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Implementation Of Model Reference Adaptive System On Induction Motor Speed Control Based On Vector Control

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Abstract: *Induction motor many used at industrial technology, because the motor having advantages in design and endurance, and at general induction motor with low speed control application,* ***From the background the researcher make implemaentation MRAS methode to control low speed indution motor without load. The application on the PC will control the microcontroller. Commands are given serially via USB to serial UART to the ATmega128 RX / TX pin. Furthermore ATmega128 will parse the data received, obtained in the system. In the experiments that have been carried out, it can be seen that the motor speed can move following the predetermined set point. Rise time of the system reaches about 5 seconds. The system reaches steady state conditions in 6.5 seconds. The same applies to low speed settings. The motor can move as well as using a controller taking into account the speed sensorit appears that the motor speed increases following the set point within 10 seconds, so that the speed reaches stability even with the presence of an oscillation peak value of ± 100rpm. This means, there is an oscillation deviation reaching 6.6% of the set points. MRAS techniques for controlling low speed induction motors can work like a controller that uses a speed sensor. During testing at low speeds using 22 Rpm, 43, 54, 105 and 194 Rpm set points, the motor can reach each steady state in the range of 5 to 7.*

Keywords–*MRAS, Vector Control, Induction Motor, Microcontroler Atmega128, Low Speed.*

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I. INTRODUCTION

Induction motor many used at industrial technology, because the motor having advantages in design and endurance, and at general induction motor with low speed control application.Induction motors have been widely used in the industrial world due to their advantages in simplicity of construction, durability, relatively low maintenance costs and production costs. Basically, an induction motor is a constant speed motor so it is a little difficult to control it especially at low speeds. The simplest control, requires a speed sensor to monitor rotational speed data so that it can be used as a reference to provide feedback on the reference variable provided. However, in some applications, the use of speed sensors has disadvantages such as reducing system reliability under certain conditions, weight gain, cost and complexity[1].

There needs to be a controller that can accommodate the induction motor speed control process. It becomes a challenge to create a controller that is able to operate a three-phase induction motor at low speed[2].To monitoring rotated of induction motor using speed sensor[3], from this sensor getting the new variable giving to variable reference, but some application using speed sensor having weeknest, where the sensor be a load to induction motor.The work performance of the controller in controlling the speed of the induction motor requires toughness in handling any model plant as difficult as any, in any range and on a scale that can be realized easily. Because the induction motor has several disadvantages, one of them has non-linear parameter characteristics, especially rotor resistance which has varying values for different operating conditions, so it cannot maintain its constant speed especially at low speeds.To control induction motor need a controller with abillity to solve difference plant model, because the motor having non linear characteristic at rotor resistance, where the rotor having variable resistance to different condition.

To getting speed constant and performance better at low speed motor, using contoler with abillity to solve difference parameters at induction motor. From some estimation technique variable speed control using Model Reference Adaptive System (MRAS), where this system having simple stucture and advantages to solve it.In scheming low speed control motor without sensor, motor speed will calculation and convert to be new variable to input close loop speed control application.At estimation induction motor speed, MRAS methode can calculation with some approach estimation, like fluks rotor, energy and back-EMF[4]. From the background the researcher make implemaentation MRAS methode to control low speed indution motor without load.

II. LITERATURE REVIEWAND THEORY

From this research having some literature review, from research Akin Acar implementation of a vector controlled induction motor drive, where this research implementation of control 3 phase induction motor using vector control methode. From research the equality voltage used to fluks estimation, stator coil resistance used to equality voltage, and inductance leak, mutual inductance, rotor resistance, used to calculate at vector control[5]. From research Joachim Holtz sensorless vector control of induction motor at very low speed using a non linear inverter model an pharameters identification. This research using integrator having hight bandwidth to stator fuks estimation, and ofset and drift identification componen to vector control implementation[6].

From the research Mohammad Haseeb Khan Sensorless Control of Induction Motor Drive During Low Speed Region Using IFLC based MRAS Speed Observer. This research improvment to control induction motor wih convert the pharameters konventional control PI-MRAS, speed observer be integrated fuzzy logic controller (IFLC), where this system can solve the induction motor speed with load. To MRAS methode having 3 estimation, reference model speed motor become a reference can changed with another setting,adaptive model is permanent pharameters at error from speed motor,and mechanism adaptive to getting rotor speed estimation [7].

