



Cristian Paul Chioncel, Petru Chioncel, Marius Babescu, Nicoleta Gillich

Simulation of the Dynamic Behavior of an Asynchronous Machine Using Direct Self-Control

The paper presents the major steps that have to be gone for the implementation of the mathematical model of the asynchronous machine in SciLab / Scicos. This implemented ASM model, will be used to check the dynamic behavior of the system, the current diagrams as well as the behavior motor speed and the torque, if the input signal has a pulsation form. This implementation's are made in Scilab / Scicos environment, a clone of the MATLAB, which provides number-crunching power similar to MATLAB, at a much better cost/performance ratio. The implemented model offers the possibility to analyze the behaviors of the asynchronous machine in different dynamic situations: speed, torques, current in motor or generator regime and to study its behavior in different possible control schemes.

1. Introduction

The asynchronous machine has a simple constructive structure and that's why it is often used in different industrial applications. One of the most recently applications are their use in wind generators. A special problem, cause of the very fluctuant wind, is the control of those ASM. It is necessary to develop a detail implementation of the ASM in a dynamic environment like Simulink from MatLab ore SciCos / Scilab.

Figure 1 presents the 3 phase symmetrical asynchronous machine with the windings (u,v,w), the stator voltage ($U_{S,U}$, $U_{S,V}$, $U_{S,W}$), the rotor voltage ($U_{R,U}$, $U_{R,V}$, $U_{R,W}$), the stator currents ($i_{S,U}$, $i_{S,V}$, $i_{S,W}$) and the rotor currents ($i_{R,U}$, $i_{R,V}$, $i_{R,W}$). Figure 1.b presents the orthogonal model of the asynchronous machine, with the parameters: U_d and U_q voltage, currents i_d , i_q in stator and I_{dr} , I_{qr} in rotor, stator ψ_d , ψ_q and rotor ψ_{dr} , ψ_{qr} fluxes as well as mutual inductances M_d and M_q .

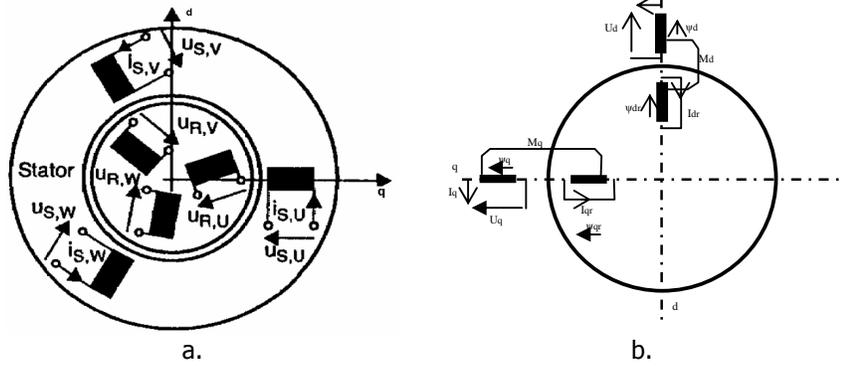


Figure 1 Three phase model of the asynchronous machine (a) Orthogonal model of the ASM (b)

2. Implementation of the ASM mathematical model in Scicos

The transformation in the time space presentation simplifies the mathematical description of the machines with rotating magnetic field. With other words, the influences and behavior of the three phase symmetric disposed windings of the machine can be described by an orthogonal two axis systems, 3Ph \rightarrow dq.

To implement the asynchronous machine model, the behavior will be analyzed separately, the electric and the mechanical part. The main steps in the simulation structure are presented in figure 2.

The description of stator and rotor behavior of an asynchronous machine leads to an equation system with five complexes and one real equation. The steps of transforming this equation in the dq coordinate system are presented in [1].

