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"Vector Speed Control of Induction Motor using self-adjusting Fuzzy controller for Grain Drying System"

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***Abstract*-— Grain drying is process of drying grain to prevent spoilage during storage and its process has the characteristics of large time delay, nonlinearity, multi disturbance and strong coupling.The Direct Torque Control (DTC) is the fastest responding method in the vector control family in the induction motor control. The torque and the flux estimation is observed directly from the voltage and the current observed from the winding unlike getting the speed and then finding the desired flux and torque.In the actual control process of grain drying, the speed of the discharging motor is controlled to realize the drying target by detecting the outlet grain moisture. In order to reduce the grain moisture content during Continuous flow drying process, to ensure the grain quality of the grain, and enable the uniform moisture content of outlet grain, to control the speed of grain flow, a new improved controller model for grain drying which called the self-adjusting fuzzy controller is proposed and the problem of fixed change rate of the parameters of general PID controller is solved. This Project implements the direct torque control on the Induction motor with low ripples and fast torque dynamics. The flux estimation, torque estimation and the speed control technique for switching the Induction motor is the prime portion of the control system which is taken care by the self-adapting fuzzy controller based system. MATLAB based simulation is carried and compared for the dynamic response and the reduced torque ripples with PI controller.**

***Keywords* -Direct Torque Control (DTC), Field Oriented Control (FOC), the Space Vector Modulation (SVM), fuzzy logic controller (FLC),grain drying; dryer, fuzzy control, intelligent control.**

I. INTRODUCTION

Grain dryers fall into two categories; batch dryers and continuous flow dryers. In batch dryers, the grain is dried either with heated air in shallow layers of less than 1 m or with low-temperature air in beds of several meters in depth. The drying may take place in hours, days, weeks, or even months. Continuous-flow dryers are high-capacity dryers and are classified according to the relative direction of grain and airflow such as: cross-flow, concurrent-flow, counter-flow, and mixed flow.The grain dryer control systems considered fall into two categories: in-bin aeration drying controllers and continuous-flow dryer controllers.

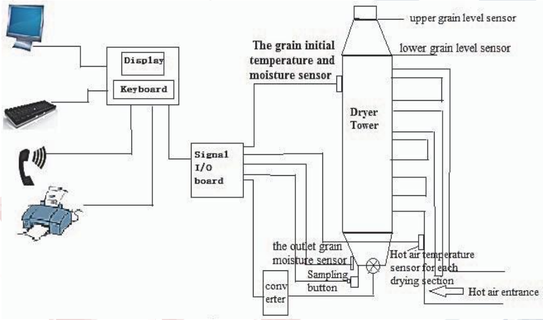
The basic objectives are usually the same for both controller types, namely, to achieve a Uniform final moisture content while maximizing the capacity under acceptable conditions of grain-quality deterioration and energy consumption. The control of in-bin drying or aeration systems consists of controlling the fan operation and sometimes the heaters. In continuous-flow dryers, the speed of the unload augers and the temperature of the drying air are the control parameters.

The moisture content of wet grain reaching a high-temperature continuous-flow dryer over a 24-hr period can vary greatly. This is due to the different harvest-procedure preferences, soil types, and variety selections of individual farmers. At commercial ele¬vators it is not unusual to encounter moisture content differences of 10-15% in lots of corn received from different growers. Yet all the grain must be dried to approximately the same average moisture content. The challenge presented to the dryer operator, or the automatic controller, is to properly vary the speed of the unload auger and thus the residence time of the grain in the dryer.

Manual control of continuous-flow dryers often leads to signifi¬cant overdrying or underdrying. The manual control decisions in changing the auger speed are based on hourly readings of the inlet and outlet moisture contents of the grain. The operator succeeded in keeping the average outlet moisture content to within 0.9% of the setpoint.Automatic control of continuous-flow dryers is usually designed to minimize the overdrying or underdrying of the grain. Secondary objectives are minimizing energy consumption and optimizing dryer capacity, both necessarily subject to grain quality constraints.

