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MRAS METHODS NOISE IMMUNITY AND IMPACT OF CURRENT ON THE PRECISION OF IDENTIFICATION.

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Abstract: *One of widespread identification methods are MRAS methods. These methods are used to identify various parameters, e.g. velocity of rotor. Our paper describes the utilization of these methods to identify the rotor resistance. Not all these methods are suitable for this purpose because the value of rotor resistance is small. In the text below we describe three MRAS methods used to identify the rotor resistance. We investigate these methods for noise immunity and impact of current on the precision of identification.*
Key words: *MRAS, rotor resistance, AC induction motor*

1. INTRODUCTION

Classical DC motors are gradually replaced by synchronous and asynchronous motors. These motors can be used for almost all needs, simply by selecting the appropriate AC motor, frequency inverter, sensors and control method. During the development of motors, the efficient control evolved and higher knowledge of controlled engine parameters was demanded. If parameters are accurate, we can achieve more efficient control with higher performance. The widely used method of on-line parameter identification is the MRAS method (Shyh-Shing, Yen-Shin & Chang-Huan, 1998; Vasić & Vukosavić, 2001; Zhen & Xu, 1998). Many types of this method are used in practice. These types are adapted for faster and more accurate identification. One of these modifications is utilization of stator current. This article describes three MRAS methods used for rotor resistance identification. Not all methods are suitable to identify rotor resistance. We assume utilization of motors with the values of rotor resistance in the range of tenths or units of ohm. These methods are tested for different conditions in Matlab Simulink. The best method for rotor resistance identification follows from result of these tests. This method is planned to be used in the predictive control algorithm for our motor.

2. AC INDUCTION MOTOR MODEL

The induction machine model is used to derive rotor resistance R_r estimation schemes that are independent of the motor control method. The $\alpha\beta$ stator and rotor voltage equations (1)-(4) and the flux linkage equations (5)-(8) of 3-phase squirrel-cage AC induction machine in the stationary reference frame are used for creating the reference and adjustable model for MRAS based identification methods .

$$u_{s\alpha} = R_s i_{s\alpha} + p\Psi_{s\alpha} \quad (1)$$
$$u_{s\beta} = R_s i_{s\beta} + p\Psi_{s\beta} \quad (2)$$
$$0= R_r i_{s\alpha} + p\Psi_{r\alpha} + \omega_r\Psi_{r\beta} \quad (3)$$
$$0= R_r i_{r\beta} + p\Psi_{r\beta} - \omega_r\Psi_{r\alpha} \quad (4)$$
$$\Psi_{s\alpha} = L_s i_{s\alpha} + L_m i_{r\alpha} \quad (5)$$
$$\Psi_{s\beta} = L_s i_{s\beta} + L_m i_{r\beta} \quad (6)$$
$$\Psi_{r\alpha} = L_r i_{r\alpha} + L_m i_{s\alpha} \quad (7)$$
$$\Psi_{r\beta} = L_r i_{r\beta} + L_m i_{s\beta} \quad (8)$$

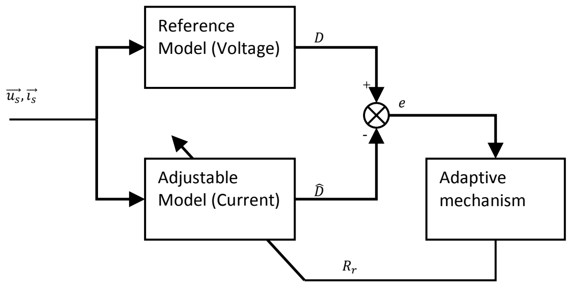

Fig. 1. MRAS

Where $u_{s\alpha\beta}$ is the stator voltage vector, $i_{s\alpha\beta}$,$i_{r\alpha\beta}$ are the stator and rotor current vector, and $\Psi_{s\alpha\beta}$,$\Psi_{r\alpha\beta}$ are stator and rotor flux linkage vector. The speed is denoted by ω_r, R_s is the stator resistence, and L_m,L_s and L_r are the magnetizing, stator and rotor inductances, respectively. Differentiating operator is denoted by p.

