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DETECTION OF SENSOR FAULT USING MRAS TECHNIQUE

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Abstract— This paper present a new speed sensor fault tolerant algorithm for vector controlled induction motor drive. In the proposed method, current estimation uses d- and q-axes currents and is independent of the switching states of the three-leg inverter. The speed is estimated using model reference adaptive system (MRAS). MRAS technique uses reference and estimated values of current and voltage for speed calculation. Speed estimation does not involve the calculation of stator and rotor flux. Such algorithm is suitable for different drives, including electric vehicles to avoid complete shutdown of the system, in case of sensor failure. The proposed MRAS technique has been simulated in MATLAB/Simulink software.

Index Terms—Adaption mechanism, Induction motor, Model reference adaptive system, Sensor, Speed estimation, Vector control,

1 INTRODUCTION

The vector controlled induction motors are extensively used in industry due to high dynamic performance and easy implementation of system using analog or digital processing system[1]-[6]. The implementation of vector controlled scheme requires the knowledge of rotor speed and machine parameters. The rotor speed is essential for coordinate transformation and closing the speed loop [6].

Speed, current or voltage sensors are required in vector controlled induction motor drive. The fast current controller operates in the inner current loop and a slower speed controller stays in the outer speed loop to generate the corresponding reference currents for the current controllers [12].

The recent trend is to make the drive fault tolerant. The failure may be due to machine, converter or maloperation of sensors. The maloperation of current and speed sensors (due to noise, dc-offset and open circuit, etc.) is not uncommon in the industrial environment, and any industrial drive system needs to be prepared to take care of such contingencies. Therefore, sensor fault-tolerant control is an extremely important area of investigation for IM drives [2].

In [7], a review of fault diagnosis, accommodation and reconfiguration in variable speed drive (VSD) was detailed. Typically faults can be classified into machine faults, sensor fault and actuator faults. The fault diagnosis strategies based on signal processing, model-based techniques and artificial intelligence are presented in this paper.

The detection and isolation of speed sensor failure are also reported in [10][14][16]. In [10], fuzzy logic is used to detect the faulty speed sensor. In [14] and [16], fault-tolerant control is based on maximum-likelihood voting (MLV) that uses the actual speed and estimated speed are obtained by using the EKF and Luenberger observer.

In [4], the effects of instrument faults in direct-torque-control-based induction motor drives are analysed and an instrument fault detection isolation scheme. (IFDIS) for the drives is proposed. The observers are designed to generate the residual, which are used to identify and isolate the faulty sensor. In [3], a bank of three rotor flux observers and a switching mechanism are presented to identify the faulty sensor. The proposed technique demands more design efforts and is computationally intensive which makes their real-time implementation difficult.

In [17]-[20], a decision block is used, which changes the control strategies, depending on the detection of sensor faults. In [17] and [18], the control reorganization is carried out by a fuzzy decision, which assures a smooth transition from the encoder-based by using sliding mode to the sensorless controller by utilizing fuzzy control. All these approaches sacrifice field orientation when fault occurs and hence offer poor dynamic performance.

A bank of three rotor flux observers and a switching mechanism are presented to identify the faulty sensor. The proposed technique demands more design efforts and is computationally intensive which makes their real-time implementation difficult [5].

Neural network/fuzzy logic technique is used to identify and isolate the faulty sensor [21]-[23]. In [21] and [22], artificial neural network is trained with the help of data obtained from phase voltages, phase currents, rotor speed, measured torque, power (per phase), and reference magnitude of dc supply. The implementation is difficult, and also, such techniques cannot be used for retrofit applications. In [23], diagnosis of sensor failure is carried out with the help of fuzzy inference.

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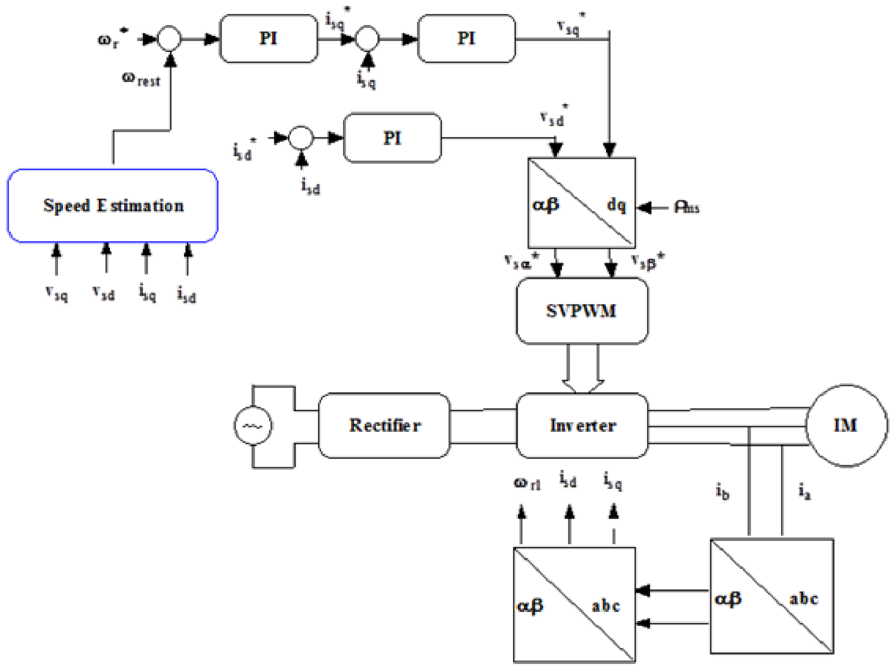