II. GRAIN DRYER PRINCIPLE

According to dry process, dryers are usually classified into cross-flow, concurrent-flow, counter-flow, and mixed-flow. In general, large-scale drying equipment is mainly composed of hoisting machine, discharged machine, hot blast furnace, blower, and granary, etc.Take the tower dryer for example, its workflow is described as followed: first finish the parameters setup; next, starts the hot air blower to work; the certain hot air is blowing into the drying tower, then, lifting machine starts to work, and the wet grain come into the granary from the grain entrance, when the lower grain level sensor alarm, the end of the grain discharged. Thereafter the hot air and wet material contact in the drying mode, and heat and mass exchange to dry grain. In the whole dry process, the speed of the discharge grain motor is adjusted by the intelligent control center every time interval according to the detected drying parameters, after the outlet grain moisture has reached the target value, the grain is discharged, and the dry process ends. The dryer control schematic diagram is shown in Figure



. *Figure 1.Schematic diagram of the tower drier*

There are many factors that affect the control of grain drying, the main factors of which are the grain initial temperature and inlet moisture, the ambient environment temperature and moisture, the hot air and cooling air flow, the hot air temperature, and the speed of the grain. Under a certain period of time and environmental conditions, some variables can be thought to be unchanged for a certain batch of grain drying, such as: the grain initial temperature and initial moisture content, the ambient environment temperature and moisture, hot air and cooling air flow. In order to further simplify the control model, in general, the air temperature and air flow are also considered as quantitative in the actual control process of grain drying, in which, the speed of the discharging motor is controlled to realize the drying target by detecting the outlet grain moisture according to the corresponding control algorithm.

III. LITERATURE SURVEY

In the sixties of the 20th century, the main control methods of grain drying process were forward control, feedback control, forward-feedback control and other traditional control which were not too much stable [2].The traditional control algorithms are dependent on the clear mathematical model of controlled object, it is difficult to reach the ideal control effect for such a complex system as grain drying.In 1970s, the research development of computer control technology and artificial intelligence have provided new ways for advanced control of grain drying [3], thereafter drying control come into the intelligent control period. Intelligent controlwith adaptive and robustCharacteristicshas the advantages of learning and reasoning.Zhang (1990) simulated a prototype fuzzy control system in conjunction with a crossflow corn dryer. In 1997, research by Taprantzis shows that the fuzzy control has better dynamic characteristics than PI control [4].

DTC was a work from three individuals Manfred Depenbrock[6-7],Isao Takahashi and Toshihiko Noguchi[8]. The DTC was introduced to be implemented on the induction motor drive and the control technique was variable frequency in approach but after the Space Vector Modulation (SVM) [9] it grown into a constant frequency operation . The DTC got introduced to PMSM in [10].

Before the SVM the hysteresis controller were used which provide a variable frequency which would provide the torque ripple in the output A thorough analysis of the torque ripples due to the hysteresis control is introduced in [11]. The torque ripples are dependent on the size of hysteresis, which is again dependent on the speed of the digital systems controlling it. Thus the torque ripple reduction can be brought in to a certain level only by the use of these techniques. Adaptation of SVM was used in many literature later on like in [12].Although the torque ripple reduction has been a reduced to a major extent but the control performance is poor with some steady state errors.

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IV. OBJECTIVE OF THE PROJECT

The grain drying process has the characteristics of large time delay, nonlinearity, multi disturbance and strong coupling.The air temperature and airflowareconsideredascontrol parametersintheactualcontrol process of grain drying, in which, the speed of the discharging motor is controlled to realize the drying target by detecting the outlet grain moisture. In order to reduce the grain moisture content during drying process, to ensure the grain quality of the grain, and enable the uniform moisture content of outlet grain, a new improved controller model for grain drying which called as the self-adjustingfuzzy controller is proposed based on feedback mechanism and the problem of fixed change rate of the parameters of general PID controller is solved.

