Speed Control of Induction Motor using Hybrid PID Fuzzy Controller

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Abstract - Fuzzy Logic Controller are evaluated as one of the best controller to the servo motors due to its less complexity in the mechanism and did not include any of the mathematical models. The purpose of this study is to regulate the change in induction motor speed by enhancing the traditional technique by using the BAT optimization algorithm for the selection of parameter of K_i and K_p for PI controller. The reason behind choosing the .bat paradigm has several merits, and the most important benefit is that is offers very rapid convergence at a very starting stage through switching from exploration to exploitation. For applications as a rapid resolution is required then this prepares it an effective paradigm.

Keywords— BAT, PID, Fuzzy Logic, Derivative Control, Proportional Control Integral Control.

1. INTRODUCTION

For the control method engineering and position control various control methods algorithms are been executed these days. Through utilizing the diverse sort of automatic procedure we can design the position control by using the digital servomotor. On the contrary, in the mechanism the nonlinearities did not occur that are load effect that shows adverse effects to the mechanism performance. For the generalized applications the generally the electrical motor is used whereas for other specific task different electrical motors were used.

Among increasing no temperature these motor can also implement to accomplish the dynamic need of the mechanisms. Therefore as choosing the electric motor it is very significant to establish the load characteristics. For the mechanism whereas choosing these motor the other factors like mission goals, availability of power and cost is also considered. As employed experimentally, the entire knowledge about the uncertainties are very hard to fetch out. In servo motors to present position control various researches has been proposed. To handle the uncertainties the fuzzy logics are considered one of the important methods which are desirable over PID controllers particularly in servo motors [1].

1.1 Induction Motor

In several domestic utilizations these motor finds its location with more than 85% of industrial motors among in its single-phase formation. A continuous speed motor among shunt feature noticeably speed drops that is less from the total percentage from no load to the full load. Therefore previously, in continuous speed applications these motors are used significantly. Dissimilar to the motors based on Direct Current the conventional mechanisms have been implemented to control the speed. These conventional mechanisms are costly or very ineffective. Nevertheless, in the dangerous and polluted atmospheres the incidence of commutate and brushes in the latter that attain recurrent maintenance construct dc motor drives not proper for utilization. Alternatively, owing to the easy, rough, inexpensive, shorter and consequently lighter build of drives for induction motors that is specifically squirrel-cage type, they are intended for blowers, traction etc. despite searching inflexible competition from dc drives.

2. PID CONTROLLER

PID controller is generally termed as Proportional-Integral-Derivative controllers. Mostly three control parameters that need to be adjusting in obtaining an output. Output i.e. obtained by combining the all the parameters i.e. integral, proportional and Derivative. The main areas of using this controller are the education and industrial sections. Figure 2 depicts the block diagram for a PID controller.

These PID controllers have application in almost every area but these two fields majorly contribute to all other areas and almost all controllers are used in these areas. PID controllers must be tuned to provide the installation of the controllers. Thus tuning is performed on the dynamic performance of the scheme [15].

In the figure three control parameters are depicted that are used to get the output, where first parameter is Proportional control which increases gain. The second parameter is integral control which leads to the reduction of steady state error. And the last one is Derivative control which improves transient response [11]. Input is taken from the world and produces output to the world.

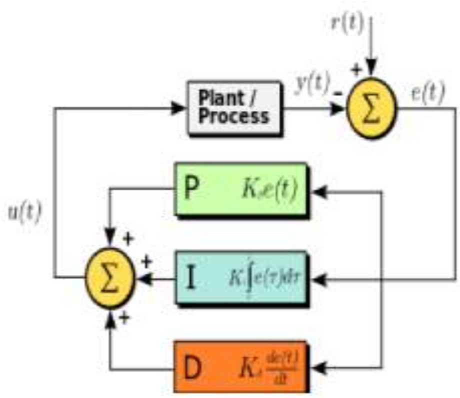

Figure1: Conventional PID Controller system design [15]

PID controller as an equation:-.

u (t)= K_p[e(t) + 1/$T_i \int_0^t e(t')dt'$ + T_d(de(t)/dt)] +b…(1)

Where, u defines the control signal, e shows the subtraction of the current value to the set point, k_p is the gain for a proportional controller, t_i integral controller scales through this parameter, t_d i.e. derivative controller that can scale through this parameter, t defined the total time taken by the error measurement, b defines the set point of the given or taken signal which is also considered as bias or offset value.

