Speed Control of Induction Motor using Hybrid PID Fuzzy Controller

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Abstract - The induction motor is in great demand now a days in various fields like residential and industrial applications. The progress in variable speed drive technology is incredible as well as admirable. The application of induction motor is increasing vastly because of its toughness and less maintenance cost in many different fields where most of the applications needs intelligent speed control along with fast response. Speed control is considered to be as main problem in order to achieve maximum torque and high efficiency. The formulation of the speed control and the techniques that are used to control the speed are introduced in this paper. This paper offers an overview to the work that has been done many authors.

Keywords - Torque control, Speed control, Fuzzy logic controller, Induction motor.

1. INTRODUCTION

In several domestic utilizations the induction motor searches 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 very few in percent from no load to the full load. Therefore previously, in continuous speed applications the induction motors have been utilized significantly [1]. Dissimilar to the DC motor the conventional mechanisms implement speed control have been costly or very ineffective. Nevertheless, in the dangerous and polluted atmospheres the occurrence of commutator 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 induction motor drives that is specifically squirrel-cage type, they are intended for blowers, traction etc [2]. Despite searching inflexible competition from dc drives.

Variable frequency drive is considered to be as special type of convertible speed drive. Different frequency drives are inverter drive, speed drive of variable, adjustable drive, Ac driver etc. [3-4]. By regulating the speed of motor helps in executing different kinds of operations and multispeed functions. Earlier many issues like unstable speed control, large consumptions and poor efficiency etc. were faced by variable speed drive. These issues were reduced gradually by the development power electronics [5]. Firstly the requirement of induction motor in different fields was needed to be understood. On comparing with other electrical motor, induction motor's advantages made a huge difference. Some of its advantages are as follows:

- As compared to dc motors or synchronous motor, the induction motors used are very cheap.
- Because of its strong construction, Induction motors is considered preferable than any other motors
- Its percentage of reliability and effectiveness is certainly better than any other motors
- Because of its simple construction, its maintenance cost is very low.

2. SPEED CONTROL

Two speed terms mostly used in induction motor are rated speed and synchronous speed. The speed in which motor's magnetic fields rotates are known as synchronous speed. It is one kind of motor theoretical speed where the fact consider that there is no load and bearing friction is ignored [6, 7]. Its synchronous speed relied on two factors i.e. magnetic pole and supply frequency. Equation for its synchronous speed is as follows:

$$Ns = \frac{120f}{p} \qquad (1)$$

Where, f = Frequency in Hz

p= Number of poles

Speed of Rotating magnetic field of an induction motor is quite different from rotor speed. Rotor's actual speed is always less than rotor's synchronous speed and the percentage difference calculated between these two is referred to be as slip of the motor [8].

$$S = \frac{NS - Nr}{Nr} \qquad (2)$$

Where,

Ns = Synchronous speed

Nr = Rotor speed

$$Ns \propto \frac{f}{p} \qquad (3)$$

The equation 3 written above basically states that synchronous speed of induction motor is directly proportional its frequency supplied and is inversely proportional to total number of stator poles calculated. The change in frequency leads to change in speed induction motor because the number of state poles is stationary.

3. SPEED CONTROL TECHNIQUES

Three types of speed control techniques are implemented now a day. These techniques are:

A. Scalar Control (v/f Control)

Supply frequency is mostly changed for changing the speed of induction motor. This scheme resulted in better performance along with wide speed range. PWM controller was used along with inverter for generating variable frequencies. These frequencies used the main motor. The v/f relation remains constant in order for achieving fixed torque [9]. Thus torque doesn't depend upon supplied frequencies although it depended upon slip size as the flux is maintained fixed or constant. This type of controller is also named as scalar control. Because of low cost, immunity and easy implementation, open loop v/f method is mostly used in industrial areas. For having accurate result in controlling the speed and torque, closed loop v/f control is used. As slip is directly proportional to induction motor torque, so it is mostly used for achieving required torque [10-11]. In order for motor to attain required speed, the difference is reduced to zero with the help of PI controller. The main limitation of this system is uncontrolled magnetic flux [11].

