

Consideration on the Characteristics of Asynchronous Machine when the Feeding Voltage is Varying With 10%

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Abstract

The aim of this paper is to illustrate the evolution: $M(t)$, $M(\omega)$, $\psi_{shd}(t)$, $\psi_{shq}(t)$, $\psi_{shd}(\psi_{shq})$, when the feeding voltage, of the asynchronous motor, is varying with 10%. The simulations are made using the programming in Matlab. This situation (when the feeding voltage is varying) is very common in auxiliary's posts of the electromotive.

Key words: asynchronous machine, software of Matlab, voltage's variation.

Introduction

The importance taken these last years by the automatic regulation established new investigation requirements. Indeed, how for example to consider the dimensioning of a regulator if we does not know the dynamic behavior of the system to be regulated? Such changes required the search for data-processing tools powerful and easy to implement. We choose MATLAB to model the dynamics of a three-phase asynchronous machine used in auxiliary's posts of the electromotive.

Because the power supply of the electromotive with three-phase tensions remove special problems with the contact system, on the majority of electromotive, which are feeding single-phase and are using asynchronous motors, there are a converter of phase and a frequency converter.

The auxiliary posts of an electromotive have the function to ensure the conditions necessary of a good operation for all other systems and activities on the electromotive. The motors of the auxiliary's posts are three phase asynchronous motors. The asynchronous motors from the auxiliary posts are classified in five classes of power. The paper brings into discussion the asynchronous motor of a fan.

Voltage's regulation in the three phase system

The voltage on the terminals of an electric motor (which drives a fan on the electromotive) depends on the value of the voltage on the contact system which changes between 17,5kV and 27,5kV. For the asynchronous motor are forced the tensions of the terminals to be constant. If the decreases of the voltage under a minimal allowed value (265V on the terminal) the torque developed is much decreases and could be less than the resistive torque.

To maintain the voltage higher than 265 V, there are two plugs: a superior plug and an inferior

plug. When the voltage is higher than 21, 5 kV the system is fed by the inferior plugs and when the voltage is under 21, 5 kV, the system is fed by the superior plugs. This paper brings into discussion this aspect and uses Matlab to simulate the variation of torque.

Model, assumptions and basic equations of the electric machine

To simulate the behavior of an asynchronous machine, we must adopt a physical model bringing into discussion the principal electro-mechanical characteristics. The basic model consists in an induction machine with constant air-gap and symmetrical three-phase wrapping in the stator and the rotor. For this machine we write the equations in complex. The electrical part of the machine is represented by a fourth - order state-space model and the mechanical part by a second-order system. The asynchronous machine's parameters are defined as in literature [1] and the basic equations, in complex, are:

$$\begin{cases} \underline{u}_s = R_s \underline{i}_s + \frac{d\underline{\psi}_s}{dt} + j\omega_B \underline{\psi}_s \\ \underline{u}_r = R_r \underline{i}_r + \frac{d\underline{\psi}_r}{dt} + j(\omega_B - \omega) \underline{\psi}_r \\ \underline{\psi}_s = L_s \underline{i}_s + L_{sh} \underline{i}_r \\ \underline{\psi}_r = L_r \underline{i}_r + L_{sh} \underline{i}_s \end{cases} \quad (1)$$

$$\begin{cases} M + M_m = \frac{J}{p} \frac{d\omega}{dt} \\ M = \frac{3}{2} p R_e [j \underline{\psi}_s \underline{i}_s^*] \end{cases} \quad (2)$$