The ASM model parameters are: i_{sd} – stator current expressed on the d axis winding, i_{sq} – stator current expressed on the q axis winding, i_{rd} – rotor current expressed on the d axe winding, i_{rq} – rotor current expressed on the q axe winding, ψ_{sd} stator flux in d axis, ψ_{sq} – stator flux in q axis, ψ_{rd} – rotor flux in d axis, ψ_{rq} – rotor flux in q axis, R_s – stator resistance, R_r – rotor resistance, X_h – main reactance, $L_h = X_h/2\pi \cdot f$ – main inductance, parameter used in simulation, $(X_1 + X_2)$ – residual stator and rotor reactance's, in the simulation considered to be equal, $L_s = L_r = \frac{1}{2} \cdot \frac{X_1 + X_2}{2\pi \cdot f} + L_h$ – residual inductance parameter used in simulation, J – inertial torque, $2p$ – number of poles.

To implement the equations in Scicos, a graphical programming language, it is preferred that the equations should be expressed in an integral form and the real and imaginary part will be separately implemented.

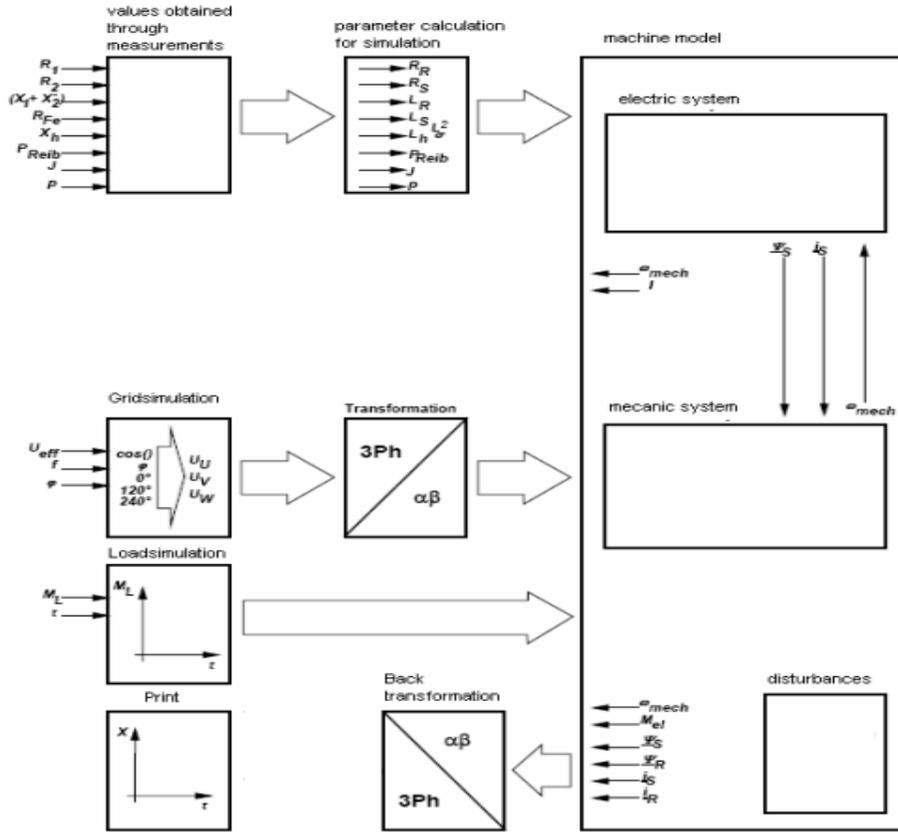


Figure 2 Block scheme of the simulation structure of the ASM machine

The electric model of the asynchronous machine ASM, in orthogonal coordination system [1], is described through the total stator flux (1), total rotor flux (2), stator current (3) and rotor current (4).

