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An influence of the chosen sensors faults to the performance of the vector controlled induction motor drive system

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In the paper the influence of the chosen sensors faults (rotor speed and stator current sensors) to the properties of induction motor drive system working in the Direct Field Oriented Control structure (DFOC) were tested. Simulations results carried out in Matlab/SimPowerSystem software. Study results contains an analysis of the state variables such as: mechanical and estimated speed, electromagnetic torque, stator's phase currents and rotor flux. Additionally the usage of these signals to develop faults detection algorithms were tested.

KEYWORDS: Fault Tolerant Control (FTC), speed sensor, current sensor, faults, induction motor drive, DFOC, MRAS

1. Introduction

Increased demands on the reliability of the drives with induction motors have generated increased interest in Fault-Tolerant Systems (*FTCS - Fault Tolerant Control Systems*) which can be divided into two main types: passive and active. The first of these are designed to provide optimum performance with the occurrence of a certain number of failures without the need to declare their presence. To this group belong drives with the adaptive or predictive control. In contrast, the active fault tolerant systems can use sensors and / or observers to detect failures [5], [6], [7]. The main objective is to regain efficiency through the use of additional redundancy circuits or by adjusting the controllers parameters or estimators as a result of the identification of a new object control [6].

In this paper the analysis of the impact of fault to the speed sensor and stator current of the drive system of induction motor controlled by a Direct Field Oriented method are analyzed. The study was performed in MATLAB-SimPowerSystem software.

2. Induction motor drive system

In the paper a well-known control structure of the induction motor was applied - the direct field-oriented control DFOC (Fig. 1) [2]. The drive system uses an active rectifier controlled by a voltage-oriented method VOC (Voltage

Oriented Control) [4]. To measure the angular velocity the incremental encoder was used (5000 imp/rev), the DC bus voltage and the switching states are observed to obtain the stator voltage components. Stator current in the course of "normal" operation is measured using the sensors in the phases A and B, the third transducer may be used in a fault-tolerant system.

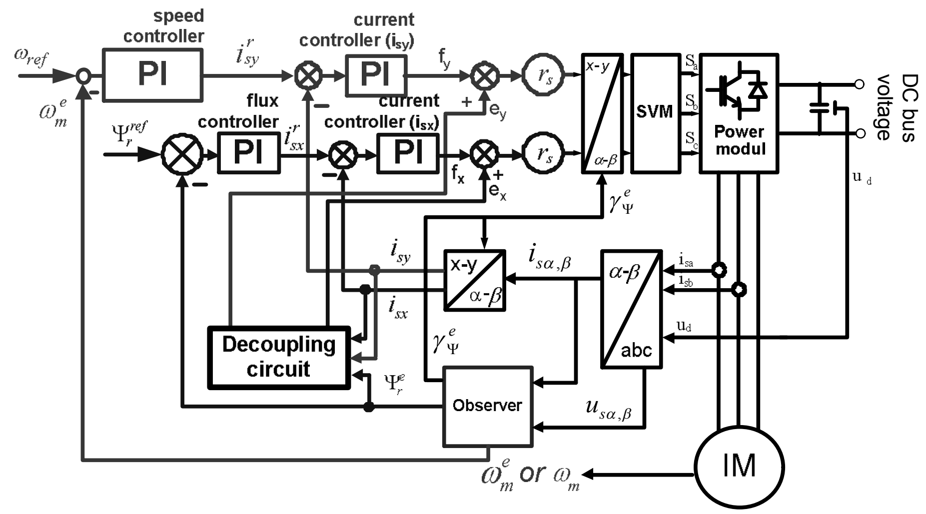

Fig. 1. The classical structure of the field oriented control for induction motor drive

3. An influence of rotor speed sensor faults the properties of the induction motor drive system

One of the most important signal used in the vector controlled induction motor drive is the measured rotor speed. This signal can be measured by different sensors. Incremental encoder is one of the most popular sensor used in the electrical drives. This mechanism is very simple and not very robust. Speed sensor failure can be divided into three types, which can be obtain by [1]:

$$\omega_m^m = (1-\gamma)\omega_m \tag{1}$$

where: $\omega_m{}^m$ – measured rotor speed, ω_m – real rotor speed, γ – positive constant: $0 \le \gamma \le 1$.