1. Model Reference Adaptive System (MRAS)

MRAS is one of the most popular adaptive control methods used in motor control applications to track and observe the conditions and parameters of a system. MRAS is a method of controlling different adaptive reference models such as series models, parallel models, direct models and indirect models or other models. Many previous studies have been carried out to eliminate the existence of speed sensors in an induction motor control. One method used to overcome the existence of a speed sensor is to only measure the current and voltage of the induction motor. This method estimates the two variables to be used as a reference for motor speed, usually known as the MRAS method[8], at figure 1 MRAS Block system.

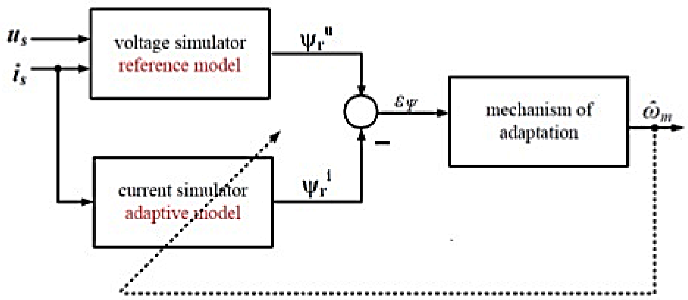

Figure 1. Block MRAS System

MRAS estimator consists of reference models and adjustable (adaptive) models as shown in Figure 1. Adaptation speed law governs the estimated speed based on the output of the reference and adaptive model. The MRAS used in this model compares the two outputs of the reference and adaptive models, and processes the errors between the two based on the appropriate adaptive law and does not interfere with the stability of the system being applied. In MRAS techniques, the desired process response to the command signal has been determined using the defined reference model parameters. The adaptation mechanism always tracks the process output and model output and then calculates the parameters that match the settings so that the difference between these outputs tends to be zero.

2. Rotor Flux MRAS Estimator

In this MRAS scheme, the rotor flux relationship (Ψ,r) is used as a tuning speed signal. Motor voltage and current are measured in a stationary reference frame. It is also easy to express this equation in a stationary framework. Speed can be calculated by the adaptive system reference model (MRAS), where the output of the reference model is compared with the output from the adaptive model until the error between the two models is exactly zero. A block diagram for speed estimation with this MRAS technique is shown in Figure 2. Based on the voltage equation the stator side model is defined as a reference model[9].

3. Flux Linkage

Flux Linkage is definition of flux from coil (stator or rotor), with value of coil is N, and value of flux linkage at rotor and stator is:

$$\vec{\lambda}_s = L_s\vec{I}_s + M\vec{I}_r \quad (1)$$

$$\vec{\lambda}_r = L_r\vec{I}_r + M\vec{I}_s \quad (2)$$

Where:
λ_s = Flux linkage at stator with value coil is N
λ_r= Flux linkage at rotor with value coil is N
L_s = Inductantion coil stator (H)
L_r = Inductantion coil rotor(H)
I_s = Current stator (A)
I_r = Current rotor (A)

4. Vector Control

Vector control is methode to controll AC motor, where from coupled system changed be decoupled system, from this system current strenghening and load current can controlled with sparate process, flux and torque can controler with sparate process, at figure 2 is block diagram decoupled induction motor[10].

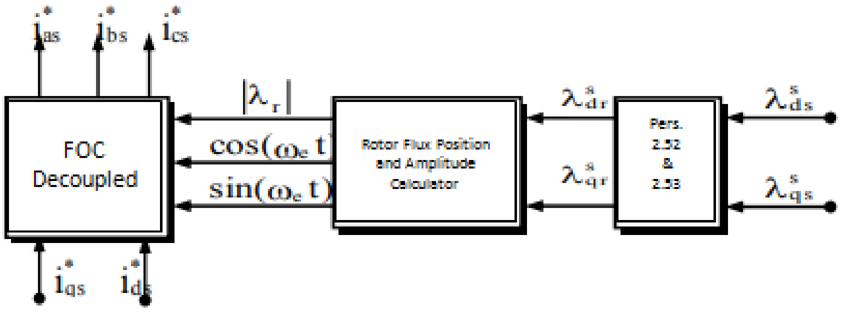

Figure 2. Block Diagram Decoupled Induction Motor

To getting stator current($i^*_{as}, i^*_{bs}, i^*_{cs}$) at decoupled induction motor used equality 3:

