Parameter identification for vector controlled induction wind turbines

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1. Introduction

Parameter identification of electrical machines is very important for the designer of the machine, facing its improvement. On the other hand, the knowledge of parameters is necessary to realise realistic simulations of the machines and is interesting for the operator of modern drives who implements the control systems.
The main drawback of conventional techniques to determine the parameters of the machines ("off-line" tests) is that they are based on a number of suppositions that are not valid in all type of conditions of operation. In addition, these techniques can be expensive to realise, require especially prepared personnel and a previous preparation of the machine before realising the tests, reason why they must be realised in test bench of the manufacturers.
The most used conventional methods are the test of locked-rotor and the no-load, widely described in basic books of Electrical Machines. By main of these methods it is possible to identify the parameters of the equivalent circuit of stationary state of the induction machine that are also applicable to the analysis of dynamic models of the machines.
Nevertheless, in many cases the machines and the converters are of different manufacturers and the parameters of the machine are not known. Given the increase of the installation of induction generators due to the proliferation of wind farms [1] and the difficulty of being able to realise the conventional tests once they are installed, it is necessary to develop new methods for the identification of induction machine parameters in a simple, economic and reliable way.
The reviewed bibliography of "online" identification, generally considers a subgroup of parameters of the machine, when the rest of parameters are known [2]. The difficulty of parameter identification has two main causes: on the one hand, the skin effect of the resistance of rotor in machines of squirrel cage and, on the other, the difficulty to identify the mechanical speed of the machine and electrical and mechanical parameters, simultaneously [2-5].
The strategies for parameter identification can be grouped in time-domain and frequency domain [5]. Frequency domain techniques are generally more accurate than time-domain because skin effect and iron losses can be taken into account.
This work presents a solution that consists of the binomial "test-algorithm of identification". The aim of the paper is not only the accuracy of the algorithm, but also the simplicity of the test. Parameters of the induction machine are obtained by an automatic measurement procedure using online signals of voltages and currents of the machine.
Simulation results of a squirrel cage induction machine of 7 kW parameters identification are shown and discussed.

Keywords: induction generator, parameter identification, frequency domain, dynamic system simulation.

2. Proposal of parameter identification tests

The method for the induction generator parameter identification has been developed from the mathematical model typically used for its dynamic analysis and the design of the vector controls. This model —called the "d-q-0" model of induction machine— is applicable to squirrel cage or doubly fed induction machines with symmetric or asymmetric feeding and consists of 6 non-linear differential equations.

$$\begin{bmatrix} v_{sD} \\ v_{sQ} \\ v_{rd} \\ v_{rq} \end{bmatrix} = \begin{bmatrix} R_s + pL_s & 0 & pL_m & 0 \\ 0 & R_s + pL_s & 0 & pL_m \\ pL_m & \omega_r L_m & R_r + sL_r & \omega_r L_r \\ -\omega_r L_m & pL_m & -\omega_r L_r & R_r + pL_r \end{bmatrix} \begin{bmatrix} i_{sD} \\ i_{sQ} \\ i_{rd} \\ i_{rq} \end{bmatrix} \tag{1}$$

$$v_{s0} = R_s i_{s0} + L_{ls} \frac{di_{s0}}{dt} \tag{2}$$

$$v_{r0} = R_r i_{r0} + L_{lr} \frac{di_{r0}}{dt} \tag{3}$$

The analysis of these equations leads to the definition of the tests to parameter identification:
The frequency response of the zero sequence stator voltage —Eq. (2)— allows the direct identification of stator resistance (Rs) and stator leakage inductance (Lls). This sequence is directly excited connecting the same voltage among the three phases.
The combination of direct and quadrature sequence of stator and rotor —Eq. (1)— in standstill condition —ωr=0— with frequency response method and the Bode diagram, leads to the identification of rotor resistance (Rr) , rotor inductance (Llr) and magnetising inductance (Lm) of the machine.

3. Simulation results

The proposed method has been applied to a squirrel cage induction machine of 7 KW with a nominal voltage of 380V and nominal current of 16 A. Its parameters are known by the classic tests: test of locked-rotor and the no-load test and manufacturer information.

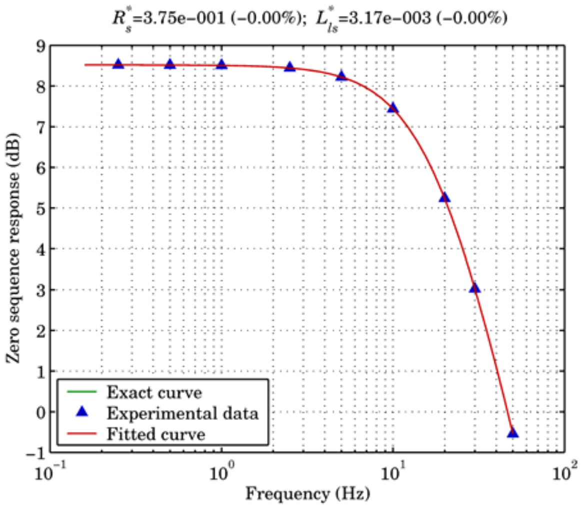

Figure 1. Zero sequence test results.

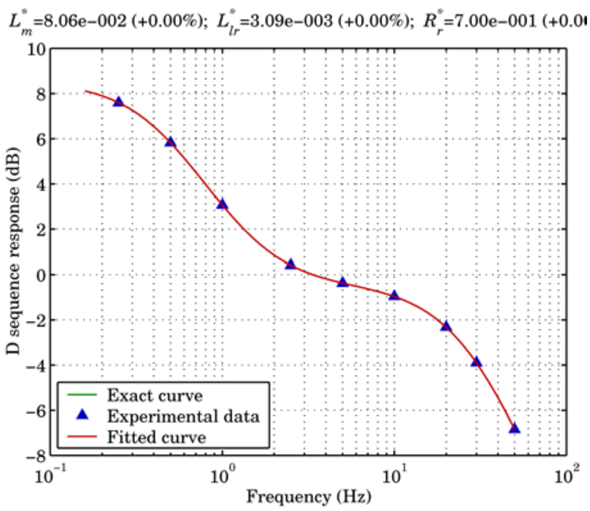

Figure 2. Direct sequence test results.

Fig 1 shows the result of the zero sequence test, where the module of the transfer function (v_{s0}/i_{s0}) for different frequencies is depicted. Based on simulation data the fitted Bode diagram is defined. It could be observed that it corresponds to a first order transfer function. The gain and the pole of this function lead to the identification of stator parameter values, with less than 0.00% error.
Fig 2 shows the result of the direct sequence test where the module of the relation (v_{sD}/i_{sD}) for different frequencies from 0.25 to 50 Hz is depicted. It can be observed that the module of the transfer function of the fitted Bode diagram corresponds to a second order system with a zero. The analysis of the zero and poles gives the rotor parameter values.
In both simulation tests fitted curve agrees with the exact curve defined with known parameter values of the 7 kW induction machine.

4. Conclusions

In the present work two tests have been proposed in order to identify the parameters of the doubly fed induction machine: zero sequence and direct sequence tests. Stator voltages and currents data for a range of frequency values are used to determine stator and rotor resistances, stator and rotor inductances and the magnetising inductance. These parameters will allow the tuning of vector controllers generally applied in wind generators [6].
The proposed method has been applied to the simulation of a squirrel cage induction machine of 7 KW obtaining values that are in agreement with the values known from the classic tests of laboratory.
These results will be validated in the real test bench of 7 kW that is being equipped at the moment.

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