We process this equation like in literature [1], and used the equation in (d,q) frames (all quantities are constants and couch in the reference frame jointly with the stator $\omega_B = 0$):

$$\begin{cases} L_s \frac{di_{ds}}{dt} + L_{sh} \frac{di'_{dr}}{dt} = u_{ds} - R_s i_{ds} \\ L_s \frac{di_{qs}}{dt} + L_{sh} \frac{di'_{qr}}{dt} = u_{qs} - R_s i_{qs} \\ L_r \frac{di'_{dr}}{dt} + L_{sh} \frac{di_{ds}}{dt} = u'_{dr} - R'_r i'_{dr} - \omega (L'_r i'_{qr} + L_{sh} i_{qs}) \\ L_r \frac{di'_{qr}}{dt} + L_{sh} \frac{di_{qs}}{dt} = u'_{qr} - R'_r i'_{qr} - \omega (L'_r i'_{dr} + L_{sh} i_{ds}) \\ M + M_m = \frac{3}{2} \cdot p \cdot (\psi_{ds} i_{qs} - \psi_{qs} i_{ds}) + M_m = \frac{3}{2} p \cdot L_{sh} (i_{qs} i'_{dr} - i_{ds} i'_{qr}) + M_m \end{cases} \quad (3)$$

Because $\omega \neq ct$, the system is not linear, so we need the motion equation to solve this system. To simplify the method are made the following **assumptions**:

a). All stator and rotor quantities are in the stator reference frame (qd frame). It is thought that $\omega_B=0$ ((d,q) axes system is united with the stator and (d) axe coincide with A axe)

$$\begin{aligned} u_{sd} &= \sqrt{2} \cdot U \cdot \cos(\omega_1 \cdot t + \varphi_A) \\ u_{sq} &= \sqrt{2} \cdot U \cdot \sin(\omega_1 \cdot t + \varphi_A) \end{aligned} \quad (4)$$

b). The rotor is in short circuit:

$$u'_{rd} = u'_{rq} = 0 \quad (5)$$

c). $\varphi = \frac{\pi}{4}$; $L_{sht} = L_{sh} = ct.$ so we process the inductances: $L_{md} = L_{mq} = \frac{1}{2} (L_{sht} + L_{sh}) = L_{sh}$; $L_{mdq} = \frac{1}{2} (L_{sht} - L_{sh}) = 0.$

Mathematical problem

The final goal of any abstract theory is its applications in practice life. The first step is to formulate the mathematical problem. Then we must choose the mathematical or numerical methods to solve it. The last step is to confront the theoretical result with those experimental. In our case the mathematical problem is to solve a non-linear system of differential equations with initial conditions. To simplify the form in the system (6) we note:

$$A = \begin{pmatrix} L_s & 0 & L_{sh} & 0 & 0 \\ 0 & L_s & 0 & L_{sh} & 0 \\ L_{sh} & 0 & L'_r & 0 & 0 \\ 0 & L_{sh} & 0 & L'_r & 0 \\ 0 & 0 & 0 & 0 & J/p \end{pmatrix}, \text{ the matrix of constant}$$

$$Y = \begin{pmatrix} i_{ds}(t) \\ i_{qs}(t) \\ i'_{dr}(t) \\ i'_{qr}(t) \\ \omega(t) \end{pmatrix}, \text{ matrix of unknowns quantities}$$

$$F(t, Y) = \begin{pmatrix} u_{ds} - R_s i_{ds} \\ u_{qs} - R_s i_{qs} \\ u'_{dr} - R'_r i'_{dr} - \omega(L'_r i'_{qr} + L_{sh} i_{qs}) \\ u'_{qr} - R'_r i'_{qr} + \omega(L'_r i'_{dr} + L_{sh} i_{ds}) \\ \frac{3}{2} p \cdot L_{sh} (i_{qs} i'_{dr} - i_{ds} i'_{qr}) + M_m \end{pmatrix}, \text{ matrix of unknowns quantities of the second}$$

member.