For different values of the coefficient γ, measured rotor speed can be:

a) interrupted - partial damage to the speed sensor consisting of a partial failure of individual pulses from the encoder - $0 \le \gamma \le 1$,
b) interrupted - partial damage to the speed sensor consisting of a cyclic interruption of specific pulses from the encoder - $\gamma = [0,1]$,
c) zero – total failure of the speed sensor - $\gamma = 1$, $\omega_m{}^m = 0$.

On the basis of reports in the literature it can be noticed that the effects of speed sensor failure in the vector-controlled induction motor drives are most visible in the real and estimated speed and in the estimated electromagnetic torque (or stator current components) [1]. In Fig. 2 – Fig. 4 the effects of the incremental encoder faults to the properties of the DFOC structure are presented. It was assumed that the damage can rely on a complete interruption of the feedback loop from the speed sensor, loss of individual pulses or cyclic loss of these pulses. In the Fig. 2 the results of the effect of interruption of the feedback loop to the transient of measured speed and estimated using an estimator MRAS[CC] [1] are presented.

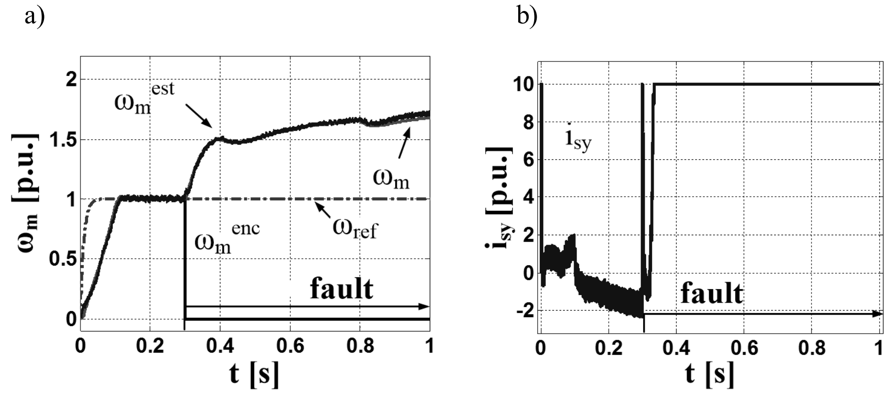

Fig. 2. Transients of the measured rotor speed (a) and the component of the stator current i_{sy} (b) in the DFOC system during total failure of the speed sensor

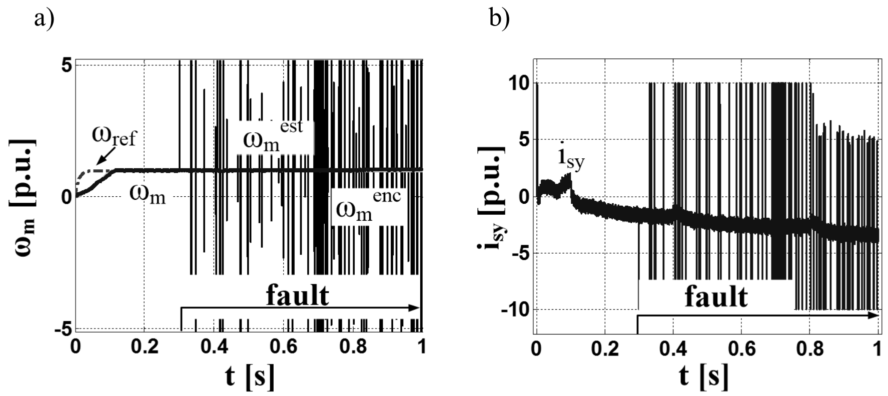

Fig. 3. Transients of the measured rotor speed (a) and the component of the stator current i_{sy} (b) in the DFOC system during the failure of individual pulses of the measurement signal from the speed sensor

In the Fig. 3 and Fig. 4 the waveforms for other types of damage of the rotor speed sensor are illustrated.

