MODELLING OF INDUCTION MOTOR & CONTROL OF SPEED USING HYBRID CONTROLLER TECHNOLOGY

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Abstract- **This paper presents a novel design of a Takagi-Sugeno fuzzy logic control scheme for controlling some of the parameters, such as speed, torque, flux, voltage, etc. of the induction motor. Induction motors are characterized by highly non-linear, complex and time-varying dynamics and inaccessibility of some of the states and outputs for measurements, and hence it can be considered as a challenging engineering problem. The development of advanced control techniques has partially solved induction motor's speed control problems; because they are sensitive to drive parameter variations and the performance may deteriorate if conventional controllers are used. Fuzzy logic based controllers are considered as potential candidates for such an application. Further, the Takagi-Sugeno control strategy coupled with rule based approach in a fuzzy system when employed to the induction motor yields excellent results compared to the other methods as this becomes a hybrid & integrated method of approach. Such a mixed implementation leads to a more effective control design with improved system performance, cost-effectiveness, efficiency, dynamism, & reliability. The closed loop speed control of the induction motor using the above technique thus provides a reasonable degree of accuracy which can be observed from the results depicted at the end. Simulink based block model of induction motor drive is used for the simulation purposes & its performance is thereby evaluated for the speed control. The simulation results presented in this paper show the effectiveness of the method developed & have got a wide number of advantages in the industrial sector & can be converted into a real time application using some interfacing cards.**

Index Terms- **TS Model, Fuzzy Logic, Controller, Simulink, Matlab, Induction motor, Closed loop, Parameter, Robustness**

I. INTRODUCTION

Recent years have witnessed rapidly growing popularity of fuzzy control systems in engineering applications. The numerous successful applications of fuzzy control have sparked a flurry of activities in the analysis and design of fuzzy control systems. Fuzzy logic based flexible multi-bus voltage control of power systems was developed by Ashok *et.al*. In the last few years, fuzzy logic has met a growing interest in many motor control applications due to its non-linearities handling features and independence of the plant modeling.

The fuzzy controller (FLC) operates in acknowledge-based way, and its knowledge relies on a set of linguistic if-then rules, like a human operator. A scalar closed loop induction motor control with slip regulation & they also compared their results with those of a PI controller. They used a new linguistic rule table in FLC to adjust the motor control speed. The design and implementation of industrial control systems often relies on quantitative mathematical models of the plants (say, induction motors, generators, dc motors, etc), the controllers, etc. At times, however, we encounter problems for which controller design becomes very difficult and expensive to obtain. In such cases, it is often necessary to observe human experts or experienced operators of the plants or processes and discover rules governing their actions for automatic control. In this context, the fuzzy logic concepts play a very important role in developing the controllers for the plant as this controller does not require that much complicated hardware & uses only some set of rules. Recently, there has been observed an increasing interest in combining artificial intelligent control tools with classical control techniques. The principal motivations for such a hybrid implementation is that with fuzzy logic, neural networks & rough sets issues, such as uncertainty or unknown variations in plant parameters and structure can be dealt with more effectively, hence improving the robustness of the control system. Conventional controls have on their side well established theoretical backgrounds on stability and allow different design objectives such as steady state and transient characteristics of the closed loop system to be specified. Several works were contributed to the design of such hybrid control schemes which was shown by various researchers.