$$\begin{pmatrix} i^*_{as} \\ i^*_{bs} \\ i^*_{cs} \end{pmatrix} = \sqrt{\frac{2}{3}} \begin{pmatrix} 1 & 0 \\ -1/2 & \sqrt{3}/2 \\ -1/2 & -\sqrt{3}/2 \end{pmatrix} \begin{pmatrix} i^{*s}_{ds} \\ i^{*s}_{qs} \end{pmatrix} \quad (3)$$

where stator currenti^{*s}_{ds}, i^{*s}_{qs}(stasionerr) calculate with equality 4:

$$\begin{pmatrix} i^{*s}_{ds} \\ i^{*s}_{qs} \end{pmatrix} = \begin{bmatrix} \cos(\theta^*_e) & \sin(\theta^*_e) \\ -\sin(\theta^*_e) & \cos(\theta^*_e) \end{bmatrix} \begin{pmatrix} i^*_{ds} \\ i^*_{qs} \end{pmatrix} \quad (4)$$

magnitude stator current (i^*_{ds}, i^*_{qs}) ad slip (ω^*_{sl}) calculate with equality 5:

$$i^*_{ds} = \frac{1 + s\tau_r}{L_m} |\lambda^*_r|$$
$$i^*_{qs} = \frac{2}{3} . \frac{2}{P} . \frac{L_r}{L_m} . \frac{T^*_e}{|\lambda^*_r|}$$
$$\omega^*_{sl} = \frac{2.2. L_r}{3. P. \tau_r} . \frac{T^*_e}{|\lambda^*_r|^2} \quad (5)$$

whera $\tau_r = L_r/R_r$ is time constant, $s = d/dt$, L_r is rotor inductance, L_m is murtual inductance, R_r is rotot resistance, $|\lambda_r|$ is flux linkage rotor, and p = is pole amount. Blok (rotor flux position and amplitude calculator) at figure 1,solve with equation 6:

$$\cos(\omega_e t) = \frac{\lambda^s_{dr}}{|\lambda_r|} \text{dan} \sin(\omega_e t) = \frac{\lambda^s_{dr}}{|\lambda_r|} \quad (6)$$

III. DESIGN SYSTEM

Hardware design uses a design like the following Figure 4. The application on the PC will control the microcontroller. Commands are given serially via USB to serial UART to the ATmega128 RX / TX pin. Furthermore ATmega128 will parse the data received, obtained in the system. The plant will also estimate the parameters obtained from the voltage and current sensors attached to the 3 phase induction motor. Changes to these parameters will be used as a reference to produce a PWM signal that will control the 3 phase inverter to provide an appropriate output on the induction motor.

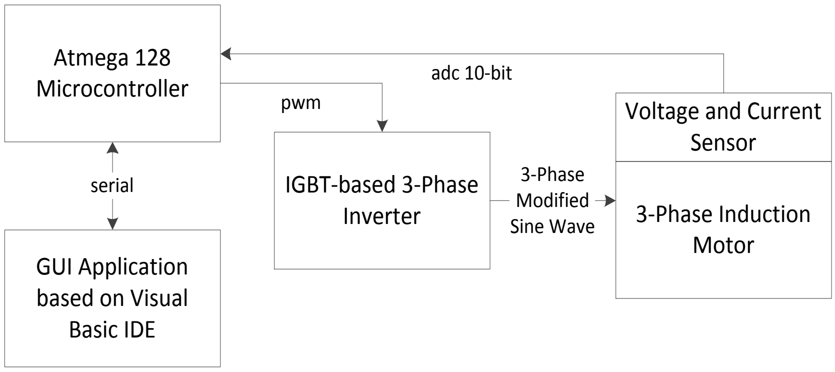

Figure 3. Design System

Software design is done by using interfacing software so that the real motor speed can be monitored directly using the application. This application utilizes features in the Windows Operating System to connect PCs with external devices. These features are COM Port that will be accommodated by USB-to-Serial devices. This device will emulate the COM PORT DB9 as a USB device with RX / TX serial output. Baudrate used in the application is 9600 bps. This program already uses a GUI-based display so that users can easily apply parameters that will be sent to the microcontroller, figure 4 is design pllant.

