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# The Generalized Predictive Control Applied to an Induction Drive

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## Abstract

*This paper deals with the generalized predictive control applied to an induction drive with vector control and static torque, with constant and speed proportional component. First, it is defined a reduced model of the ensemble formed by the drive and the vector electronic control and then are presented the generals characteristics of the generalized predictive control that are applied to considered drive speed control. Finally, using Matlab-Simulink environment are presented and then are analyzed the performances.*

**Key words:** *predictive control, inductive drive, speed control.*

## Mathematical Drive Model

Let $u_s$ consider a three-phase induction motor with $a_s, b_s$ and $c_s$ the stator phases and $a_r$, $b_r$ and $c_r$ the rotor phases (Fig. 1). The time variable electrical angle $\alpha$, defines the instantaneous position between magnetic axes of $a_s$ and $a_r$ phases chosen as reference axes, and $d$ axis of the orthogonal axes reference system $d-q$. The angles $\alpha_s$ and $\alpha_r$ are the angles between a stator phase respectively a rotor phase with $d$ axis of the orthogonal reference system $d-q$.

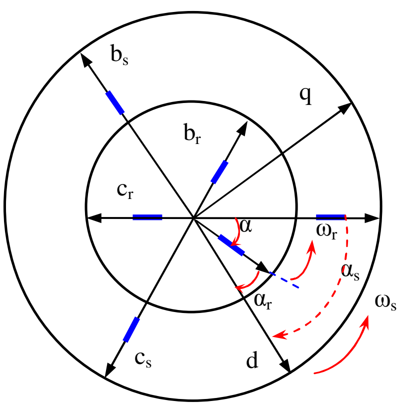


**Fig. 1.** Explanatory for the position of the system of stator and rotor axes for an induction motor

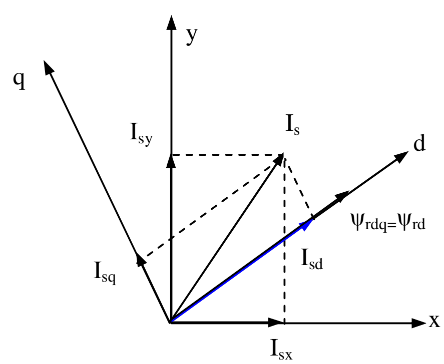


**Fig. 2**. Explanatory for the position of reference system related to rotor flux

where $(x, y)$ is the axis system related to stator and $(d, q)$ the axis system related to motor rotating field. The induction motor equations, without saturation are

$$U_{as} = \frac{d\psi_{as}}{dt} - R_s \cdot i_{as} \quad U_{bs} = -\frac{d\psi_{bs}}{dt} - R_s \cdot i_{bs} \quad U_{cs} = -\frac{d\psi_{cs}}{dt} - R_s \cdot i_{cs}$$

$$0 = \frac{d\psi_{ar}}{dt} + R_r \cdot i_{ar} \quad 0 = \frac{d\psi_{br}}{dt} + R_r \cdot i_{br}; \quad 0 = \frac{d\psi_{cr}}{dt} + R_r \cdot i_{cr} \tag{1}$$

where $R_s$ and $R_r$ are the resistances for one stator phase respectively one rotor phase; $U_{mn}$, $i_{mn}, \psi_{mn}$ are the voltages, the currents and the flux (m index denotes a, b or c phase and n index denotes the stator or the rotor). The relations between fluxes and currents are given by the equations (2) where $L_{as}$, $L_{ar}$ are the inductances for one stator phase respectively one phase inductances rotor; $L_{mas}$, $L_{mar}$ are the mutual inductances between two stator phases respectively rotor phases; $L_{mrs}$ is maximum mutual inductances.

$$\begin{bmatrix} \psi_{as} \\ \psi_{bs} \\ \psi_{cs} \\ \psi_{ar} \\ \psi_{br} \\ \psi_{cr} \end{bmatrix} = \begin{bmatrix} L_{as} & L_{mas} & L_{mas} & L_{mrs}\cdot\cos\alpha & L_{mrs}\cdot\cos(\alpha-\frac{4\pi}{3}) & L_{mrs}\cdot\cos(\alpha-\frac{2\pi}{3}) \\ L_{mas} & L_{as} & L_{mas} & L_{mrs}\cdot\cos(\alpha-\frac{2\pi}{3}) & L_{mrs}\cdot\cos\alpha & L_{mrs}\cdot\cos(\alpha-\frac{4\pi}{3}) \\ L_{mas} & L_{mas} & L_{as} & L_{mrs}\cdot\cos(\alpha-\frac{4\pi}{3}) & L_{mrs}\cdot\cos(\alpha-\frac{2\pi}{3}) & L_{mrs}\cdot\cos\alpha \\ L_{mrs}\cdot\cos\alpha & L_{mrs}\cdot\cos(\alpha-\frac{2\pi}{3}) & L_{mrs}\cdot\cos(\alpha-\frac{4\pi}{3}) & L_{ar} & L_{mar} & L_{mar} \\ L_{mrs}\cdot\cos(\alpha-\frac{4\pi}{3}) & L_{mrs}\cdot\cos\alpha & L_{mrs}\cdot\cos(\alpha-\frac{2\pi}{3}) & L_{mar} & L_{ar} & L_{mar} \\ L_{mrs}\cdot\cos(\alpha-\frac{2\pi}{3}) & L_{mrs}\cdot\cos(\alpha-\frac{4\pi}{3}) & L_{mrs}\cdot\cos\alpha & L_{mar} & L_{mar} & L_{ar} \end{bmatrix} \tag{2}$$