There is a number of significant control methods available for induction motors including scalar control, vector or field-oriented control, direct torque and flux control, sliding mode control and the adaptive control. Scalar control is aimed at controlling the induction machine to operate at the steady state, by varying the amplitude and frequency of the fundamental supply voltage. A method to use of an improved V/f control for high voltage induction motors was proposed in. The scalar controlled drive, in contrast to vector or field-oriented controlled one, is easy to implement, but provides somewhat inferior performance. This control method provides limited speed accuracy especially in the low speed range and poor dynamic torque response. Two researchers, Takagi & Sugeno developed a excellent control scheme for control of various applications in the industrial sector. This controller had many advantages over the other methods discussed so far. Many researchers started using their models for their applications. Zie, Ling & Jhang presented a TS model identification method by which a great number of systems whose parameters vary dramatically with working states can be identified via Fuzzy Neural Networks (FNN). The suggested method could overcome the drawbacks of traditional linear system identification methods which are only effective under certain narrow working states and provide global dynamic description based on which further control of such systems may be carried out. Since, the induction motor is a complex nonlinear system; the time-varying parameters entail an additional difficulty during the controller design. Vector control methods have been proposed by various researchers to simplify the speed control of induction motors so they can be controlled like a separately excited dc machine. Indirect vector control methods decouple the motor current components by estimating the slip speed, which requires a proper knowledge of the rotor time constant. Classical control systems like PI, PID control have been used, together with vector control methods, for the speed control of induction machines. The main drawbacks of the linear control approaches were the sensitivity in performance to the system parameters variations and inadequate rejection of external perturbations and load changes. As an attempt to solve all these deficiencies, problems & difficulties encountered in designing the controller as mentioned in the above paragraphs, we have tried to devise a control strategy using the Takagi-Sugeno fuzzy scheme for the speed control of IM in our paper which has yielded excellent results & this has been applied to the control of electrical drive systems (induction motor). The results of our work have showed a very low transient response and a non-oscillating steady state response with excellent stabilization.

The structure of the work (flow / organization of the paper) presented in this research paper is organized in the following sequence. A brief review of the literature survey of the related work was presented in the previous paragraphs in the introductory section.

II. CONTROLLER DESIGN

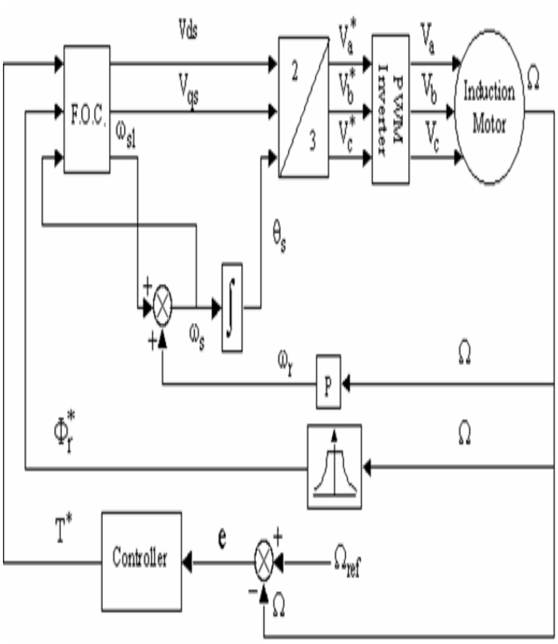
A controller is a device which controls each & every operation in the system making decisions.

From the control system point of view, it is bringing stability to the system when there is a disturbance, thus safeguarding the equipment from further damages. It may be hardware based controller or a software based controller or a combination of both. In this section, the development of the control strategy for control of various parameters of the induction machine such as the speed, flux, torque, voltage, stator current is presented using the concepts of Takagi-Sugeno based fuzzy control scheme. To start with, we design the FLC, and then combine with the TS scheme, finally to obtain the hybrid controller. Fuzzy logic is one of the successful applications of fuzzy set in which the variables are linguistic rather than the numeric variables & emerged as a consequence of the 1965 proposal of fuzzy set theory by Lotfi Zadeh. Linguistic variables, defined as variables whose values are sentences in a natural language (such as large or small), may be represented by the fuzzy sets. Fuzzy set is an extension of a ‘crisp’ set where an element can only belong to a set (full membership) or not belong at all (no membership). Fuzzy sets allow partial membership, which means that an element may partially belong to more than one set. A fuzzy set A of a universe of discourse X is represented by a collection of ordered pairs of generic element $x \in X$ and its membership function $\mu : X \rightarrow [\ 0\ 1]$, which associates a number $\mu A(x) : X \rightarrow [\ 0\ 1]$, to each element x of X. A fuzzy logic controller is based on a set of control rules called as the fuzzy rules among the linguistic variables. These rules are expressed in the form of conditional statements. Our basic structure of the fuzzy logic coordination controller to damp out the oscillations in the power system consists of 3 important parts, viz., fuzzification knowledge base – decision making logic (inference system).