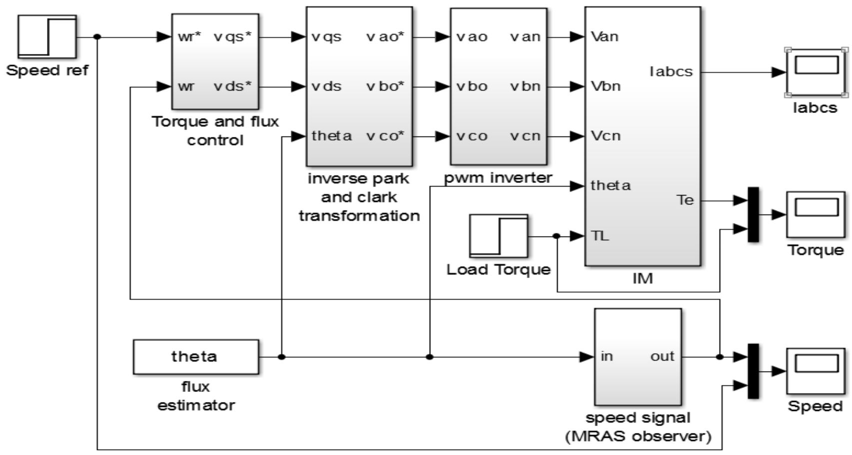

Figure 4. Design Plant System

Furthermore, to produce a 2-way communication process, a program is also embedded in the ATmega128 microcontroller. This program is made using C language base which is compiled using Codevision AVR. This program will read the set point given serially on the application on the PC. Then the microcontroller will read the ADC data, calculate it so that the PWM output is obtained which will then control the output of the 3 phase inverter. The plant is designed using simulation modeling that has been done using Matlab as in Figure 5. This design was applied using C language and planted on an ATmega128 microcontroller.

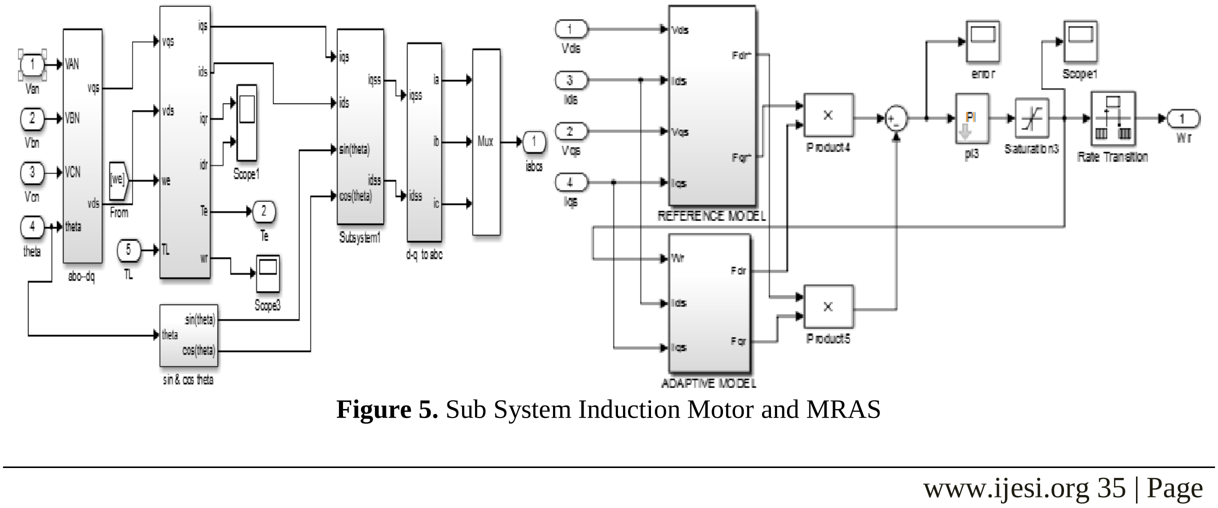

Figure 5. Sub System Induction Motor and MRAS

IV. RESULT AND ANALYSIS

In this study there are several experimental parameters, including: data retrieval parameters characteristic of 3-phase induction motor with Open Loop controller and MRAS Close Loop.