*Park transformation* turns the stator and rotor windings into orthogonal equivalent windings. Thus, the $a_s$, $b_s$ and $c_s$ windings are changed by two equivalent windings $d_s$ and $q_s$, and the rotor windings $a_r$, $b_r$ and $c_r$ by the equivalent windings $d_r$ and $q_r$. Choosing a reference system related to the rotary field such as

$$\frac{d\alpha_s}{dt} = \omega_s; \ \frac{d\alpha_r}{dt} = \omega_r = p_s \cdot \omega \tag{3}$$

where $p_s$ are the number of stator poles pairs and $w_r$, $w_s$ are the mechanical and electrical angular speed, the equations (1) becomes:

$$\frac{d\psi_{sd}}{dt} = \omega_s \cdot \psi_{sq} - R_s \cdot i_{sd} + u_d, \ \frac{d\psi_{sq}}{dt} = -\omega_s \cdot \psi_{sd} - R_s \cdot i_{sd} + u_q,$$

$$\frac{d\psi_{rd}}{dt} = (\omega_s - p_s \cdot \omega) \cdot \psi_{rd} - R_r \cdot i_{rd}, \frac{d\psi_{rq}}{dt} = -(\omega_s - p_s . \omega) \cdot \psi_{sq} - R_r \cdot i_{rq}. \tag{4}$$

The differential equation of the movement for a rigid coupling is

$$J \cdot \frac{d\omega}{dt} = M_e - M_s = M_e - M_0 - K_1 \cdot \omega \,, \tag{5}$$

where $M_0$ is the constant component part of the static torque $M_s$; $K_1$ is a proportional constant; $M_e$ is the electromagnetic torque; $\omega$ is the angular speed.

The electromagnetic torque $M_e$ can be expressed by currents

$$M_e = p_s \cdot L_m (i_{sq} \cdot i_{rd} - i_{sd} \cdot i_{rq}) \tag{6}$$

The relations between fluxes and currents in *Park* model are

$$\psi_{sd} = L_s \cdot i_{sd} + L_m \cdot i_{rd} \,, \;\; \psi_{sq} = L_s \cdot i_{sq} + L_m \cdot i_{rq} \,,$$
$$\psi_{rd} = L_m \cdot i_{sd} + L_r \cdot i_{rd} \,, \;\; \psi_{rq} = L_m \cdot i_{sq} + L_r \cdot i_{rq} \,, \tag{7}$$

where: $\psi_{sd}$, $\psi_{sq}$, $\psi_{rd}$, $\psi_{rq}$ are the stator and rotor fluxes along the axes $d$ and $q$; $i_{sd}$, $i_{sq}$, $i_{rd}$, $i_{rq}$ are the stator and rotor currents along the axes $d$ and $q$; $L_s$ and $L_r$ are the inductivity of the stator and rotor windings; $L_m$ is the periodical mutual inductivity between the stator and the rotor, such as

$$L_s = L_{as} - L_{mas} \,, \;\; L_r = L_{ar} - L_{mar} \,, L_m = 3/2 \cdot L_{mrs} \,.$$

Chosen a reference position such as the axis d is along the rotor flux vector $\psi_r$ (Fig.2), then the vector control will allow the rotor flux regulation by controlling the current $i_{sd}$ and the electromagnetic torque developed by the motor. If it is considered an induction motor with short circuit rotor ($u_r = 0$), and if the rotor flux vector is along $d$ axis of the $(d,q)$ axes system, then the $q$ axis flux component part is null

$$\psi_r = \psi_{rdq} = \psi_{rd} \quad \Rightarrow \psi_{rq} = 0 \,. \tag{8}$$

and the equations (4) becomes

$$\frac{d\psi_{sd}}{dt} = \omega_s \cdot \psi_{sq} - R_s \cdot i_{sd} + u_d \,, \;\; \frac{d\psi_{sq}}{dt} = -\omega_s \cdot \psi_{sd} - R_s \cdot i_{sd} + u_q$$
$$\frac{d\psi_{rd}}{dt} = -R_r \cdot i_{rd} \,, \;\; 0 = -(\omega_s - p_s.\omega) \cdot \psi_{sq} - R_r \cdot i_{rq} \tag{9}$$

