

Aspects Regarding the Measurement of Electrical Parameters in the Case of Simulating Discrete Electric Drives Using Asynchronous Motors

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Abstract

Simulating an electrical drive with asynchronous motors, while using the PWM system, in the Simulink-SimPowerSystems environment, requires the use of a discrete simulation mode set by the Powergui block from the block diagram, specifying an appropriate time-step. The discrete simulation mode needs a particular way of using the diagram blocks, and the three-phase supply system can no longer be considered sinusoidal, although it can remain symmetrical. Measuring the electrical parameters in these simulation conditions will be discussed in the following.

Key words: *electric drives, asynchronous machine, simulation, Simulink, SimPowerSystems*

Introduction

Under some aspects, this paper can be considered the continuation of another paper of ours [1], which has almost the same topic, but the simulation is realised continuously, allowing for the entire drive system to be considered a three-phase symmetrical system and the supply source is sinusoidal. The fact that we are working with three-phase symmetrical sinusoidal voltage, the block diagram is simplified and it allows the use of several blocks from the library that only permit three-phase symmetrical sinusoidal systems, such a block that outputs instantaneous values of the active/reactive power consumption; in other conditions, the output values for these blocks would be completely erroneous. Or, in the conditions of using the PWM system for controlling the asynchronous motor speed/electromagnetic torque, the three-phased system of the supply voltages no longer is sinusoidal, although it can remain symmetrical, meaning that in the (d, q) coordinate system, the homopolar component of the voltage or current remains null.

The following simulation also refers to a drive with an asynchronous motor with a squirrel-cage rotor, keeping in mind the reliability and relative simple operation of this type of motor. In this simulation was used an ASI type motor (not one of the preset models of the Asynchronous Machine block of the SPS library) of 7.5kW, 380V, 50Hz whose parameters are inserted in the text fields inside the dialog box of the motor block.

The main goal of this simulation is to find methods of obtaining the main electrical parameters of an electrical drive. The main problem of this simulation diagram will be the creation of a three-phased symmetrical sinusoidal supply with wide-range variable voltage amplitude and

frequency to allow for the according pulse with modulation (PWM) to power the drive motor; it is required that the motor load should also be modifiable in a wide range.

Presenting the Main Blocks Diagram for Simulation

The block diagram for simulating a drive, in the proposed conditions, is very complex, even though they group in subsystems, with conveniently chosen inputs and outputs.

The full block diagram is presented in Figure 1.