- Total stator flux

$$\begin{aligned} \psi_{sd} &= \int (u_{sd} - R_s i_{sd}) dt \\ \psi_{sq} &= \int (u_{sq} - R_s i_{sq}) dt \end{aligned} \quad (1)$$

- Total rotor flux

$$\begin{aligned}\psi_{Rd} &= \int (-R_R i_{Rd} - p\omega_{mec} \cdot \psi_{Rq}) dt \\ \psi_{Rq} &= \int (-R_R i_{Rq} + p\omega_{mec} \cdot \psi_{Rd}) dt\end{aligned}\quad (2)$$

- Stator current

$$\begin{aligned}i_{Sd} &= \psi_{Sd} \frac{L_R}{L_\sigma^2} - \psi_{Rd} \frac{L_h}{L_\sigma^2} \\ i_{Sq} &= \psi_{Sq} \frac{L_R}{L_\sigma^2} - \psi_{Rq} \frac{L_h}{L_\sigma^2}\end{aligned}\quad (3)$$

- Rotor current:

$$\begin{aligned}i_{Rd} &= -\psi_{Sd} \frac{L_h}{L_\sigma^2} + \psi_{Rd} \frac{L_S}{L_\sigma^2} \\ i_{Rq} &= -\psi_{Sq} \frac{L_h}{L_\sigma^2} + \psi_{Rq} \frac{L_h}{L_\sigma^2}\end{aligned}\quad (4)$$

These set of equations in the orthogonal system dq will be implemented in the block scheme *Electric system*, as shown in figure 3.

The mechanic part of the ASM equations describes the machine torque (5) and the rotor speed (6). They are implemented in the SuperBlock *Mechanical System*, figure 4, having as outputs the rotor speed and the machine torque.

- machine torque:

$$M_{el} = \frac{3p}{2} (\psi_{Sd} i_{Sq} - \psi_{Sq} i_{Sd}) \quad (5)$$

- rotor speed

$$\omega_{mec} = \frac{1}{J} \int (M_{El} - M_{Load} - M_{Friction}) dt \quad (6)$$

This set of equation, as well as the equations of the three phase energy network, the electrical equations and the mechanical equations of the asynchronous

machine ASM are introduced in so called *SuperBlocks* in Scilab. This toll offer's the possibility to divide the simulation model in different subsystems, which can be in this way easily handled, efficiently compiled and offers in the same time a better overview of the hall simulated structure. A complex system can be brought in a clear and well structured form, with evident connections and feedbacks.

