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Model Reference Adaptive Technique for Sensorless Speed Control of Induction Motor Using MATLAB\SIMULINK

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***Abstract*: Over the past two decades technological advances in power electronics and an increasing demand for high performance industrial machinery has contributed to rapid developments in digital motor control. The aim of this paper is to develop a vector controlled induction motor drive operating without a speed sensor but having a dynamic performance comparable to a sensored vector drive. The reason behind adopting the MRAS based speed sensorless estimation strategies in thesis is so obvious because it has been proclaimed as one of the best methods available, especially when the motor parameters are poorly known or have large variation. Though the performance of MRAS based estimators is considerably good at high speed but operation at low and zero speed is still a problem to overcome. By using sensorless control technique, we can reduce the cost of drive i.e. shaft encoder, we can also increase the ruggedness of the motor as well as fast dynamic response can be achieved.**

***Keywords*- Sensorless control of IM, Speed Sensorless estimation strategies, MRAS.**

I. INTRODUCTION

Speed sensorless estimation as its name implies, is the determination of speed signal from an IM drive system without using rotational sensors. It makes use the dynamic equations of the IM to estimate the rotor speed component for control purposes. Estimation is carried out using the terminal voltages and currents which are readily available using sensors. Controlled induction motor drives without mechanical speed sensors at the motor shaft have the attractions of low cost and high reliability. To reduce total hardware complexity, costs and to increase mechanical robustness, it is desirable to eliminate speed and position sensors in vector-controlled drives. Drives operating in hostile environments or in high speed drives speed sensors cannot be mounted. To replace the sensor the information on the rotor speed is extracted from measured stator voltages and currents at the motor terminals.

Basic Theory:

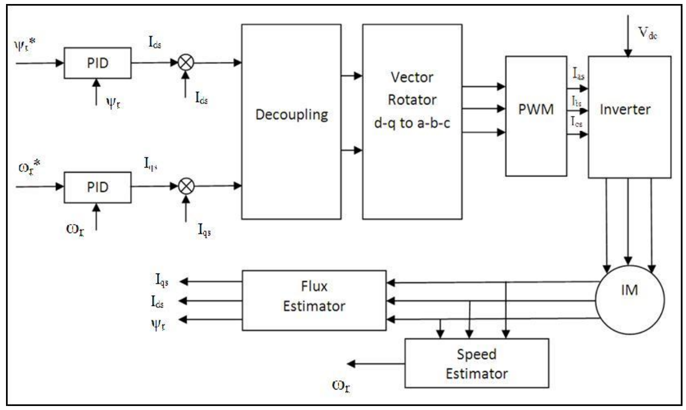

Fig: 1 Block Diagram of Sensorless Control of Induction Motor

The schematic diagram of control strategy of induction motor with sensorless control is shown in Fig.1 Sensor less control induction motor drive essentially means vector control without any speed sensor [17, 18]. The inherent coupling of motor is eliminated by controlling the motor by vector control, like in the case of as a separately excited motor. The inverter provides switching pulses for the control of the motor. The flux and speed estimators are used to estimate the flux and speed respectively. These signals then compared with reference values and controlled by using the PI controller.

SPEED SENSORLESS ESTIMATION STRATEGIES

For drives where only moderate dynamic performance is required, three types of open loop control approaches may be used:

- Back emf-based estimation
- Constant V/Hz control
- Space harmonics-based speed estimation For high performance drives, vector control based systems can be used. These methods include:
- Rotor field orientation
- Model reference adaptive systems
- Feedforward control of stator voltages
- Stator flux orientation
- Estimation of rotor flux and torque current

MODEL REFERENCING ADAPTIVE SYSTEM (MRAS)

W. Yaonan [5] has proposed one of the speed estimation technique based on the Model Reference Adaptive System (MRAS) in 1987. Two years later, Schauder [6(a)][6(b)] presented an alternative MRAS scheme which is less complex and more effective.