1. Low speed control Induction Motors Without Load (Open-Loop)

In this thesis progress reporting, it will be explained about the experiment of regulating the speed of induction motor using hardware, because in the progress of the previous thesis the speed of the induction motor has been simulated. Before doing the speed control in Vector Control, this experiment was tried to refer to the basic setting of the induction motor speed, namely the scalar control method or commonly referred to as Volt / Hz (V / f). Here will be presented the results of the open-loop speed management using Volt / Hz (V / f) and MRAS controller usage.

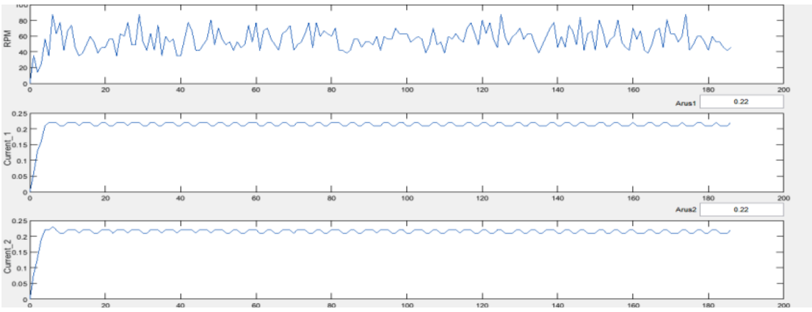

Figure 6. Current MotorSpeed Chart 10Hz (Open-Loop)

At very low set point speeds (10Hz), it is difficult to control the speed of the induction motor. In close loop control, sensor data is not used as feedback to correct motor speed. From the experimental data, it is obtained data that the inverter can work as expected by entering the frequency input. This input will determine the desired rotational speed. Frequency input is obtained from the controller that has been designed before using the controller 128 AVR microcontroller.

The provision of PWM frequency values is done through the software interface that has been designed. Software on a computer is connected to controller 128 hardware via a serial interface. Data will be transferred to serial hardware on the controller 128 RX pin. This value will be converted into an integer number which is then entered into the Timer register. So in essence, to generate the PWM frequency, we can give the corresponding values in the Timer registers. The following figure is the result of testing several PWM frequency values with the open loop controller.

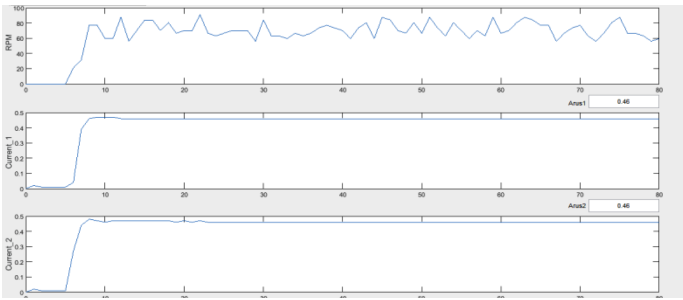

Figure7. Current MotorSpeed Chart 15Hz (Open-Loop)

The greater the frequency value desired, the longer it takes to reach its stable speed. However, from all the experiments that have been carried out, the system can achieve stable conditions even though there are still ripple / oscillations on the system. This happens because it is basically difficult to control the speed of the induction motor, especially at low frequencies. At 100 rpm, the oscillation value also increases with the rise time value which is also getting bigger. To produce a steady state with a minimum peak, an experiment will be done using close loop control by reading the current parameters. This parameter is used as a variable to estimate the actual speed. This value will be processed and fed back to the Adaptive Model to produce close loop control. This controller will theoretically produce a more stable system and overcome the shortcomings of the open loop model controller.

