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Speed Control Analysis and Performance Comparison of Induction Motor Using Improved Hybrid PID Fuzzy Controller

Sartaj Singh, Prof. Priya Sharma (HOD)
Department of Electrical Engineering,
The Institute of Engineering & Technology,
Bhaddal, India

***Abstract*- To control the speed of an induction motor is very difficult. The speed control relies on the electric power factor offered to the motor. Many researchers have performed a significant number of studies to enhance the mechanism of vector control. They have used different controllers such as PI (Proportional Integral), PD (proportional derivative), Fuzzy-PI, Fuzzy PID (Proportional Integral derivative). In this paper, a novel approach is developed which used hybrid controller. This controller is developed by the amalgamation of Fuzzy type-2 and PID controller. Fuzzy type-2 has various advantages over type-1 fuzzy which overcome the limitations of the traditional system. A literature survey is given with the detailed information of the works done in this field. The mechanism is developed by taking into consideration different parameters such as rise time, settling time and overshoot. The proposed model is analysed using MATLAB. Simulation results showed the better efficiency of the novel controller. Is observed that, developed controller reduced the time required by the motor to achieve its target speed, thus, gives excellent outcome.**

***Keywords*- Speed Control, Fuzzy Type 2, PID, Hybrid Controller.**

I. INTRODUCTION

Due to various characteristics of motor such as robustness, small size, low cost and requirement of less maintenance [1], there is a wide range of applications ranging from simple home equipments to huge machines in the industry. It is observed that more than 50% of electricity is consumed by electric motor driven system (EMDS) in industries. [2], [3] Also, total consumption of electricity for motor driven system is estimated to gain the demand due to development of electric vehicles and the growth of industrial activities. In the past few years, concept of vector and torque control in the asynchronous motor drives has gained noteworthy popularity.

In the past, the different speeds were acquired by using dc motors only. These motors were employed due to because they were comprised of speed control methods [4]. The traditional techniques of speed control of an induction motor (IM) were either too profligate or too ineffective, which arose the limitation of their application be employed on only constant speed drives.

However, there is a difficulty faced by control system of three phases Induction Motor (TIM), it does not have the decoupled current required to control the speed. It consists of the current responsible to produce the torque and the current responsible to produce flux. The solution to this problem is the implementation of enhanced control methods using Vector Control. The principle of vector control was introduced by Blaschke [5] to comprehend the features of dc motor in IM drive.

According to the principle of speed control, the two components of induction motor current that produce torque and flux are decoupled and each component is controlled independently, just like the working of a separately excited DC motor. This principle can assist in developing a drive system with an excellent dynamic response to the varying load or reference speed. Moreover, the limitations of the vector control can be solved by using field oriented control (FOC) [6].

FOC is classified into two different categories, as direct FOC (DFOC) and indirect FOC (IFOC) [7]. In DFOC, there is a requirement of two hall sensors placed on the air gap for estimating the flux rotor. But, it is difficult to implement and use the flux sensors in IM which results in inefficiency of the motor drive. For this reason, IFOC has been introduced by Hasse [8] with the advantages in of its estimation techniques. Further, IFOC is simple and easy to implement device that makes it popular in industrial application [1] [9].

To control the operations of the motor, motor controller controls are deployed into the motors. A variety of controllers have been used by the researchers for IMs. PI controller AND proportional-integral-derivative (PID) are used as conventional speed controllers to control the IM

drive's speed. Using both these controllers induces many concerns like high overshoot, speed and torque oscillation because it experiences rapid changes in load and external disturbances.

PI controller has the major disadvantage of ineffective performance because it had poor ability to deal with system uncertainty, i.e. varying parameters and external disturbances. With the advancement in the technology, the next step chosen to enhance the performance of controller is the implementation of fuzzy to the controller which is also referred to intelligent control act. Fuzzy logic is an approach that represents human-like thinking into a control system [10, 11 and 12].

Fuzzy Logic Control (FLC) approach is very useful for induction motor speed drives since, no exact mathematical model of the motor is required. Figure 1 demonstrates the basic controller used for an induction motor. This controller is further modified by applying fuzzy logic, PI, PD and PID controller. This paper is divided into the sections which consist of literature survey, fuzzy typr-2 and the explanation of the proposed work along with its results.

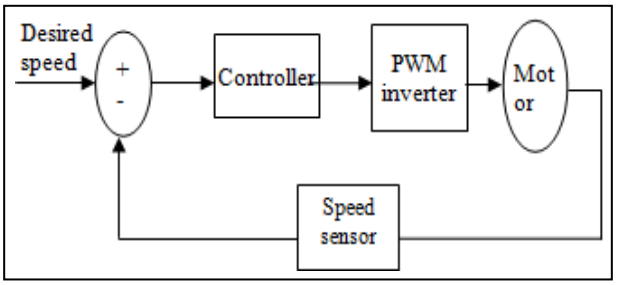

Fig 1. General controller for induction motor. [13]

II. RELATED WORK

There are significant numbers of researchers that have been performed to achieve the vector control of the inductions motor. Different technologies have been applied to develop efficient controllers.