Drive is operated in a nominal speed, for $t = 0.4s$ and $t = 0.8s$ motor has been loaded with torques $0,5m_{oN}$ and m_{oN} respectively. For $t = 0.3s$ the speed sensor is damaged.

a) b)

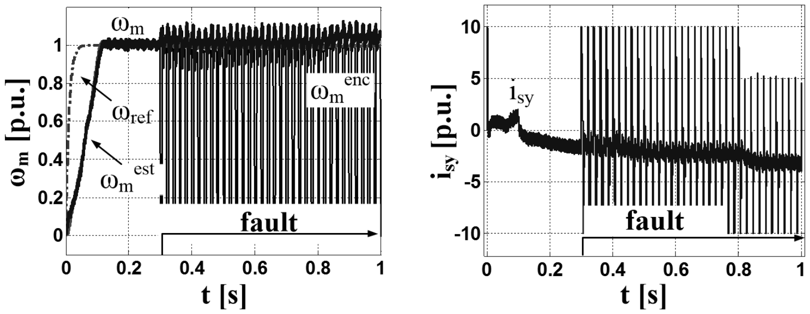

Fig. 4. Transients of the measured rotor speed (a) and the component of the stator current i_{sy}, (b) in the DFOC system during the failure of the loss of cyclical pulses from the speed sensor

It is clearly visible that any type of speed sensor fault adversely affects the operation of the drive. The worst result are observed for a complete interruption of the measurement loop. It must be noticed that this damage is easiest to detect in the diagnostic system. Cyclic shedding pulse and loss of pulses from the encoder does not cause loss of stability of the drive, but long-term work in such conditions may cause damage to the motor or components of power electronics.

4. An influence of stator current sensor fault the properties of the induction motor drive system

In this section the effects of the stator current sensor failure to the performance of the drive controlled by DFOC method are presented. The study was performed for the conditions as before.

The current sensor may indicate erroneous measurements due to saturation of the magnetic core or phase shift signal in the feedback loop. Basic types of damage current sensor are shown in Table 1.

Table 1. Basic types of faults and the value of the output current sensor

Type of fault	Intermittent signal	Saturation of signal	Noise	Loss of signal
Output signal [p.u.]	$i_s^m = [0,1]$	$i_s^m = i_{sat}$	$i_s^m = i_a + n(t)$	$i_s^m = 0$

On the Fig. 5 - Fig. 8 the effect of the damage the current sensor in phases A and B to the properties of the DFOC drive system.

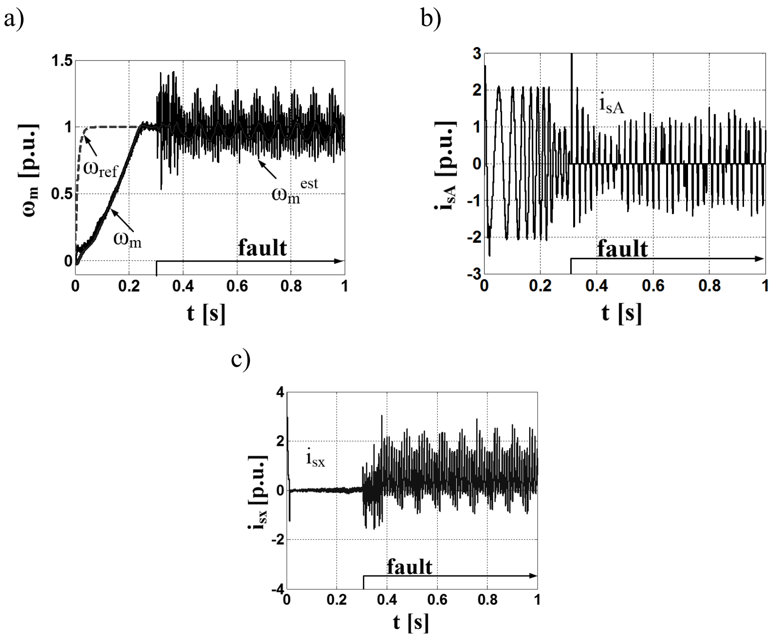

Fig. 5. Transients of the measured and estimated rotor speed (a) the stator current in phase A, (b) and the stator current i_{sx} (c) for the cyclic intermittent measurement signal from the sensor phase A