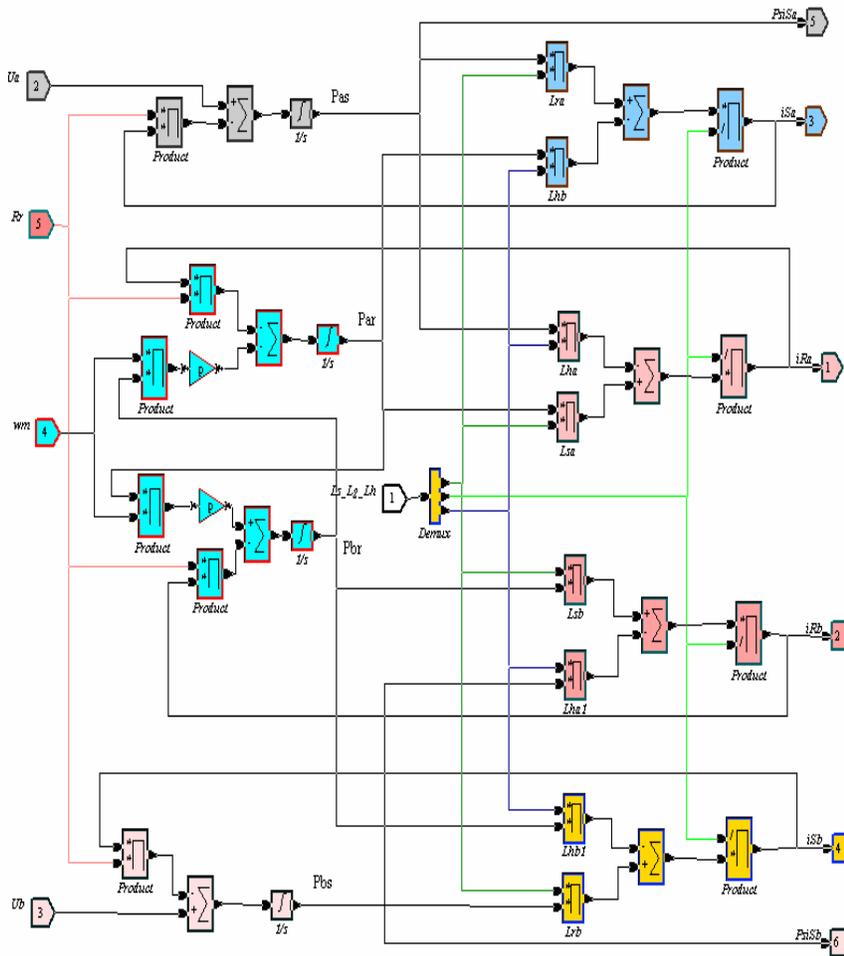


Figure 3 Implementation of the electrical part of the machine equations

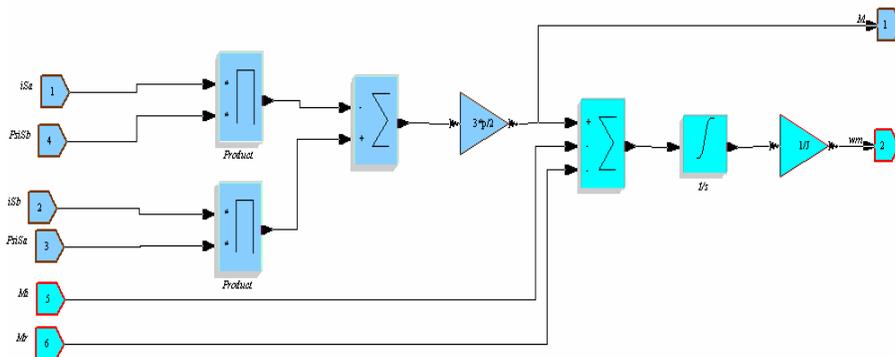


Figure 4 Implementation of the mechanical part of the machine equations

The different Blocks separately defined as upper shown in the paper, are now combined in a unique simulation scheme block, figure 5.

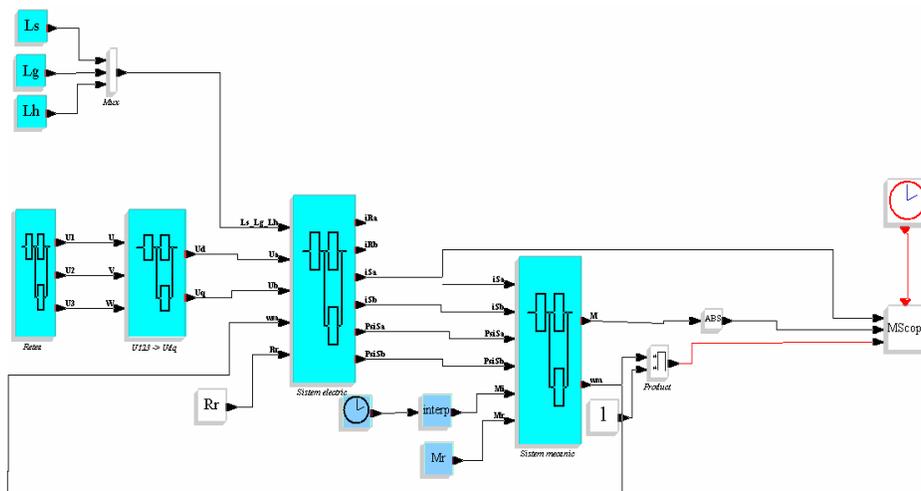


Figure 5 Implementation of the ASM block scheme

3. Simulation results of the ASM behavior

Starting from figure 6 until figure 9, using the implemented ASM model, we can analyze the behavior of different main parameters for different ways of starting the ASM, with or without a connected resistant torque.