V. DTC OF INDUCTION MOTOR PRINCIPLE

The basic idea of the DTC technique is to choosing the optimum vector of the voltage, which makes the flux rotate and produce the desired torque. In conventional DTC method, the control of an induction motor involves the direct control of stator flux vector by applying optimum voltage switching vectors of the inverter. For this control, the stator current should be decoupled two independent components as flux and torque components like dc motors. The Clarke transformation method is uses in this decoupling process in the DTC method. The DTC allows for very fast torque responses, and flexible control of the induction motor.The DTC bases on the selection of the optimum voltage vector which makes the flux vector rotate and produce the demanded torque. In this rotation, the amplitude of the flux and the torque errors are kept within acceptable limits by hysteresis controllers.

The speed of the motor is controlled by controlling the electromagnetic torque. To control the electromagnetic torque, the actual torque and change in torque is processed through fuzzy logic controller (FLC) which will produce the controlled electromagnetic torque in proportional to the speed of the motor. A nonlinear variable structure is used to control the flux and the torque with constant frequency. But the computational cost is higher in this method.

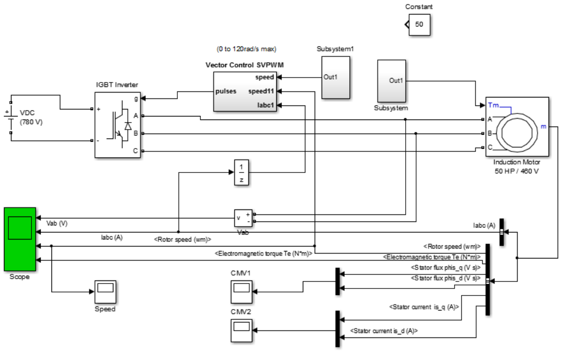

Figure 2: Direct Torque Control Process Simulink model using vector control SVPWM.

In order to get the reduced torque ripple with the constant frequency the above block diagram based Implementation is carried out.The observed values of the flux and the torque errors are compared to reference the flux and the torque values and the resultant errors are applied to the hysteresis comparators as inputs. Two different hysteresis comparators, as flux and torque comparators, generate other control parameters on the DTC method. According to the hysteresis comparators outputs, the observed angle of flux linkage and using a switching table, optimum voltage vectors are selected and applied to the inverter.

VI.SELF ADJUSTING FUZZY CONTROLLER

Fuzzy logic control (FLC) is a control algorithm based on a linguistic control strategy which tries to account the human's knowledge about how to control a system without requiring a mathematical model [11]. The approach of the basic structure of the fuzzy logic controller system is illustrated in Fig.3.

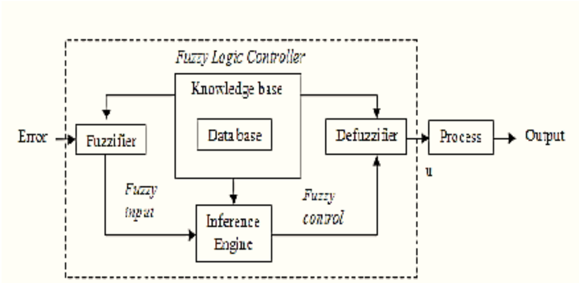

Figure 3: Structure of fuzzy logic controller.

Input and output are non-fuzzy values and the basic configuration of FLC is featured in Fig.4. In the system presented in this are sugeno type of fuzzy logic and is used for speed controller. Inputs for Fuzzy Logic controller are the speed error (e) and change of speed error. Speed error is calculated with comparison between reference speed, ωref and the actual speed, ωact.
The output of the fuzzy controller u(k) is given by:
$u(k)= Ff\ [e(k)- \Delta e(k)]$
whereFf is a non-linear function determined by fuzzy parameters, e(k), Δe(k) are the error and change of error respectively. The fuzzy logic controller was used to produce an adaptive control so that the motor speed,ωact can accurately track the reference speed, ωref. The most important things in fuzzy logic control system designs are the process design of membership functions for input, outputs and the process design of fuzzy if-then rule knowledge based.