B.DEVELOPMENT OF SIMULINK MODEL

The block model of the induction motor system with the controller was developed using the power system, power electronics, control system, signal processing toolboxes & from the basic functions available in the Simulink library in Matlab / Simulink. In this paper, plots of voltage, torque, speed, load & flux, etc are plotted as functions of time with the controller and the waveforms are observed on the corresponding scopes after running the simulations. The entire system modeled in

Simulink is a closed loop feedback control system consisting of the plants, controllers, samplers, comparators, feedback systems, the mux, de-mux, summers, adders, gain blocks, multipliers, clocks, sub-systems, integrators, state-space models, subsystems, the output sinks (scopes), the input sources, etc.



III. SIMULATION RESULTS & DISCUSSIONS

Simulink model with the controller for the speed control of IM is developed in Matlab 7. The simulation is run for a specific amount of time (say 2 to 3 secs) in Matlab 7 with a reference speed of 100 rads / sec { ( ) } 2π

i.e., 100 × 60 = 955 rpm & with a load torque of 2 N-m. Note that the fuzzy coordinated TS controller consists of 3 basic blocks viz., fuzzification, inference, and the de-fuzzification blocks as shown. A set of 49 fuzzy rules are written and called in the form of a file in the developed Simulink model with the controller. While the simulation is run, the 2 fuzzy inputs are then given to the controller (Takagi-Sugeno-fuzzy), where the output is obtained thereafter. The response curves of flux, load, torque, terminal voltage, and speed & stator currents v/s time are observed on the respective scopes & are shown in the Figs. 5 – 9 respectively after importing the scope data into the workspace and plotting them.

From the simulation results, it is observed that the stator current does not exhibit any overshoots, undershoots, the response of the flux, torque, terminal voltage, speed & stator currents, etc. takes lesser time to settle & reach the desired value compared to the results presented. It was observed using the Mamdani control strategy for the same set speed & the 49 rules, the speed reaches its desired set value (becomes stable) at 1.4 seconds, whereas in this paper using the TS-fuzzy control for the sam mathematical model & for the same set speed & for the same 49 rules, the speed reaches its desired set value at 0.7 seconds.

This shows the effectiveness of the developed controller. It is also observed that with the controller, the response characteristics curves take less time to settle & reach the final steady state.

IV. CONCLUSIONS

A systematic approach of achieving robust speed control of an induction motor drive by means of Takagi-Sugeno based fuzzy control strategy has been investigated in this paper. Simulink models were developed in Matlab 7 with the TS-based fuzzy controllers (hybrid controller) for the speed control of IM. The control strategy was also developed by writing a set of 49 fuzzy rules according to the TS control strategy. The main advantage of designing the TS based fuzzy coordination scheme to control the speed of the IM is to increase the dynamic performance & provide good stabilization. Simulations were run in Matlab

7 & the results were observed on the corresponding scopes. Graphs of speed, torque, stator current, flux, etc. vs. time were observed.

The outputs takes less time to stabilize, which can be observed from the simulation results. But, from the incorporation of the TS based fuzzy coordination system in loop with the plant gave better results there by stabilizing the plant very quickly. The developed control strategy is not only simple, reliable, and may be easy to implement in real time applications, but also cost-effective as when this control scheme is implemented in real time, the size of the controller will become very small. Collectively, these results show that the TSfuzzy controller provides faster settling times, has very good dynamic response & good stabilization.

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