

USE OF DIFFERENTIAL EQUATIONS IN MODELING AND RESEARCH OF ASYNCHRON MOTOR OPERATING MODES

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ANNOTATION

In this article given information about the analysis of the dynamic mode of an induction motor using differential equations is performed in the Matlab program.

Keywords: *Asynchronous motor, differential equation, stator, rotor, coil, bipolar, moment, frequency, voltage, current, active resistance, inductance, angular velocity, visualization, mechanical, electrical energy.*

INTRODUCTION

Since the main consumer of electricity in industrial enterprises are asynchronous machines, the study of their dynamic modes is of particular interest. We analyze the dynamic mode using differential equations using the Matlab calculation program. This calculation program gives us a lot of convenience in analyzing differential equations. In this paper, we have obtained a graph of the change in torque and speed in the dynamic mode of an induction motor using the Matlab program.

Experimenting with a real object can be inconvenient and dangerous for a number of reasons. The reasons for this are:

- long duration of the experiment;
- risk of demolition or destruction of the object;
- research poses a threat to human health and life;
- the absence of a real object.

Matlab experiments do not cause these inconveniences and are very cost effective.

MAIN BODY

In implementing the computational program, we use a well-known system of differential equations of an asynchronous machine.

$$\left. \begin{aligned} u_{1\alpha} &= r_1 i_{1\alpha} + \frac{d\psi_{1\alpha}}{dt} \\ u_{1\beta} &= r_1 i_{1\beta} + \frac{d\psi_{1\beta}}{dt} \\ 0 &= r_2 i_{2\alpha} + \frac{d\psi_{2\alpha}}{dt} + \omega_p \psi_{2\beta} \\ 0 &= r_2 i_{2\beta} + \frac{d\psi_{2\beta}}{dt} + \omega_p \psi_{2\alpha} \\ \frac{di_{\alpha}}{dt} &= \frac{u_{1\alpha} - ri_{\alpha}}{L} \\ \frac{di_{\beta}}{dt} &= \frac{u_{1\beta} - ri_{\beta}}{L} \\ M &= \frac{mpM}{2(L_1 L_2 - M^2)} (\psi_{1\beta} \psi_{2\alpha} - \psi_{1\alpha} \psi_{2\beta}) \\ \frac{d\omega_p}{dt} &= \frac{p}{J} (M - M_c) \end{aligned} \right\} \quad (1.1)$$

There $u_{1\alpha} = U_m \cos(\omega t)$, $u_{1\beta} = U_m \sin(\omega t)$ - stator voltage along the a, b axes; $i_{\alpha 1}, i_{\beta 1}, i_{\alpha 2}, i_{\beta 2}$ the current of the stator and rotor windings along the axes a, b; $\psi_{\beta 1}, \psi_{\alpha 1}, \psi_{\beta 2}, \psi_{\alpha 2}$ - current connection of stator and rotor; r_1, r_2 - stator, rotor active resistors; ω, ω_p - network frequency and rotor speed (el. rad / s); L_1, L_2 - total inductance

of stator and rotor windings; L_m – mutual inductance between windings; M , M_S – the electromagnetic moment of an induction motor and the static moment of the load; m - number of phases; p - the number of pole pairs; J - moment of inertia of the engine and mechanism.

The flow of muds according to 1.2:

$$\left. \begin{aligned} \psi_{1\alpha} &= L_1 i_{1\alpha} + M i_{2\alpha} \\ \psi_{1\beta} &= L_1 i_{1\beta} + M i_{2\beta} \\ \psi_{2\alpha} &= L_2 i_{2\alpha} + M i_{1\alpha} \\ \psi_{2\beta} &= L_2 i_{2\beta} + M i_{1\beta} \end{aligned} \right\} \quad (1.2)$$