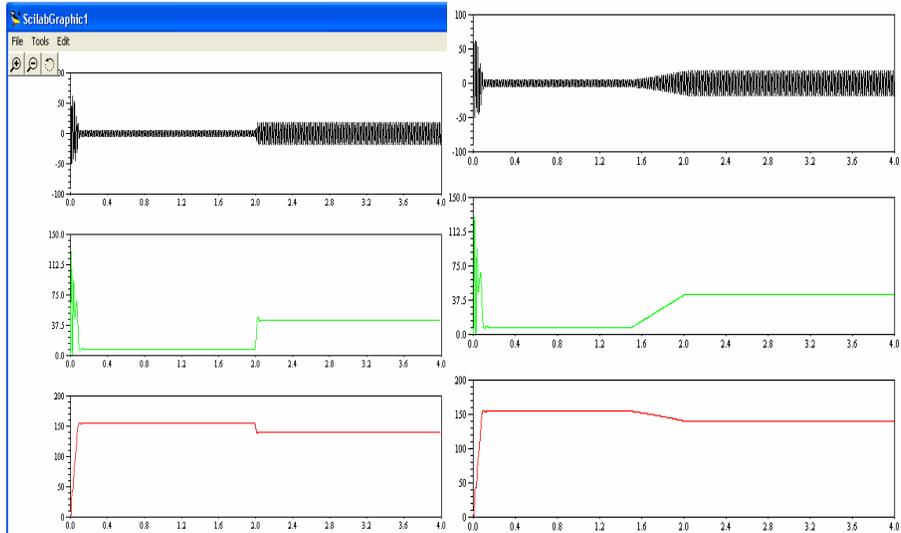


Figure 6 Resistant torque connected by $t=2s$

Figure 7 Resistant torque connected between $t=1.5s$ and $t=2s$

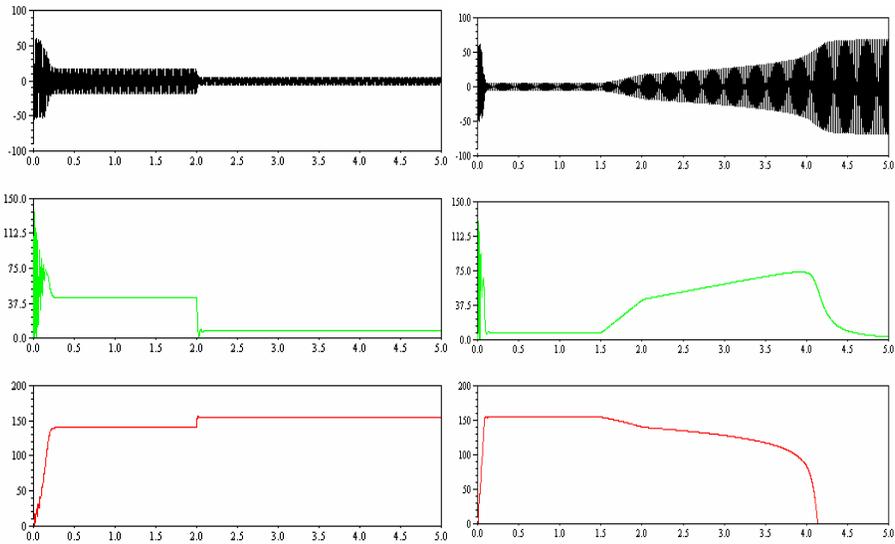


Figure 8 Resistant torque disconnected by $t=2s$

Figure 9 Resistant torque connected by $t=1.5s$ until $\omega=0$

4. Implementation of the direct self control in Scicos

The direct self control represents a special case from the direct torque and flux control. This control way is often used in practice cause of her simplicity. The advantages of this control way are: a low control frequency, a robust behavior, a short identifications amount. It has also disadvantages, like a short dynamic by a low angular speed.

Figure 10, presents a general overview of the direct self control.