Collaborated with three parameters given, PID can be referred as transfer function in MATLAB defined below:

We can define the Transfer function of the controller as follows:

C(s) = $K_p(1 + \tau_d s + 1/\tau_i s)$……………………………………..(2)

Where K_p shows proportional gain, τ_d describes Derivative time and τ_i defines integral time.

Proportional term of the controller shows proportional of the generated error and can be written as follows:

P_{out} = K_p e (t)……………………………. (3)
Proportional control value depends upon the error rate demonstrate that higher the error, higher the proportional control as explained in the equation above. Thus it can be concluded that proportional control brings the system at fast set point [12]. Alternatively, as the mechanism attains the set point then it generates error based on the steady state that directs to an overshoot. There is another possibility of increasing the gain of the proportion but that makes the system unstable.

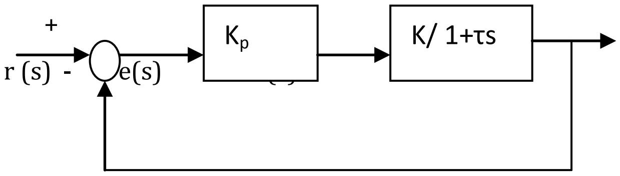

Figure 2: Proportional control

Proportional control as depicted in figure 2, can expressed as closed loop transfer function like:

$$\frac{c(s)}{r(s)} = \frac{\frac{KK_p}{1+\tau s}}{1+\frac{KK_p}{1+\tau s}} = \frac{KK_p}{1+KK_p+\tau s} = \frac{KK_p}{1+KK_p}\frac{1}{1+\tau' s} \text{………………}(4)$$

Where $\tau' = \frac{\tau}{1+KK_p}$

Step input r(s) $=\frac{A}{s}$

c(s) $=\frac{KK_p}{1+KK_p}\frac{A}{s(1+\tau' s)}$ or c(t)= $\frac{AKK_p}{1+KK_p}(1-e^{-s\tau/\tau'})$ … … ….(5)

From above given equation (4), it is declared that:

(1) Factor $\frac{1}{1+KK_p}$ can be used for improving time which means that time constant can be decreased by this.

(2) Difference between desired response and output response steady state offset is

A $\left(1-\frac{KK_p}{1+KK_p}\right) = \frac{A}{1+KK_p}$ … … … … ..(6)

Fundamental portion of the controller influence with the variations of the error on time given as:

I_{out}= $K_i \int_0^t e(T)\, d_T$…………………………… (7)

It helps in eliminating the problem of proportional term which was steady state error but it has a disadvantage too i.e. it affects the stability of the system. Thus it can be concluded that most of the portion depends on the error's pass values [13].

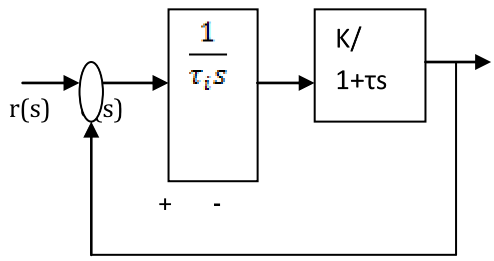

Figure 3: Integral control action

Above figure 3 obtain following equation as:

$$\frac{c(s)}{r(s)} = \frac{\frac{KK_p}{\tau_i s(1+\tau s)}}{1+\frac{K}{\tau_i s(1+\tau s)}} = \frac{K}{K+\tau_i s+\tau\tau_i s^2} \text{… … ….}(8)$$

Where step input r(s) $=\frac{A}{s}$,

$$e(s) = \frac{1}{1+\frac{k}{\tau_i(1+\tau s)}}\frac{A}{s} = \frac{\tau_i s(1+\tau s)}{\tau_i s(1+\tau s)+K}\frac{A}{s} \text{… … … ..}(9)$$

$e_{ss} = \underset{s\to 0}{Lt}$ se(s) =0……….(10)

Unlike other terms **Derivative control** is relative to the rate at which error is changed and defined as per the equation below:

D_{out}= K_dd/dt e (t)……….. (11)

The above equation helps in estimating the forthcoming error which leads to correction speed reduction or enhancement. This term helps in taking decision soon which provides detection of any changes on the error and system remains stable. This term is very sensitive to disturbances. If there is no change in the error then derivative influence will not be generated.