2. Low speed control Induction Motors Close Loop Using MRAS

The implementation of MRAS is carried out on programs embedded in the controller 128 controller. Speed control is managed by the PID controller. The input from the controller is the deviation between the reference speed and speed measured by the rotary encoder sensor which will be replaced by the MRAS algorithm. The power part of the motor consists of an inverter voltage source which is realized by 6 IGBT with DC link voltage (Omron Sysdrive). At each calculation step, the phase and voltage values of the DC link are read from the ADC and the voltage vector is calculated. The two voltage and current vectors change into two coordinate phases. Then, the model for the MRAS algorithm is calculated, the speed value is adjusted, the torque reference is calculated in low speed control.

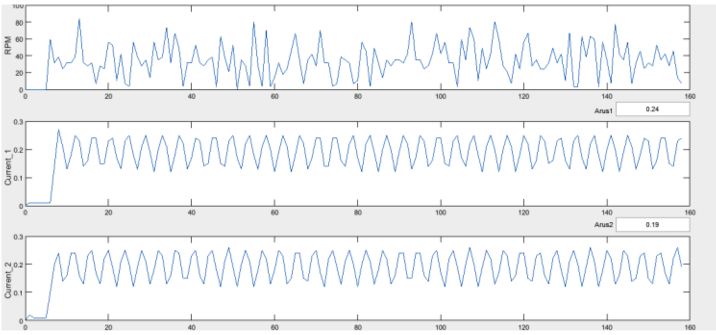

Figure 8. ChartSpeed Motor With Setpoint 22 rpm MRAS

In the experiments that have been carried out, it can be seen that the motor speed can move following the predetermined set point. Rise time of the system reaches about 5 seconds. The system reaches steady state conditions in 6.5 seconds. The use of the controller has been done without involving the rotary encoder speed sensor. By calculating using the MRAS method, the output from the system can go to stability according to the given speed.

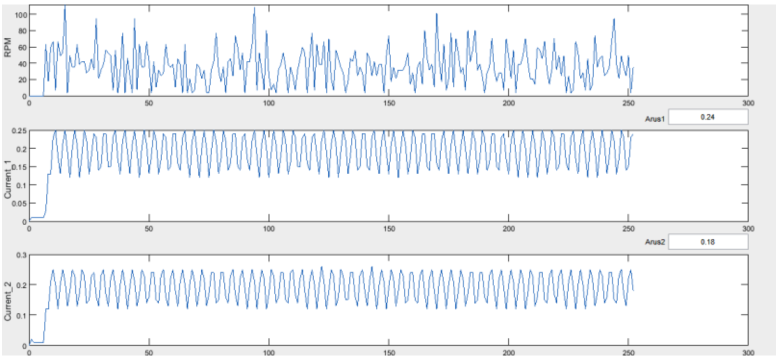

Figure 9. ChartSpeed Motor With Setpoint 43 rpm MRAS

The same applies to low speed settings. The motor can move as well as using a controller taking into account the speed sensor. In figure 14, it appears that the motor speed increases following the set point within 10 seconds, so that the speed reaches stability even with the presence of an oscillation peak value of ± 100rpm. This means, there is an oscillation deviation reaching 6.6% of the set points. This is indeed reasonable because controlling low-speed induction motors has many variables that also vary in each model and condition so as to produce more precise speeds, the addition of another sensor system should be used.

V. CONCLUSION

From several experiments that have been carried out about the control of induction motors using the MRAS method, the following conclusions can be drawn. The voltage equation on the variable 3 phase induction motor is used to determine the parameter values that exist on the induction motor so that it can be used as a reference as controlling the speed while the motor is operating.Vector control is used to extract the system coupled to an induction motor to be a decoupled system so that the gain current and the motor load current can be controlled separately, thus torque and flux can also be set separately, as well as a dc motor to control its output speed.MRAS techniques for controlling low speed induction motors can work like a controller that uses a speed sensor. During testing at low speeds using 22 Rpm, 43, 54, 105 and 194 Rpm set points, the motor can reach each steady state in the range of 5 to 7 second.

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