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Discrete PI and PID Controller Based Three Phase Induction Motor Drive: A Review

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ABSTRACT: In this paper we give review of discrete PI and PID control have found high applications in most of the nonlinear systems like the electric motor drives. Proportional, Integral and Derivative (PID) parameters controller for vector control of induction motor. The l parameters for current loop, flux loop, and speed loop as functioned required settling time and motor parameters will be computed by the proposed method of reliability & performance of the AC drive increases. This paper presents a discrete PI and PID control based speed controller and its design for vector controlled induction motor drive.

Key words: Induction motor, Vector control, PI, PID Control

I. INTRODUCTION

Induction motors are widely used in industries due to its robust construction and low maintenance. Separately excited dc drives are simpler in control because independent control of flux and torque can be brought about. In contrast, induction motors involve a coordinated control of stator current magnitude and the phase, making it a complex control. The stator flux linkages can be resolved along any frame of reference. This requires the position of the flux linkages at every instant. Then the control of the ac machine is very similar to that of separately excited dc motor. Since this control involves field coordinates it is also called field oriented control. The requirement of the phase angle of the flux linkages in the control process gives the name vector control [1].

Along with industrial progress high performance drives are essential. Recent advances in semiconductors, converters and new control techniques have great role in this progress. Usually classical control requires accurate mathematical model of the system and also its performance decreases for nonlinear system such as drives. Recently by adapting non linear speed control techniques the dynamic performance of electric drives can be improved.

This paper review of implementation of discrete PI and PID control scheme applied to model of Induction motor. Both the controllers are developed on MATLAB environment. The performance of discrete PI and PID controller is compared with that of classical controller in terms of rise time and steady state error. The developed control scheme was verified by simulation and the results obtained demonstrate the effectiveness of intelligent controllers.

II. PID CONTROLLERS

PID controllers use a 3 basic behavior types or modes: P - proportional, I - integrative and D -derivative. While proportional and integrative modes are also used as single control modes, a derivative mode is rarely used on its own in control systems, such as PI and PD control are very often in practical systems.

P Controller: In general it can be said that P controller cannot stabilize higher order processes. For the 1st order processes, meaning the processes with one energy storage, a large increase in gain can be tolerated. Proportional controller can stabilize only 1st order unstable process. Changing controller gain K can change closed loop dynamics. A large controller gain will result in control system with:

a) smaller steady state error, i.e. better reference following

b) faster dynamics, i.e. broader signal frequency band of the closed loop

system and larger sensitivity with respect to measuring noise

c) smaller amplitude and phase margin

When P controller is used, large gain is needed to improve steady state error. Stable systems do not have problems when large gain is used. Such systems are systems with one energy storage (1st order capacitive systems). If constant steady state error can be accepted with such processes, than P controller can be used. Small steady state errors can be accepted if sensor will give measured value with error or if importance of measured value is not too great anyway.

PD Controller: D mode is used when prediction of the error can improve control or when it necessary to stabilize the system. From the frequency characteristic of D element it can be seen that it has phase lead of 90°.Often derivative is not taken from the error signal but from the system output variable. This is done to avoid effects of the sudden change of the reference input that will cause sudden change in the value of error signal. Sudden change in error signal will cause sudden change in control output. To avoid that it is suitable to design D mode to be proportional to the change of the output variable.

PD controller is often used in control of moving objects such are flying and underwater vehicles, ships, rockets etc. One of the reason is in stabilizing effect of PD controller on sudden changes in heading variable y(t).

Often a "rate gyro" for velocity measurement is used as sensor of heading change of moving object.

PI Controller: PI controller will eliminate forced oscillations and steady state error resulting in operation of on-off controller and P controller respectively. However, introducing integral mode has a negative effect on speed of the response and overall stability of the system. Thus, PI controller will not increase the speed of response. It can be expected since PI controller does not have means to predict what will happen with the error in near future. This problem can be solved by introducing derivative mode which has ability to predict what will happen with the error in near future and thus to decrease a reaction time of the controller.

PI controllers are very often used in industry, especially when speed of the response is not an issue. A control without D mode is used when:

a) fast response of the system is not required

b) large disturbances and noise are present during operation of the process

c) there is only one energy storage in process (capacitive or inductive)

d) there are large transport delays in the system.

