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CONTROLLING PIDs USING NEURO FUZZY EXPERT SYSTEMS

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ABSTRACT

Proportional Integral Derivative (PID) controlling mechanism is found in several applications in industries where speed of motors or induction motors is to be controlled. The PID controller is specifically useful since it tries to minimize the steady state error as well as increase the response or speed of the system, thereby incorporating the benefits of proportional derivative and proportional integral control. However, the real time operation of PID controllers is challenging due to its tuning. The controlling mechanism is critically important for the application of the PID. Previously, manual tuning was used which needed experts and was also prone to errors. With the advent of sophisticated optimization tools, automatic tuning has gained momentum. In this paper, a combination of neural networks and fuzzy logic often called neuro fuzzy expert systems has been used for automatic tuning of PID controllers. It has been shown that proposed system is capable to attain better results compared to conventional techniques. The system has been designed on Matlab/Simulink.

KEYWORDS: Self-Tuning Controller, Speed Control, Scalar Controllers, Fuzzy logic controller (FLC), Neuro Fuzzy Expert Systems, Proportional integral Derivative (PID) controller.

INTRODUCTION

Controllers are used in the industry for a wide spectrum of applications. The major aspects which a controller tries to control are:

- Error
- Speed

The proportional integral derivative (PID) controlling mechanism is useful since it minimizes the steady state error given by:

$$\lim_{t\to\infty} e_{ss}(t) = R_s - Y_s \qquad (1)$$

Here,
$e_{ss}(t)$ represents the steady state error
R(s) is the reference input
Ys is the output

The error is often viewed as the overshoot above the reference value. Lesser values of overshoot render lesser steady state errors. Practically, the time to compute the steady state error is not actually infinite time but rather 6-10 time constants of the system. Another critical aspect of the system is the speed of the time response of the system. In this case the rise time is critical to be analyzed. The rise time is defined as the time needed for the output to attain 0% to 100% of its output (for an under-damped system). It is considered as the time needed for the output to reach form 10% to 90% of the output for an over-damped system. Mathematically,

$$t_{rise} = t_{Y=100\%} - t_{Y=0\%}; underdampled\ systems \qquad (2)$$

And

$$t_{rise} = t_{Y=90\%} - t_{Y=10\%}; over - dampled\ systems \qquad (3)$$

Thus the PID action improves both the speed and stability of the system. However, controlling the parameters for optimal PID operation is very complex. It involves controlling the system parameters of the PID controller so as to controlling the actual mechanism that the PID is controlling. This is often termed as tuning the PID. The tuning can be categorized as:

- Manual Tuning
- Automatic Tuning

Manual tuning refers to the manual control of the PID parameters. This may be time consuming and even erroneous. Moreover, it needs highly skilled and experienced professionals. On the other hand, automatic tuning is defined as the automatic or human less controlling of the PID parameters. This obviously needs a system that can behave like humans and has human attributes. The paper proposes a neuro fuzzy expert system for the automatic controlling of PID controllers.

MATERIALS AND METHODS

Speed Control of PID controllers

The fundamental necessity of using PID controllers is generally controlling the speed of the induction motor that is generally used for speed control. For industries, generally a three phase mechanism is used. A generic classification of speed control is given below:

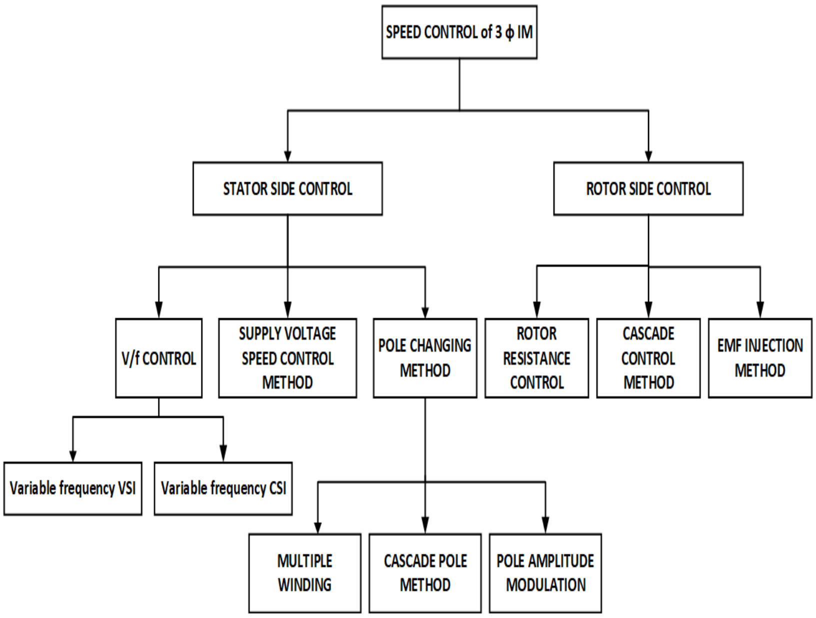

Fig.1 Speed Controlling Techniques

The most common technique is the V/f control. Implementing the V/f control can be implemented using several artificial intelligence based optimization techniques.

The Neuro Fuzzy (ANFIS) Expert System Control

Fuzzy rule based approaches are generally needed in optimization problems that do not possesses a clear boundary. The any system that is follows the following aspects are needed for IDS are the following:

- Parallel data processing architecture.
- Learning from updating the parameters of the IDS library.
- Capability for the system to detect fuzziness in the taking decisions.

The major reason for the need of fuzzification in automatic tuning is the fact that often it may be critically important to take decisions which do not have a clear boundary of decision making and hence a crisp output needs to be rendered. Fuzzy logic can render crisp values as the output subsequent to Fuzzification. Fuzzy rule based learning generally utilizes the uncertainty in the outcomes the PID parameters which generally tend to exhibit a non-linear idiosyncratic nature or pattern. Membership functions allow you to quantify linguistic term and represent a fuzzy set graphically. A membership function for set A can be defined as the super-set of discourse X as:

$$\mu A : X \rightarrow [0,1] \quad (4)$$

Here, all the elements of the superset X is mapped between values of possible yes or no termed as 0 and 1. Often the term coined for the above function is called the membership value or degree of membership. It helps in the quantification of the set value in the discourse of A into the crisp values as:

- x axis denotes the entire range of the random discourse or variable.
- y axis denotes the value of the probability in the interval of [0, 1].

A physical illustration is given below:

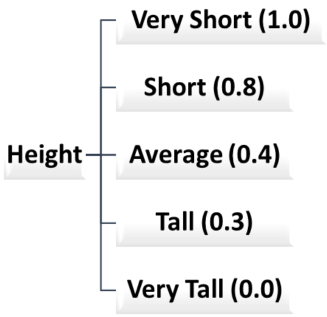

Fig.2 Case representation in fuzzy logic with membership value

The Fuzzy Logic Controller

The fuzzy logic controller can be considered as the fuzzy controlling mechanism that converts non-fuzzy values to fuzzy values and vice versa.