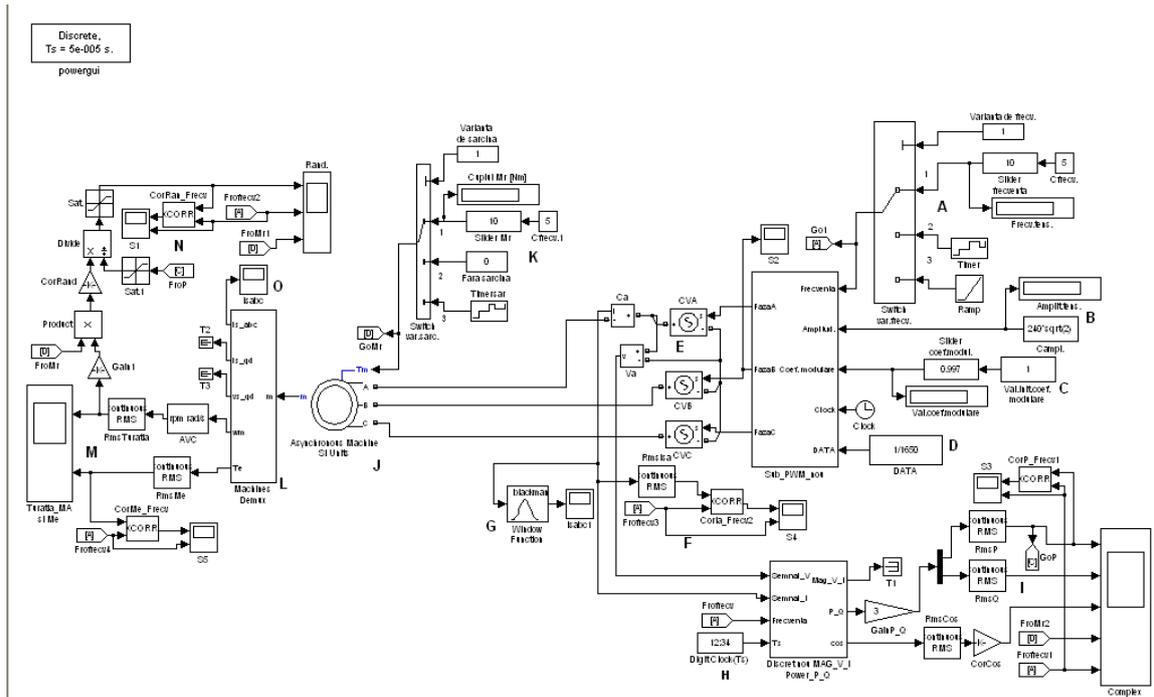


Fig. 1. The main blocks diagram for simulating a squirrel-cage asynchronous motor descreet drive, PWM method, with a wide-range variation of supply voltage amplitude and frequency.

The whole block diagram is divided into main zones named with alphabetical letters (uppercase), so they can be presented and discussed in detail in the following.

Zone A refers to a Multiport Switch that allows for 3 versions for modifying the frequency of the supply voltage: using a slider, using a Timer block that sets the frequency with a step variation, and the Ramp block that allows for the continuous modification (increase) of the frequency with a certain mean.

In zones B and C, the supply voltage amplitude is set and, using a slider, the modulation coefficient can be selected; actually the 2 methods are complementary to each other because ultimately they refer to the same parameter of the supply voltage. The width modulation value for the PWM synthesis can be modified through the D (DATA) constant block.

Zone E refers to the interface blocks between the Simulink signals from the synthesized PWM voltage supply and the physical signals (SPS) that supply the asynchronous motor (zone J). The current signals are analyzed (correlated), while the current/voltage signals are processed in zone H to determine the instantaneous values for the active/reactive powers and the power factor, after that they are registered (after they are RMSed) in zone I with a scope.

In zone K is a Multiport Switch block which helps with setting different methods (similarly to the frequency case) of applying a load to the drive motor.

In zone M, the speed and the electromagnetic torque are set for graphing, and the drive operation efficiency is determined in zone N; the correlation between the electromagnetic torque and the efficiency with the supply voltage frequency is graphed in both these zones.

These would be some of the detail elements for the main block diagram, but other supplementary details must be highlighted for some subsystems or new processed blocks.

As such, the Sub_PWM_nou subsystem from Figure 1 is detailed in Figure 2.

