Sensorless control scheme based on the back-EMF

This chapter presents an overview of the sensorless control scheme for Permanent Magnet machines based on the Back EMF calculations. The steps used to derive the rotor position and speed estimation are presented, assuming the machine variables in the stationary reference frame.

5.1 Back EMF calculation

As mentioned in chapter one, the estimation scheme based on the Back EMF information can be done based on voltage model, kalman filter or flux observer. In the following, the Back EMF is derived using the voltage model of the machine.
Since, it is known that the per-phase equivalent model of the Permanent Magnet motor can be represented as depicted below:

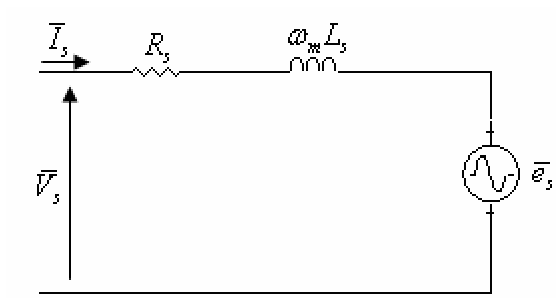


Figure 5.1: *The Per-phase equivalent circuit of the Permanent Magnet machine.*

The voltage equation corresponding to this model can be written as in the following equation (vectorial complex form):

$$\overline{V}_s = R_s \overline{I_s} + j\omega_m L_s \overline{I_s} + \overline{e_s} \tag{14}$$

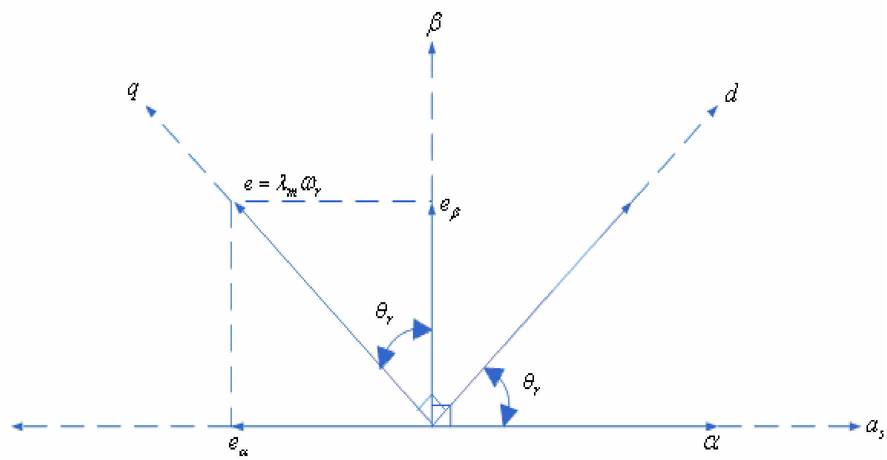
Where $\overline{e_s}$ represents the Back EMF of the machine.

It is clear from equation (14) that, the Back EMF of the machine can be calculated if the voltage is known.

5.2 Rotor position knowing the Back EMF

In Permanent Magnet machines, the rotor flux (permanent magnet flux) is known to be aligned with the rotor d-axis. The Back EMF from the rotor side can be seen as the Permanent Magnet flux induced voltage, and always lies on the q-axis (in the rotor reference frame).
Therefore, in the stationary reference frame, if the position of the Back EMF vector is known, then the rotor position is known. This is illustrated in the figure below.

Figure 5.2: *The back-EMF vector in the stationary reference frame.*



Based on the illustration in figure 5.2, the following coordinates of the back-EMF vector in the stationary reference frame can be derived:

$$-e_\alpha = \lambda_m \omega_r \sin\theta_r$$
$$e_\beta = \lambda_m \omega_r \cos\theta_r \tag{15}$$

Then the rotor position can be obtained based on equation (15).

$$\theta_r = \tan^{-1}\left(\frac{e\beta}{e\alpha}\right) \tag{16}$$

5.3 e_α and e_β calculation

The voltage coordinates of the voltage vector described in equation (14) can be derived in the stationary reference frame as presented below:

$$V_\alpha = R_s i_\alpha + L_s \frac{di_\alpha}{dt} + e_\alpha$$
$$V_\beta = R_s i_\beta + L_s \frac{di_\beta}{dt} + e_\beta \tag{17}$$

e_α and e_β can be calculated using equation (17), then substituted in equation (16) to obtain the rotor position information (obviously, to obtain the speed information).

At low speed, the back-EMF of the machine is relatively small and the estimated rotor position results in noise; meanwhile at zero speed the back-EMF becomes zero, providing no possibility to estimate the rotor position.
Therefore, this approach is presented in this project just to review the principle (since it is known as one of the traditional approaches), and will not be implemented in Simulink.

Bibliography

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