Replacing the fluxes in equations (9) by theirs expression, these becomes

$$u_d = R_s \cdot i_{sd} + L_s \frac{di_{sd}}{dt} - \omega_s \cdot L_s \cdot i_{sq} + L_m \frac{di_{rd}}{dt} - \omega_s \cdot L_m \cdot i_{rq}$$

$$u_q = \omega_s \cdot L_s \cdot i_{sd} + R_s \cdot i_{sq} + L_s \frac{di_{sd}}{dt} + \omega_s \cdot L_m \cdot i_{rd} + L_m \frac{di_{rq}}{dt}$$

$$0 = L_m \frac{di_{sd}}{dt} - (\omega_s - p_s \cdot \omega) L_m \cdot i_{sq} + R_r \cdot i_{rd} + L_r \frac{di_{rd}}{dt} - (\omega_s - p_s \cdot \omega) \cdot L_r \cdot i_{rq}$$

$$0 = (\omega_s - p_s \cdot \omega) L_m \cdot i_{sd} + L_m \frac{di_{sq}}{dt} + (\omega_s - p_s \cdot \omega) \cdot L_r \cdot i_{rd} + R_r \cdot i_{rq} + L_r \frac{di_{rq}}{dt} \tag{10}$$

and the electromagnetic torque is

$$M_e = p_s \cdot \frac{L_m}{L_r} \cdot \psi_{rd} \cdot i_{sq}. \tag{11}$$

The rotor currents expressions will be resulted from the equation (7) and these will be replaced in equations (10). It is obtained [1], [2]

$$\frac{di_{sd}}{dt} = \frac{u_d}{\sigma L_s} - \frac{L_m}{\sigma L_s L_r}\frac{d\Psi_{rd}}{dt} - \frac{R_s}{\sigma L_s} i_{sd} + \omega_s i_{sq},$$

$$\frac{di_{sq}}{dt} = \frac{u_q}{\sigma L_s} - \frac{R_s}{\sigma L_s} i_{sq} - \omega_s \frac{L_m}{\sigma L_s L_r}\Psi_{rd} - \omega_s i_{sd}, \quad \frac{d\Psi_{rd}}{dt} = \frac{R_r}{L_r}\Psi_{rd} + \frac{L_m R_r}{L_r} i_{sd}, \tag{12}$$

where the angular speed $\omega_s$ is given by the relation (13)

$$\omega_s = \omega + \frac{L_m R_r}{L_r}\frac{i_{sq}}{\Psi_{rd}}, \tag{13}$$

and $\sigma = (1 - L_m^2/(L_s L_r))$ is the dispersion coefficient of the induction motor. Noting the ratio $L_s / R_s$ and $L_r / R_r$ with $T_s$ and $T_r$ (stator and rotor electromagnetic time constant) and taking into account the electromagnetic torque expression and the equations (12), is determined the block structural schema of the induction drive, illustrated in Fig. 3.

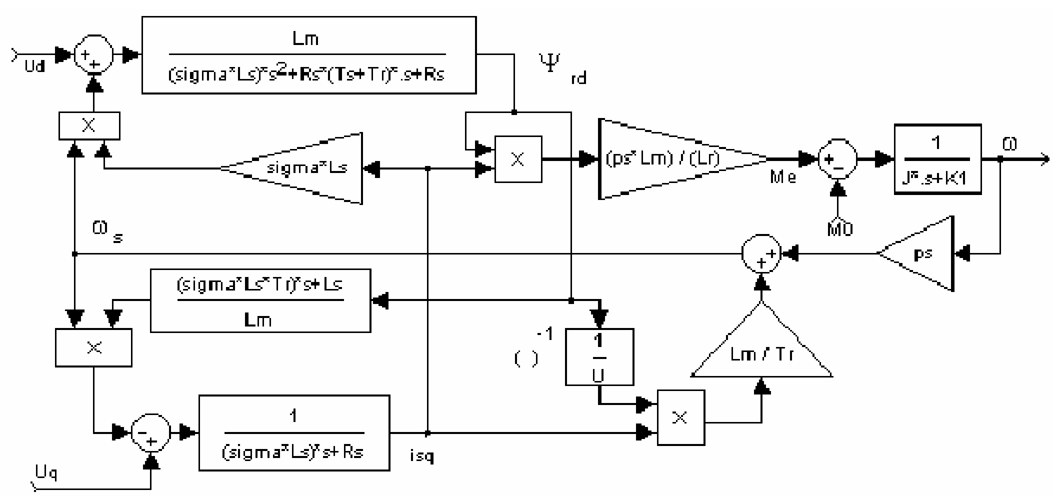


**Fig. 3.** The block structural schema of the induction drive.

Decoupling by a state feedback allows canceling the q axis action over the d axis, by a state feedback, keeping the $\Psi_{rd}$ flux constant (Fig. 4).