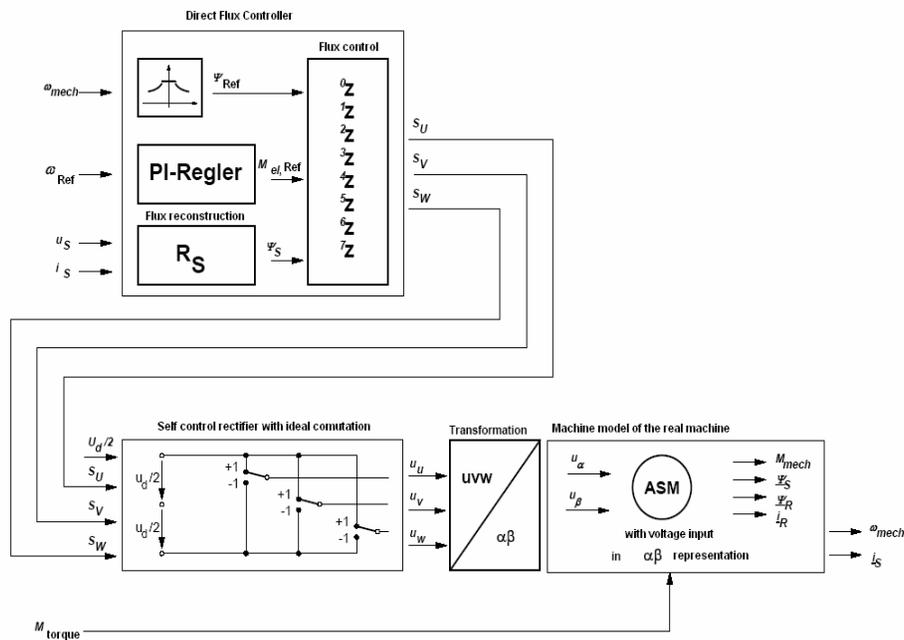


Figure 10 General overview of the direct self control

As shown in the General overview of the direct self control, figure 10, the Direct Self Control Block with the ideal commutation is presented in figure 11 and the whole control scheme, in figure 12.

When the angular speed of the ASM has an step character by $t=0.5$ sec, the evolution of the electric field of the machine, the stator current and stator flux are presented in figure 13, 14 and 15.