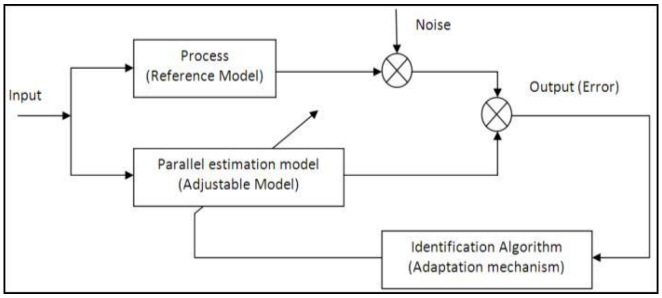

Fig: 2 Three basic identification structures and their correspondence with MRAS.

The MRAS approach uses two models. The model that does not involve the quantity to be estimated (the rotor speed, ωr) is considered as the reference model. The model that has the quantity to be estimated involved is considered as the adaptive model (or adjustable model). The output of the adaptive model is compared with that of the reference model, and the difference is used to drive a suitable adaptive mechanism whose output is the quantity to be estimated (the rotor speed).The adaptive mechanism should be designed to assure the stability of the control system. A successful MRAS design can yield the desired values with less computational error (especially the rotor flux based MRAS) than an open loop calculation and often simpler to implement.

The model reference adaptive system (MRAS) is one of the major approaches for adaptive control. The model reference adaptive system (MRAS) is one of many promising techniques employed in adaptive control. Among various types of adaptive system configuration, MRAS is important since it leads to relatively easy- to-implement systems with high speed of adaptation for a wide range of applications.

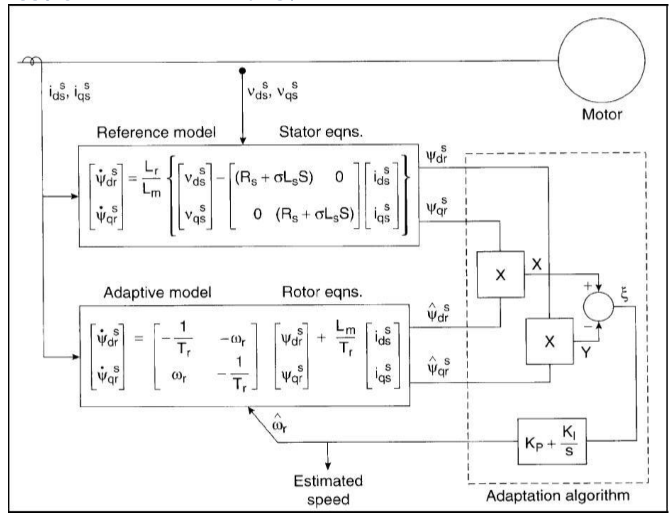

Fig: 3 Basic Block Diagram of MRAS speed estimation

The speed can be calculated by the Model Referencing Adaptive System (MRAS). The basic block diagram of MRAS speed estimation system is shown in Fig 3. The model reference approach (MRAS) makes use of redundancy of two-machine model of different structures that estimate the same state variables. Both models are referred to in the stationary reference frame. As the name implies it consists of two models namely reference model and adaptive model, where the output of a reference model is compared with the output of an adjustable or adaptive model until the errors between the two models vanish to zero [16]

REFERENCE MODEL

$$\frac{d}{dt}\varphi_{dr} = \frac{L_r}{L_m}[V_{ds}-(R_s+\sigma SL_s)i_{ds}] \quad \ldots\ldots\ldots\ldots(1)$$

$$\frac{d}{dt}\varphi_{qr} = \frac{L_r}{L_m}[V_{qs}-(R_s+\sigma SL_s)i_{qs}] \quad \ldots\ldots\ldots\ldots(2)$$

Where, $\sigma = 1 - \frac{L_m^2}{L_r L_s}$; $L_{ls}=L_s-L_m$ & $L_{lr}= L_r-L_m$

Adaptive Model:

$$\frac{d}{dt}\varphi_{dr} = \frac{L_m}{T_r}ids - \omega_r\varphi_{qr} - \frac{1}{T_r}\varphi_{dr} \ldots\ldots\ldots\ldots (3)$$

Similarly,

$$\frac{d}{dt}\varphi_{qr} = \frac{L_m}{T_r}ids - \omega_r\varphi_{dr} - \frac{1}{T_r}\varphi_{qr} \ldots\ldots\ldots\ldots (4)$$

Where,

$$T_r = \frac{L_r}{R_r}$$

The voltage model's stator-side equations (1) and (2) which are defined as a reference model. The model receives the machine stator voltage and current signals and calculates the rotor flux vector signals. The current model flux equations (3) and (4) are defined as an adaptive model.