Fig 1 Block diagram of proposed vector controlled induction motor drive

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The available speed estimation techniques may be broadly classified into model-based and signal injection-based ap proaches. Of the model-based methods, several observer-based approaches are very attractive. In this area, the use of extended Kalman filter is popular due to its robustness and the need of reduced numbers of PI controllers [8] [13].

Of the model-based techniques, model reference adaptive system (MRAS) [9][11][15] based speed estimation is an alternative. Such adaptive methods do not require any modification in hardware and hence are more suitable for retrofit applications. Depending on the formulation of error signal, the MRAS is broadly categorized as 1) flux-based [9], 2) back-emf based [11], and 3) reactive-power-based [15], methods.

The flux and back-emf based MRAS are dependent on stator resistance. On the contrary, the air-gap reactive-power-based MRAS is independent of stator resistance [9]. The block diagram of proposed vector controlled induction motor is shown in Fig 1.

2 PROPOSED MRAS TECHNIQUE

Fig. 2 shows the block diagram of the proposed MRAS for speed estimation. The fictitious quantity X in the reference model is calculated using the reference values of voltages and currents, whereas X in the adjustable model is computed with the help of reference values of voltages and actual currents. The actual values of *d*- and *q*-axis currents are obtained by transforming two-phase currents with the help of vector rotator (which, in turn, depends on speed).

TABLE 1
MACHINE DETAILS

Rated shaft power	1.3KW
Line to line voltage	400V
Rated speed	1430 rpm
Pole pair	2
Stator self-inductance	0.6848 mH
Rotor self-inductance	0.6848 mH
Magnetizing inductance	0.6705 mH
Stator resistance	5.71 ?
Rotor resistance	4.08 ?
Machine inertia	0.011 Kg-m^2

The error (= $X_r - X_s$) is fed to the adaptation mechanism to generate the speed signal. This estimated value of the rotor speed will be used to make the drive fault tolerant against speed sensor failure.

The proportional–integral (PI) controllers used in the current and speed loop may get saturated in case the motor has to develop a rated speed from start (with rated torque) or during operation in field-weakening mode. The estimated magnitude of current and speed will deviate from the actual variables. Under such circumstances, an antiwindup controller may be implemented, or the fault-tolerant controller may be disabled until the speed and cu rent controllers come out of saturation [2]. The X-MRAS can also be used for stator resistance estimation, if speed signal is available from speed encoder [6].