PID Controller: PID controller has all the necessary dynamics: fast reaction on change of the controller input (D mode), increase in control signal to lead error towards zero (I mode) and suitable action inside control error area to eliminate oscillations (P mode). Derivative mode improves stability of the system and enables increase in gain K and decrease in integral time constant Ti, which increases speed of the controller response. PID controller is used when dealing with higher order capacitive processes (processes with more than one energy storage) when their dynamic is not similar to the dynamics of an integrator (like in many thermal processes). PID controller is often used in industry, but also in the control of mobile objects (course and trajectory following included) when stability and precise reference following are required. Conventional autopilot is for the most part PID type controllers.

III. REVIEW

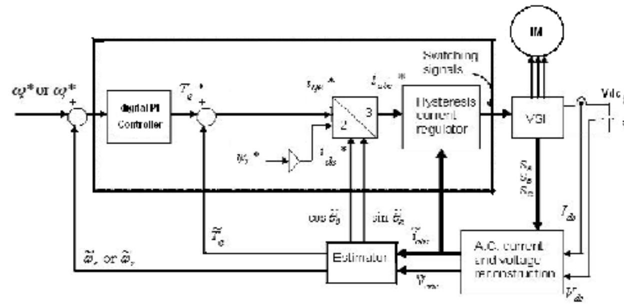
Mohammad H. Moradi Pouria G. Khorasani [2] in 2008 proposed a very fast simulation approach to analysis the transient behavior of three-phase squirrel-cage type induction motor. The well known model with four differential equations of voltage and current in rotor reference frame along with the torque equation is used to model the motor. Also, in the proposed model, the saturation of both magnetizing and leakage inductances is considered as function of magnetizing current. The commercial software package, MATLAB, is used to implement the transient behavior of the model. The validation and speed of obtained model is tested and compared with Matlab/Simulink conventional model and published paper**.** Mohamed Boussak [8] in 2006 proposed A new method for the implementation of a sensor less indirect stator-flux-oriented control (ISFOC) of induction motor drives with stator resistance tuning is proposed in this paper. The proposed method for the estimation of speed and stator resistance is based only on measurement of stator currents. The error of the measured q-axis current from its reference value feeds the proportional plus integral (PI) controller, the output of which is the estimated slip frequency. It is subtracted from the synchronous angular frequency, which is obtained from the output integral plus proportional (IP) rotor speed controller, to have the estimated rotor speed. For current regulation, this paper proposes a conventional PI controller with feed forward compensation terms in the synchronous frame. Owing to its advantages, an IP controller is used for rotor speed regulation. Stator resistance updating is based on the measured and reference d-axis stator current of an induction motor on $d-q$ frame synchronously rotating with the stator flux vector. Adnan Derdiyok [4] in 2005 proposed. This paper presents a continuous approach of sliding-mode current and flux observers for an induction machine. The proposed observer structure both decouples machine equations and makes them completely insensitive to rotor resistance variation. An estimation algorithm based on these observers is proposed to calculate speed and rotor resistance independently. In the proposed algorithm, the speed and rotor resistance are considered to be unknown constants, because the speed and rotor resistance change slowly compared to the electrical variables such as currents and fluxes.Giuseppe Guidi [5] in 2000 proposed a method for online estimation of the stator resistance of an induction machine is presented and a speed-sensor less field-oriented drive equipped with the proposed estimator is built. The drive is particularly suitable for low-speed operation. Resistance estimation is based on a two-time-scale approach, and the error between measured and observed current is used for parameter tuning. The simple full-order observer in use allows for direct field orientation in a wide range of operation.Cristian Lascu, Ion Boldea [7] in 2004 proposed a new, direct torque and flux control strategy based on variable-structure control and space-vector pulse width modulation is proposed for induction motor sensor less drives. The DTC transient merits and robustness are preserved and the steady state behavior is improved by reducing the torque and flux pulsations. R. Bojoi, P. Guglielmi, G. Pellegrino [8] in 2006 proposed A Sensor less Direct Rotor Field Oriented Control (SDRFOC) scheme of three-phase induction motors for low cost applications is presented in this paper controlled induction motor drives without employing mechanical speed sensors have the advantage of reduced cost and high reliability. Hongrae Kim, [9] in 2006 proposed Three-phase current measurement using only a single current sensor in the inverter dc link is appealing for ac motor drives because it minimizes the number of current sensors, thereby reducing sensor cost, weight, and volume. However, the basic dc link single current sensor technique poses special challenges because the duration of the active voltage vectors must belong enough to measure the dc link current reliably during every pulse width modulation switching interval.