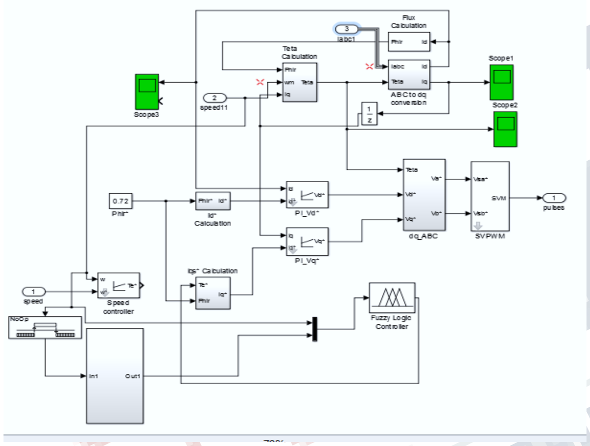

Figure 4: Simulink design of vector control SVPWM using fuzzy logic controller for DTC .

The three main stages involved in the development ofa fuzzy self-adapting controller are Development of system model using block diagram, Selection of membership function, Formation of rule base.
PI controller has a simple control structure which is easy to understand but the response of PI controller is not fast and it robustness to un-modeled dynamics is not enough. To overcome this problem fuzzy logic controller is designed. Fuzzy logic controllers (FLCs) are based on experience of a human operator and they are increasingly applied to many systems with nonlinearity and uncertainty.A fuzzy controller measures the outputs of the processand continuously controls the process actions. The fuzzycontroller utilizes a form of quantification of inexplicitinformation (input fuzzy sets) and a knowledge base togenerate control force to be applied to the system.

VII. RESULTS

Theself- adjustable fuzzy PID controller rule based DTC technique was implemented in Matlab platform. From the proposed model, the speed, torque, current, flux and voltage were analyzed. The new methodology has improved low ripple and dynamicresponses can be analyzed from the DTC of IM. The results are shown in figure 4.

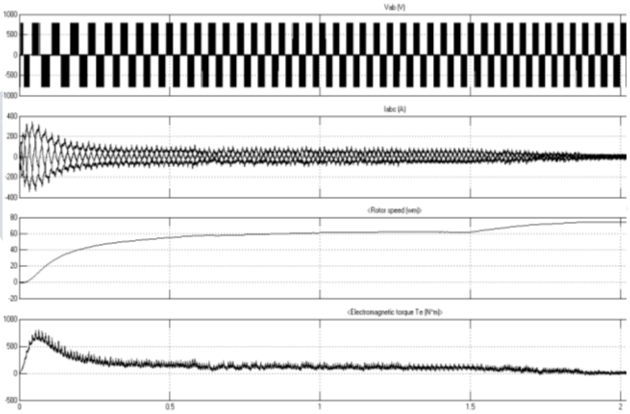

Figure 4:voltage, current, speed and Electromagnetic torque waveform of self-adjusting fuzzy logic controller for DTC of IM.

VIII. FUTURE WORK

By simulation on the performance comparisons of different control methods, it is testified that in future controlling design planning to combining the Fuzzy and PID controller with immune feedback mechanism expecting faster response speed, better accuracy and strong anti- jamming, which can be effectively applied in the control of grain dryingprocess.

IX. CONCLUSION

The proposed self- adjustable fuzzy controller rule based DTC technique was implemented in MATLAB-SIMULINK platform. Then, the speed control performance of proposed control technique was compared with other control techniques. From the proposed model, the speed, torque, current, flux and voltage were analyzed. The new methodology has low ripple and fast dynamic responses can be applied to DTC of IM.

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