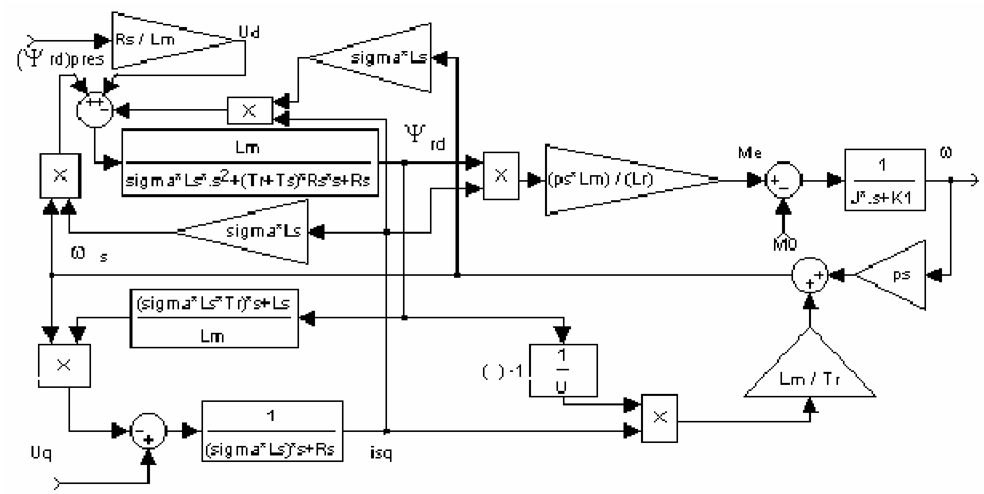


**Fig. 4.** The block structural schema of the drive with feedback state decoupling and static torque with constant and speed proportional component.

In a circuit feedback requiring that the $\Psi_{rd}$ flux is the same, using the voltage $u_d$, the equations (12) become

$$u_d = R_s i_{sd} + \sigma L_s \frac{di_{sd}}{dt} + \frac{L_m}{L_r}\frac{d\Psi_{rd}}{dt} - \omega_s \sigma L_s i_{sq}\,,$$

$$u_q = R_s i_{sq} + \sigma L_s \frac{di_{sq}}{dt} + \omega_s \frac{L_m}{L_r}\Psi_{rd} + \omega_s \sigma L_s i_{sd}\,,$$

$$\frac{d\omega}{dt} = -\frac{K}{J}\omega + \frac{1}{J}T_{em} - \frac{1}{J}T_r\,,\quad Mi_{sd} = \Psi_{rd} + \frac{L_r}{R_r}\frac{d\Psi_{rd}}{dt} \qquad (14)$$

with $\omega_s = p_s\omega + \frac{L_m R_r}{L_r}\frac{i_{sq}}{\Psi_{rd}}$ and $M_e = p_s \frac{L_m}{L_r}\Psi_{rd} i_{sq}$ and the block structural schema illustrated in Fig. 5.

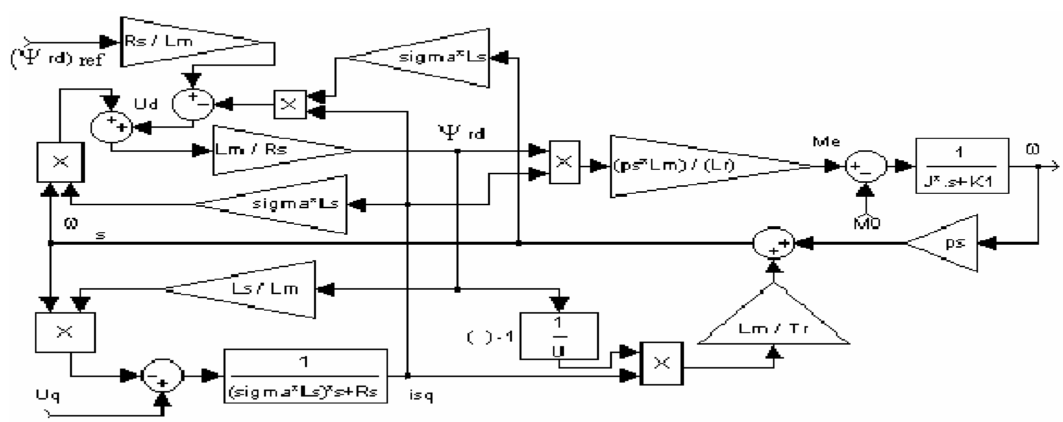


**Fig. 5**. The block structural schema of an induction drive with $\Psi_{rd}$ constant flux.

To get the simplified model of the induction drive it is considered that the flux has a constant value and from the equation (13) results

$$u_q = \left( R_s + \frac{L_s}{L_r} R_r \right) i_{sq} + \sigma L_s \frac{di_{sq}}{dt} + p_s \omega \frac{L_s}{L_m} \Psi_{rd} . \tag{15}$$

The block structural schema of the induction drive after q axis is reduced to the block structural schema illustrated in Fig. 6.