An adaptation algorithm with P-I control can be used to tune the speed value until the two flux values match.The estimated speed is derived as follows [16]:

$$\omega_r = \varsigma(K_p + \frac{K_I}{s}) \quad \dots\dots\dots\dots (5)$$

Where, $\varsigma = A - B = \varphi^s_{dr}\,\varphi^s_{qr}\text{-}\varphi^s_{qr}\,\varphi^s_{dr}$ ……… (6)

In steady state, $\varsigma = 0$ balancing the fluxes

In practice, the rotor flux synthesis based on the reference model is difficult to implement, particularly at low speeds, because of the pure integration of the voltage signals. The MRAS speed estimation algorithm remains and valid if, instead of integration, the corresponding CEMF signals are compared directly through some low-pass filters. Estimation accuracy can be good if machine parameters are considered as constant. However, accuracy, particularly at low speeds, deteriorates due to parameter variation.

SIMULINK BLOCK DIAGRAM

Sensorless control of induction motor:

The Sensorless control of induction motor using Model Reference Adaptive System (MRAS) is simulated on MATLAB/SIMULINK - platform to study the various aspects of the controller. The actual system can be modeled with a high degree of accuracy in this package.Here we are going to discuss the realization of Sensorless control of induction motor using MRAS for simulink blocks. Main subsystems are the 3-phase to 2-phase transformation, 2-phase to 3-phase transformation, induction motor model, Model Reference Adaptive System (MRAS) and optimal switching logic & inverter.

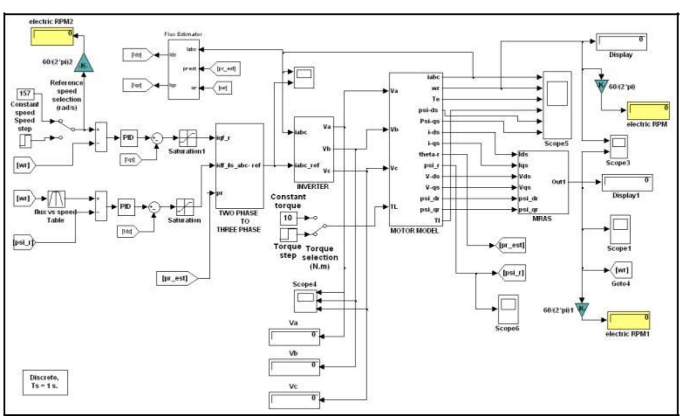

Fig4: Simulink root block diagram of Sensorless control of induction motor using MRAS

Model Reference Adaptive System (MRAS):

Fig 5 shows the Simulink block diagram Model Referencing Adaptive System (MRAS).The voltage model's stator-side equations, (1) & (2) are defined as a Reference Model. The Adaptive Model receives the machine stator voltage and current signals and calculates the rotor flux vector signals, as indicated by equations, (3) and (4). By using suitable adaptive mechanism the speed ω_r, can be estimated and taken as feedback

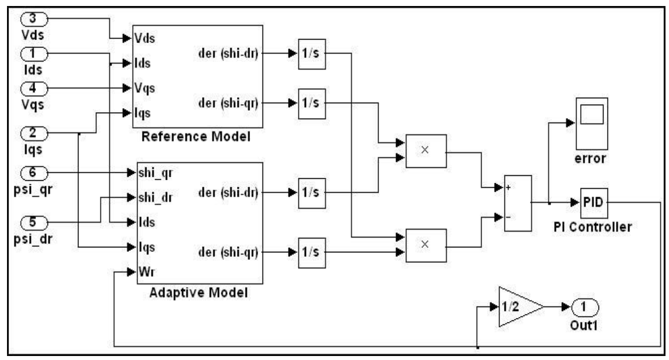

Fig5: Simulink block diagram of Model Referencing Adaptive System

SIMULATION RESULT

Sensorless Speed Control of Induction Motor:

The Simulation of Sensorless Vector Control of Induction Motor is done by using MATLAB/SIMULINK. The results for different cases are given below.