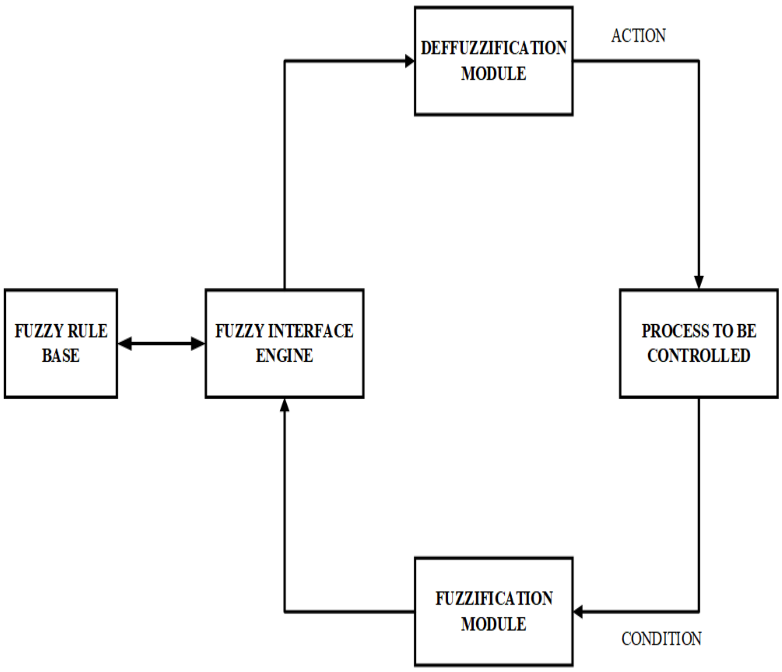

Fig.3 Block Diagram of Fuzzy Logic Controller

Neuro Fuzzy Expert Systems

Neuro Fuzzy Systems can be seen as an amalgamation of :

- Neural Networks
- Fuzzy Logic

The block diagram for the neuro fuzzy (Sugeno) architecture is shown in the subsequent figure. In the figure, it can be seen that the parallel data stream is used to train the neural network and update its weights. Subsequently, the output of the neural network is fed to the fuzzy inference engine that is used to de-fuzzify the data and render a crisp output value in the form of a decision even if there is no clear demarcation among the data set. The following figure clearly illustrates the concept explained.

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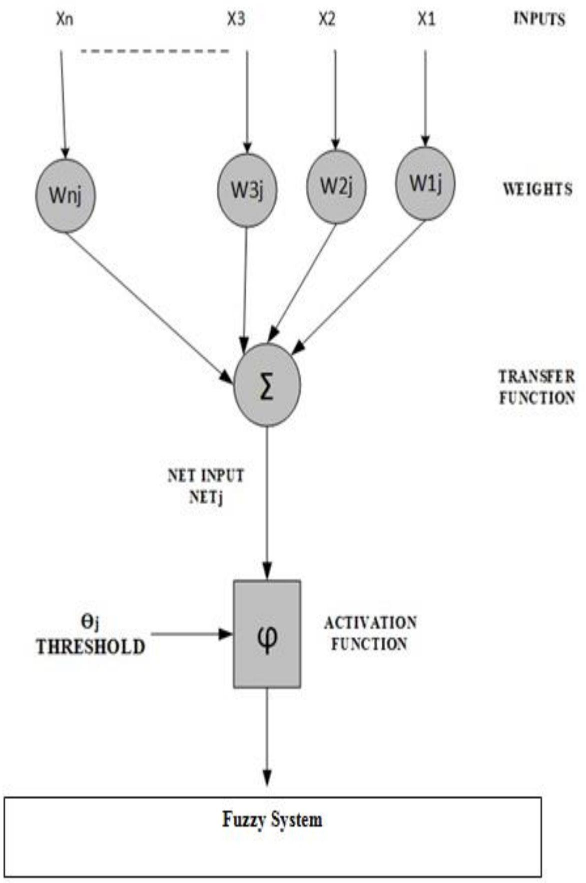

Fig.4 Block Diagram of Neuro Fuzzy Expert Systems

The V/f control of PID Controller-Based Speed Control Model

In present work in order to trace the reference speed curve the first technique utilizes is closed loop controller comprises of V/f control method along with PID controller. The V/f control is used here to generate the i/p signal for inverter is feed by PID controller after calculating error signal and limiting slip value.

