Simulation and Measurement on the Asynchronous Machine under Transient Phenomena

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Abstract
This thesis deals with verification of induction machines in transient regimes. The thesis describes how to obtain machine parameters for a later mathematic model and its verification with measured motor. The main part focuses on the mathematical model of induction machine. Mathematical model was processed in Matlab Simulink. In the last part of the thesis the measured characteristics of real motor is compared with the output of the proposed model. Comparison was made for the „start“ transient phenomena.

1. Introduction
Simulation is an imitation of the real thing, state or process. The simulation itself displays basic key characteristics or behaviors for selected physical or abstract systems.

Simulation is used in many contexts, including the modeling of natural systems or human systems in order to gain insight into their functioning. Other contexts include simulation of technology for performance optimization, safety engineering, testing, training and education.

In this case I focused on the behavior of induction motor SIMENS, type 1LA7163-4AA10 with výkone11kW. Label values are U = 230/400V, I = 37.3 / 21.5 A and speed 1460ot/min.

2. Determination of parameters of induction machines
Parameters of the machine needed for the mathematical model and subsequent verification were obtained by measuring of machine in the basic modes and by measuring the moment of inertia.

2.1 No-load measurement
The motor is physically disconnected from the propulsive device and driven machine.

The start-up resistors are disconnected after starting up the machine. When measuring the voltage is set between 110% and 30% U_N.

During measurement the following readings are recorded: voltage U_{10}, current I_{10} and power requirement P_0.

The requirement is used to cover losses in stator windings ΔP_{j0}, mechanical losses ΔP_m, and losses in iron ΔP_{Fe}.

Losses in the iron rotor and losses in the rotor windings are negligible, because the slide is during no-load. Losses in the stator windings are determined from the Joule's law. The purpose of the no-load measurement is to determine the size of losses in the iron, mechanical losses and no load current.

2.2. Measurement of Short-circuit test
It is steady state. Assuming that the rotor winding is short circuited and the rotor is a brake.

During measurement the voltage U_K, current I_K and power requirement are read.

The purpose of measurement is to determine the size of losses in the windings, short-circuit current, starting current and starting torque.

2.3 Determination of torque of inertia
I used the torque of inertia method of measurement with an external flywheel to determine the characteristics.

Where the external flywheel with given torque of inertia was used.

Torque of inertia is directly proportional to the time at which the machine will stop spontaneously.

This is given by the formula:

\[ J_F = J_F \cdot \frac{t_1}{t_2 - t_1} \]  

(1)

2.4 Obtained parameters for modeling
Following parameters were obtained during measurement and were used for creating the model of induction machine:

L_s=L_R= 86,8 mH, R_s= 0,4 Ω, 2p= 4, J_F= 0,112 kgm^3
L_{sf}=L_d= 83,9 mH, R_d= 0,1 Ω, J_m= 0,061 kg m^3

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3. Mathematical model

In order to establish universally valid mathematical model, it is necessary to take two simplifying assumptions:
- neglecting magnetic resistance of the non-linear active iron
- magnetic flux goes through the air gap only in the radial direction.

Additionally, it is possible to simulate the magnetic tension in various parts of the magnetic circuit by adding fictitious winding.

For a description of the electrical machine, which is symmetrical about the axis of rotation is best suited for the use of polar coordinates.

Courses of the electromagnetic values are spatially periodical functions. Therefore in the theory of electrical machines is used Fourier expansion since the early times, which breaks down into a series of periodic waveforms of sine functions. Another important fact for the use of Fourier development is that the amplitude of individual components of Fourier development is determined by integration. This means that Fourier development of sum of the various functions equals to sum of these functions.

This is important for sub-functions that are of the same type.

This condition best meets variable called "current layer".

Distribution of instantaneous currents at the periphery of the rotor or stator is called current layer (A) of stator or rotor. Current layer can be considered as the current per angle for the needs of the mathematical model.