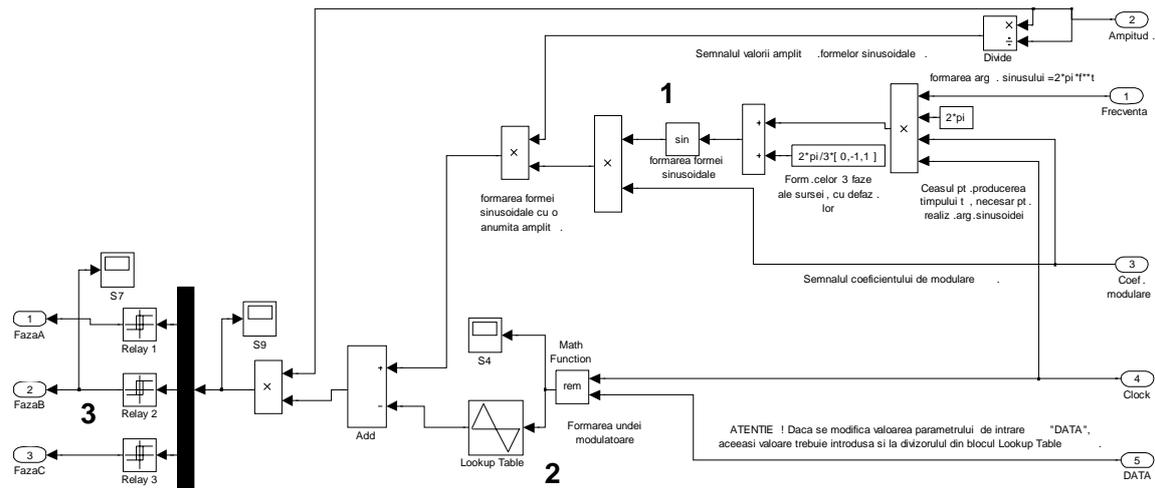


Fig. 2. PWM-forming subsystem (from Simulink blocks) using a three-phased sinusoidal voltage with a wide-range amplitude and frequency variation.

The diagram from Figure 2 can be divided into 3 zones, named accordingly. Zone 1 refers to the formation of a three-phased symmetric sinusoidal system that has been presented in more detail in our work from [1]. In zone 2, a saw-tooth function is created to help the width modulation of the sinusoidal voltage (initially it has a unitary amplitude). The saw-tooth function is created using a simple Simulink Look-up Table block, so that in a period of time of $[0 \ 0.25 \ 0.5 \ 0.75 \ 1]/1650$ (divided by 1650 which is the constant DATA from figure 1) to achieve the values $[0 \ 1 \ 0 \ -1 \ 0]$, that can be combined with the sinusoidal unit variation of the voltage, to produce the width modulation for the voltage, the final amplitude for this being obtained by multiplying the signal accordingly.

Regarding this detail, there are mainly 2 aspects: the modulation function (achieved using the Look-up Table block) can be different from the saw-tooth function, so the DATA constant must be adjusted accordingly to obtain a corresponding symmetry for the modulated three-phased voltage.

In zone 3 from Figure 2, Relay blocks are used (mounted on the three phases mentioned earlier) to display values for « Output when on/off » for voltages (for this case, it was set to $375 \cdot \sqrt{2/3}$), according to the drive motor parameters.

A specific problem to this type of simulation of an electrical drive is the fact that it cannot work « continuously » as in case [1], because the supply voltage for the motor is modulated, which imposes a « discreet » simulation with an appropriate sample-time ($T_s = 50e-6$ [s]), set through the Powergui block (fig. 1). This simulation version doesn't allow the use of blocks as in case [1], but specialised blocks are needed for a discreet mode, but because a wide range

modification for the supply voltage amplitude/frequency was accepted, the discrete blocks themselves, which in most cases require an explicit work frequency, must be modified accordingly because setting the frequency for a block from the Simulink/SPS library is done through the block's dialog box, which doesn't correspond to the possibility of modifying the parameter, that being a dynamic system. The block Discretnou MAG_V_I Power_P_Q from Figure 1 is in such a situation, helping to measure the active/reactive power on a phase, in the discrete mode, then multiplying this by 3 (the drive system is symmetrical) leads to the « three phased » consumption, but needs the work frequency set through the dialog box, but in this case it is highly modifiable.

Adapting Library Blocks to the Required Simulation Conditions

The block Discretnou MAG_V_I Power_P_Q is a modified block for the required simulation version. First, the block is extracted from the SPS Extra Library > Discrete Measurements > Discrete Active & Reactive Power, then the link to the original library is disconnected through the option "Look Under Mask", allowing modifications to its internal diagram. The internal diagram of the block mentioned above has 2 Discret_Fourier blocks, one for each signal of voltage/current, and for the frequency, on which it is used the Fourier analysis, keeping in mind that for a PWM supply, the signals are no longer sinusoidal. Fourier blocks require fundamental frequency and a sample-time (T_s) to analyze the harmonics. But the work frequency is modified on a wide range, and the T_s can be modified, especially when simulating load periods. This logic requests a modification accordingly to the Discrete Fourier blocks from the internal diagram of the Discrete Active & Reactive Power block, which can be done through disconnecting from the original library. In Figure 3 is presented the first level of modifications mainly that for the Discrete Active & Reactive Power block. It is clear that besides the voltage and current signals, there are the signals for frequency and time T_s ; the notations of the authors/company of the original block diagram has been preserved.