As an example, we calculate the starting dynamic mode of an induction motor with the following parameters: $P_2 = 10\text{kVt}$; $U_n = 220\text{V}$; $r_1 = 0,1155\ \Omega$; $r_2 = 0,055\ \Omega$; $L_1 = L_2 = 0,0106\text{H}$; $M = 0,01038\text{H}$; $J_{dv} = 0,41\text{kgm}$; $p = 3$. The parameters of the rotor winding are given in the stator winding:

```
% Software for calculating the transients of a short-circuited rotor induction motor
% fun_AD function, the right side of the system of differential equations and outputs the parameters of
the induction motor (file: fun_AD.m).
```

```
global U r_1 L_1 r_2 L_2 M p J w_1 M_c_nabp t_nabp;
```

```
U=220; % The effective value of the stator voltage.
```

```
r_1=0.02155; % Active resistance of the stator.
```

```
L_1=0.010606; % The total inductance of the stator winding.
```

```
r_2=0.01231; % Active resistance of the rotor.
```

```
L_2=L_1; % The total inductance of the rotor winding.
```

```
M=0.01038; % Mutual inductance.
```

```
p=2; % Number of pairs of poles.
```

```
J=2.3; % Moment of inertia.
```

```
f_1 =50; % Network frequency.
```

```
w_1 = 2*3.14159*f_1; % Tarmoq chastotasi.
```

```
M_c_nabp =706.4; % The static moment of the load is equal to the nominal moment of the induction
```

motor.

```
t_nabp = 1 ; % Static torque loading time.
```

```
tspan = 0:0.0005: 1.4; % account start time. Calculation step. End time.
```

```
y_0 = [0; 0; 0; 0; 0]; % Initial values of variables.
```

```
[T,Y]=ode45(@fun_AD, tspan, y_0);
```

```
Y_out =[];
```

```
Y_out(:,1) = (Y(:,1).*L_2 - Y(:,3).*M)/(L_1*L_2 - M*M); % Stator current along the alpha axis
```

```
Y_out(:,2) = (Y(:,2).*L_2 - Y(:,4).*M)/(L_1*L_2 - M*M); % Stator current along the beta axis
```

```
Y_out(:,3) = (Y(:,3).*L_1 - Y(:,1).*M)/(L_1*L_2 - M*M); % Rotor current along the alpha axis
```

```
Y_out(:,4) = (Y(:,4).*L_1 - Y(:,2).*M)/(L_1*L_2 - M*M); % Rotor current along the beta axis
```

```
Y_out(:,5) = Y(:,5)/p; % Angular velocity of the rotor.
```

```
Y_out(:,6) = 1.5*p*M*(Y(:,1).*Y(:,4) - Y(:,2).*Y(:,3))/(L_1*L_2 - M*M); % Electromagnetic torque of
```

an induction motor.

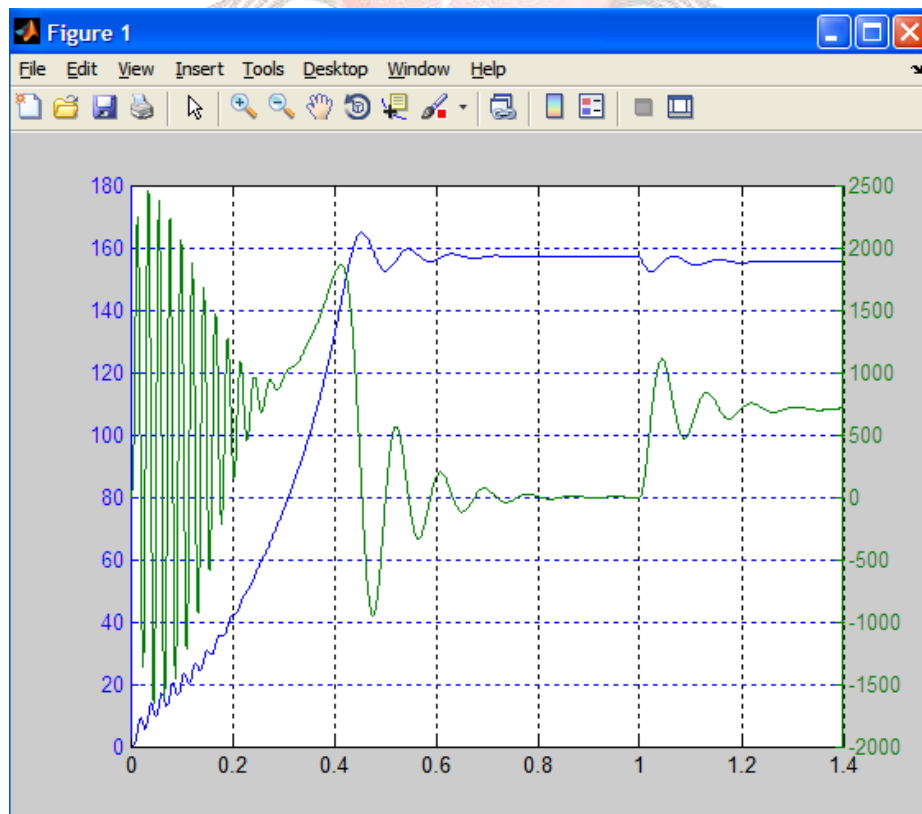
```
% Construction of a rotor speed and electromagnetic torque graph of an induction motor.
```

```
plotyy(T,Y_out(:,5),T,Y_out(:,6))
```

