Novel Full-Order Flux Observer Structure for Speed Sensorless Induction Motors

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Abstract — This paper deals with the flux estimation for sensorless induction motor drives. A new full-order observer structure, which uses the stator and rotor fluxes as state variables in their respective reference frames, is proposed. The stator flux state equation is simulated in the stator reference frame, whereas the rotor flux equation is simulated in the rotor reference frame. This natural combination of reference frames gives well-behaving observer poles in the whole speed region, even without feedback terms. The simple Forward Euler discretization can thus be used. Furthermore, existing adaptation rules can be directly adopted for this structure.

I. INTRODUCTION

The well-known problem of full-order flux observers is that they require very sophisticated discretization methods in order to be capable to work stably and accurately at high speeds (or even at nominal speed). Complicated discrete models or very short sampling periods are often undesirable.

Observers are usually implemented in the stator reference frame or in the rotor flux reference frame. It is usual that feedback gains are not used in the speed sensorless case since the electrical dynamics of the induction motor is stable and, on the other hand, the adaptive speed estimation behaves as a feedback. If feedback gains are used, they are often chosen so that the open-loop poles of the induction motor (Fig. 1 (a)) are scaled or shifted to the left in the complex plane. In either case, the absolute value of the imaginary part of one of the roots increases when the motor speed \( \omega_m \) increases. This may lead to discretization errors or even instability.

II. PROPOSED OBSERVER STRUCTURE

This paper proposes a new full-order observer structure, which uses the stator and rotor fluxes as state variables in their respective reference frames (Fig. 2). The stator flux dynamics is calculated in the stator reference frame, whereas the rotor flux dynamics is calculated in the rotor reference frame, i.e.,

\[
\frac{d}{dt} \psi_s = -\frac{1}{\tau_s} \psi_s + \frac{1}{\tau_s R_e} \psi_s e^{j\omega_m} + u_s
\]

\[
\frac{d}{dt} \psi_m = -\frac{1}{\tau_m} \psi_m + \frac{1-\sigma}{\tau_m} \psi_s e^{-j\omega_m}
\]

\[
\dot{\psi}_s = \frac{\psi_s - \psi_m e^{j\omega_m}}{L_s}
\]

where \( (d/dt)\omega_m = \dot{\omega}_m \) and the stator reference frame is denoted by superscript \( s \) and the rotor reference frame by superscript \( m \). This natural combination of reference frames gives well-behaving observer poles in the whole speed region, even without feedback terms ((Fig. 1 (b)). The simple Forward Euler discretization can thus be used. It is to be noted that the proposed observer could be easily augmented with feedback gains.

III. RESULTS

The validity of the proposed method was proved by simulations and experiments. The speed adaption rule by Kubota et al. was implemented in the new observer structure. When using the conventional observer structure, a large error in the speed estimate occurs at high speeds. The proposed observer structure eliminates the discretization error of the flux observer, and the accuracy is good even at high speeds.