Dynamic Sensorless Testing of PMSMs

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Abstract—To be able to control a PMSM the rotor position is needed. The most conventional method to do that is by using a rotor position sensor. Because of the cost and the complicated structure of the rotor position sensor, sensorless control is prefered. A method for dynamic sensorless testing of PMSMs is presented in this article. Because of the conditions with dynamic testing a combination of two sensorless methods is used. The combined sensorless method from simulations has showed to be useful in dynamic testing.

Index Terms—Dynamic Testing, Sensorless Control, PMSM.

1 Introduction

In order to control a PMSM the information about the rotor position is required. Normally the rotor position is obtained by a rotor position sensor because of the drawback of the rotor position sensor such as costs, calibrations and that some PMSMs do not come with a rotor position sensor, Sensorless control is preferred.

In this article it has been investigated if it is possible to use Dynamic Testing of PMSM together with Sensorless Control of the PMSMs. In order to do so a literature study is performed about different sensorless methods, and from the literature study some sensorless methods is implemented in Simulink Models in order to conclude if it is possible to use Sensorless Control during Dynamic Testing.

1.1 Background

In order to cut emissions from vehicles, the automotive industry has started to look at ways of power vehicles with electrical machines mainly PMSMs[1]. When the PMSM is becoming more common in vehicle applications it is getting more important for the automotive industry to find easy ways of testing PMSMs. As an answer to that matter, the Industrial Electrical engineering and Automation division at Lund University are working on a project that aims to investigate and develop a new method for testing electrical machines named Dynamic Testing [2].

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1.2 Dynamic Testing of PMSMs

The procedure for the Dynamic Test method goes like this: first is the PMSM accelerated to a pre-defined speed, then it is braked and accelerated up to the pre-defined speed but in opposite rotor direction. The voltages are measured when braking and accelerating the PMSM, and the flux in equation is calculated for each speed. Finally the flux is given by the average. By performing the calculations in equation 1 and 2, the losses disappears according to the equivalent circuit of the PMSM [3].

$$\Psi_d = \frac{v_q^{\omega} - v_q^{-\omega}}{2\omega} \tag{1}$$

$$\Psi_q = \frac{v_d^{-\omega} - v_d^{\omega}}{2\omega} \tag{2}$$

$$T_e = \frac{p}{2}(\bar{\Psi}_d \bar{i}_q - \bar{\Psi}_q \bar{i}_d) \tag{3}$$

From equation 1 and 2 and by using the number of pole pairs, the torque can be calculated according to equation 3.

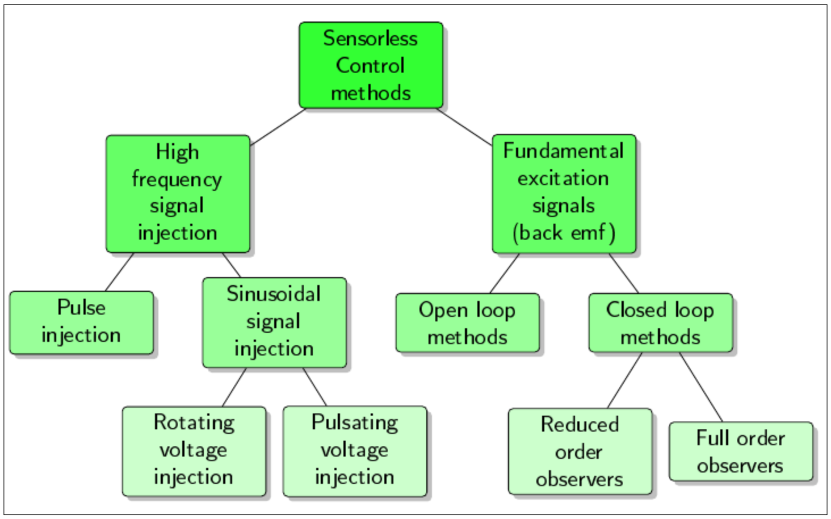

Fig. 1. Shows a tree over the relationships between different Sensorless Control methods for PMSMs.