grid on % Сетка.

fun_AD.m-файл.

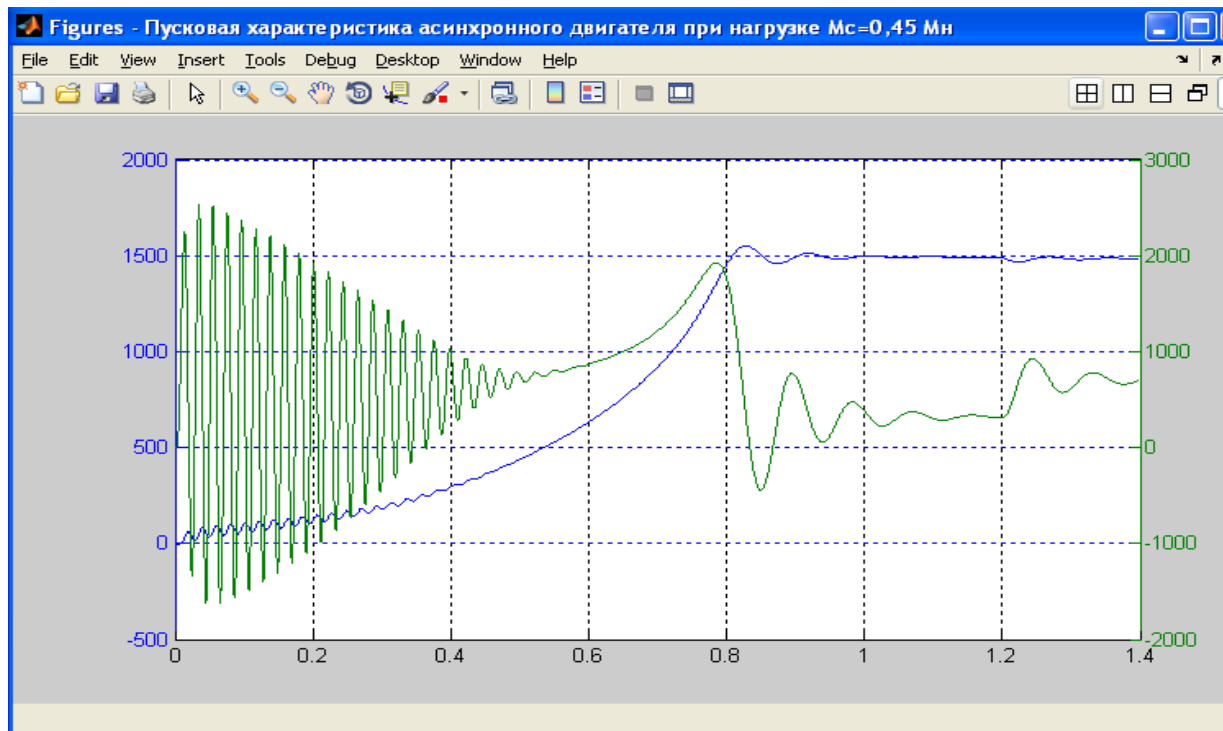
```
% fun_AD Right side of the system of differential equations (file:
fun_AD.m).
% dydt declare the matrix
function dydt= fun_AD(t, y)
global U r_1 L_1 r_2 L_2 M p J w_1 M_c_nabp t_nabp;
dydt=zeros(5,1); % The type of matrix given
if t<t_nabp % t=t_nabp download during
    M_c=0;
else
    M_c=M_c_nabp;
end
dydt(1) = - ((y(1)*L_2 - y(3)*M)/(L_1*L_2 - M*M))*r_1 + sqrt(2)*U*sin(w_1*t);
dydt(2) = - ((y(2)*L_2 - y(4)*M)/(L_1*L_2 - M*M))*r_1 + sqrt(2)*U*cos(w_1*t);
dydt(3) = - ((y(3)*L_1 - y(1)*M)/(L_1*L_2 - M*M))*r_2 + y(5)*y(4);
dydt(4) = - ((y(4)*L_1 - y(2)*M)/(L_1*L_2 - M*M))*r_2 - y(5)*y(3);
dydt(5) = p*(1.5*p*M*(y(1)*y(4) - y(2)*y(3))/(L_1*L_2 - M*M)-M_c)/J;
end
```



