On line magnetic characterization of a switched reluctance motor based on a Dspace data acquisition board

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1. Introduction

To analyze the behaviour of a switched reluctance motor (SRM) the determination of its magnetic characteristic is essential [1]. The objective of this paper is to present an alternative method for the real time magnetic characterization of switched reluctance motors [2]. To carry out this work a platform based on a Dspace data acquisition board has been developed.

The paper is organized as follows. First, the model of a phase and the flux linkage estimation method, to determine the magnetic characteristics of the motor, are introduced in Section 2. Next, the test bench, the excitation circuit, and the platform to carry out the experimental tests are described in sections 3, 4 and 5 respectively. The results from the experimental magnetic characterization of the motor are shown in Section 6. Finally, some conclusions are reported in Section 7.

Key words: Switched reluctance motor, on line magnetic determination, model, magnetic core effects.

2. Flux linkage estimation method

If the mutual inductance between phases is not considering, the voltage equation for a switched reluctance motor is given as:

$$V_F = R \cdot I_F + \frac{d\lambda(\theta, I_F)}{dt} \qquad (1)$$

where R is the copper resistance, and $\lambda(\theta, i)$ is the flux linkage, which depends on the phase current, I_F, and the rotor position, θ.

The copper resistance can be estimated by means of the following expression:

$$R_C = \frac{\int_{t_1}^{t_2} V_F \, dt}{\int_{t_1}^{t_2} I_F \, dt} \qquad (2)$$

where the integration domain, t_1-t_2, is defined between the initial phase excitation instant and the phase voltage cancellation instant for zero phase current.

From (1) and (2), the flux linkage can be deduced as:

$$\lambda(\theta, I_F) = \lambda_0 + \int (V_F - RI_F) dt \qquad (3)$$

where the residual flux linkage, λ_0, can be assumed as insignificant.

3. Test bench description

The tests have been carrying out for a flat shape SRM prototype, which has been adapted to be housed as a direct drive back side the drum of a domestic washing machine. The stator and the rotor have 24 teeth and 18 teeth, respectively. The number of phases is 4 yielding an angular step of 5 degrees. More details about the test bench are reported in a previous communication [3].

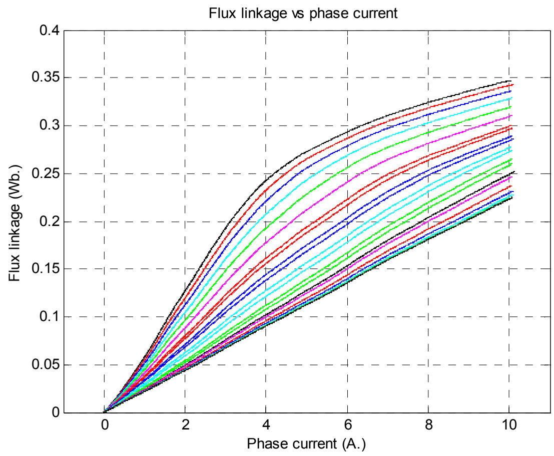
4. Proposed excitation circuit

The 220V/50Hz line signal is attenuated by an autotransformer and applied through a thyristor to a phase of the motor. To achieve a signal with a low harmonic distortion the thyristor is triggered at zero degrees. A significant variation of the cooper resistance is avoided limiting the number of gate pulses to one and therefore the number of conduction cycles. The maximum current value is controlled by the autotransformer.

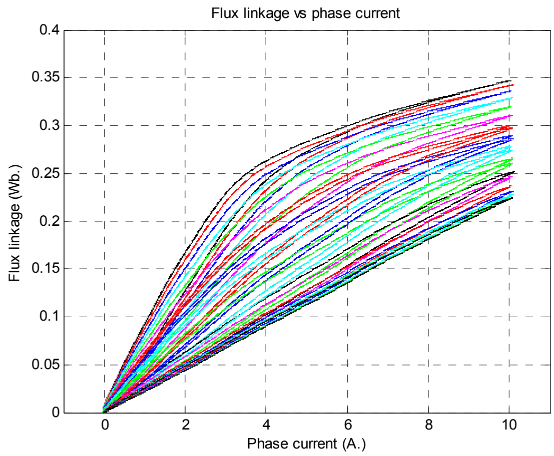
5. On line magnetic characterization

The control algorithms for the excitation circuit, as well as the operations to estimate the flux linkage have been described by means of Matlab-Simulink. Through the Dspace Real Time Workshop tool, the models described in Simulink are implemented in the real-time hardware.

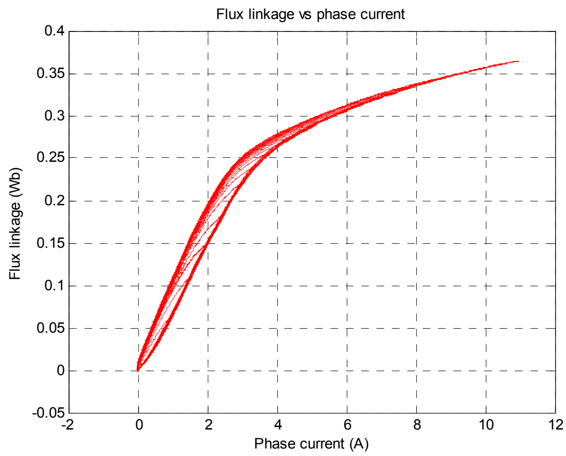
By means of the Dspace ControlDesk software a control panel with virtual instruments has been developed. This graphical interface allows the user to modify the turn on angle of the thyristor and the width of the gate pulse for triggering, to estimate and to adjust the value of the copper resistance, the dc offset of the phase current and the phase voltage. As result of the experiment, the real-time representation of the phase current, the phase voltage, the flux linkage and the magnetic characteristic for each rotor position are displayed in the control panel.



(a)



(b)



(c)

Fig.1. Flux linkage vs. phase current: (a) test for the rising interval of the phase current; (b) test for the rising and the falling interval of the phase current; (c) test for different maximum values in the rising and falling interval of the phase current at the aligned position.

6. Experimental results

Some results from the magnetic characterization of this motor are depicted in fig.1. In fig.1 (a) are only represented the magnetic characteristics obtained during the rising interval of the phase current. The tests has been carried out for a maximum phase current of 10A, and for 20 rotor positions taken each 0.5 mechanical degrees between the aligned and the unaligned positions.

In fig.1 (b) are shown again the magnetic characteristic of the motor, but in this case are depicted the results for the rising and the falling intervals of the phase current. As can be observed, the flux linkages vs. current characteristics depend on the rate of change of the current.

To analyse the influence of the maximum current applied on the determination of the magnetic characteristics, a new experiment has been carried out. The rotor has been locked at the aligned position and the magnetic characteristic has been obtained for different maximum phase current values, taken between 0 y 11A with increments of 0.5A. The results are depicted in fig.1 (c), where, in the falling interval of the phase current, can be seen that the flux linkage depends of the maximum value of the phase current reached in the experiment.

This behaviour of the motor is related to magnetic core effects (hysteresis and eddy currents), and can be an error source for determining the rotor position by sensorless methods based on a univocal flux-current-position relation [4], as in the magnetic characteristics shown in fig.1 (a).

7. Conclusions

In this paper, a platform based on a Dspace data acquisition board, for the real time determination of the magnetic characteristics of a switched reluctance motor, is presented.

The results of the experimental tests show the magnetic characteristics dependence on the rate of change of the current. Moreover, if the magnetic characterization is carried out for different maximum values of phase current, during the falling interval of the phase current, different magnetic characteristics have been obtained.

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