Discrete Active & Reactive Power at fundamental frequency

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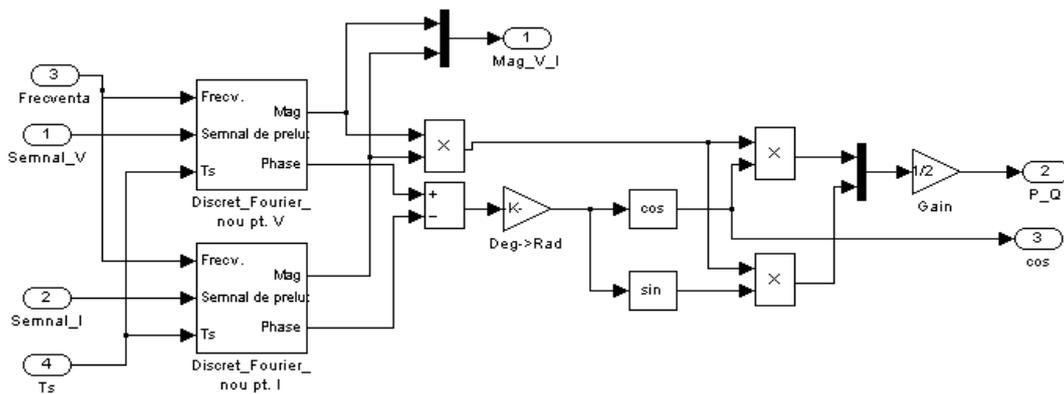


Fig. 3 The Discrete Active & Reactive Power block internal diagram after it was modified to access the signal for the frequency and T_s .

The diagram is relatively clear and doesn't need any additional explanations, only mentioning that once the phase shift \cos between the voltage and current is determined, it was used to create an output port for the \cos variable, thus improving the block.

The second level of modifications refers to the Discret_Fourier blocks for the V and I signals, as presented in Figure 4. This diagram also doesn't require any additional explanations, only the remark that we also find 2 mediation blocks picked from the original library with the possibility of accessing the work frequency. By opening the dialog box for these blocks, it is found that the minimum work frequency is 5 Hz (but can be changed at a later date), allowing for the fact that during the current simulation, the frequency will not be modified lower than the minimum value. In the case of the modified Discrete Fourier block, the author/company logo has been retained from the original library.

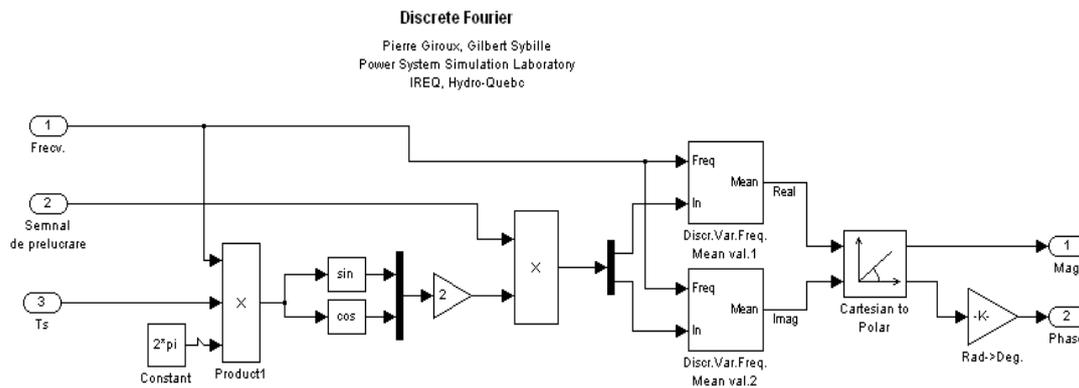


Fig. 4 Correction to the Discrete_Fourier block to allow access to the work frequency and Ts time, outside of the processed signal..

On this basis, when necessary or possible, some adaptations to the original blocks from the SPS library can be made, with the remark that the blocks from the Simulink library do not allow for such operations, being considered as base blocks from a block diagram, while the modified blocks can form a user-created block library.