Some of the works of researchers are mentioned in this section:

Nader Jamali et al [14] represented a mathematical formulation based method which worked upon the basis of the variations in parameters of PD controllers particularly for fuzzy based servo motor.

Ahmed J. Fattah and Ikhlas Abdel-Qader, [15] a hybrid control system was introduced in this paper for the speed control of a three-phase squirrel cage induction motor (SCIM) in which fuzzy logic is combined with the conventional controllers.

Meghana Singh in [16], presented a review to the various types of controllers that can be used for compensating the various issues in network control communication systems. In network communication, the data travels from one node to another node in order to reach the destination. While covering such a long route, sometimes data packets suffers from various loses such as delay in communication, misplacements of data packets etc. Network control system is geographically dispersed network in which the actuators and controllers are deployed and shared by the network.

Cui Hao et al in [17] adopted the fuzzy logics and smith predictor and developed a single mechanism which was named as fuzzy adaptive smith predictive control system to recoup the problem of three tank system. The PID controller was used for settling the PID parameters in order to enhance the resistance capability of random disturbance and smith control so that the time delay can be reduced.

L. Zhang [18] addressed the robust stability in the paper. Stability was introduced for a class of linear discrete- time stochastic systems with convex poly-topic uncertainties. Author used uncertainties of convex poly- topic type and delays due to varying interval.

From the literature study, it is observed that, a new model is required to be developed in order to enhance the system performance which is mentioned in the next section.

III. FUZZY LOGIC

The fuzzy logic is the meticulous area of concentration in study of AI and its main concept is that it's neither true nor false. Like the human use the information to make their decisions on daily basis. The membership grade for each element in fuzzy type 2 set has value [0,1], whereas in type- 1, membership grade is a crisp number in [0,1]. These sets are utilized in the scenarios with uncertainties about the membership functions (MFs) like an ambiguity in the parameters of MF or in of its shape. Fuzzy logic is implemented in vector control of induction motors as it is more efficient than PID controller [19], [20].

Fuzzy type-2 is used in the proposed system as it is more efficient than fuzzy type 1. It deals with the uncertainties, unlike type-2 fuzzy, there are no crisp functions. The rules are generated on the basis of e (error) and eo (change in error). The Sugeno fuzzy model is implemented into the controller.

Sugeno Model [20]: Sugeno and Kang projected a fuzzy model in which a systematic approach was developed in order to build fuzzy rules from a given dataset of inputs and outputs. The syntax of the rule in this model is:

if x is A and y is B then z=f(x,y)

Where, z = f (x,y) is a crisp function in the conclusion, A and B are fuzzy sets in antecedent. In general, f (x, y) is

polynomial in the input variable x and y. also it can be any function if it can properly describe system's output within the antecedent of rule.

IV. PRESENT WORK

Over the years, the conventional control such as the proportional-integral (PI), and proportional-integral-derivative (PID) controllers have been used together with vector control traditional method in this field was proposed to better control the speed of induction motors.

This method combined the advantages of fuzzy logic controller and conventional PI controllers to improve the speed response of the three-phase induction motor. The PI controller utilizes the parameter such as Kp and Ki. These parameters selection is done on the basis of hit and trail method and when these parameters meet any variations in their values; the whole controller gets affected in such case. Another loophole was the implementation of fuzzy inference system based controller.

As the fuzzy can produce the output only on the basis of the generated rules that are derived from the set of input values. So a new approach is proposed that will implement hybrid of PID and type-2 Fuzzy due to the advantages of fuzzy type 2 over fuzzy type 1.

1. Objectives of Proposed Work:

- Implementation of hybrid of PID and Type-2 Fuzzy based Controller to enhance the performance.
- Implementation of the Simulink model of induction motor with hybrid controller
- Performance evaluation of proposed work in terms of determined parameters such as rise time, settling time, overshoot

2. Methodology:

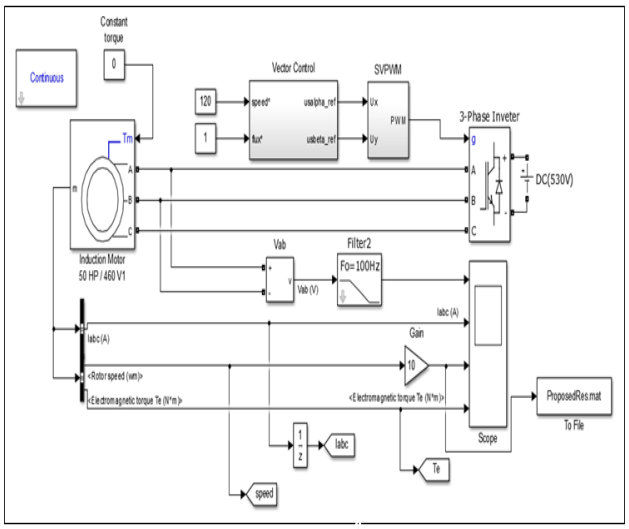

Fig 2. Model of Proposed System.