Transfer function of PD controller expressed as:

C(s) = K_p (1+τ_ds)…………….(12)

Derivative controller cannot be used alone due to its some drawbacks thus Proportional Derivative controller has been used to provide stability to the closed loop system. To prove this fact process transfer function can be explained as [14]

P(s)= $\frac{1}{js^2}$

Therefore resultant transfer function of the closed loop is given as:

$$\frac{c(s)}{r(s)} = \frac{\frac{K_p(1+\tau_d s)}{js^2}}{1+\frac{K_p(1+\tau_d s)}{js^2}} = \frac{K_p(1+\tau_d s)}{js^2+K_p(1+\tau_d s)} \ldots\ldots(13)$$

Where $js^2 + K_p\tau_d s + K_p=0$ represents characteristics equation which will provide stable closed loop response.

In this research paper, controller based on fuzzy logic is used for controlling a plant with the help of human knowledge with linguistic variables. The main benefits of using this system are good popularization and high fault tolerance. It can also apply to non linear systems due to which it is famous for years [20].

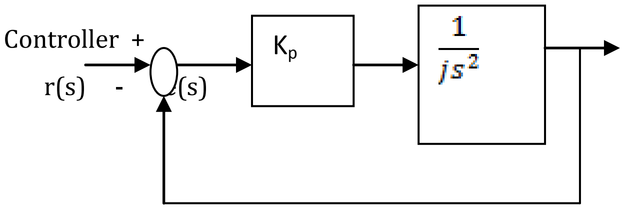

Figure 4: Control action with a higher order process [20]

With the use of P and P-D controller step response will be compared as depicted in figure 4.

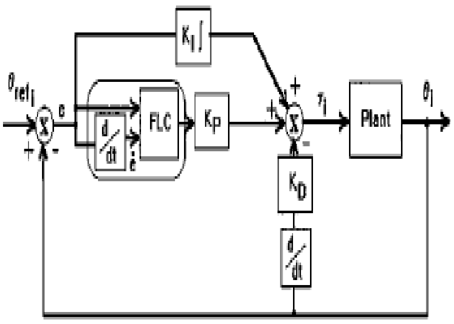

Figure5: Fuzzy based PID controller system design

Controller's performance can be improved by using the the hybrid fuzzy controller i.e. combination of P and ID controller depicted in figure 5 where proportional term is replaced with incremental FL controller and integral as well as the derivative term will remain same [15].

$$\Delta Ti\ (Ki)= KPi\Delta ui(k) + KIiTei(k)- KDi\frac{\theta i\ (K)-2\theta i(k-1)+\theta i(k-2)}{T} \ldots\ldots(14)$$

From above equation, Δu_i (k) shows output of incremental FL controller.

3. PROBLEM FORMULATION

In the projected mechanism the fuzzy logic among the traditional controllers are incorporated and the vector control mechanism was utilized. In order to enhance the speed response of the three-phase induction motor the fuzzy logic controller with the old PI controllers is used collaboratively. Where the PI controller utilizes the parameter such as K_p and K_i. These parameters selection is done on behalf of hit and trail method and when these parameters meet any variations in their values, the whole controller gets affected in that condition. Therefore, in that condition the induction motor speed can be altered. So there is a need to develop such a system that can handle the induction motor speed in each and every case.

4. PROPOSED WORK

As defined in above section that in order to regulate the induction motor speed, various authors conduct various study by using different type of controllers such as PI, PID controllers, arduino controllers and controllers based on fuzzy logic. The controller based on the fuzzy logic are evaluated as appropriate controller to the servo motors due to its less complexity in the mechanism and did not include any of the mathematical models The purpose of this study is to control the variations in speed of the induction motor by enhancing the traditional technique by using the BAT optimization algorithm to select the parameter of K_p and K_i for PI controller. The reason behind choosing the bat paradigm has several merits, and main benefit is that it can offer very rapid convergence at a very starting stage through switching from exploration to exploitation. For applications as a quick resolution is required then this prepares it an effective paradigm.

5. RESULTS

The Figure 6 shows the proposed Simulink model. Initially a constant along with the reference speed are given to the speed controller that is utilized to regulate the reference speed. PID controller is used for controlling the speed. After that a space vector modulator is used to modulate the speed. The output of space vector machine is given to the gate whose outcomes are further offered to the SI units of Asynchronous Machine. The output obtained from the machine is then offered to the Subsystem. The speed of Rotor and the Torque obtained from the Subsystem are provided to the Scope 1.