B. Vector Control

Long term stability of system is ensured by motor driver with the help of closed-loop control and particularly better performance is provided by Field oriented control. This control is also named as indirect torque control or flux oriented control. These control systems are basically divided into three kinds i.e. rotor flux control, stator flux oriented control and magnetizing flux oriented control. Different commercials and process applications that needs high performance mostly uses induction motor. To accomplish those high performance, the speed of the engine need to keep up a particular reference direction irrespective of any parameter changes, uneven load and model vulnerabilities. Coordinate vector control strategy is identified with the unit vector began from the stator motion. These vector signals are figured specifically or suspicion from the stator voltage and current signals. The parts of stator motion are computed from the stator amounts. To acquire rotor field edge data rotor speed isn't required in this plan [12-13]. The transition estimation process likewise includes all the more additional hardware cost and the estimation isn't precise. That is the reason vector control method isn't extremely satisfactory strategy for speed control. Roundabout vector control strategy is most normal and more solid technique than coordinate vector control strategy. In this strategy the unit vectors and rotor field points are estimated ultimately by summation of slip frequency and speed of the rotor.

C. Direct Torque Control (DTC)

The DTC technique is acquired from the basic fact of the fallacy in the middle of the real reference and torque so estimated. The inverter states can be specifically controlled inside a prefixed band breaking point to decrease the torque and motion blunders [14, 16]. This control strategy is another method for speed refinement of Induction engine by utilizing frequency converter. Distinctive parameter like mutual inductance, stator resistance, co-efficiency of saturation etc. is essential of this control strategy. Field introduction is achieved without speed if the rotor or position feedback with the help of motor so developed to register the motor torque without utilizing modulation. Engine torque and polarizing motion are the principle controlling factors in this procedure that is the reason it is called coordinate torque control technique. Quick response time, destruction of feedback devices, decrease mechanical disaster are the plus points of DTC technique [15]. There many limitations like higher torque ripple flux, comparator hysteresis. Figure 4 demonstrates the essential development of direct torque control technique. In DTC strategy, stator motion is controlled in such way that required torque is gotten. This is proficient by choosing the mix of a modify switch that drives the stator vector. The proper alteration is forcing the right voltages to the windings directly.

- **Space Vector Modulation**

Selecting right inverter condition is basically method for establishing the exact stator flux. This flux is particularly divided into 6 different positions. The stator flux modulus and torque is achieved by denounce on peripheral components of the contact space vector on its locus. The elements so achieved are symmetrical to the components in same direction of same voltage components. Figure 5 illustrates stator flux locus based on VSI [17, 19]. Locus is divided into six different positions gestures by its continuous line. Although in VSI only 8 different states are predicted. Out of which only 6 states provides non-zero output also known as non-zero switching states. Rest is zero outputs. These are labeled as A1 to A6.

- **Fuzzy Logic Controller (FLC)**

This method is considered to be as modern method to think like human beings into control schemes. These are planned to copy human beings. Fuzzy linguistic description is principally used to control the procedure frameworks as fuzzy logic controller [18, 20]. Industries having high non-linear process and complex work functions use extraordinary type of design referred as FLC. In induction motor, this method is considered to be beneficial.

4. RELATED WORK

Siti Nur Wahidah Binti Abdul Wahab [8], in this paper the author had illustrated that the PID controllers were the paradigms which could regulate the input values on the basis of the historical data and the emergence rate of differences to prepare the mechanism much correct and steady. For a DC servo motor this study was centered majorly on deliberating and implementing PID controller. As the speed motor were influenced through manually run among a particular presentation necessitation the PID controller were utilized in order to control position of the Dc servo motor. On the basis of the MATLAB/Simulink software the PID controller were deliberated in order to attain the optimum position control of PID controller parameters and realized through utilizing microcontroller to the real Dc servo motor it was realized. For embedded mechanism on MPLAB X IDE the entire codes in microcontroller were generated.

Jakub Talla [9], in this paper the creator had anticipated an adaptive controller for speed control of acceptance engine (IM) drives among off base models. Especially, in the state space model of the drive every condition was subjected to gradually shifting error. The projected mechanism contained an adaptive feed forward control term that compensates for the nonlinear and uncertain factors and a feedback control term that assures the mechanism steadiness. The projected mechanism had offered a specific and quick speed tracking and also the projected mechanism was easy and simple to employ. By applying a Lyapunov theorem and a related lemma the steadiness of the projected mechanism was assured. Comparative to the competitors on a generated IM drive prototype of rated power of 4 kW the practices assured improved control presentation, for controller deliberation within the real drive and model were utilized specifically in the terms of the severe parameter mismatch.