3.1.- picture. Rotor speed and electromagnetic torque graph of an induction motor obtained in the Matlab program.

The results of the calculation of the dynamic operating modes of the induction motor are shown in Figure 3.1. The engine starts without loading. At time $t = 1c$, a static load moment is connected to the shaft of the induction motor, in which case this load is equal to the rated torque, ie, $M_{nom} = (P_{2nom} * 60)/(2\pi n_{nom}) = 706,4 \text{ Nm}$. The damping vibration process is observed both at start-up and during lifting. At rated speed, this asynchronous motor will start in less than 0.6 seconds if no load is connected to the shaft.

When starting an asynchronous motor with 45% of the rated torque, the starting time increases (Figure 1). An increase in the moment of inertia and a decrease in the voltage lead to a similar result.



1-rasm. $M_s = 0,45 M_n$ is the starting characteristic of an induction motor at load.

DISCUSSION AND RESULTS

It should be noted that as the computational program becomes more complex, the problems associated with correcting it also increase. An m-file debugger compatible with the file editor makes it much easier to find errors.

Let's look at the work of a debugger using the last program example. Suppose, `fun_AD` function a $M_c = M_c_{nabp}$ we need to check when the appointment operation will take place.

To do this, set the breakpoint on this row by clicking on the breakpoint column. Alternative options: Breakpoints-Set / Clear the button on the toolbar is used; The F12 key is used. Pressing again removes the breakpoint. After that, `example_1_1` goes to the program window and launches it by clicking the "Start" button located on the toolbar. The program then drops to a breakpoint and goes into MATLAB debugging mode, in the command window `>> question K >>` and the green arrow next to the stop point. If it is necessary to determine the content of a variable, it is sufficient to bring an arrow to it. After that, a window with information about the variable will appear, in which case the time variable t .

In troubleshooting mode, you can step through the program. All you have to do is use the buttons on the toolbar or the F10 key. Here you can see the content of variables and expressions. Just press the red button to exit the troubleshooting mode.

CONCLUSION

The methods of programming and visualizing the results described above are now available in other computing systems. However, one of the strengths that has enabled MATLAB to become a leader in modern mathematical and scientific software is that it has many extensions for technical computing. These extensions allow you to create a model of the whole device, despite the differences in its physical nature. For example, if we are talking about a machine, then simultaneously calculate the dynamic properties of its interconnected energy, mechanical, electrical and other units, ie. to mimic the movement of the whole machine during acceleration, braking, turning, etc. This allows a significant portion of errors to be identified and rectified at the design stage, rather than at the prototype creation stage. Since the price of the prototype is not comparable to the price of its model, such “bug fixes” can save a great deal of money in creating a new technical device.

In the field of electric power, the use of MATLAB and its extensions allows: adjustment of relay protection devices on the model of the power system or its plot, rather than on the object itself; simulation of power system stability and other operating modes, taking into account electrical, mechanical and other components; receiving and processing data from control and accounting devices.

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