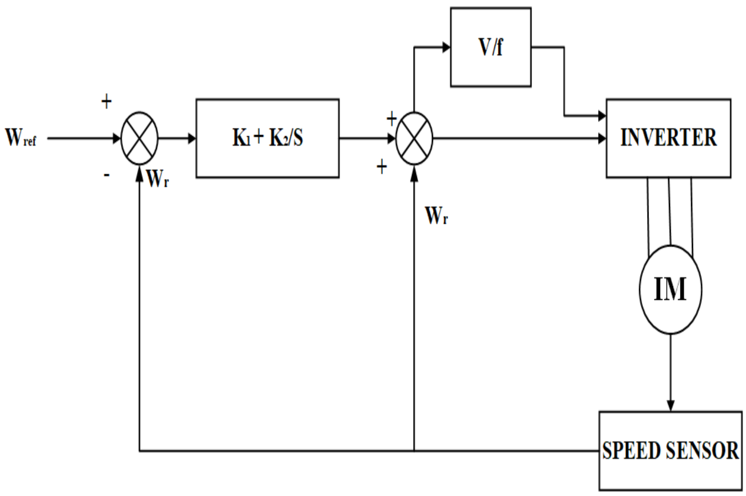

Fig.5The V/f controlling mechanism

The signal will guide inverter to generate respective supply so as to keep motor speed constant as required with the variation in load. The work is done on MATLAB/SIMULINK software. The signal is feed to Voltage Source Inverter (VSI) which is further connected to IM to supply 3ϕ power. On simulating the above model following

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results are obtained.

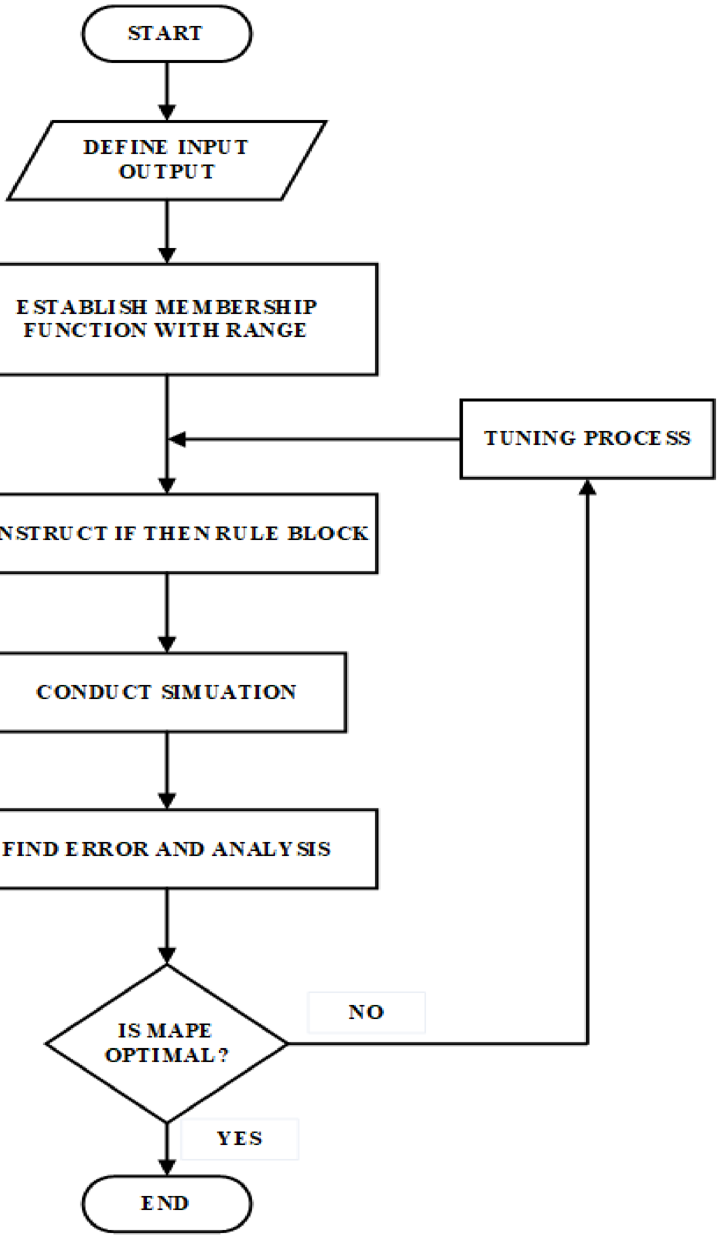

Fig.6 Flowchart of Proposed System

RESULTS AND DISCUSSION

The results have been simulated on Matlab 2017a and Simulink. The various parameters which are computed are:

1) Stator Voltage
2) Stator Current
3) Speed versus time
4) Torque versus time

The different parameters have been computed and plotted as a function of time. The comparative analysis of the parameters with and without the proposed system has also been provided.