Ashraf Abd El-Raouf [10], the performance of induction motors is greatly affected by the waveform of the supplied terminal voltage. In many practical cases voltage waveform suffers from problems such as sag, swell or voltage fluctuations, in these cases bad impact on motor is occurred that ranges from reduced performance characteristics to damage. The objective of this paper is to assess the effect of optimized two different shunt compensators in enhancing performance of induction motor voltage profile either in steady state or in transient periods. These two compensators, namely static VAR Compensator (SVC) and static synchronous compensator (STATCOM), are connected one at a time to motor coupling bus to compensate voltage sag or swell. To achieve near optimal dynamic performance, controllers' parameters of compensators are tuned by ant lion optimizer (ALO). MATLAB simulation is performed to study the motor performance at different loading and supply voltage conditions. Three study cases are considered to critically asses the performance of the two compensators regarding motor starting performance with variable loads, and the effect of voltage sag. Results of simulation proved that both SVC and STATCOM enhanced and regulated bus voltage, leading to; decreasing startup time, increasing motor capability to start with loads and improving voltage profile. Moreover, STATCOM has better impact on motor performance compared to SVC.

M.M.M. Negm ; J.M. Bakhashwain ; M.H. Shwehdi, in this paper the author had implanted based on the optimal preview control mechanism theory a synthesized mechanism for speed control of a three-phase induction motor (IM). By applying the vector mechanism an IM model was employed that contained three-input variables and three-output variables that coincide among the synchronous reference frame. The motor speed control, field orientation control, and constant flux control was obtained by the synthesized control mechanism that was the major aim of this mechanism. In order to enhance the vigorousness of the mechanism a new error mechanism was generated and established into the control law. The preview feed-forward controller that involves the preferred and disturbance signals was utilized in order to enhance the transient response of the mechanism. On the dynamic presentation of the IM to detect the effect of the projected space vector modulation mechanism the spectral study of the output voltage was estimated.

Rodrigo Padilha Vieira; Hilton Abilio Grundling, in this paper the author had investigated the trouble of the single-phase induction motor (SPIM) sensorless speed control. On a PC-based platform a discrete time PI controller and a sensorless mechanism were employed through utilizing a standard three-phase inverter drive and vector control. For the rotor speed evaluation a MRAS among a Kalman filter paradigm is generated. The simulation results had demonstrated the efficiency of the mechanism.

Aung Zaw Latt ; Ni Ni Win, in this paper the author had illustrated that in home devices and industrial control the single phase induction motors were broadly utilized. The variable speed drive of induction motor utilizing frequency control mechanism was introduced in this work. Among the fractional horse power motors it was to generate the state control mechanism to be flexible and economically possible to utilize. In this drive there are a couple of power supplies. For the frequency control circuit and the driver circuit the 12 V power supply was utilized. For H-bridge inverter the 300 V power supply was utilized. In order to regulate the frequency the pulse width modulation SG3525A IC was utilized in this drive. In the constructed variable speed drive the drive mechanisms of single-phase induction motor, principle operations of components were utilized and to construct this drive deliberated computation was involved in this work.

Mengxiang Chen ; Weidong Zhang, in this paper the author had projected the application of H2 optimal control to speed regulator for vector controlled induction motor drives. In the deliberation a mechanical movement model generated from vector control was implanted. An analytical optimal speed controller is attained that has a formation of PI controller. To prove the control mechanism the simulation based on MATLAB/ Simulink was carried out. The simulation results had demonstrated that for several speed commands the deliberated controller has good speed tracking capacity and against load torque alterations it was vigorous.

A. H. M. Yatim ; W. M. Utomo, in this paper the author had illustrated that the for variable speed drive mechanism the generation of an effective optimization control was significant that was useful to save the energy and also utilized in the greenhouse emission. For variable speed compressor induction motor drive the author defined the deliberation of a back propagation based efficiency optimization control (BPEOC). Concurrently, in order to produce the signal voltage and signal frequency references the controller was deliberated. The control of aped and effectiveness was permitted in this mechanism. An online learning paradigm was implanted to attain the vigorous BPEOC from alteration of motor parameters. The simulation results had demonstrated the effective enhancement in effectiveness and and advancement in the speed.

Yong Feng ; Minghao Zhou ; Xuemei Zheng ; Fengling Han ; Xinghuo Yu, in this paper the author had projected a nonsingular terminal sliding-mode control mechanism for induction motors. In the existing terminal sliding-mode control the chattering and singular phenomena occurred were removed. The simulation results had demonstrated that the projected mechanism can enhance the mechanism response speed, steady-state presentation and vigorousness of induction motor speed control mechanisms.

