the population of programs until the criterion for the termination has been achieved:

i) Each program in the population is executed and fitness value using the fitness measure is applied.

ii) A new population of programs is created by applying the following operations that is (a) Reproduction (b) Crossover (c) Mutation.

Step 3- The identified individual program is designated by result designation .This result may be a solution or an approximate solution to the problem.

The Figure 5 shows that the flowchart of parameter optimizing procedure using GA.

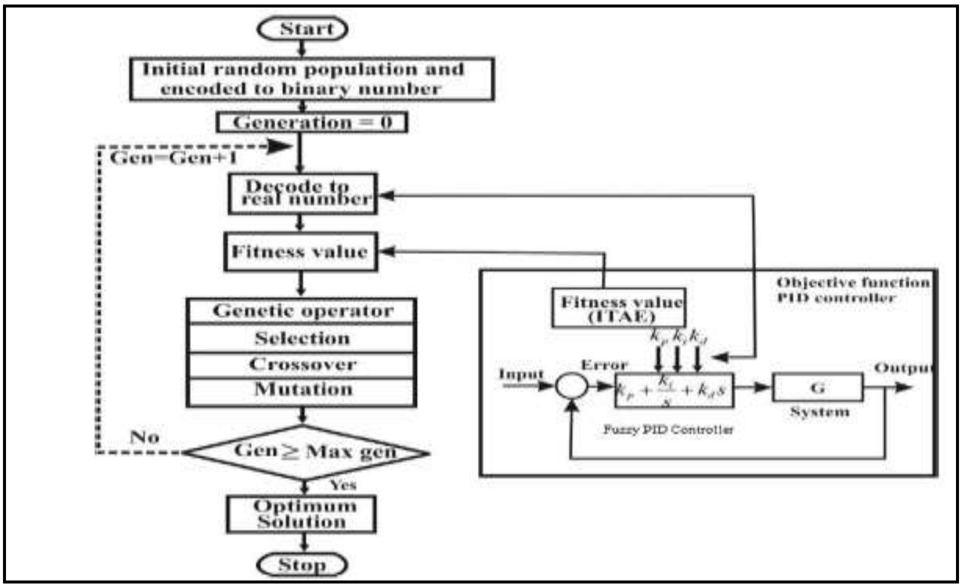

Fig. 5. Flow chart for simulation of GA based Fuzzy PID controller

7. Result and Discussion

CASE I: IAE criteria with Partial Swarm Optimization technique

From the fig 6 graph it is clear that the best fitness value is 7.687e+6.

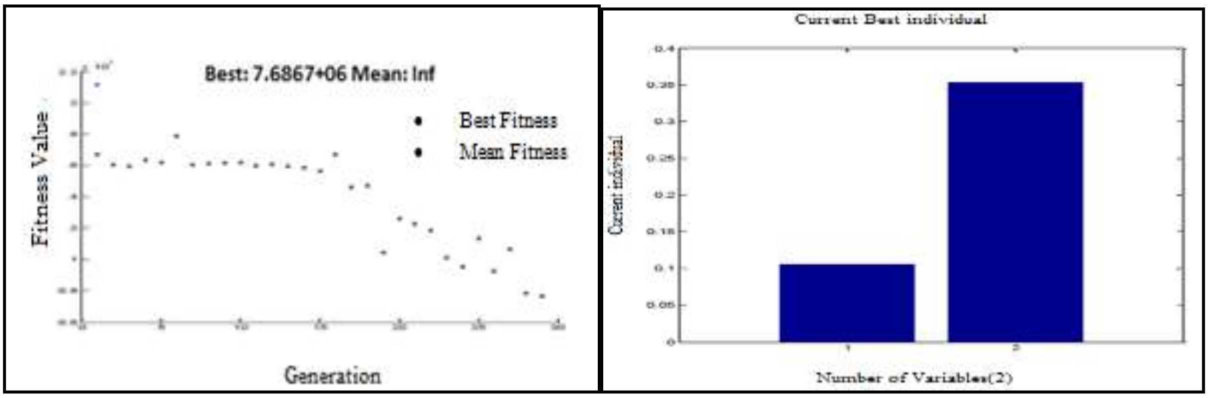

Fig.6. Output of Partial Swarm Optimization technique using IAE

Table1.1 Output parameter of IAE

S.NO	K_P	K_I	Fval
1	3.5501	18.5478	7.2798$_e$+06

At no load condition the PMSM drive simulink model was evaluated for the wave form of Speed response, motor torque and current by using PI-Controller. The waveforms are presented below. The simulation result for speed reference input of 3000 rpm with controller gains are KP =3.5502, KI = 18.5479with a load torque of 0 Nm, i.e. no load is applied to the motor at 0.1 sec which is shown in fig 7.Under this condition Motor torque is shown in fig.8at No-load condition.