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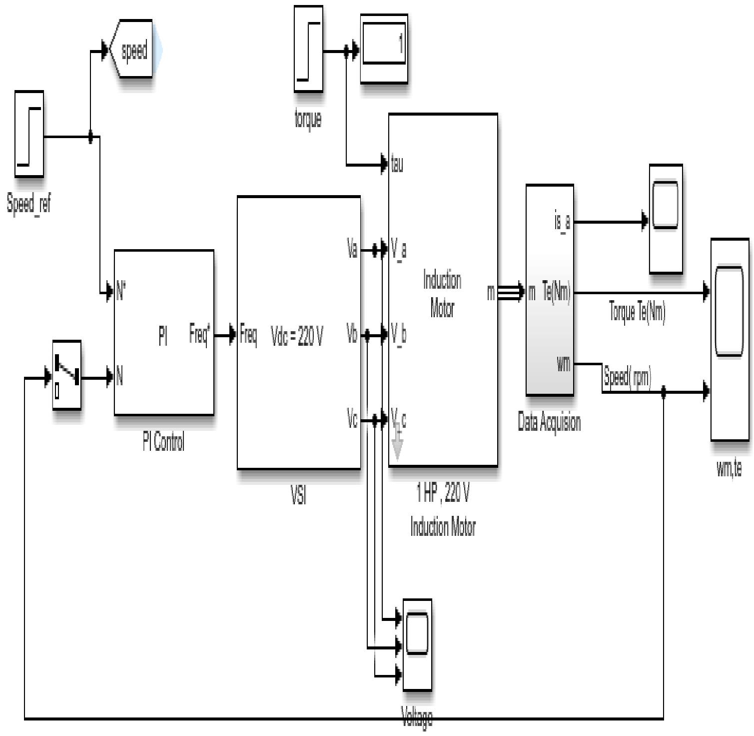

Fig.7 Simulink model for PID control for V/f control method

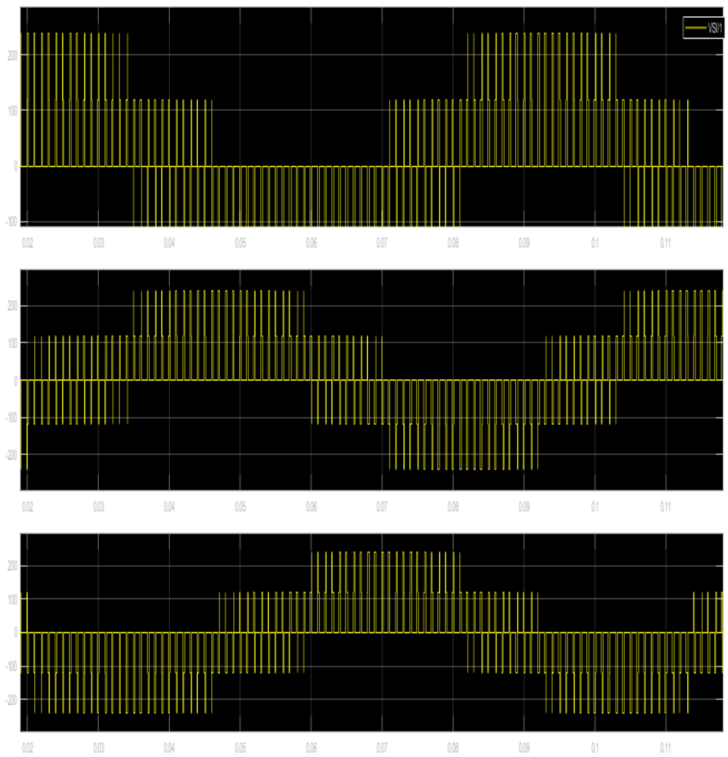

Fig8. Stator voltage for PID control for V/f control method

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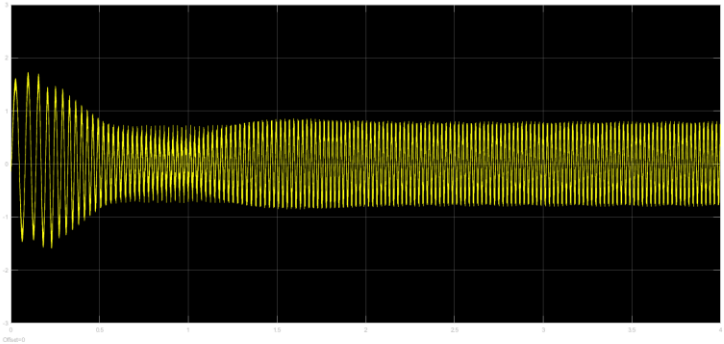