1.3 Sensorless Control of PMSMs

In order to evaluate which sensorless methods can be useful in sensorless dynamic testing a literature study is conducted. In figure 1 shows the relationship between different kind of sensorless control methods. Briefly it could be said that the left part of the tree in figure 1 that contains sensorless control methods requires external voltage injection. The methods on the right part of the tree does not require any external input, instead they requires a rotor speed since they build on sensing the back emf-force, for which is speed dependent[4] [5].Two sensorless Control methods are chosen and are explained more in detail below.

1.3.1 Voltage Injection Sensorless Method

A voltage injection sensorless control method is selected because it does not require any knowledge about the motor parameters to work. On the downside for this sensorless method is that the injected high frequent voltage signal can disturb the voltage measurements, it is also shown from simulations that the method does not work in some current combinations which is crucial for the dynamic testing application [6] and [7].

1.3.2 Open Loop Method

Because of the drawbacks with the voltage injection method, a open loop method is also chosen. The open loop method does not require any external voltage input, instead it requires some information about one motor parameters which is usually unknown prior to testing of the PMSM[8].

Since none of the sensorless method works perfectly on its own, it is decided to use the voltage injection method to acquire a rough estimation about the motor parameter that is needed for the open loop method. Then with the estimated motor parameter it is possible to use the open loop sensorless method in all current combinations to make a proper testing of the PMSM.

In order to refine and improve the sensorless control of the PMSM, it could also be thought about using the sensorless methods together with the dynamic test method in iterations in order for each iteration come closer to the correct motor parameters. Another way to improve the sensorless control with the open loop method is to implement the compensation method that is based on a value that is added to the rotor position estimation [8].

2 Conclusion

In figure 2 and 3, they shows how the motor parameters obtained with the sensorless dynamic testing as explained above with compensation differs from the actual motor parameters from simulations in Matlab Simulink. It could be concluded that for many voltage combinations the obtained motor parameters does not differ more than 20%.

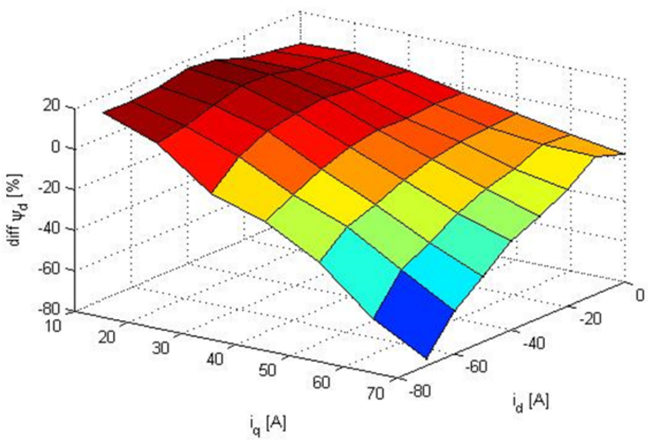

Fig. 2. The difference between obtain and actual d-flux value.

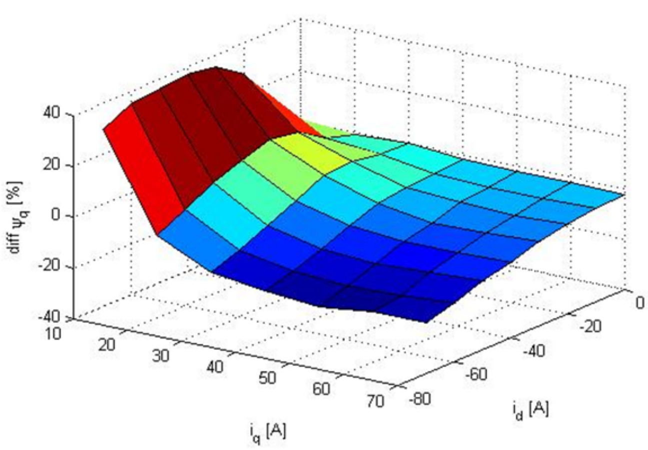

Fig. 3. The difference between obtain and actual d-flux value.

When two sensorless control methods is combined it is possible with dynamic sensorless testing of PMSMs. Probably can the sensorless methods be improved if filters and control loops in the actual methods is better tuned. It is shown from this paper that it is worth to investigate further with dynamic sensorless testing of PMSMs since the simulations showed promising results.

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