ANALELE UNIVERSITĂŢII
"EFTIMIE MURGU" REŞIŢA
ANUL XVIII, NR. 3, 2011, ISSN 1453 - 7397

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Study Regarding the Identification of the Induction Motor

In the framework of the paper, we analyze some theoretical and practical aspects regarding the identification of the induction motor. The problem is important in the synthesis of different driving systems with automatic induction motors, usually with variable speed of rotations. The performances in the transitory and stationary regime of these quick adjustment systems are influenced by the precision of the mathematical model of the chosen driving motor. We present different mathematical models of the induction motor, obtained in an experimental way.

***Keywords**: identification, induction motor, driving system, transitory regime, stationary regime*

1. Theoretical considerations

The modeling of the induction motor in short-circuits was achieved using the following simplifying hypotheses:

a) the resistance of the phase winding of the stator is neglected, $R_s=0$;

b) the supply frequency of the stator is suddenly modified;

c) the stator flow is constant for: $f_x \in (20 \div 60)Hz$, $\frac{U}{f} = ct$ and for $f_x \in (0 \div 20)Hz$, $U = af + b$.

The testing signal of the motor of unitary step type, applied in the origin of the reference system has the following relation definition:

$$u(t) = \begin{cases} 1 & for \quad t \geq 0 \\ 0 & for \quad t < 0 \end{cases} \tag{1}$$

1.1. The indicial response of the element PT1

The transfer function of the element PT1 without idle time/dead time is:

$$H(s) = \frac{K}{1 + T \cdot s} \quad (2)$$

the mathematical model in the time field is:

$$T \cdot \frac{dy}{dt} + y(t) = K \cdot u(t) \quad (3)$$

for the element of automatic system, represented in figure 1.

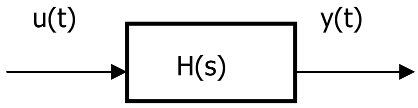

Figure 1. The symbols of the studied automatic element.

The form of the indicial response a(t) as solution of the linear differential equation (5) is represented in figure 2.

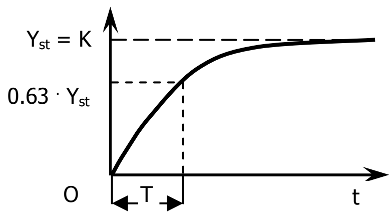

Figure 2. The graphic of the a(t) indicial response of the element PT1 without lost time.

$Y_{st} = K \cdot I_0$, if the step height is I_0.

The analytical relations determined on the basis of the ideal step signal are also valid in the case of real signals (measured or recorded), due to the fact that the constants of time delay of real processes are higher than the growing time of the step signal physically generated in the case of the experiment.

The transfer coefficient of the PT1 element is expressed by the relation:

$$K = \frac{Y_{st}}{I_0} \quad (4)$$

For t=T, we obtain: $Y(T) = Y_{st}(1-e^{-1}) = Y_{st}(1-0.37) = 0.63 \cdot Y_{st}$ (5)

Where T is the time delay constant of the element and represents the time after which the indicial response reaches the value 0,63 in Y_{st}, starting from the origin of the reference system.

For the elements characterized by the dead time constant, the transfer function is of type:

$$H(s) = \frac{K \cdot e^{-T_\mu \cdot s}}{1 + T \cdot s} \tag{6}$$

Where T_u is constant for the lost time and the indicial response have a form as the one presented in figure 3.

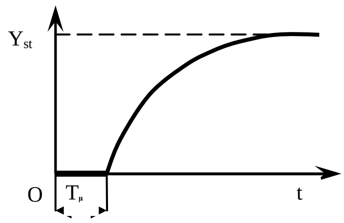

Figure 3. The indicial response for the element PT1 with dead time.

1.2. The indicial response of the element PT2

The transfer function of the element PT2 no-lost time is:

$$H(s) = \frac{K}{1 + T_m \cdot s + T_e \cdot T_m \cdot s^2} = \frac{K}{1 + 2 \cdot \xi \cdot \tau \cdot s + \tau \cdot s^2} \tag{7}$$

and the established indicial response on analytical way is:

$$a(t) = Y_{st} \cdot (1 - \frac{1}{\sqrt{1-\xi^2}} \cdot e^{-\xi \omega_n t} \cdot \sin(\omega_n \sqrt{1-\xi^2}\, t + \varphi) \tag{8}$$

for $0 < \xi < 1$,
and:

$$a(t) = Y_{st} \cdot (1 - \frac{T_m}{T_m - T_e} \cdot e^{-\frac{t}{T_m}} + \frac{T_e}{T_m - T_e} \cdot e^{-\frac{t}{T_e}}) \tag{9}$$

for $\xi > 1$,
ω_n - is the natural pulse of the non-harmonized element; ξ – is the amortization factor; T_e - is the electrical time constant; T_m - is the electromechanical time constant; K - Is the transfer coefficient. $\tau = \frac{1}{\omega_n}$

The mathematical model in the time domain is:

$$T_e \cdot T_m \cdot \frac{d^2 y}{dt^2} + T_m \cdot \frac{dy}{dt} + y(t) = K \cdot u(t) \tag{10}$$

The forms of the a(t) indicial response as solution of the linear differential equation (13) – the most frequently met in practice – are represented in figure 4 and figure 5.

