Discussion on ” A Differential Algebraic Estimator for Sensorless Permanent-Magnet Synchronous Machine Drive ”

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Diao et al. [1] are to be commended for proposing a new approach for permanent magnet synchronous machine (PMSM) position estimation, using the differential algebraic theory. In the following comments, we would like to highlight some points concerning the machine observability under the applied approach.

In the paper by Diao *et al.* [1], it is claimed that the rotor position observability of the non-salient PMSM is ensured regardless the speed, based on the relationship (8) in [1]. Indeed, (8) is another way to write the back-electromotive force (EMF)-based estimator equation for the non-salient PMSM:

$$\tan\theta = \frac{-e_\alpha}{e_\beta} \tag{1}$$

where[1]:

$$e_\alpha = v_{s\alpha} - R_s i_{s\alpha} - L_d \frac{di_{s\alpha}}{dt} = -\omega\phi_m \sin\theta \tag{2}$$

$$e_\beta = v_{s\beta} - R_s i_{s\beta} - L_d \frac{di_{s\beta}}{dt} = \omega\phi_m \cos\theta \tag{3}$$

At standstill, both the rotor position estimate (described by (9) in [1]) and its initial value (described by (10) in [1]) will be indeterminate since their numerator and denominator are null. Physically speaking, if the non-salient (cylindrical) permanent-magnet rotor is fixed with respect to the stator, it will have no effect on the electromagnetic behavior of the stator circuit; the machine model reduces to two spatially static RL circuits without rotational back EMF, and the rotor position cannot be observable using the conventional PMSM model used in [1]. More details on the PMSM observability at standstill are presented in [2] [3].

The fact that the rotor position observability is not ensured at standstill is illustrated in the Fig. 4 of the paper [1], where an initial position estimation error is introduced; the position estimate is not corrected at standstill.

The salient PMSM position estimation expression is not presented in the paper [1]. In contrast to the non-salient PMSM, the rotor position of the salient PMSM can be observable at standstill [2] [3]. Therefore, the study of the non-salient PMSM cannot be generalized to the salient PMSM. Nevertheless, the extended back-EMF (E-EMF) concept introduced by Chen *et al.* [4] [5] can be used to calculate a differential algebraic expression for the salient PMSM. The E-EMF vector can be written as:

$$\begin{bmatrix} e_{\alpha_{ext}} \\ e_{\beta_{ext}} \end{bmatrix} = \left\{ (L_d - L_q)(\omega i_d - \frac{di_q}{dt} + \omega\phi_m \right\} \begin{bmatrix} -\sin\theta \\ \cos\theta \end{bmatrix} \tag{4}$$

Then, the rotor position can be estimated using the following differential algebraic relationship:

$$\tan\theta = -\frac{\dot{y}_1 L_d + R_s y_1 + \omega(L_d - L_q)y_2 - u_1}{\dot{y}_2 L_d + R_s y_2 - \omega(L_d - L_q)y_1 - u_2} \tag{5}$$

In this case, the rotor position can be identified at standstill if the first derivative of i_q is different from zero.

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Manuscript received March 23, 2015; accepted July 7, 2015.

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[1]The same notations as [1] are used.