A new single current sensor algorithm for reconstructing the phase currents called the measurement vector insertion method (MVIM) is presented that overcomes this problem using active voltage vectors that are applied for brief measurement intervals only when needed during each fundamental frequency cycle. Suman Maiti ,Chandan Chakraborty,Yoichi Hori and Minh C. Ta [12] in 2006 proposed The Model Reference Adaptive Controller (MRAC) utilizing the reactive power is presented for the online estimation of rotor resistance to maintain proper flux orientation in an Indirect FOC Induction Motor Drive. Selection of reactive power as the functional candidate in the MRAC automatically makes the system immune to the variation of stator resistance. Moreover, the unique formation of the MRAC with the instantaneous and steady-state reactive power completely eliminates the requirement of any flux estimation in the process of computation.R. Bojoi, P.Guglielmi, G. Pellegrino [10] in A in 2006 proposed Sensor less Direct Rotor Field Oriented Control (SDRFOC) scheme of three-phase induction motors for low cost applications is presented in this paper. The SDRFOC algorithms based on a sensor less rotor flux closed-loop observer whose main advantages are its simplicity and robustness to motor parameter detuning. The whole algorithm has been developed and implemented on a low-cost fixed-point DSP controller. C. Lascu, I. Boldea, F. Blaabjergl [11] in A in 2006 proposed a variable structure, direct torque controlled, sensor less induction machine drive. is presented, in which the principles of Direct Torque Control (DTC), Variable Structure Control, and Space Vector Pulse Width Modulation are combined to ensure high-performance operation, both In the steady state and under transient conditions. Bimal K. BOSE "Modern Power Electronics and AC drives." [1] Proposed Sensor-less control in the wide spread industrial use of induction motor (IM) has been simulated over the years by their relative cheapness, low maintenance and high reliability. The control of induction motor variable speed drives. FOC has been widely used for the high-performance drive of the induction motor. As in dc motor, torque control of the induction motor is achieved by controlling torque and flux components independently. FOC techniques can be separated into two categories: direct and indirect flux vector orientation control schemes. For direct control methods, the flux vector is obtained by using stator terminal quantities, while indirect methods use the machine slip frequency to achieve field orientation.

IV. VECTOR CONTROL

Indirect vector control method is very popular in industrial applications. The block diagram of VCIMD is shown in fig.1. The motor current is decomposed in two components ids and iqs, direct and indirect axis current with respect to synchronously rotating reference frame. These current are responsible for producing flux and torque respectively. Here unit vector signals are generated in feed forward manner. This method uses indirect procedure to ensure presence of rotor flux in the direct axis.

With the help of an intelligent controller, the speed error is converted into a torque controlling current component iqs, of the stator current. This current component is used to regulate the torque along with the slip speed. [1]



(Block diagram of vector control)

The following equations are necessary to implement vector control scheme.

$$\theta_e = \int (w_r + w_{sl}) \quad \text{-------------} (1)$$

The rotor circuit equation can be written as,

$$\frac{d\Psi_{dr}}{dt} + R_r i_{dr} - (w_e - w_r)\Psi_{qr} = 0 \quad \text{-------------} (2)$$

$$\frac{d\Psi_{qr}}{dt} + R_r i_{qr} + (w_e - w_r)\Psi_{qr} = 0 \quad \text{-------------} (3)$$

For decoupling control,

$$\Psi_{qr} = 0$$

$$\frac{L_r}{R_r}\left(\frac{d\Psi_r}{dt}\right) + \Psi_r = L_m i_{ds} \quad \text{-------------} (4)$$

The slip frequency can be calculated as,

$$w_{sl} = \frac{L_m R_r}{\Psi_r L_r} I_{qs} \quad \text{-------------} (5)$$

$$\Psi_r = L_m i_{ds}$$

Thus, rotor flux is directly proportional to current i_{ds} in steady state. The motor developed torque is directly related to i_{qs} as follows:

$$T_e = \left(\frac{3}{2}\right)\left(\frac{P}{2}\right)\left(\frac{L_m}{L_r}\right)\Psi_r i_{qs} \quad \text{-------------} (6)$$

$$i_{qs} = \left(\frac{4}{3P}\right)\left(\frac{L_r}{L_m}\right)\left(\frac{T_e}{\Psi_r}\right) \quad \text{-------------} (7)$$

This current component is used to regulate the torque. [2]

V. CONCLUSION

This paper introduces review of discrete PI and PID controller based three phase induction motor drive with indirect vector control of induction motor using intelligent techniques. It successfully demonstrates the application of PID controller for vector controlled induction motor drive.

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