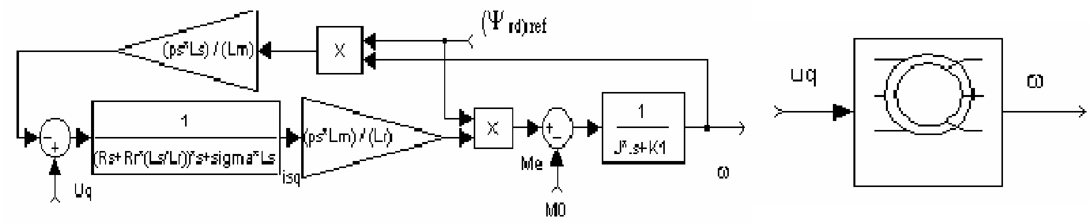


**Fig. 6.** The reduced block structural schema of an induction drive with static torque, with constant and speed proportional component, a) non-masked schema ; b) masked schema.

It is considered $u_d = \frac{R_s}{L_m} (\Psi_{rd})_{ref} - \hat{\omega}_s \sigma L_s \hat{i}_{sq}$ and the flux is fixed. Neglecting the electromagnetic time constant, $\frac{\sigma L_s}{R_s + R_r L_s / L_r}$, the current $i_{sq}$ is estimated by the expression [3]

$$\hat{i}_{sq} = \frac{U_q - p_s \omega \frac{L_s}{L_m} (\Psi_{rd})_{ref}}{R_s + \frac{L_s}{L_r} R_r} \tag{16}$$

and the angular speed $\omega_s$ is estimated taking into account the equation (13), by (Fig. 6a)

$$\hat{\omega}_s = \omega + \frac{L_m R_r}{L_r} \frac{\hat{i}_{sq}}{(\Psi_{rd})_{ref}} . \tag{17}$$

Starting from the reduced drive model defined in q axis, it is established the transfer function $H(s) = b/(a_2 s^2 + a_1 s + 1)$ represented by the input-output block structural schema (Fig. 6.b), where ω is the motor angular speed, $U_q$ is the motor applied voltage and the $a_1$, $a_2$, b coefficients that characterized the transfer function in time range, are

$$b = \frac{p_s \frac{L_m}{L_r} \Psi_{rd}}{p_s^2 \frac{L_s}{L_r} \Psi_{rd}^2 + R_e K_1}, a_1 = \frac{R_e + K_1 \sigma L_s}{p_s^2 \frac{L_s}{L_r} \Psi_{rd}^2 + R_e K_1}, a_2 = \frac{J \sigma L_s}{p_s^2 \frac{L_s}{L_r} \Psi_{rd}^2 + R_e K_1}$$

with $R_e = R_s + \frac{L_s}{L_r} R_r$.

## Generalize Predictive Control

Although, many of the self-tuning control structures use a CARMA (C*ontrolled* A*uto*R*egressive* M*oving* A*verage*) type model, this model is inadequate for many of the industrial applications where the disturbances are unsteady (random steps at random time moments). The considered model by the generalized predictive control, is a CARIMA model (C*ontrolled* A*uto*R*egressive and* I*ntegrated* M*oving* A*verage*), of type

$$A\left(q^{-1}\right)y\left(kT_e\right)=B\left(q^{-1}\right)u\left[\left(k-1\right)T_e\right]+\frac{\xi\left(kT_e\right)}{\Delta} \quad (18)$$

with : $y(kT_e)$ and $u(kT_e)$ are the input respectively the output of the process, $\xi\left(kT_e\right)$ is a sequence of independent random variables, having the null mean and finite variance (inadequate), $T_e$ is the sampling period, $\Delta=1-q^{-1}$ is the differentiation operator and $q^{-1}$ is the step delay operator, a $T_e$ period. The $A(q^{-1})$ and $B(q^{-1})$ polynomials are such as

$$A\left(q^{-1}\right)=1+a_1q^{-1}+...+a_{n_a}q^{-n_a}, \qquad B\left(q^{-1}\right)=b_0+b_1q^{-1}+...+b_{n_b}q^{-n_b},$$

where $n_a$ and $n_b$ are the A and B polynomial degrees.

Because the $A(q^{-1})$ polynomial is non-zero, the predictive output of the process at the $(k+j)T_e$ discrete time moment is

$$y\left[(k+j)T_e\right]=\frac{B(q^{-1})}{A/(q^{-1})}u\left[\left(k+j-1\right)T_e\right]+\frac{1}{A(q^{-1})\Delta}\xi\left[(k+j)T_e\right] \quad (19)$$