Some Simulation Results

The operation mode is discrete with $T_s=50e-6$ [s], the motor supply is done by using PWM, where the amplitude and frequency can be modified on a wide range, with the goal of finding some electrical parameters of the drive, such as: active/reactive power, the power factor, drive efficiency, speed and electromagnetic torque produced by the asynchronous motor, while the motor shaft load can be modifiable in a wide range. Most references are made regarding the main block diagram from Figure 1, and the results will be presented under the form of instantaneous value graphs of different parameters.

According to the settings from Figure 1 for frequency/amplitude and load (the relatively simple cases were considered), Figure 5 is obtained referring to the evolution (starting the drive) of the speed/electromagnetic torque

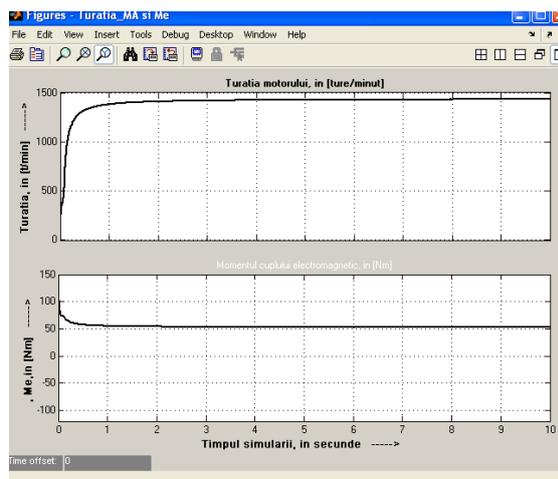


Fig. 5. Motor speed and electromagnetic torque in the given simulation conditions.

when the load on the motor shaft is 50Nm.

The instantaneous values graphs for those parameters are normal: the speed is set at the nominal value for the given motor, considering that the load at the motor shaft is nominal, and the electromagnetic torque seems somewhat higher than the applied load, taking into consideration the corresponding losses.

The simulation is done in a discrete mode in a 10 second interval; the extended time for the simulation was chosen to better observe the setting of the instantaneous values for the resulting parameters.

In Figure 6, in the scope with 5 windows are presented the graphs for the following electrical parameters: the absorbed active power in [W], the absorbed reactive in [var], the drive power factor and load torque in [Nm], work frequency in [Hz], where the stabilization of the absorbed reactive power can be slowly observed; the simulation interval is also seconds.

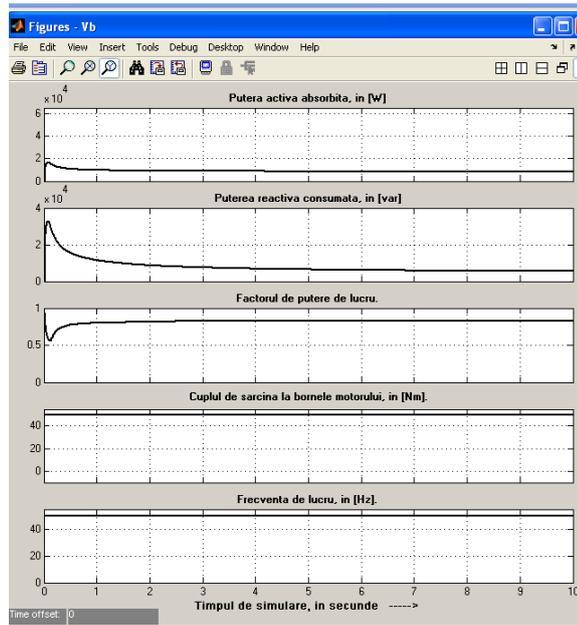


Fig.6. Graphs of the electrical parameters after simulation, in the given conditions.

Figure 7 shows the graphs for the drive efficiency, the motor shaft load and the work frequency. This also shows that the stabilization interval for the efficiency parameter is very long.

Besides the graphs for the main electrical parameters, the main block diagram (fig. 1) also contains some correlation graphs between 2 random parameters as highlighted in the diagram. As an example, the correlation can be made between the active power and the work frequency, as represented in Figure 8.