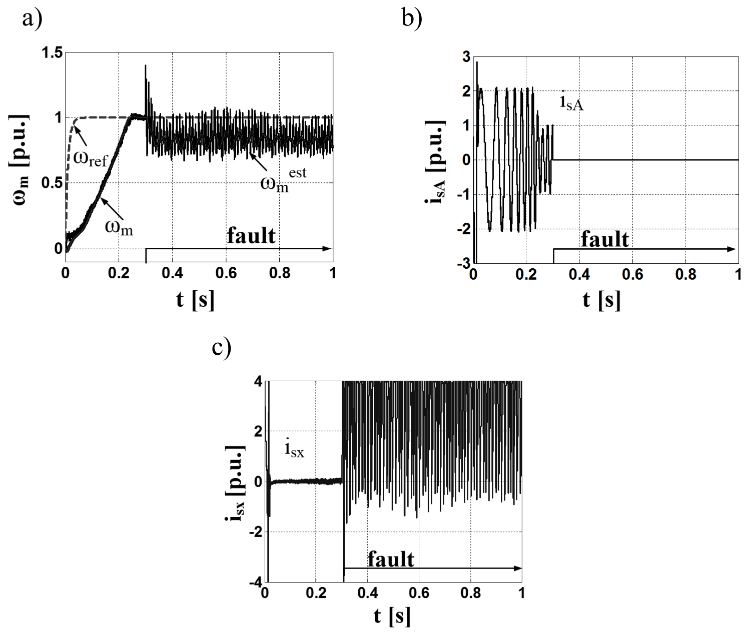

Fig.6. Transients of the measured and estimated rotor speed (a) the stator current in phase A, (b) and the stator current i_{sx} (c) for the disappearance of the measurement signal from the sensor phase A

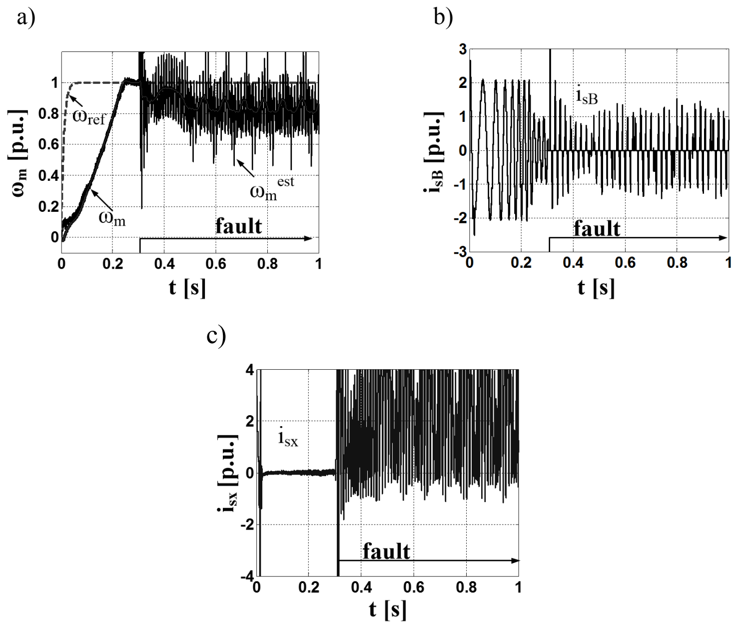

Fig. 7. Transients of the measured and estimated rotor speed (a) the stator current in phase B, (b) and the stator current i_{sx} (c) for the cyclical intermittent measurement signal from the sensor phase B