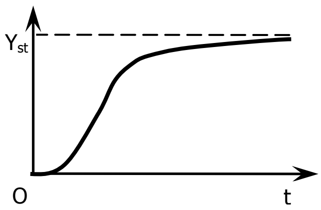

Figure 4. The indicial response of the element PT2 for 0<s<1.

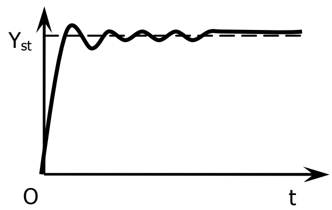

Figure 5. The indicial response of the element PT2 for s>1.

Using the notations dedicated to the models of the induction motor, we obtain:

$$\tau^2 = T_e \cdot T_m \ ; \ \tau = \sqrt{\frac{h}{2 \cdot M_K}} \qquad (11)$$

which correspond to:

a) for $\xi \geq 1$; $T_m \geq 4 \cdot T_e$

b) for $\xi \langle 1$; $T_m \langle 4 \cdot T_e$

2. Experimental results

Experiments referring to the identification were achieved on the induction motors with the rotor in short-circuit with the installation represented in figure 6.

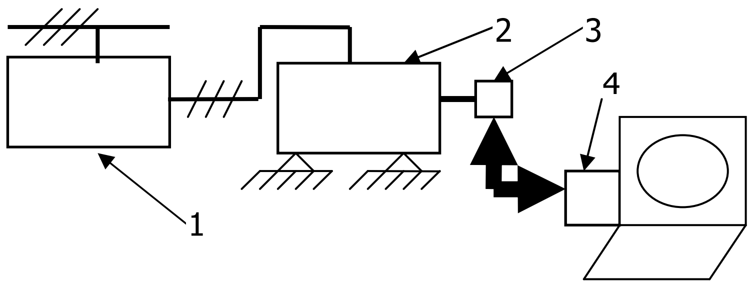

Figure 6. The main scheme of the induction motor identification: 1 – the static converter of frequency, 2 - the induction motor in short-circuit, 3 – rotation transducer, 4 – acquisition system and PC.

2.1. The interpretation of the indicial response of the induction motor having the constant measures

i(t) – the frequency step (U/f); y(t) – rotation speed.

2.1.1. The indicial response of the induction motor in short-circuit with nominal data P_N=0,25 kW, n_N=1405 rot/min

In figure 7 we have presented the indicial response of motor for three frequency steps: 50 Hz, 25 Hz and 5 Hz.

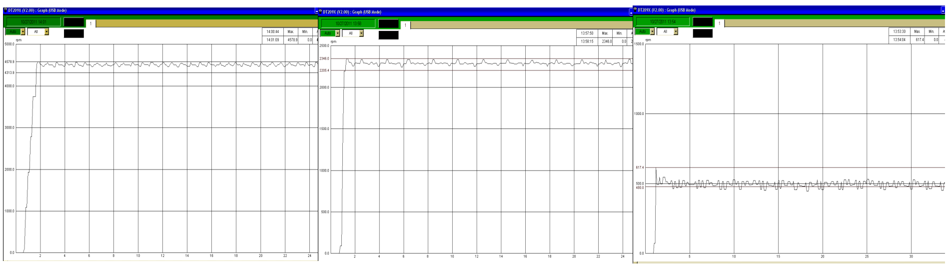

Figure 7. The indicial responses for: a) f = 50 Hz, b) f = 25 Hz, c) f = 5 Hz.

2.1.2. The indicial responses of the induction motor with short - circuit rotor with nominal data P_N = 3,6 kW, n_N = 1710 rot/min

In figure 8 we have presented the indicial responses of the three step frequency motor: 60 Hz, 30 Hz, 5 Hz.

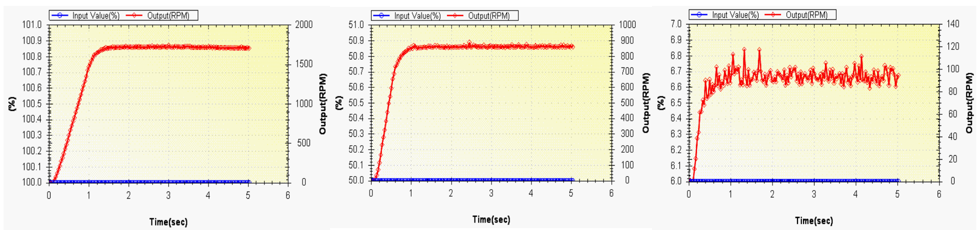

Figure 8. The indicial responses for: f = 60 Hz, b) f = 30 Hz, c) f = 6 Hz.

3. Conclusion

After the experiments we have reached the following conclusions:

a) the experimental results confirm the analytical models of the induction motor;

b) the exactness of the mathematical model obtained in an experimental way depends on the performances of the supply source with electric energy of variable frequency and tension and the technical performances of the measurement and registration equipment;

c) indicial response a figure 7 a), b) indicate PT1 element and c) indicate PT2 element;

d) indicial response a figure 8 a), b), c) indicate PT1 element with dead time;

The used equipments and the experience of the researchers allow the achievements of some models as exact as possible of the induction motor using the method of the indicial response.

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