The system (6), become:

$$A \cdot \frac{dY(t)}{dt} = F(t, Y(t)) \quad (6)$$

We solve this non-linear system, with differentials equations, in the numerical manner with the software of Matlab. Stages of solve are:

a. First step is to multiply the equation (6) at left with: A^{-1}

$$A^{-1} \cdot A \cdot \frac{dY(t)}{dt} = A^{-1} \cdot F(t, Y(t)) \Leftrightarrow \frac{dY(t)}{dt} = A^{-1} \cdot F(t, Y(t)) \quad (7)$$

b. Second step is to use Matlab software to solve the equation (7). This part represents the originality of this paper. The program consists in three subroutines:

1. With symbolic calculus we built a subroutine, which compute the inverse of matrix A.
2. In the script M1.m we define the elements of product: $A^{-1} \cdot F(t, Y(t))$
3. We built the script M2.m to define $\frac{dY(t)}{dt}$.
4. The script M3.m call the function ode45 to solve the equation (7) in agreement with the initial state $Y(t)=0$. We use function ode45. (Ode45 is based on an explicit Runge-Kutta (4,5) formula, the Dormand -Prince pair. It is a *one-step* solver - in computing $y(t_n)$, it needs only the solution at the immediately preceding time point, $y(t_{n-1})$. In general, ode45 is the best function to apply as a "first try" for most problems.[4]. The above algorithms are intended to solve non-stiff systems. If they appear to be unduly slow, try using one of the stiff solvers like ode15s, ode23s, ode23t, ode23tb.)

The parameters of the studied machine are: $P_n = 4 \text{ kW}$; $U_n = 220/380 \text{ V}$; $m = 3$; $f = 50 \text{ Hz}$; $p = 2$; $J = 0,024 \text{ kg m}^2$; $R_s = 1,16 \text{ } \Omega$; $R_r = 3,515 \text{ } \Omega$; $L_{s\sigma} = 0,024 \text{ H}$; $L_{r\sigma} = 0,0034 \text{ H}$; $L_{sh} = 0,2986 \text{ H}$.

Simulations

We represent the graphic of this solution for ($\pm 10\%$) rated voltage's variation (418 V and 342 V).