The term $1/(A(q^{-1})\Delta)$, can be factorize in two terms by means of Euclid algorithm that allows the division by 1 of the $A(q^{-1})\Delta$ polynomial, until j number order [4], [5], [6] :

$$1/A(q^{-1})\Delta=E_j(q^{-1})+q^{-j}F_j(q^{-1})/A(q^{-1})\Delta \quad \Leftrightarrow \quad E_j(q^{-1})A(q^{-1})\Delta+q^{-j}F_j(q^{-1})=1 \quad (20)$$

the $E_j$ and $F_j$ polynomials having ( j-1) polynomial degrees (j is a prediction interval also called output prediction horizon) and respectively n. The predictive output at the $(k+j)T_e$ time moment is

$$y\left[\left(k+j\right)T_e\right]=E_j\left(q^{-1}\right)B\left(q^{-1}\right)\Delta u\left[\left(k+j-1\right)T_e\right]+F_j\left(q^{-1}\right)y\left(kT_e\right)+E_j\left(q^{-1}\right)\xi\left[\left(k+j\right)T_e\right] \quad (21)$$

The predictor that takes into account the known information at the $kT_e$ discrete time moment is

$$\hat{y}\left[\left(k+j\right)T_e\right]=G_j\left(q^{-1}\right)\Delta u\left[\left(k+j\right)T_e\right]+F_j\left(q^{-1}\right)y\left(kT_e\right) \quad (22)$$

where $G_j\left(q^{-1}\right)=E_j\left(q^{-1}\right)B\left(q^{-1}\right)$ and *grad*$G_j$ = j-1 + *grad*$B(q^{-1})$.

The generalized predictive control low determination is based on the minimization of a mean square estimation, of type

$$J\left(N_1,N_2,N_u\right)=\sum_{j=N_1}^{N_2}\left\{y\left[\left(k+j\right)T_e\right]-y_{ref}\left[\left(k+j\right)T_e\right]\right\}^2+\sum_{j=1}^{N_u}\left\{\lambda\left(jT_e\right)\Delta u\left[\left(k+j-1\right)T_e\right]\right\}^2 \quad (23)$$

where $y_p[(k+j)T_e]$ is the process control input, $N_1$ is the minimum prediction horizon, $N_2$ is the maximum prediction horizon, $N_u$ is the control horizon and $\lambda(jT_e)$ is a sequence of control weighting factors. It can be observed that in this expression there are all the control future values that affect the outputs inserted in J. The first criterion term limits the error values and the second term limits the control values that avoid the saturation and result in low energy consumption for control action.

Let be $h[(k+j)T_e]$ the output $y[(k+j)T_e]$ components that comprises all the known signals, thus

$$h\left[\left(k+N_1\right)T_e\right]=\left[G_{N_1}\left(q^{-1}\right)-g_{N_1,0}\right]\Delta u\left(kT_e\right)+F_{N_1}y\left(kT_e\right)$$

$$h\left[\left(k+N_1+1\right)T_e\right]=\left[G_{N_1+1}\left(q^{-1}\right)-q^{-1}g_{N_1+1,1}-g_{N_1+1,0}\right]+F_{N_1+1}y\left(kT_e\right)$$

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Noting $\Delta u = \tilde{u}$, the previous equations can be written in matrix type

$$\hat{y} = G\tilde{u} + h \tag{24}$$

Thus, the criterion becomes

$$J=\left(G\tilde{u}+h-y_{ref}\right)^T\left(G\tilde{u}+h-y_{ref}\right)+\lambda\,\tilde{u}^T\tilde{u} \tag{25}$$

whence the control low results

$$\tilde{u}=\left[G^TG+\lambda I\right]^{-1}G^T\left(y_{ref}-h\right) \tag{26}$$

with

$$G=\begin{pmatrix} g_{N_1-1} & \cdots & g_0 & 0 & \cdots & 0 \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ g_{N_u-1} & \cdots & \cdots & \cdots & \cdots & g_0 \\ \cdots & \cdots & \cdots & \cdots & \cdots & \cdots \\ g_{N_2-1} & \cdots & \cdots & \cdots & \cdots & g_{N_2-N_u} \end{pmatrix}.$$

## Drive Control

The induction drive function is simulated through the generalized predictive control. The control performances are analyzed depending on the results obtained by simulation. The generalized predictive control is applied at an induction drive with static torque with constant and in proportional to speed component. The motor has a nominal power of 0,25 kW is electric supplied at 220 V and has a nominal speed of 1500 rot/min. The motor is also characterized by the following data: $L_s$=0,116H, $L_r$=0,115H, $L_m$=0,113H, $J$=4.10$^{-3}$kg.m$^2$, K=2,5.10$^{-4}$Nms, $R_s$=1,9 $\Omega$, $R_r$=1,7 $\Omega$ and the static torque is 1,6 Nm. For discretization of drive equivalent model, the transfer function is

$$H(s)=H(s)=\frac{b/a_2}{\alpha\beta}\frac{\alpha\beta}{\left(s+\alpha\right)\left(s+\beta\right)}, \tag{27}$$

where $\alpha$ and $\beta$ are the transfer function poles. Using the transformation function, from the continuous transfer function it is obtained the sampling transfer function in $q^{-1}$

