Online Torque Estimator of Switched Reluctance Motor Running under Hysteresis Current Control

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Abstract—An online torque estimator for Switched Reluctance Motor operating under hysteresis current control is proposed. It requires very little pre-measured machine data. Most parameters are estimated on-line, in real-time, using rotor position, motor phase currents and voltages. Comparison between the outputs of the estimator and cubic spline model shows satisfactory results.

I. Introduction

Online estimation of the instantaneous torque of switched reluctance motor (SRM) is difficult, because of the presence of highly saturated iron cores and doubly salient structure. Hitherto, high accuracy is obtained by virtue of using look-up-tables that comprise of a large amount of magnetic and static torque data obtained either experimentally or from Finite Element Models (FEM) [1]. The use of artificial neural network (ANN) [2] is an alternative that requires less data storage at the expense of excessive computational power.

In this paper, an online torque estimator for SRM operating under hysteresis current control is proposed. The estimator only requires the pre-measured inductance profile at low current, the saturating phase current, real-time on/off status of the power electronic switches, the DC-link voltage, phase currents and rotor position. Results obtained from the estimator agree well with those obtained experimentally.

II. Proposed Torque Estimator Algorithm

The estimator determines the phase flux linkage λ_{phase} from the phase current i_{phase}, phase voltage v_{phase}, and winding resistance R as follows.

$$\lambda_{phase} = \int v_{phase} - i_{phase} R \, dt \tag{1}$$

where the phase voltage is deduced from the DC-link voltage and states of the switches and the resistance is computed online. Depending on the magnitude of the phase current, the co-energy W_c is estimated from either the linear or the non-linear magnetic characteristic of the machine as given below.

When the phase current is smaller than the saturating current i_s, the flux linkage–current relationship is assumed to be linear and the co-energy is calculated as:

$$W_c = \tfrac{1}{2} \lambda_{phase}\, i \tag{2}$$

When the phase current is larger than the saturating current, the portion below saturating current is linear and is described using the pre-measured inductance profile L as follows:

$$\lambda = L\, i \tag{3}$$

As for the portion above the saturating current, a Fröhlich-like equation describing the relationship is proposed as:

$$\lambda = L i_s + a(i - i_s)/(b + i - i_s) \tag{4}$$

where, a and b are constants which can be expressed in terms of the phase current, phase flux linkage and inductance. The co-energy can then be estimated by integrating the flux linkage with respect to current:

$$W_c = \int_0^{i_{phase}} \lambda \, di \,. \tag{5}$$

The co-energy, phase current, and rotor position are stored in memory. The differences in co-energy and rotor positions between the new values and those obtained in the previous switching cycle at the same current are used to estimate the electrical torque output.

III. Results

The simulation result of the torque estimator and those obtained from cubic spline model with the SRM running at 200rpm are compared in Fig. 1.

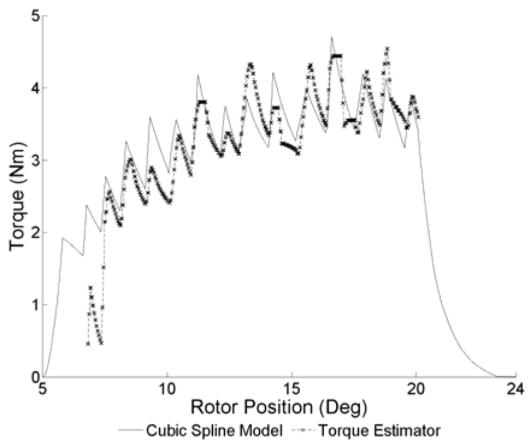

Fig. 1 Comparison between the torque estimator and cubic spline model

It can be seen that the torque estimator output agrees well with those obtained from the cubic spline model. More results will also be presented in the full paper.

IV. References

[1] R. B. Inderka, R. W. De Doncker, M. Krehenbrink, "On-line Estimation of Instantaneous Torque in Switched Reluctance Machine Control," *ISIE 2000. Proceedings of the 2000 IEEE International Symposium on Industrial Electronics, 2000.*, Vol. 2, 4-8, Dec., 2000 pp. 385-389.

[2] S. S. Ramamurthy, J. C. Balda, "Intelligent and adaptive on-line direct electromagnetic torque estimator for switched reluctance motors based on artificial neural networks," *IEEE International Electric Machines and Drives Conference, 2001*, pp. 826 – 830.