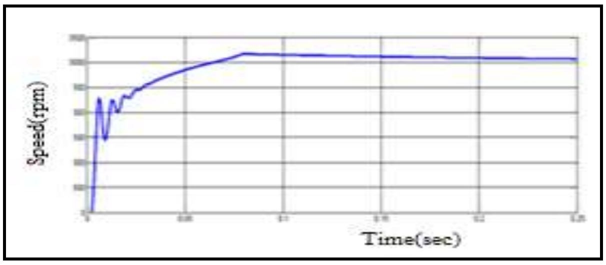

Fig.7. Simulation result of speed response using PI-Controller when no load is applied to the motor at 0.1 sec when TL = 0 Nm, t=0.1 sec.

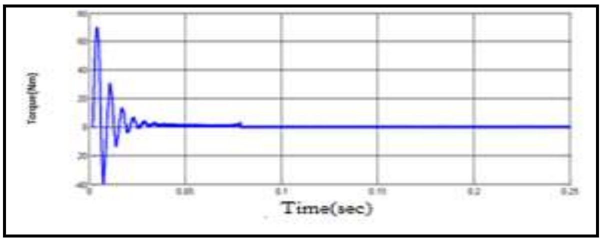

Fig.8.Simulation result of Motor torque using PI-Controller when no-load is applied to motor at 0.1 sec when TL=0Nm, t=0.1sec

CASE II: IAE criteria with generic algorithm technique

From the fig 9 graph it is clear that the best fitness value is 5.9178e+06.

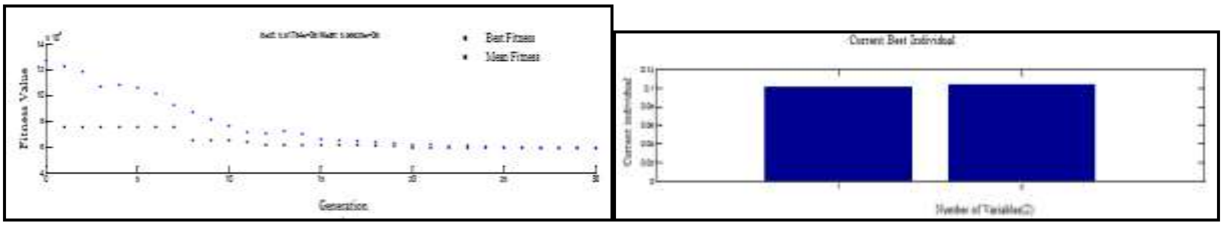

Fig.9. Output of Generic Algorithm technique using IAE

Table1.2 Output parameter of IAE

S.NO	K_P	K_I	Fval
1	0.1072	0.1038	5.9178+06

In this condition the PMSM drive simulink model was evaluated for the wave form of Speed response, motor torque and current by using PI-Controller. The waveforms are presented below. The simulation result for speed reference input of 3000 rpm with controller gains are KP =0.7651, KI = 4.8748 with a load torque of 0 Nm, i.e. no load is applied to the motor at 0.1 sec which is shown in fig 10.Under this condition Motor torque is shown in fig.11 at No-load condition.

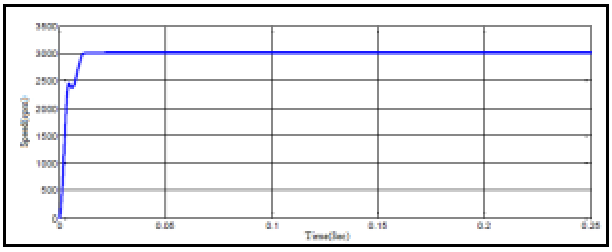

Fig.10 Simulation result of speed response using Fuzzy PID-Controller when no load is applied to the motor at 0.1 sec when TL = 0 Nm, t=0.1 sec

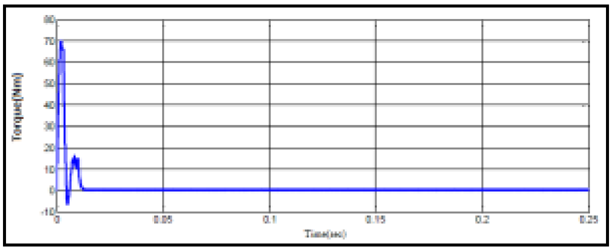

Fig.11.Simulation result of Motor torque using Fuzzy PID -Controller when no-load is applied to motor at 0.1 sec when TL=0Nm, t=0.1 sec

CASE III: Comparison of GA and PSO Using Integral Time Absolute Error (IAE)

From figure12 it is clear that the response parameters for GA are better as compared to PSO.

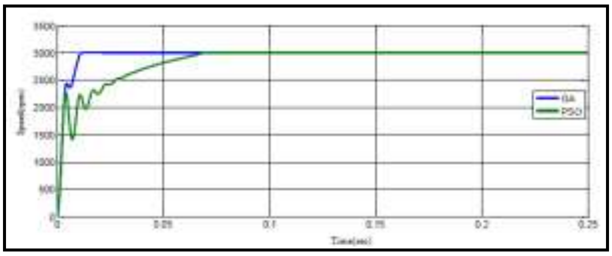

Figure.12 Comparison of GA and PSO using IAE

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