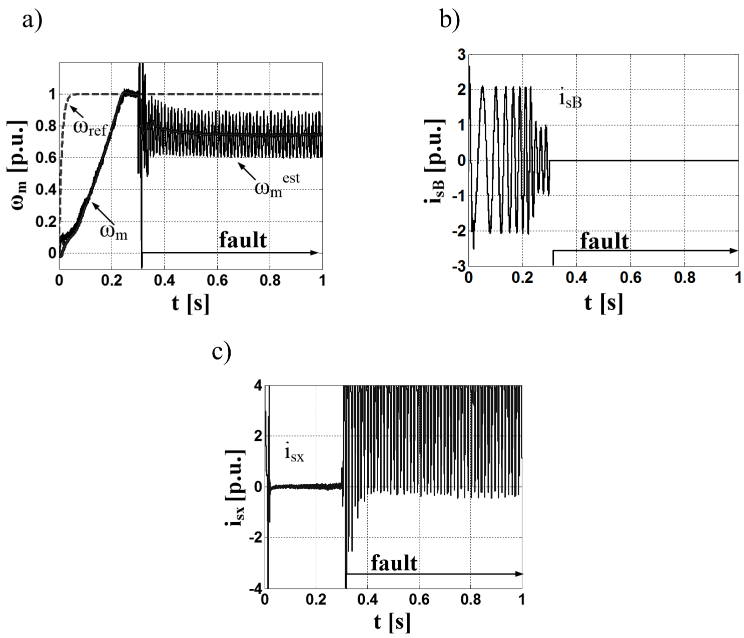

Fig.8. Transients of the measured and estimated rotor speed (a) the stator current in phase B, (b) and the stator current i_{sx} (c) for the disappearance of the measurement signal from the sensor phase B

The most dangerous for induction motor drive operation was presented in the Fig. 6 – Fig.8. In this case the stator current sensors are completely broken or periodically intermittent. The results include the impact of such faults for both sensors phase (A and B). The measurement signal causes big oscillations of the measure and estimated rotor speed and oscillations on the stator current components.

Interruption of current sensor in the both phases causes oscillation of the rotor speed and electromagnetic torque of less than in the previous case. Characteristic of this damage is the fact that, after the failure of the current sensor the speed value is dropped to 0.8 [p. u.]. All faulted operation can be detect using information from the internal control structure (i_{sx} current component).

Rotor flux is estimated using the current model of the induction motor, on the basis of the stator current. The rotor speed is estimated using the information from current sensors and drive cannot work stable when this sensor is broken. Very important is the fact that this operation should be detect as fast as possible.

5. Conclusions

In the paper the influence of speed and stator current sensors faults to the properties of the induction motor drive are presented. All speed and current sensor faults can be visible on the state variables of the drive. Those signals can be used in the detection algorithm.

Acknowledgment

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References

[1] Dybkowski M., "Estimation of speed in a vector controlled induction motor drive - selected problems", Scientific Papers of the Institute of Electrical Machines, Drives and Measurements of Wroclaw Univ. of Technology, No. 67, ser. Monographs, No. 20, (2013), Wroclaw, Poland, 2003 (in Polish).

[2] Orłowska-Kowalska T., "Sensorless induction motor drives", Wroclaw University of Technology Press, Wroclaw, Poland, 2003 (in Polish).

[3] Orlowska-Kowalska T., Dybkowski M., "Stator Current-based MRAS Estimator for a Wide Range Speed-Sensorless Induction Motor Drive", IEEE Trans. on Industrial Electronics, vol. 57, no. 4, April 2010, pp. 1296-1308.

[4] Knapczyk M., Pieńkowski K., "Sensorless control of reversible AC/DC converters", Scientific Papers of the Institute of Electrical Machines, Drives and Measurements of Wroclaw Univ. of Technology, No. 56, ser. Studies and Research, No. 24, (2004), Wroclaw, Poland, 2003 (in Polish).

[5] Khalaf Salloum Gaeid, Hew Wooi Ping, "Fault Tolerant Control of Induction Motor", Modern Applied Science Vol. 5, No. 4; August 2011, pp 83-94.
[6] Li Jiang, "Sensor fault detection and isolation using system dynamics identification techniques", PhD thesis, The University of Michigan, 2011.
[7] K.-S. Lee, J.-S. Ryu, "Instrument fault detection and compensation scheme for direct torque controlled induction motor drivers", IEE Proc.-Control Theory Appl., Vol. 150, No. 4, 2003.