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Grid-connected vector-controlled slip-ring induction machine drive with out speed sensor

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ABSTRACT

A speed estimation method is presented in this paper for a grid-connected doubly-fed slip-ring induction machine drive. The proposed method is formulated with reactive power based model reference adaptive system (MRAS). The method does not require the estimation of stator/rotor flux. So, the integrator related problems at synchronous speed are overcome. Also, the estimation method is independent of stator and rotor resistance variation. Extensive simulation results are presented to validate the technique.

1. Introduction

The doubly-fed induction motor (DFIM) drives are becoming popular in industry applications due to its high power handling capability without increasing the power rating of the converters. The speed of a DFIM can be controlled by injecting or extracting power from the rotor side. The power from the rotor side can be extracted by manually varying the resistance in the rotor circuit. This type of speed control leads to high power loss in the rotor circuit and hence suffers from lower efficiency. With this technique, motor speed can be controlled below synchronous speed. In Sen and Ma [1], the rotor side resistance is varied through a rectifier–chopper arrangement. The use of rectifier restricts the power flow in one direction (i.e. outwards from rotor).

Two different configurations, viz. Scherbius and Kramer drives are very well known for doubly fed induction motors. Both of these concepts in their original forms used additional electric machines. The basic difference is that the Kramer drive deals with power in both mechanical and electrical forms, whereas the Scherbius drive controls power only in electrical form. Obviously, these drives are only used for multi-megawatt system, where the cost of additional machine is justified [2]. The schematic diagram of these drives is available in Fig. 1.

The electromechanical arrangement of the Scherbius drive is replaced by the static devices in [3–5] as shown in Fig. 2(a). Here also, the slip power is flowing in one direction, i.e. from rotor side to the grid due to the presence of the diode rectifier. So, the super-synchronous speed of operation is not possible. The diode bridge is replaced by a controlled converter in Pena et al. [6], as shown in Fig. 2(b). Such configuration of the DFIM drive can be able to perform both in the sub-synchronous and super-synchronous modes. The DC link voltage is controlled through the front-end converter (FEC). The FEC exchanges power (active/reactive) with the grid maintaining the desire power factor.

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Nomenclature

v_{sd}, v_{sq}	d and q components of the stator voltage vector
i_{sd}, i_{sq}	d and q components of the stator current vector
ψ_{rd}, ψ_{rq}	d and q components of the rotor flux vector
ω_{sl}	Slip speed
ω_{ms}	speed of stator flux
ω_r, ω_{rest}	actual and estimated rotor speed
K_P	proportional gain of the adaptation mechanism
K_I	integral gain of the adaptation mechanism
K_1	$= \sigma L_r + \frac{L_m^2}{L_s}$

The stator flux oriented vector control is considered for the operation of rotor side converter. The power factor of the stator side can be controlled by judicious choice of the control variables, e.g. d-axis rotor current (i_{sd}) and stator magnetizing current (i_{ms}). The details of the rotor side controlled grid-connected slip-ring induction motor drives are available in Datta and Ranganathan [7].

Speed information is must for the stator flux oriented vector-controlled drive [6,8]. The speed information is obtained from speed sensor, mounted on the shaft of the rotor. Mounting, signal transmission and hazardous environment are the reasons to avoid the use of speed sensor. Also, the cost of the sensor is an important issue. So, speed estimation from current and voltage signals are preferred than the measurement.

Various speed estimation methods are available in the literature for DFIM drives. In [9], rotor flux is used to calculate the speed. Rotor flux is computed from the rotor voltage and current signals through integration. The integrator may be saturated at low frequency. So, the algorithm may not perform well at synchronous speed corresponding to the zero rotor frequency. This problem is overcome in a ROTODRIVE [10], where stator flux is computed from stator side variables. The integrator related problems are avoided, as the stator side is directly connected to the grid. Note that the ROTODRIVE is heavily sensitive to the variation of stator resistance and leakage inductance. Datta and Ranganathan in Ref. [7] proposes a stator flux based speed estimation method, which performs well at synchronous speed and posses less parameter dependency.

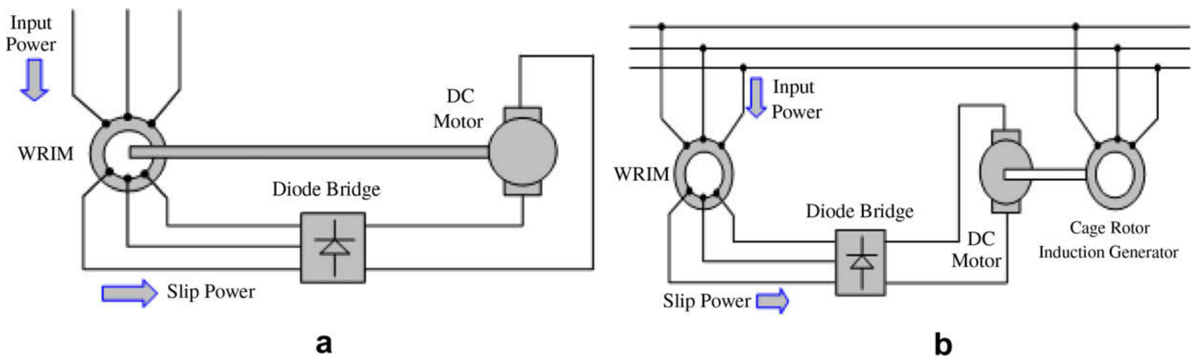

Fig. 1. SRIM drive (a) Kramer drive (b) Scherbius drive.

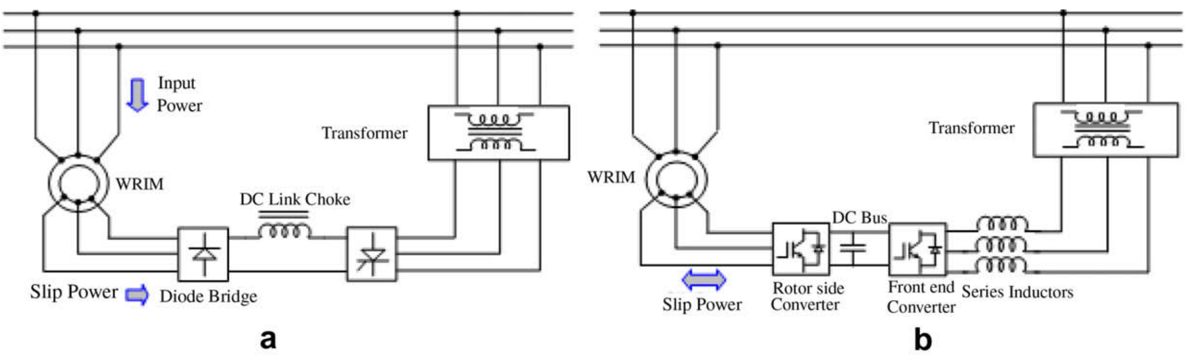

Fig. 2. SRIM drive (a) static Scherbius drive (b) arrangement with controlled converters in the rotor side.