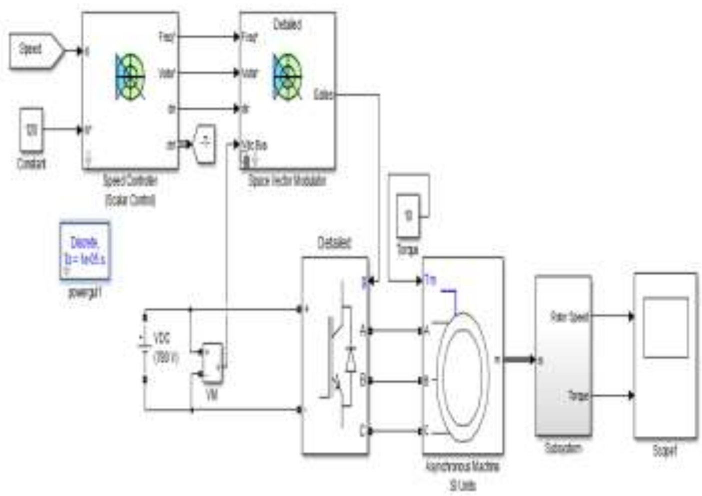

Figure 6 Simulink model of the proposed work

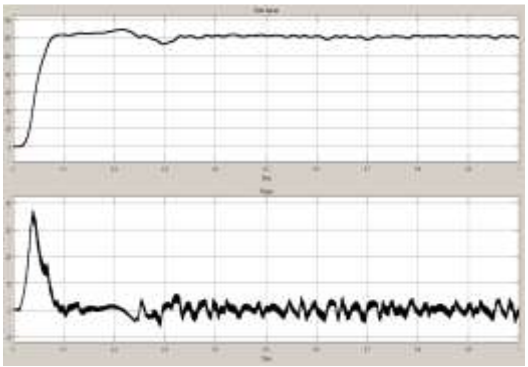

Figure 7 Output of PID model (Traditional mechanism)

The graph of Figure 7 shows the traditional mechanism Output in which the speed of Rotor and the torque is represented in the graph. In this graph fluctuations are shown in the rotor speed.

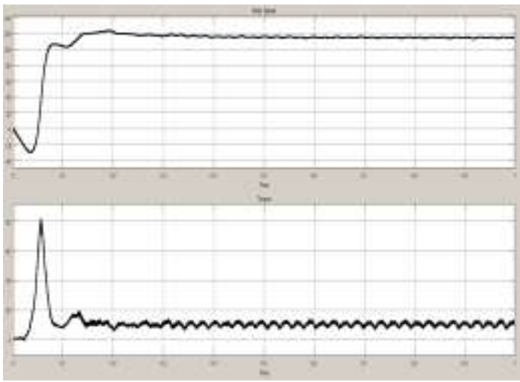

Figure 8 Output of Bat-PID model (Proposed mechanism)

The graph of Figure 8 shows the Output of the Proposed mechanism in which the Rotor speed and the torque is shown. Here in this graph it is shown that the variations in the speed of rotor that is less when compared to the traditional mechanism and the torque has also less variation in this output. Therefore the proposed model has very less settling time.

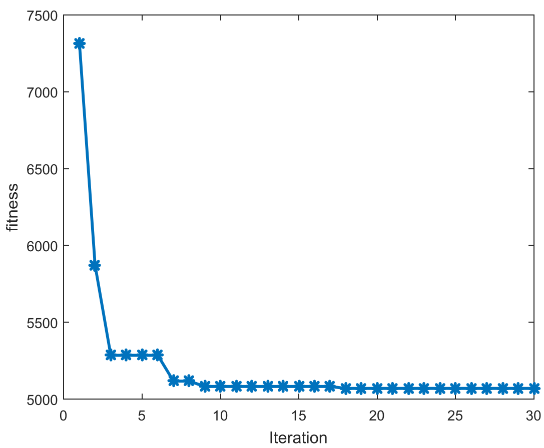

Figure 9 Fitness values of the proposed model.

The graph of Figure 9 depicts the Fitness values of the planned model. The number of iterations is shown on the x-axis and it ranges from 0 to 30. The fitness values are shown over the y-axis that ranges from 5000 to 7500. From this graph the best fitness value is attained.