Fig.9 Stator current of a 3 phase IM motor for PID control by V/f control method

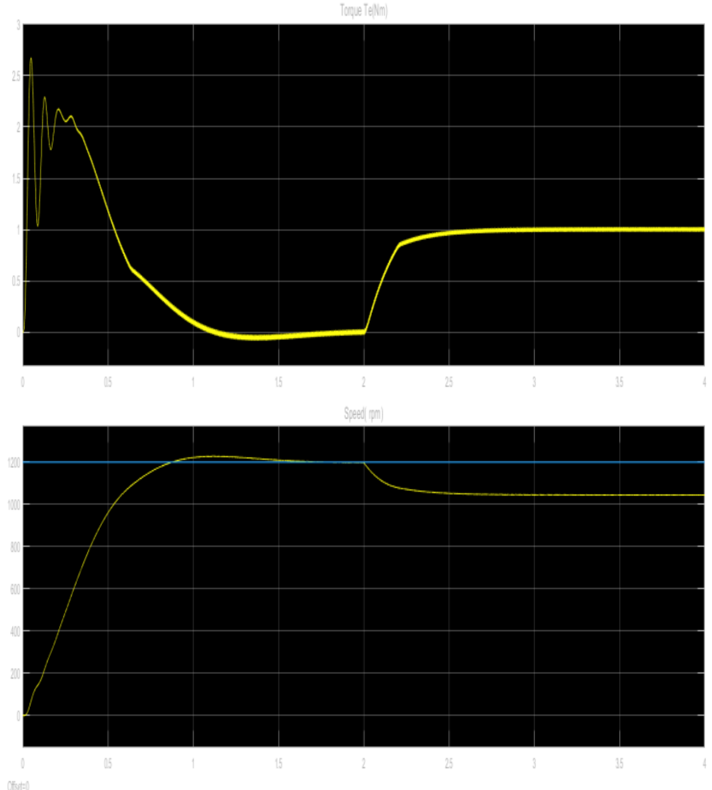

Fig.10 Load torque and Speed vs. Time of a PID control for V/f control method

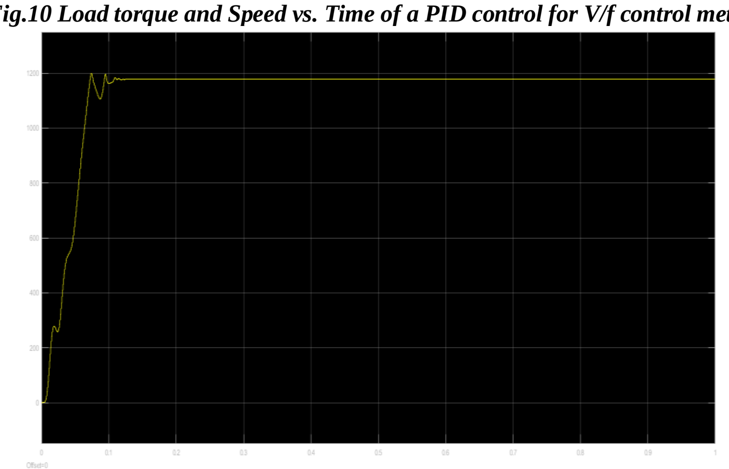

Fig.11 Speed vs. Time plot using Fuzzy controller

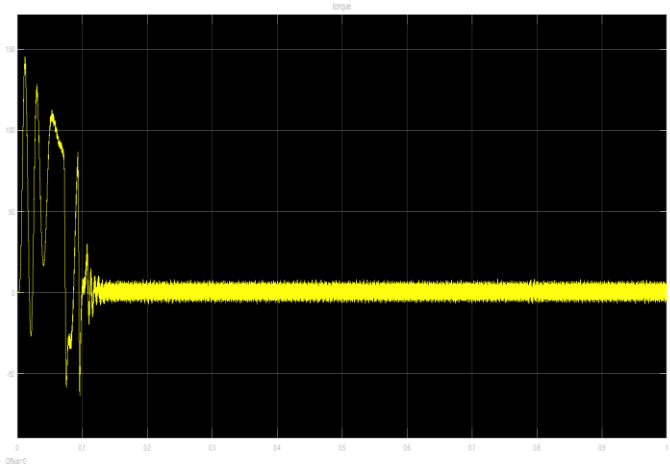

Fig.12 Torque vs time plot using Fuzzy controller

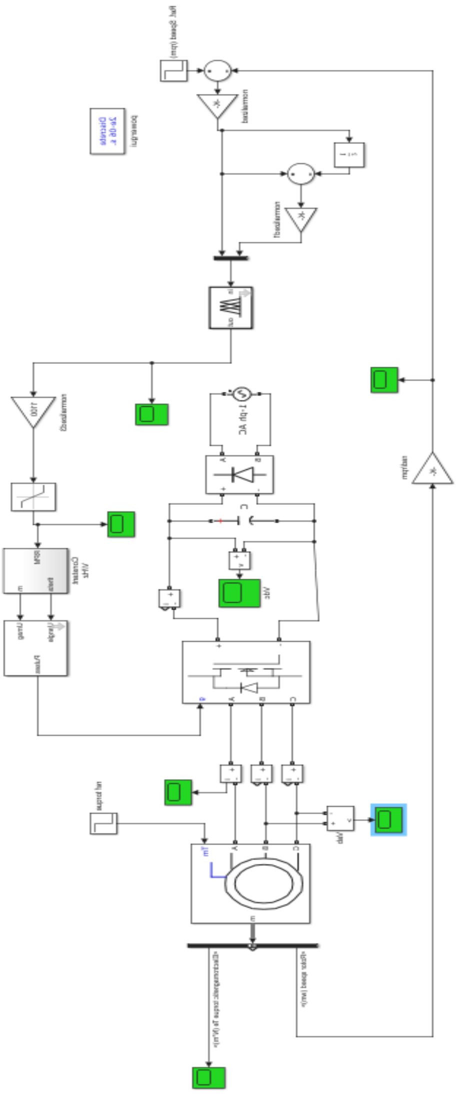

Fig.13 Block diagram of Fuzzy Logic based Speed controller

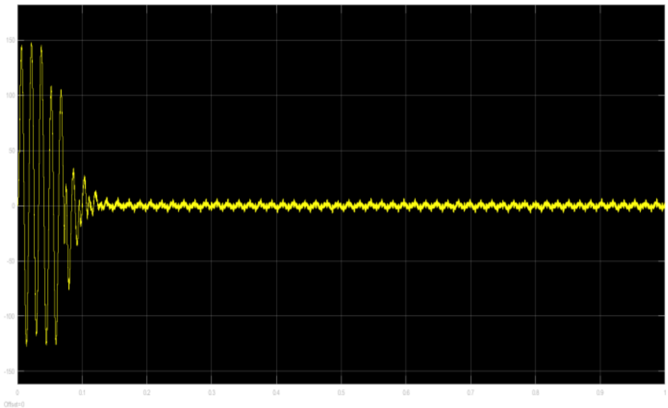

Fig.14 Stator Current vs time plot using Fuzzy controller

CONCLUSION

It can be concluded from the previous discussions that automatic tuning of PID controllers is a complex task and evolutionary optimization techniques are being used for the same. In this paper, work a comparative analysis of a conventional (PID) controller and PID controller with neuro fuzzy expert systems has been done for the effective controlling and tuning. It can be observed from the results that the proposed system outperforms the conventional techniques in term of steady state error and response.

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