3. MRAS

MRAS uses two models for parameters identification. One of then is reference model which works with known variables. The second model is adjustable one. The results of this model directly depend on unknown parameter to be identified. The difference between these models outputs called error is used in adaptive mechanism to find identified parameter. These two models are derived using (1)-(8) under the assumption that the rotor resistance is varying slowly compared to the electrical or mechanical dynamics of the system. It is also assumed that stator voltage vector $u_{s\alpha\beta}$, stator current vector $i_{s\alpha\beta}$, and speed ω_r measurements are made (Lee et al., 2000).

After adjusting these equations we get the equations for the reference (voltage) model

$$\frac{L_m}{L_r} p\Psi_{r\alpha V} = u_{s\alpha} - R_s i_{s\alpha} - \sigma L_s p i_{s\alpha} \quad (9)$$
$$\frac{L_m}{L_r} p\Psi_{r\beta V} = u_{s\beta} - R_s i_{s\beta} - \sigma L_s p i_{s\beta} \quad (10)$$

and the equation for adjustable (current) model

$$\frac{L_m}{L_r} p\Psi_{r\alpha I} = \frac{L_m}{L_r}\left(-\frac{\hat{R}_r}{L_r}\Psi_{r\alpha I} - \omega_r\Psi_{r\beta I} + L_m\frac{\hat{R}_r}{L_r} i_{s\alpha}\right) \quad (11)$$
$$\frac{L_m}{L_r} p\Psi_{r\beta I} = \frac{L_m}{L_r}\left(-\frac{\hat{R}_r}{L_r}\Psi_{r\beta I} + \omega_r\Psi_{r\alpha I} + L_m\frac{\hat{R}_r}{L_r} i_{s\beta}\right) \quad (12)$$

These equations are same for all of the following methods. They differ in computing error signal and adaptive mechanism as it is described in following subsections.

3.1 Method working with rotor fluxes

Stator current interfere mutual linkage of these methods. As it is shown in the previous section, model num.1 can estimate the rotor resistance by using two estimators (a reference-model-based estimator and an adaptive-model based one), which independently estimate the rotor flux-linkage components in the stator reference frame ($\Psi_{r\alpha}$,$\Psi_{r\beta}$), and by using the difference between these flux-linkage estimates to drive the rotor resistance of the adaptive model to that of the actual resistance. The stator current is not used in this type of model (Vas, 1998).

$$e_{R1} = Im(\Psi_{rV}\Psi_{rI}) = \Psi_{r\alpha I}\Psi_{r\beta V} - \Psi_{r\beta I}\Psi_{r\alpha V} \qquad (13)$$

3.1 Method working with rotor fluxes and stator current

Next method num. 2 is similar to the previous one. The same components of flux deducted by voltage and current models are multiplied by the stator currents $i_{s\alpha\beta}$.

$$e_{R2} = i_{s\alpha}(\Psi_{r\alpha V} - \Psi_{r\alpha I}) + i_{s\beta}(\Psi_{r\beta V} - \Psi_{r\beta I}) \qquad (14)$$

3.2 Method working with rotor fluxes, their derivatives and stator current

In order to obtain a method num.3 for estimating R_r which is independent of R_s a reference model that only consists of measured or known variables or parameters, and an adjustable model in which the only unknown quantity is R_r, are required. It is also required to eliminate influence of R_s in both models so that R_r estimation is independent of R_s. The stator resistance can be eliminated by multiplying (9) by $i_{s\beta}$ and (10) by $i_{s\alpha}$ and taking the difference.

$$e_{R3} = Im(\Delta\bar{e}\bar{\iota_s}) = \bar{\iota_s} \times \bar{e} - \bar{\iota_s} \times \hat{\bar{e}} = D - \hat{D} \qquad (15)$$

$$e_{R3} = \frac{L_m}{L_r}(p\Psi_{r\beta V}i_{s\alpha} - p\Psi_{r\alpha V}i_{s\beta}) - \frac{L_m}{L_r}(p\Psi_{r\beta I}i_{s\alpha} - p\Psi_{r\alpha I}i_{s\beta}) \quad (16)$$

$$D = (u_{s\beta}i_{s\alpha} - u_{s\alpha}i_{s\beta}) + \sigma L_s(i_{s\beta}pi_{s\alpha} - i_{s\alpha}pi_{s\beta}) \qquad (17)$$

An equation of adjustable model can be obtained by performing multiplication of equation (11) with $i_{s\alpha}$and subtracting equation (12) multiplied with $i_{s\beta}$.

$$\hat{D} = \frac{L_m}{L_r}\left(\frac{\hat{R}_r}{L_r}(\Psi_{r\alpha I}i_{s\beta} - \Psi_{r\beta I}i_{s\alpha}) + \omega_r(\Psi_{r\alpha I}i_{s\alpha} + \Psi_{r\beta I}i_{s\beta})\right) \quad (18)$$

Equations (17) and (18) can then be used in a final implementation of the rotor resistance observer. The scheme is insensitive to stator resistance. (Vas, 1998).