Finally a simulation is done with the pronounced modification of the work frequency (option 2 for the frequency in figure 1) where the Timer block sets the following vector for time [0 1.5 4 6.5 8] in seconds and the vector for frequency [15 30 50 35 50], the simulation being done in 10 seconds, as in the previous cases. The variation graph for the drive motor speed and the electromagnetic torque is presented in Figure 9.

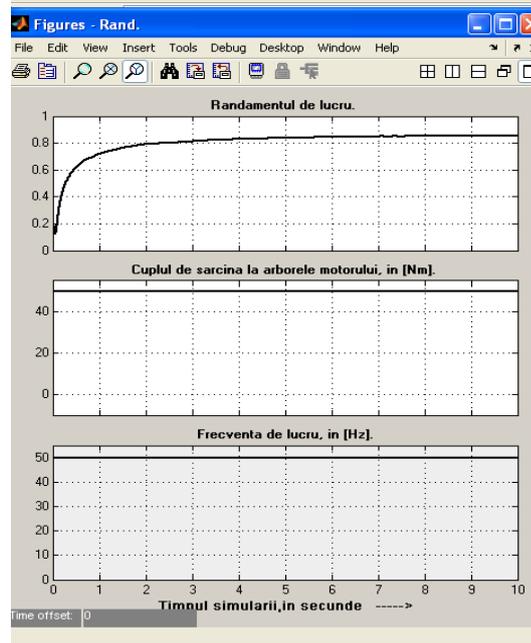


Fig.7. Drive efficiency, load torque and work frequency graphs.

It is relatively easy to see that the last modification to the frequency to 50 Hz, produced by the Timer block at second 8 of the simulation does not lead, in the remaining 2 seconds of the 10 second simulation time, to the nominal values for the speed or the electromagnetic torque

because of the electromagnetic-mechanic inertia of the drive system. A conclusion can be that in the case of a fast variation for the work frequency, supply voltage amplitude or the motor shaft load, resetting some functional parameters will be relatively slow, meaning that the drive system dynamic is slow.

Conclusions

1. In the case of a drive with a PWM supply, the simulation being done in a discrete mode, it is possible to obtain some of the drive main electrical parameters by using Simulink blocks or SPS blocks, some of them being easily modifiable, especially when it is about the current work frequency, the supply voltage amplitude and the drive motor shaft load. In general, blocks can be used inside the block diagram that were correspondingly modified, from the libraries of other toolboxes, blocksets (Simulink derivatives) such as: Control System Toolbox, Instrument Control Toolbox, RF Blockset, Signal Processing Blockset, SimMechanics, Simulink Extras. Also other user-created custom blocks can be used, created using an Embedded MATLAB Function or an S-Function (either using a Level-2 M-file or the S-Function Builder).

2. A preset motor (available through the Asynchronous Machine Block) can be used as a drive motor or a motor from a catalogue for which all the data required by the asynchronous motor block dialog box is known. If such a motor is used, some catalogue values will not be obtained, such as the nominal current, the nominal efficiency or the nominal power factor, when a nominal load is applied to the motor shaft because the asynchronous machine block is (as are the other blocks in the diagram) a “model of an asynchronous motor” and not a real motor for which the catalogue values are set. Consequently, an adjustment to the simulation diagram can be made (using multiplier/divider elements for the main parameters) in the case of a nominal load applied to the motor; this can even become the initial simulation step (for adjusting the diagram) before executing the necessary simulation set.

3. The base diagram in Figure 1 has a flaw, in the sense that forming the supply in PWM with the work frequency, or the supply voltage amplitude, having a wide range variation is formed using Simulink blocks, without using industry specific systems such as resistor

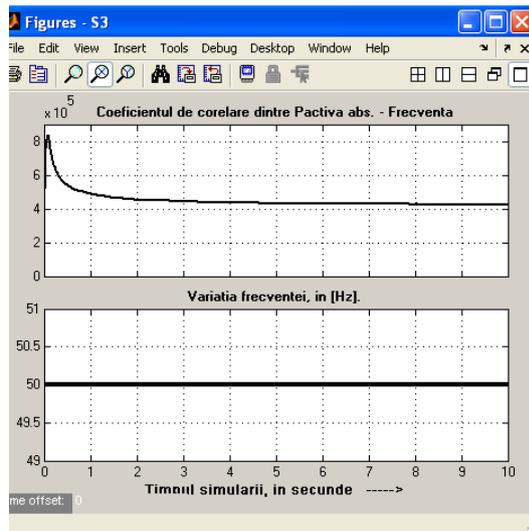


Fig.8. Graph for the correlation coefficient between the active power/work frequency.