Current layer is a function of polar coordinates and time, because the currents flowing in conductors deposited in the grooves change in time.

Current layer is a discontinuous function, since it consists of pulses. These pulses are given for each variable.

Field in the air gap is given by the sum of the current layers of stator and rotor, which are expressed in the same coordinate system.

3.1 The basic equations for induction motor

Applies for the stator voltage

\[ u_j = R_i i_j + L_s \frac{di_j}{dt} + L_{sh} \frac{di_{sh}}{dt} \]  

(2)

Model using the phasors is not suitable for modeling by computer, so I expressed equations in the complex plane.

\[ u_{\alpha\beta} + j u_{\beta\alpha} = R_i (\psi_\alpha + j \psi_\beta) + L_s \frac{di_\alpha}{dt} + L_s \frac{di_\beta}{dt} + \]  

(3)

For modeling it was necessary to spread the equation for the real and imaginary part, as I mention in further text.

The equation for the cage rotor looks like

\[ 0 = R_s \frac{di_\alpha}{dt} + L_s \frac{di_\beta}{dt} + j \omega M \]  

(4)

(5)

(6)

For modeling it was necessary to spread the equation for the real and imaginary part, as I mention in following paragraphs.

For the moment generally applies

\[ M = F \cdot r \]  

(7)

(8)

3.2 The resulting equations for modeling the verified machine

\[ u_{\alpha\alpha} = R_i i_{\alpha\alpha} + L_s \frac{di_{\alpha\alpha}}{dt} + L_{sh} \frac{di_{sh\alpha}}{dt} \]  

(9)

\[ u_{\beta\beta} = R_i i_{\beta\beta} + L_s \frac{di_{\beta\beta}}{dt} + L_{sh} \frac{di_{sh\beta}}{dt} \]  

(10)

\[ 0 = R_s i_{\beta\alpha} + L_s \frac{di_{\beta\alpha}}{dt} + L_{sh} \frac{di_{sh\alpha}}{dt} - \]  

(11)

\[ 0 = R_s i_{\alpha\beta} + L_s \frac{di_{\alpha\beta}}{dt} + L_{sh} \frac{di_{sh\beta}}{dt} + \]  

(12)

\[ M - M_\gamma = \frac{1}{p} \frac{d\omega}{dt} \]  

(13)

\[ M = \frac{3}{2} pL_{sh} (i_{\beta\alpha} R_{\alpha\alpha} - i_{\alpha\alpha} R_{\beta\beta}) \]  

(14)
4. Simulation
Mathematical model of the machine in the transient phenomena I worked out in Simulink, software package MATLAB. MATLAB is an integrated environment for scientific computing, modeling, design of algorithms, simulation, analysis, measurement and signal processing, design management and communication systems. MATLAB was originally developed to access mathematical libraries. The name originated as short for words matrix and laboratory. Simulink is an integrated part of MATLAB, which uses MATLAB and its function in the simulation of dynamic systems. Based on knowledge of the mathematical description of the induction machine and the parameters of this particular machine I created its simulation.

Fig.1. Model of induction machine
5. Verification

With the help of computer technology and the use of program Simulink I carried out verification of the transient regimes of induction machines.

As transient phenomena for verification, I chose the start of induction motor. Simulation of the motor was done for several different input parameters.

As shown in the charts on the figures 2 and 3, characteristics which I calculated and measured, are approximately the same. Characteristics (curves) do not completely coincide because of the need to simplify the principles of the machine due to the possibility of mathematical description and subsequent modeling.

![Characteristics graph](image1)

Fig. 2. Display characteristics of the transient phenomena induction machine fed $U=80\sqrt{2}$ V by a moment of inertia $J=0.061$kg·m²

![Characteristics graph](image2)

Fig. 3. Display characteristics of the transient phenomena induction machine fed $U=100\sqrt{2}$ V by a moment of inertia $J=0.061$kg·m²

Bibliography


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