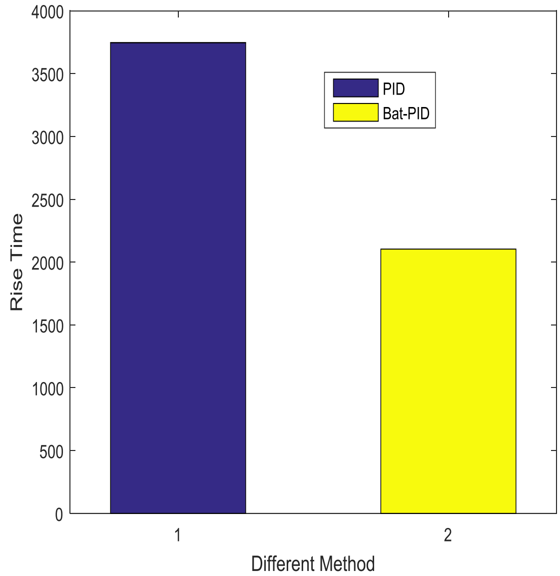

Figure 10 Rise Time of the proposed model.

The graph of Figure 10 shows the Rise Time of the proposed model to the conventional model. The Rise of the proposed model that is of Bat-PID is shown in yellow color and the rise time of the conventional model that is PID is shown in the Blue color. The Rise time ranges from 0 to 4000 and shown on the y-axis. Here the Rise time of the proposed model is less comparative to the traditional mechanism.

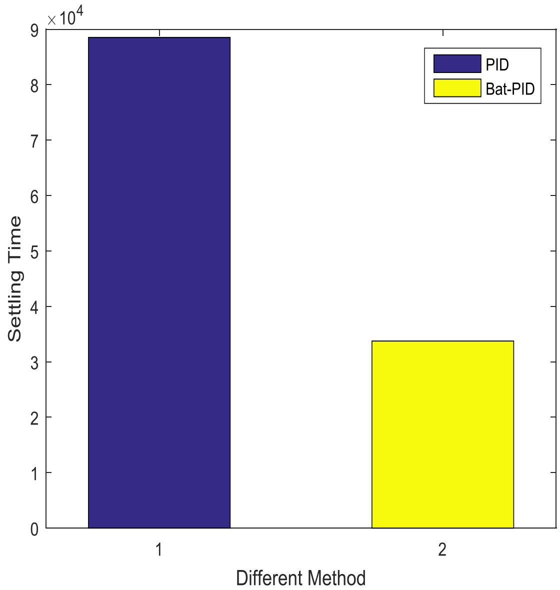

Figure 11 Settling Time of the proposed model.

The graph of Figure 11 depicts the Settling Time of the proposed model to the conventional model. The settling time of the model should always be less to make the model efficient. The settling time of the proposed model is shown on the y axis and ranges from 0 to 9x 10^4. Therefore the settling time of the proposed model is less than the conventional model.

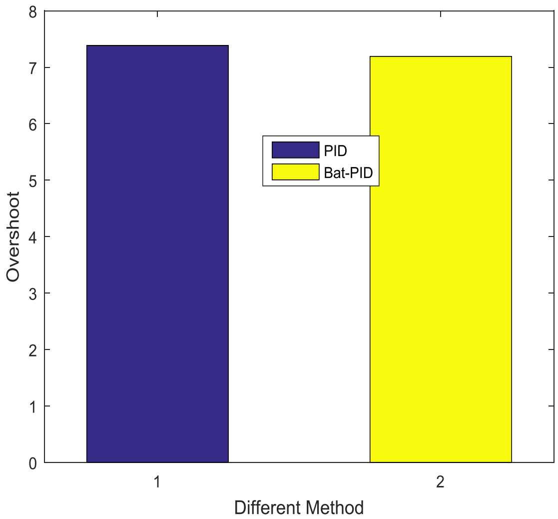

Figure 12 Overshoot of the proposed model.

The graph of Figure 12 shows the Overshoot of the proposed model. The overshoot of the proposed model that is Bat-PID is slightly less comparative to the traditional method that is PID. The overshoot is shown on the y-axis and ranges from 0 to 8. The Bat-PID is shown in the yellow color in graph whereas the PID is shown in the blue color.

6. CONCLUSIONS

The conventional control such as the proportional-integral (PI), and proportional-integral-derivative (PID) controllers have been used together among vector control components for the induction motors speed control from step by step. However, for controlling the speed of a three-phase squirrel cage induction motor (SCIM) the hybrid control mechanism was utilized in the conventional mechanism. The fuzzy logic controllers are evaluated as the most suitable controller to the servo motors as this is the less complex mechanism and did not include any of the mathematical models. In this work the variations in speed of the induction motor are controlled by enhancing the traditional technique by using the BAT optimization algorithm to select the K_p and K_i parameters for PI controller.

As the projected mechanism is very effective but in future for the induction motor speed control at another level the hybridization of the Neuro-Fuzzy paradigm with the PID controllers can be utilized.

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