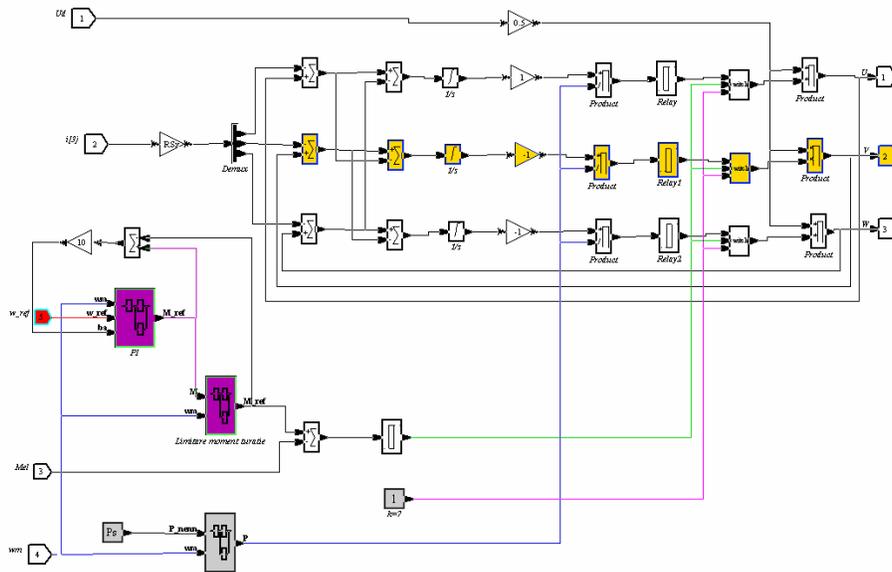


Figure 11 Direct Self Control Block implemented in Scicos

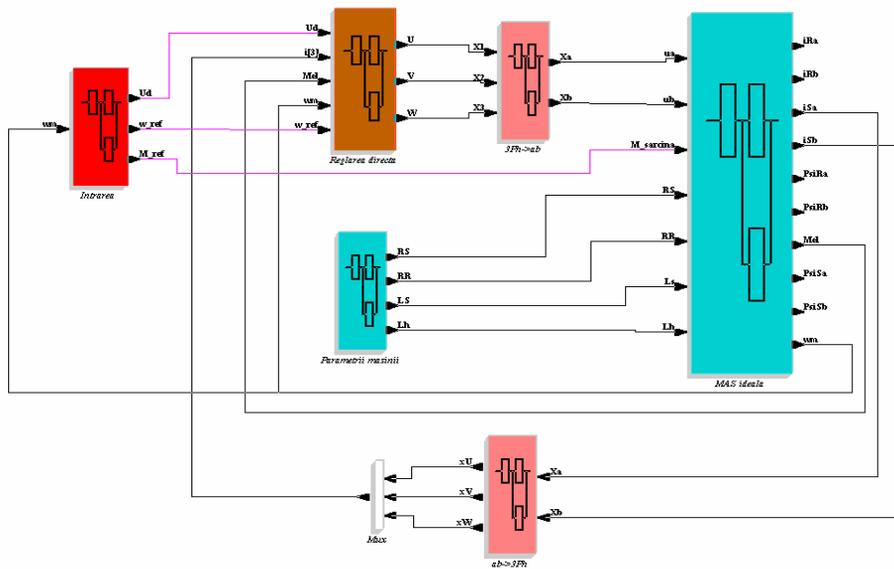


Figure 12 General control scheme with direct self control

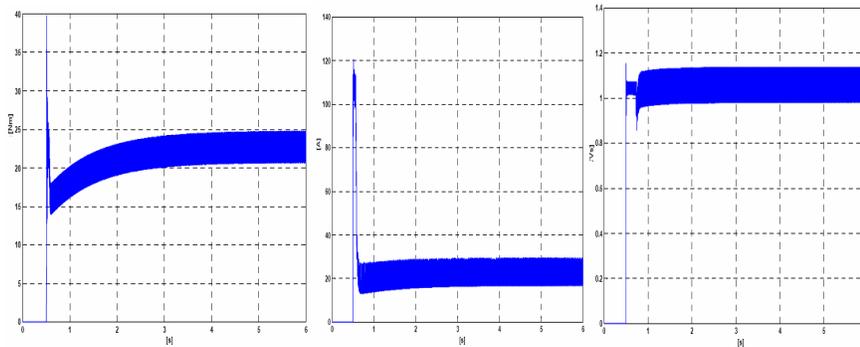


Figure 13 Electric field **Figure 14** Stator current **Figure 15** Stator flux

5. Conclusion

This paper presents the behavior of the main parameter of an ASM: current, electromagnetic torque and rotor speed for different resistant torque, without and with self direct control regulation scheme. The implemented scheme offers the possibility to simulate and interpret more other situations for the ASM in generator ore motor regime.

Reference

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- [3] Chioncel, C.P. – *Limbaje de simulare. Aplicații de modelare și simulare*, Editura „E. Murgu” Resita, 2004

Addresses:

- Assist. Eng. Cristian Paul Chioncel, “Eftimie Murgu” University of Reșița, Piața Traian Vuia, nr. 1 - 4, 320085, Reșița, c.chioncel@uem.ro
- Prof. Dr. Eng Marius Babescu, “Politehnica” Timisoara, Facultatea de Electrotehnica, m.mabescu@upt.ro
- Prof. Dr. Eng. Petru Chioncel, “Eftimie Murgu” University of Reșița, Piața Traian Vuia, nr. 1 - 4, 320085, Reșița, p.chioncel@uem.ro
- Prof. Dr. Eng. Nicoleta Gillich, “Eftimie Murgu” University of Reșița, Piața Traian Vuia, nr. 1 - 4, 320085, Reșița, n.gillich@uem.ro