Ping Liu; Lanying Hao, in this paper the author had projected a sliding-mode speed controller among integral sliding surface to remove the control of parameter uncertainties on field-oriented control for induction motor drive. On the basis of the calculated terminal quantities through an adaptive paradigm the evaluated rotor speed utilized in speed feedback loop was evaluated. The rotor speed is exponential convergent was illustrated by the steadiness investigation on the basis of the Lyapunov theory that was offered. The simulation results had demonstrated that the features of the projected mechanism overall control mechanism was assured.

Sun Kai; Zhao Yanlei, in this paper the author had projected a new speed sensorless control mechanism for induction motor drives based on active-disturbance rejection controller. The dynamic model of q-axis current was an initial order nonlinear state equation having synchronous speed and rotor speed on the basis of the field-oriented control mechanism. The internal disturbance of q-axis current was the synchronous speed and rotor speed. Immediately the method uncertainties and disturbance could be approximated and compensated consistent with the active-disturbance rejection controller theory (ADRC). The rotor speed was monitored as the disturbance involving rotor speed was evaluated in real time. Among no information of the correct mechanism parameters the speed observer projected in this work realizes the disturbance compensation correctly by using the extended state observer (ESO) and state error feedback control law (NLSEF). The simulation results had demonstrated the rotor speed could be exactly evaluated from 0r/min to rated speed among load or not. Through this mechanism a better dynamic and static presentation of the sensorless vector control mechanism was attained.

Vo Thanh Ha, Nguyen Van Thang et al., in this paper the author had projected a mechanism of evaluating the speed of an induction motor Luenberger. Through the Lyapunov's theorem a steadiness of the projected adaptive flux observer would be verified. In order to evaluate motor speed among no speed sensors an adaptive mechanism could be utilized. Moreover, among no speed sensor utilizing DSP 1104 the experimental results of an indirect field-oriented induction motor control were offered. In order to confirm the principles and illustrated the practicality of this mechanism the simulation and experimental results were offered. In the observer those outcomes were attained under the situation that the motor parameters utilized were exact.

Bahram Kimiaghalam; Meisam Rahmani; Hassan Halleh, in this paper the author had projected a hybrid fuzzy logic controller (FLC) among vector-control mechanism for induction motors. Through utilizing FLC comparative to easy PD controller the vector-control mechanism had been enhanced. With the utilization of the FLC in this hybrid controller high quality regulation was attained, whereas the steadiness of the mechanism throughout transient and around wide range of operating points were ensured by application of the vector-control.

Qinghui Wu ; Lin Li ; Yanwei Pang ; Yang Wang,, in this paper the author had illustrated that consistent with the rotor flux oriented dynamic mathematical model from Induction motor, the speed can been approximated among synchronous speed based on the torque current differential. The speed sensorless vector control mechanism of Induction motor among current hysteresis loop control inverter was constituted arranging among slip formula. The simulation results had demonstrated that the control mechanism was valid and the speed evaluation mechanism was characterized through higher accuracy, faster dynamic response performance and higher steady precision.

S.T. Qiao; J.G. Jiang; X.J. Wu, in this paper the author had projected the Passivity-based control (PBC) or energy shaping mechanism. A distinctive characteristic of PBC for induction motor (IM) was that the state observer was not required comparative to the conventional mechanisms. For torque control the PBC mechanism was utilized to electrical subsystem of cage type induction motor in this work. The projected mechanism was non-linear proportional-integral (PI) controller for speed control. The specified filter and feedback filter were utilized to restrict the derivative of reference torque to restrict the torque instant variation. Through MATLAB/Simulink the Simulation model of speed control system was introduced. The simulation results had demonstrated that the projected composite passivity mechanism was useful in speed control of IM and the speed presentation was well at low speed. For other type motors and power converters the projected mechanism was appropriate.

5. CONCLUSION

For the mechanism whereas choosing the electric motor the other factors like mission goals, availability of power and cost can also be taken into an account. As employed experimentally, the entire knowledge about the uncertainties are very hard to fetch out. In induction motors to present position control a lot of research had been done. The basic motive of this paper was to review the origin and progress of speed control techniques. Various modern principles are revealed and the developments are reviewed in this paper. In this paper the author had surveyed different speed control techniques in order to search the better speed control technique that will be used to control the speed of the induction motor.

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