$$\frac{\alpha\beta}{(s+\alpha)(s+\beta)} \Rightarrow^{H} \frac{b_1 q^{-1} + b_2 q^{-2}}{1 + a_1 q^{-1} + a_2 q^{-2}}, \tag{28}$$

and the coefficients of the discrete transfer function depending on the continuous system poles $\alpha$ and $\beta$ are

$$b_1 = \frac{\beta\left(1-e^{-\alpha T_e}\right) - \alpha\left(1-e^{-\beta T_e}\right)}{\beta-\alpha}, \quad b_2 = \frac{\alpha\left(1-e^{-\beta T_e}\right)e^{-\alpha T_e} - \beta\left(1-e^{-\alpha T_e}\right)e^{-\beta T_e}}{\beta-\alpha},$$

$$a_1 = -\left(e^{-\alpha T_e} + e^{-\beta T_e}\right), \; a_2 = e^{-(\alpha+\beta)T_e}$$

For $T_e$ =0,001s and the previous motor parameters, the discrete transfer function is obtained by multipling the $b_i$ (i=1,2) coefficients with the $\frac{b/a_2}{\alpha\beta}$ factor, whence

$$H\left(q^{-1}\right) = \frac{0,01039 q^{-1} + 0,0082 q^{-2}}{1 - 1,5215 q^{-1} + 0,53326 q^{-2}}. \tag{29}$$

Depending on the input-output, this expression can be written

$$\omega(kT_e) = 1,5215\omega\left[(k-1)T_e\right] - 0,53326\omega\left[(k-2)T_e\right] + 0,01039U_q\left[(k-1)T_e\right] + 0,00842U_q\left[(k-2)T_e\right].$$

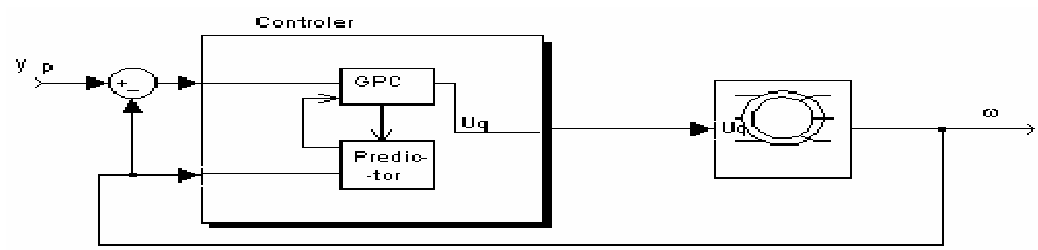


**Fig. 7.** Control structural schema by generalized predictive control.

## Experimental Results

To establish the control parameters some simulations are performed (it is studied the behavior of the $i_{sq}$ stator current component, in accordance with q axis and the behavior of the $\omega$ drive speed) for an unload start-up at a prescribed speed of approximate 150 rad.s$^{-1}$ when the initial conditions are null (excepting the $\Psi_{rd}$ rotor flux, initialized at 0,3Wb), by fixing three of the control parameters and by changing the fourth one.

For $N_2$=8, $N_u$=1, $\lambda$=150 and $N_1$ by changing from 2 to 8, increase the response time of the drive speed, being maximum when $N_1$=8, and the $i_{sq}$ current value decreases being less than 8A when $N_1$=6 (Fig. 8). It is proceeded in analogous mode for $N_1$=2, $N_u$=1, $\lambda$=150 and by changing $N_2$ from 2 to 8, finally it is established that the time response of the drive speed increase, being maximum when $N_2$=8, and the $i_{sq}$ current value decreases being less than 8A when $N_2$=6.

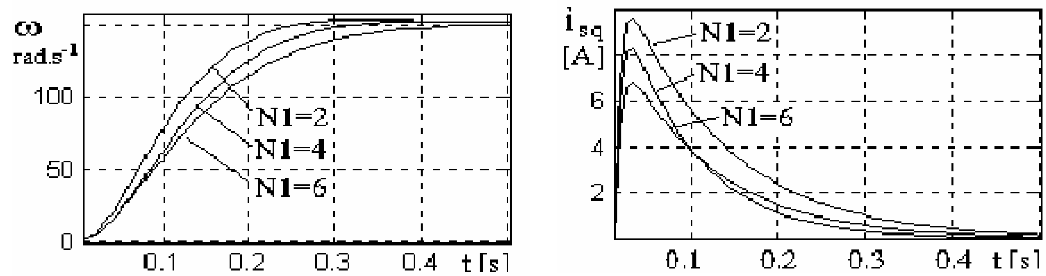


**Fig. 8.** The influence of $N_1$ minimum prediction horizon at unload start-up drive: a) on the speed; b) on the stator current.