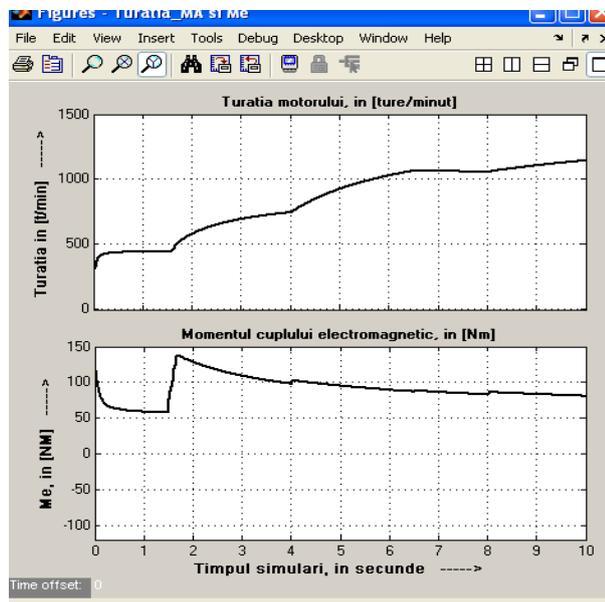


Fig.9. Graphs for the variation of the drive motor speed and electromagnetic torque when the work frequency has a pronounced variation.

bridges/controllable invertors, etc. In this respect, this study can be considered the first step in approaching of such a subject, with some conclusions that can be used in a future stage of the study.

4. The main block diagram from Figure 1 must be considered for only a proposed work option for the studying that specific simulation; e.g. it can be simplified even further, by forming a subsystem, thus showing only the most necessary elements, mainly the scopes for obtaining the parameter graphs that are important for the study; it is worth mentioning that more specialized scope options can be used, other than those used in Figure 1, that can be found in the other blocksets and toolboxes libraries.

References

1. Lupu, C.D., Siro, B., Ianache, C. – Aspects Regarding the Measurement of Electrical Parameters in the Case of Simulating Continuous Electric Drives Using Asynchronous Motors, *Buletinul U.P.G., Seria Tehnică*, Vol. LXV, Nr. 2/2013, pp. 61-67.
2. Costea, S.V. – *Studiul și simularea unei acționări electromecanice cu motor asincron controlat de microcontroler, în mediul MATLAB-Simulink-SimPowerSystems*, proiect de licență, U.P.G. Ploiești, specializarea Electromecanică, 2010, conducător: prof.dr.ing. Boris Siro.
3. *** – *SimPowerSystems for use with Simulink*, www.math.carleton.ca/old/help/matlab/MathWorks_R13Doc/pdf_doc/powersys/powersys.pdf.
4. Ghinea, M., Fireșteanu, V. – *Matlab-Calcul numeric, grafică, aplicații*, Editura Teora, București, 2007.
5. *** – *Tehnici PWM (MID) utilizate în comanda invertoarelor*, <http://ep.etc.tuiasi.ro/site/Tehnici%20M.I.D./LAB1-2.pdf>.

Asupra unor aspecte privind măsurarea parametrilor electroenergetici în cazul simulării în regimul discret al acționărilor electrice cu motoare asincrone

Rezumat

Simularea funcționării unei acționări electrice cu motoare asincrone, în condițiile folosirii sistemului PWM, în mediul Simulink-SimPowerSystems, impune folosirii regimului discret, ce se stabilește cu ajutorul blocului Powergui din diagrama de blocuri, pecizând un eșantion al timpului de lucru corespunzător. Regimul discret al simulării presupune o anumită variantă de folosire a blocurilor din diagramă, iar sistemul trifazat de alimentare nu mai poate fi considerat sinusoidal, deși în principiu, poate rămâne simetric