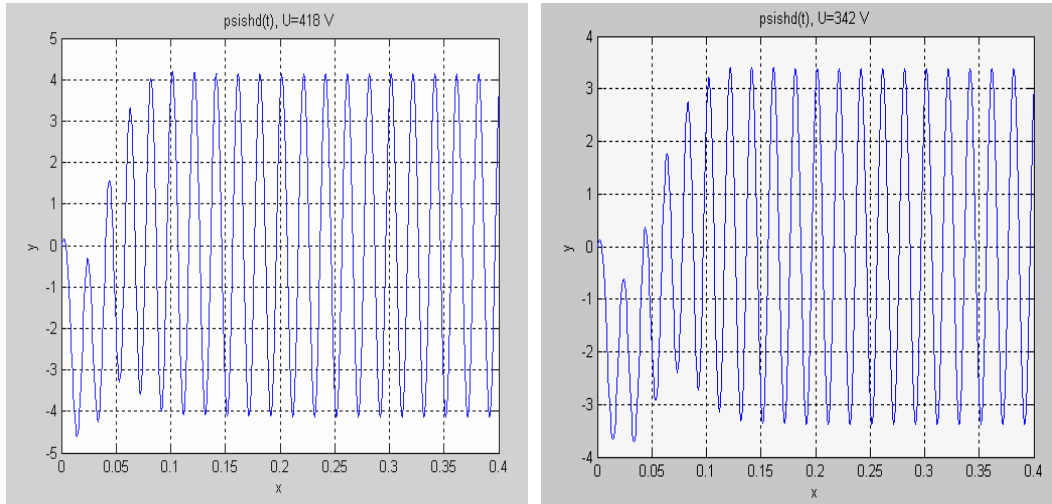


Fig 1. Flux variation: $\psi_{shd}(t)$

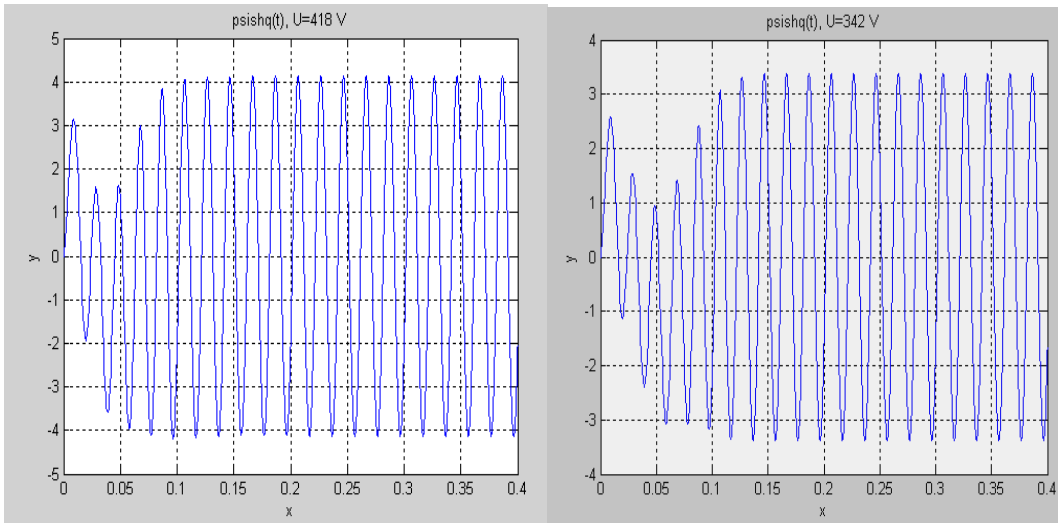


Fig. 2. Flux variation: $\psi_{shq}(t)$

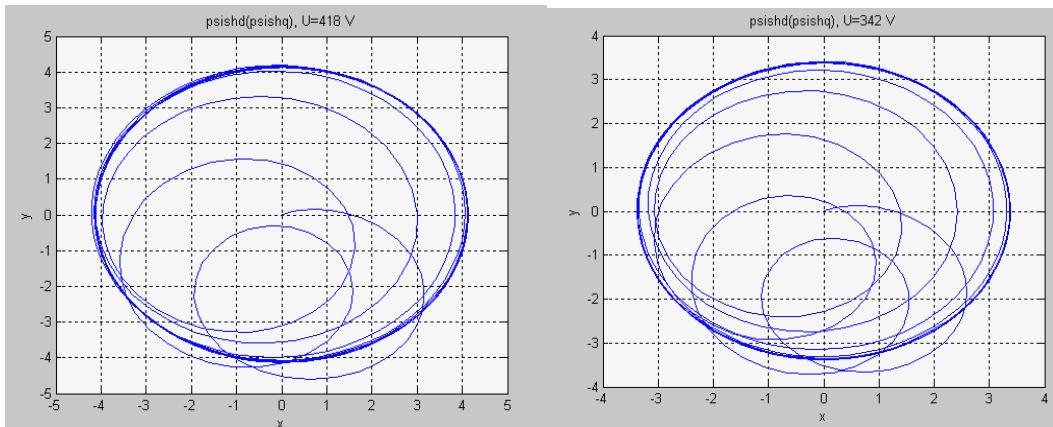


Fig. 3. Flux variation: $\psi_{shd}(\psi_{shq})$

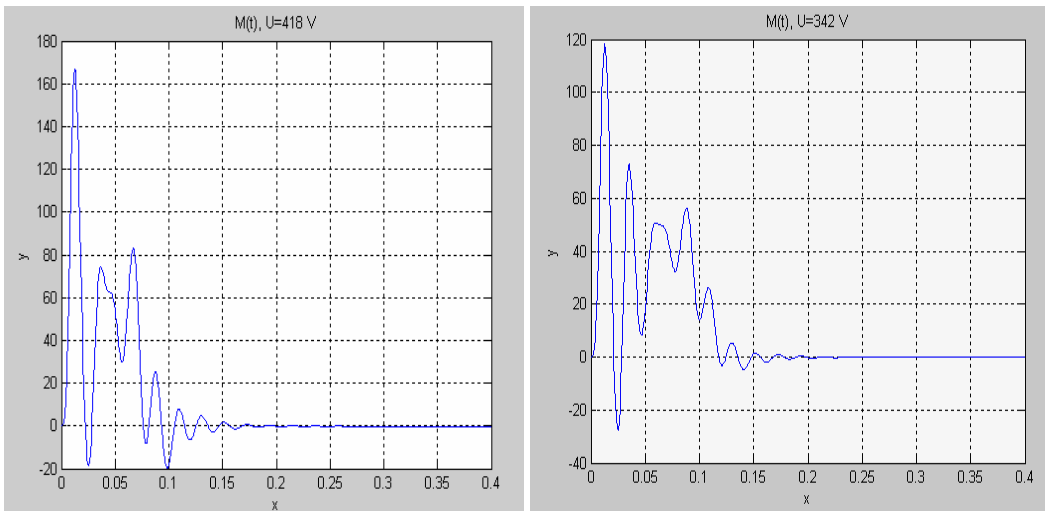


Fig. 4. Torque variation: $M(t)$

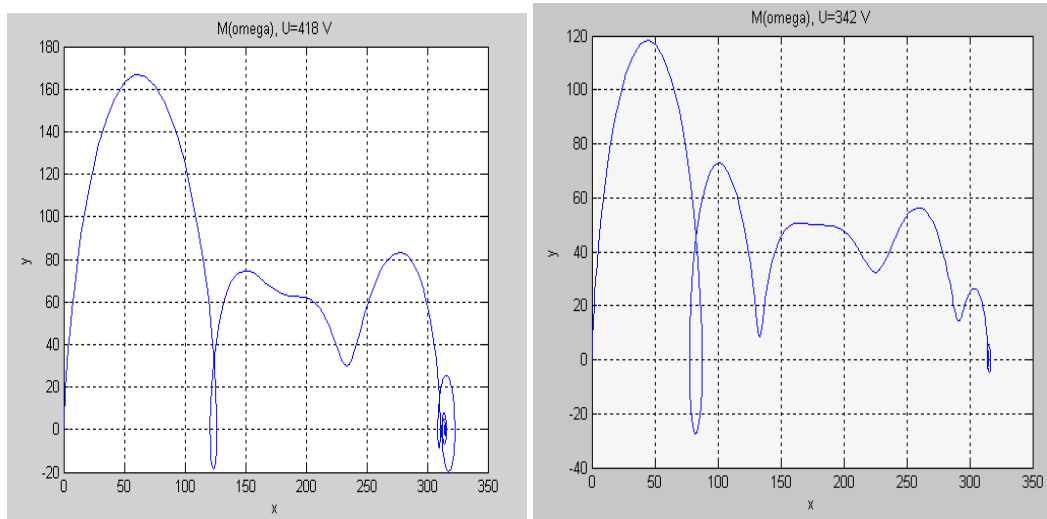


Fig. 5. Torque variation: $M(\omega)$

Conclusions

The results illustrate the aim of paper to show the influence of the variation of feeding voltage. One can also benefit from it to solve more complicated problems. It will be the subject of a forthcoming article.

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Considerații asupra caracteristicilor mașinii asincrone când tensiunea de alimentare variază cu 10%

Rezumat

Scopul acestei lucrări este de a ilustra variația: $M(t)$, $M(\omega)$, $\psi_{shd}(t)$, $\psi_{shq}(t)$, $\psi_{shd}(\psi_{shq})$, când tensiunea de alimentare a motorului asincron variază cu 10%. Simulările sunt făcute în Matlab. Această situație (când tensiunea de alimentare variază) este des întâlnită la serviciile auxiliare ale locomotivei electrice.