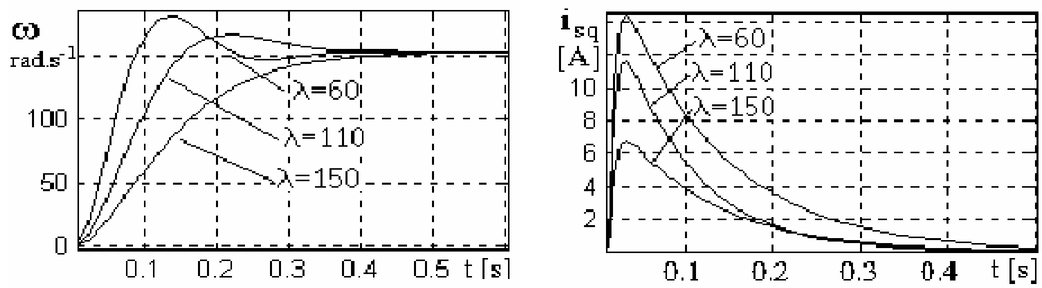


**Fig. 9.** The influence of the $\lambda$ weighting factor at unload start-up drive: a) on the speed; b) on the stator current.

The drive moment of inertia can be changed until a 100% percent of nominal value, due to some load disturbances. The simulations show that by changing the moment of inertia between 50% and 100% over the nominal value, the speed building-up time increases a little, simultaneous with a little decrease of the stator current amplitude, the speed and the current curves having approximately the same shape with those illustrated in Fig. 10.

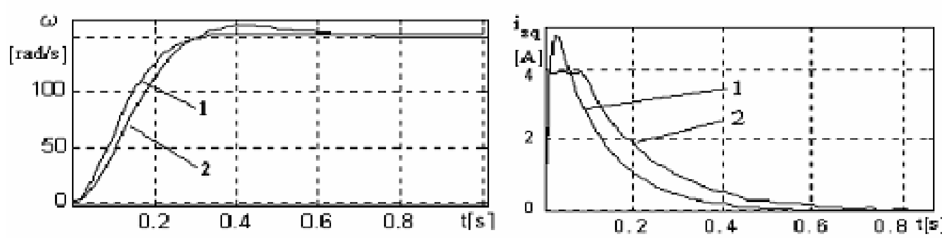


**Fig. 10.** Drive speed shape (a) and current stator shape (b) at unload start-up drive, without simultaneous change of stator and rotor resistance (curve 1) and with simultaneous change of stator and rotor resistance with 50% opposite to their nominal values (curve 2).

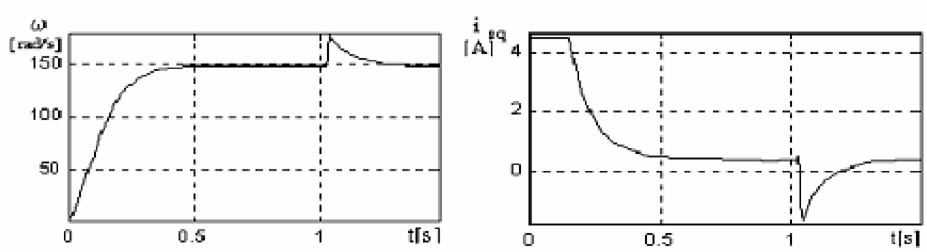


**Fig. 11.** On load start-up drive (with static torque with constant component and in proportional to speed, 1.6 Nm) and load change at t=1s: a) speed shape; b) stator current shape

## Conclusions

These simulations show that the control performances are satisfying when the generalized predictive control is applied to an induction drive. The generalized predictive control also presents the modify advantage of control parameters depending on the desired performances.

Because the control is based on a linear drive model, it is also necessary a drive control analysis with speed depending static torque, using non-linear drive model.

## References

1. Bemiloud F., Boucherit M.S. - *Predictive control simulation of an induction motor with vector control*, Conference on modelling and simulation of electrical systems, CMSES'94, Skida, 1994.
2. Boucher P., Dumur D. - *Predictive control of induction motor,* Electrotechnic and Automation Tunis Journal, 1991.
3. Manolea Gh. - *Electromechanics drives* (in Romanian), Vol. 2, Universitaria Press, Craiova, 1993.
4. Călin S., Popescu Th., Jora B., Sima V. - *Adaptive and flexible control of industrial processes,* (in Romanian), Technical Press, Bucharest, 1988
5. Fransua Al., Măgureanu R. - Electrical motors and drives. *Actuators* (in Romanian), Technical Press, Bucharest, 1986.
6. Popescu M.C. - *Optimizations in climatizers used in enclosures with release of noxious* (in Romanian), PHdThesis, Craiova, 2002.

# Comanda predictivă generalizată aplicată unei acționări asincrone

## Rezumat

*Această lucrare studiază comanda predictivă generalizată, aplicată unei acţionări asincrone, cu control vectorial şi cuplu static cu componente constantă şi proporţională cu viteza. După definirea unui model simplificat al ansamblului format din acţionare şi controlul electronic vectorial, se prezintă caracteristicile generale ale comenzii predictive generalizate care se aplică comenzii vitezei acţionării considerate. În finalul lucrării este prezentată o analiză, prin simulare, a performanţelor.*