Under No-Load Condition

Reference speed = 100 rad/sec

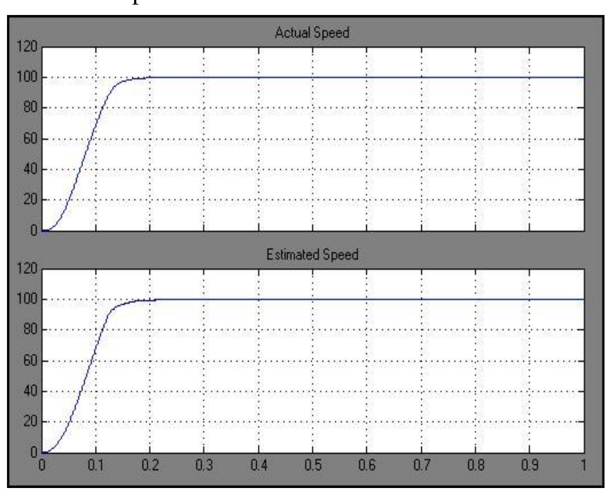

Fig 6: Simulation results of Actual Speed and Estimated speed Using MRAS in rad/sec

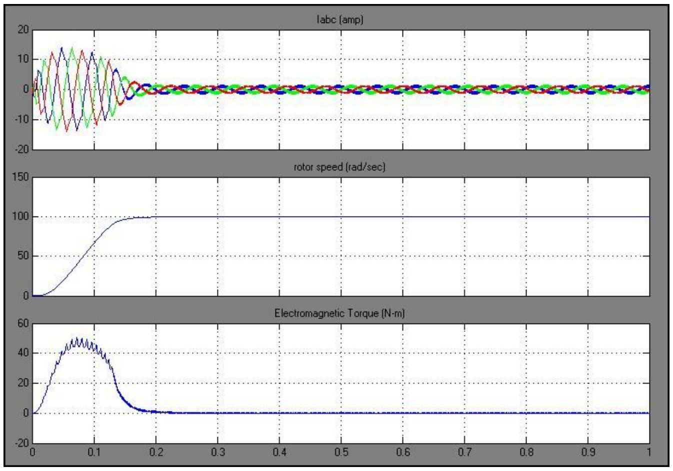

Fig 7: Simulation results of 3-Ø currents, Speed and Torque for no-load reference speed of 100 rad/sec

Comments:

- Fig.6 shows that the actual speed of induction motor and estimated speed using MRAS are same.
- Fig.7 shows the no load line currents, speed and torque wave forms. It can be seen that at starting the values of currents and torque will be high. The motor reaches to its final steady state position wit in 0.2 sec. Hence it has fast dynamic response.

CONCLUSION

Sensorless control of induction motor using Model Reference Adaptive System (MRAS) technique has been proposed. Sensorless control gives the benefits of Vector control without using any shaft encoder. Simulation results of Sensorless Control of induction motor using MRAS technique were carried out by using Matlab/Simulink and from the analysis of the simulation results, the transient and steady state performance of the drive have been presented and analyzed.

From the simulation results, it can be observed that, in steady state there are ripples in torque wave and also the starting current is high. The main results obtained from the Simulation, the following observations are made.

i) The transient response of the drive is fast, i.e. we are attaining steady state very quickly.
ii) By using MRAS we are estimating the speed, which is same as that of actual speed of induction motor.
iii) Thus by using sensorless control we can get the same results as that of vector control without shaft encoder. Hence by using this proposed technique, we can reduce the cost of drive i.e. shaft encoder's cost, we can also increase the ruggedness of the motor as well as fast dynamic response can be achieve

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