The proposed model OF developed controller for three phase induction motor used the concept of hybridization of PID and type-2 fuzzy. The figure illustrates the speed control mechanisms for induction motor. The motor has three phases which are interfaced with the three face inverter.

This converts changes the DC current to AC current. It implemented hybrid controller by the amalgamation of type-2 fuzzy and PID controller. The vector control mechanism relies on the voltage provided o the motor.

The voltage decides the speed of the motor. Moreover, in the proposed work, reference speed (required speed) is determined and further errors are identified by fuzzy type-2 model.

V. RESULTS AND DISCUSSIONS

The problem of vector control in the IM is resolved by proposing a new system in which fuzzy type 2 is combined with PID for speed regulation. The different parameters are taken into account such as rise time, settling time and overshoot for the induction motor. These parameters are considered for determining the efficiency of the motor's speed.

The rotor vector is determined with respect to the time. Using MATLAB software, the simulation results are obtained. This section describes the results of the proposed system with respect to the different parameters.

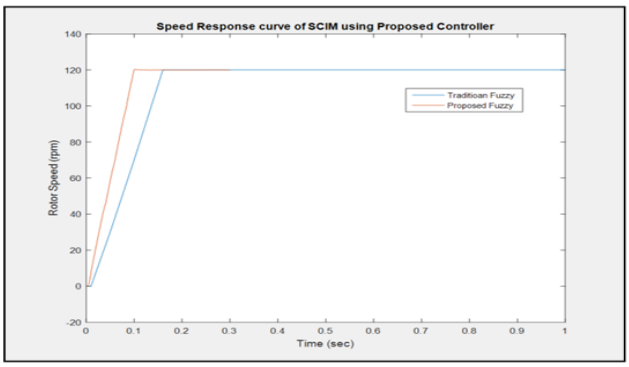

Fig 3. Rotor speed of IM.

These parameters are explained as follows:

1. Rise Time:

Time required for a signal to move from its specified low to a high value is known as rise time. It is the time required for a system to achieve its final stage. Here, the rise time is said to be time taken by the motor to achieve the stable speed.

2. Overshoot:

Overshoot as cleared from its name, it a time when the system exceeds the determined target or the requirements. In this system, overshoot is referred to the time when the

specified speed of induction motor crossed the target speed.

3. Settling Time:
Settling time is the time taken by the motor to be into a stable position, i.e. when the target speed is achieved and motor performs well without causing any errors.

4. Rotor Speed:
It is the speed of the motor. The rotor rotates when motor is powered with the voltage. The speed in measured as rpm (revolution per minute). The rotor speed is measured with the proposed and anticipated controller.

Figure 3 is showing the graph obtained for the speed of motor for traditional as well as proposed system. It is inferred from the graph that the time taken by the proposed system is less than that of the traditional system. The settling time is reduced by approximately 0.05 seconds. There is a decline in the rise time of the proposed system which in turn offers the effectiveness to the system.

Rise time, Settling time and overshot are measured with respect to different controllers (conventional and proposed). Comparative analysis is performed between PI, Fuzzy-PD, Fuzzy-PI, Fuzzy-PID controllers and proposed controller. Their results are recorded in the tabular chart given below (Table 1).

Table 1. **Text Here Your Table title.**

Parameter	PI	PD-Fuzzy	PI-Fuzzy	PID-Fuzzy	proposed
Rise time (sec)	0.5439	0.1649	0.1071	0.1071	0.076983
Settling time (sec)	1.9326	0.2246	0.1386	0.1386	0.097782
Overshoot (sec)	61.2028	0	0.1423	0.0763	0.0298578

The table depicts that rise time and settling time is minimum for the proposed work however, overshoot is minimum from the other controllers except PU-Fuzzy controller as it does not comprised of overshoot. Overall, the novel controller has better performance and it surpassed the traditional approach.

VI. CONCLUSION

A novel approach of vector control in the induction motor is developed with the amalgamation of type-2 Fuzzy system with PID (proportional Integral Derivative) controller. The type-2 fuzzy is better in terms of tackling the uncertainties. The controller is developed using the hybrid approach. Fuzzy type-2 with Sugeno model is implemented in this controller. The system was proposed by taking into account different parameters such as rise time, settling time and overshoot. The parameters are measured with respect o the rotor speed of the motor. Simulation results were attained using MATLAB software.

The results showed that proposed system consumed less time as compared to the time taken by traditional system. The comparative analyses is performed in terms of rise time, settling time and overshoot with respect to the different conventional controllers and proposed controller. The proposed system is proved to be more effective in respect of rise and settling time and overshoot.

In future, the speed controller of the induction motor can be enhanced and made cost effective by replacing multiple fuzzy type-2 systems with the optimizations techniques.

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