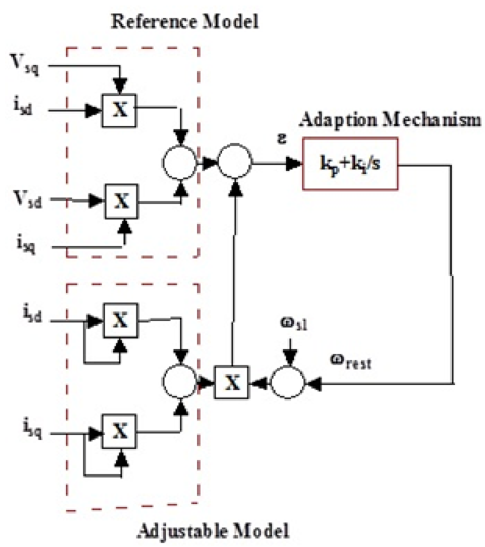

Fig 2 Structure of XMRAS technique

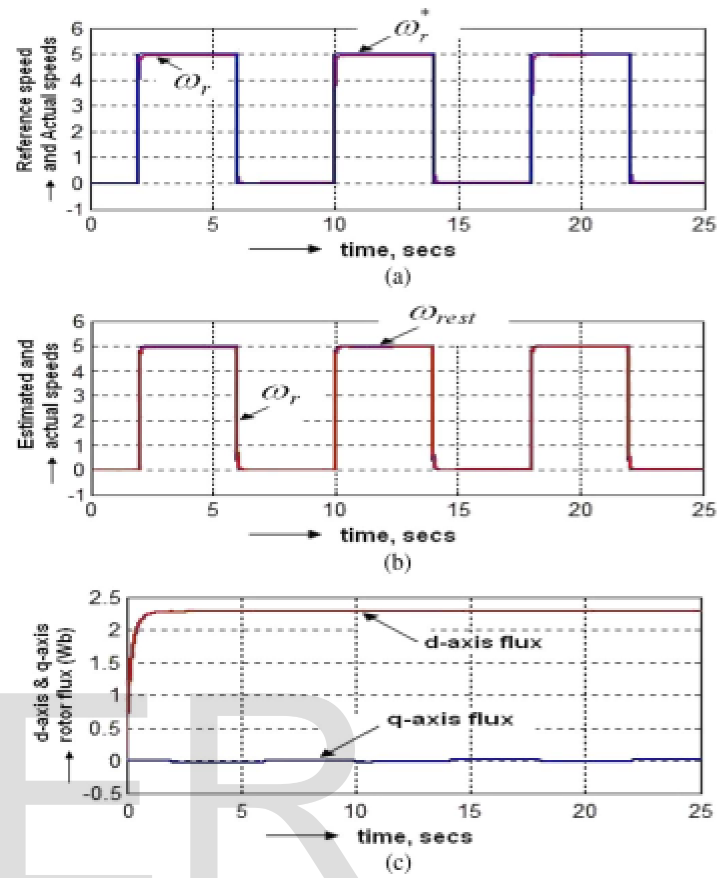

Fig. 3. (a) Reference speed and actual speed [rad/s] versus time [s]. (b) Actual speed and estimated speed [rad/s] versus time [s]. (c) d-axis and q-axis rotor flux [Wb] versus time [s].

3 SIMULATION RESULTS

The X-MRAS technique for speed sensor fault detection is simulated in MATLAB/ SIMULINK and the results are presented here. The machine rating and parameters are available in Table I. The various controller gains are given in Appendix. The controller is tested for several cases

3.1 Step Change of Rotor Speed and Zero-Speed Operation

The response of the induction motor for a step change in reference speed and zero-speed operation can be seen in Fig. 3. A step change in speed of 5 rad/s is applied every 4 s, and the actual speed is found to track the reference speed satisfactorily. The estimated speed is available in Fig. 3(b), which shows that the same is very close to the actual rotor speed. Flux orientation is well maintained, as depicted in Fig. 3(c).

3.2. Ramp Response

The tracking performance of the algorithm at low speeds (near zero speed) is tested by applying a triangular wave input as in Fig. 5. The estimated speed is following the actual speed which in turn is matching with the reference speed, as shown in Fig. 5(a). In all these operations, the flux orientation is not disturbed as observed in Fig. 5(b). Load arrangement is kept same. The results have also confirmed stable operation in forward and reverse-motoring modes.

4 CONCLUSION

A new MRAS-based speed estimation technique is presented in this paper. In the proposed system, a fictitious quantity is used as the functional candidate to form the MRAC. Such selection has resulted in several merits over the existing approaches. The computation of flux is not needed. While the current estimation is based on the reference currents in synchronously rotating refe ence frame and the vector rotator, the speed estimation exploits a different form of X-MRAS. Both the techniques do not involve stator resistance. Hence, the proposed controller works very well at low speed. The proposed concept is extensively simulated in MATLAB/Simulink.

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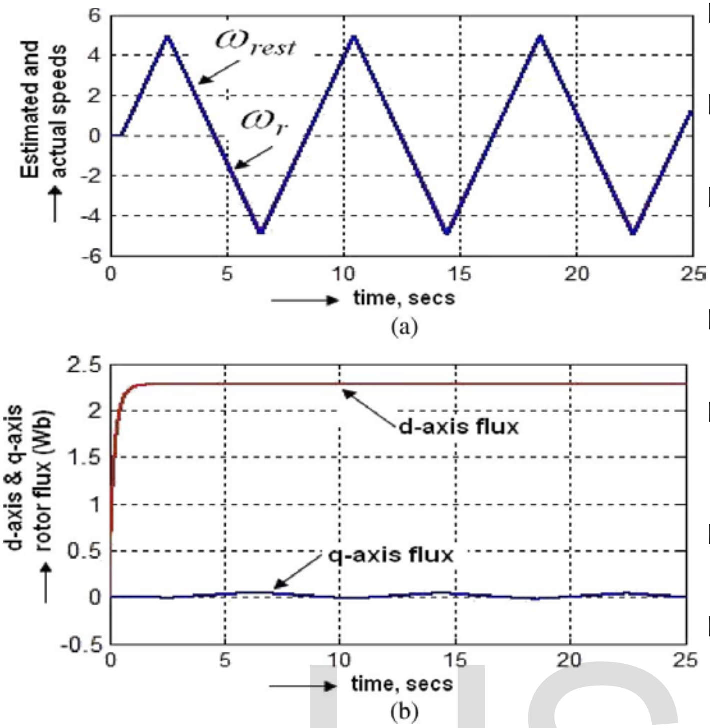

Fig. 4. (a) Actual speed and estimated speed [rad/s] versus time [s]. (b) d-axis and q-axis rotor flux [Wb] versus time [s].

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