Adaptive mechanism is $\hat{R}_r = K_p e_r + K_i \int e_r dt$ where K_p and K_i are gain constants.

4. SIMULATION RESULTS

This section tries to compare methods described in previous section in simulation in Matlab Simulink environment. Identifications were carried out on an AC induction motor model with parameters $U_n = 300V, R_s = 0.894\Omega, \mathrm{R_r} = 0.85\Omega, \mathrm{L_s} = 0.1192\mathrm{H}, \mathrm{L_r} = 0.1181, \mathrm{L_m} = 0.112\mathrm{H}, \mathrm{p} = 3$.
Simulations also included variation of the rotor resistance value so as to emulate the influence of heating the engine. Rotor resistance has been identified for various conditions. The methods were tested by varying load torque T and with different noise- power spectral densities (PSD). Simulation results are shown in Table 1 and Table 2.

One of the most important properties of described methods is their convergence speed. These convergence speeds are considerably different for these methods. Rotor resistance identification waveforms are shown in Fig. 2 for $U_m = 150V, f = 25Hz, T = 18Nm$ and no noise.

PSD	U[V]	f[Hz]	T[Nm]	$\delta_{R_{r1}}$[%]	$\delta_{R_{r2}}$[%]	$\delta_{R_{r3}}$[%]
0	300	50	20	1.1	0.95	0.05
0	300	50	10	1.2	1	0.04
0	24	4	20	0.14	0.12	0.02
0	24	4	10	0.13	0.2	0.06

Tab. 1. Maximum error of method without noise

PSD	U[V]	f[Hz]	T[Nm]	$\delta_{R_{r1}}$[%]	$\delta_{R_{r2}}$[%]	$\delta_{R_{r3}}$[%]
1e-9	300	50	20	1.1	0.95	1.4
1e-9	300	50	10	1.2	0.9	1.3
1e-9	24	4	20	0.15	0.13	1.5
1e-9	24	4	10	0.15	0.21	Slow

Tab. 2. Maximum error of method with noise

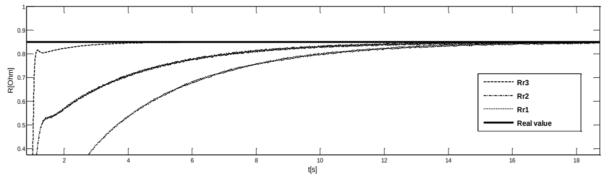

Fig. 2. Convergence speed without noise

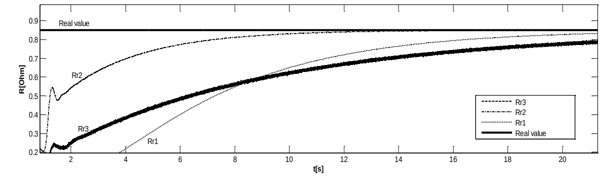

Fig. 3. Convergence speed with noise

The figure 3. shows rotor resistance identification waveforms for low speed and noisy signal. $U_m = 24V, f = 4Hz, T = 18Nm$.

5. CONCLUSION

This article describes three methods which we used to identify rotor resistence.These methods have diferent attribute. Method num.3 which works with multiplication by current is faster then other two methods under ideal conditions but it is unusable for identification with noisy signals and in low speeds, because it is very slow (see Fig. 3.). Much better results are achieved with methods num.1 and num. 2 which are based on working with rotor flux-linkages. Their accuracy does not change with the noise and method num. 2. is also faster than the method num.1 because it uses the stator currents. This method will be implemented to DSP and its functionality will be verified by real motor and further research will be addressed to reduce the computational complexity of algorithms applied to DSP.

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