BULETINUL Universității Petrol – Gaze din Ploieşti	Vol. LXV No. 2/2013	61 - 67	Seria Tehnică

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

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Abstract

Most electric drives are done using asynchronous motors with squirrel cage rotors, in which can induce modifications to the supply voltage, the frequency of the supply voltage and the load in typically wide ranges. During the simulation of such drives, it's usually needed to measure the main electrical parameters, which is what this article aims to address.

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

Introduction

Most electrical drives are done using asynchronous motors with squirrel-cage rotors because of the well-known qualities of this kind of motors. In most cases of more special drives, this type of engines can replace direct current motors, under the special development of systems with different types of semiconductor elements, which help with changing the supply voltage in large ranges (in three-phased systems), and even the frequency of the supply voltage under the strong variation of the resistant torque applied on the motor's drive shaft. Simulating these drive systems has become almost mandatory before starting designing the system and there are several simulation options, one of which being Simulink/SPS (SimPowerSystems) – MATLAB. Usually, the block diagram is created from Simulink blocks and SPS blocks, meaning it operates with Simulink signals and physical (SPS) signals in the same block diagram. But one of the goals of simulating such a drive (it can even be the main goal) is to determine how the drive will react from an electrical aspect, meaning to obtain data regarding the consumption of active/reactive power, the power factor and efficiency; other parameters can also be claimed, such as some correlation coefficients between some electrical pairs of parameters. A significant part could be the scope representation of various parameters, some of which, in most cases, can only be represented in this way, such as the variation (in time) of the electromagnetic torque of the engine (or its speed) while the resistant torque at the motor shaft has a step variation type, or in other words, how does the given drive react from the stand point of the system's mechanical inertia.

Generally speaking though (in the above environment), simulations can be run continuously or discretely on a block diagram depending on several elements such as the type of blocks used to build the block diagram. In this paper will be discussed the continuous case, keeping in mind that the discrete case has its specifications.

A Type of Diagram for a Three-Phase Drive with an Asynchronous Motor

A type of block diagram relatively complete for an asynchronous motor drive with a squirrel cage rotor, powered by a three-phased symmetrical and sinusoidal voltage source, and the possibility of adjusting the voltage amplitude or the frequency of the supply voltage is presented in Figure 1.

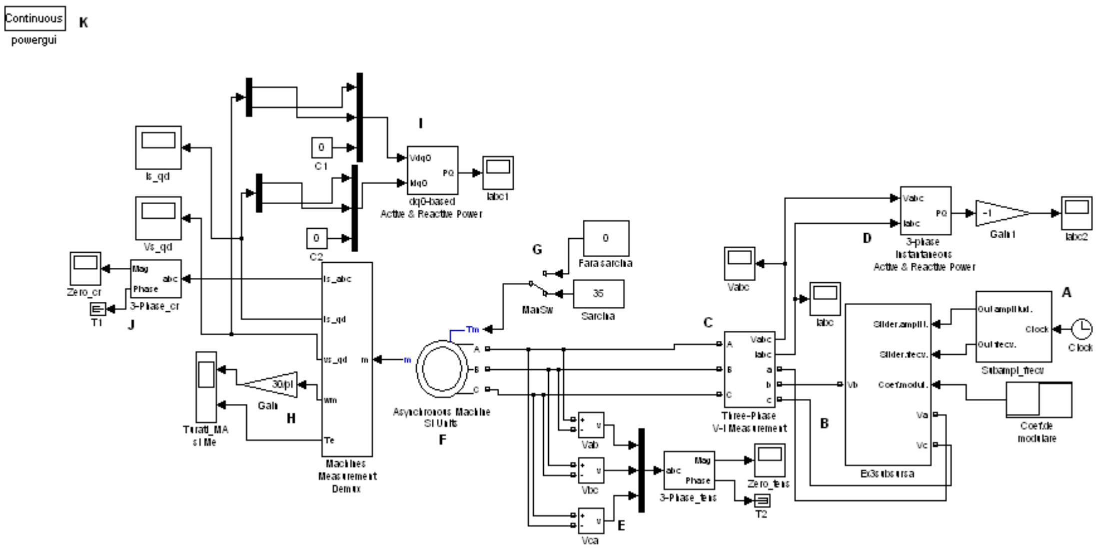


Fig. 1. Block diagram for an asynchronous motor drive, powered by a three-phased voltage system, with adjustable frequency and amplitude in a wide working range, while in a continuous mode.

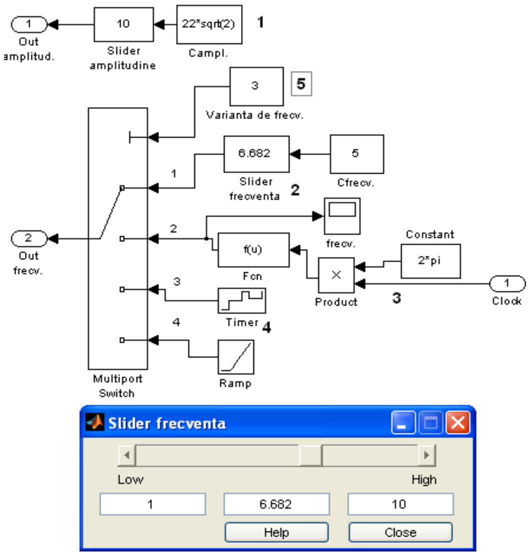


Fig.2. The subsystem for controlling the amplitude and frequency of the supply voltage of the drive system.

For a better understanding of the explanations regarding the block diagram, it has been divided into several zones, marked by alphabetical capitals (initially the zones were colored with differently, but this paper's editing required to be in black and white, so this solution was chosen).

Thus, zone A refers to the subsystem that controls the amplitude and frequency of the supply voltage. By double-clicking on this subsystem's block, the details of this subsystem are presented, as they are in Figure 2. As in the case of the previous figure, the zone of this representation has been marked with several numbers. The slider in zone 1 controls the amplitude of the supply voltage from 22*sqrt(2) [V] to a multiple of ten. Zone 2 refers to the slider (the lower part of figure 2 displays this slider and its control) that controls the frequency of the supply voltage from 5 [Hz], to 50 [Hz]. Zone 3 controls the frequency using a certain analytical expression inserted using the Fcn block, while the Clock input and the “2*pi” constant allows for the definition of an argument such as 2*pi*t = ω*t. Zone 4 of Figure 2 shows that the frequency can be set using a Timer block for a step variation or a Ramp block for a ramp variation with a certain slope. Finally, zone 5, with the help of a Constant block and a Multiport Switch block, allows the setting and switching between the 4 possible options of modifying the frequency.

Obviously that in Figure 2 could have had a similar ensemble for controlling the supply voltage amplitude, but for this schema it was not considered sufficiently necessary.

It is important to mention that all of these value changes can be made during the simulation process, to directly view the effects of these modifications (this means that, to a certain extent, the simulation time needs to be sufficiently long to allow for the changes to take place).

Zone B of the block diagram from Figure 1 is for a subsystem that simulates from Simulink blocks a three-phase sinusoidal and symmetric supply voltage source, that allows for a wide range control of the voltage amplitude and its frequency; the subsystem detail appears in Figure 3.

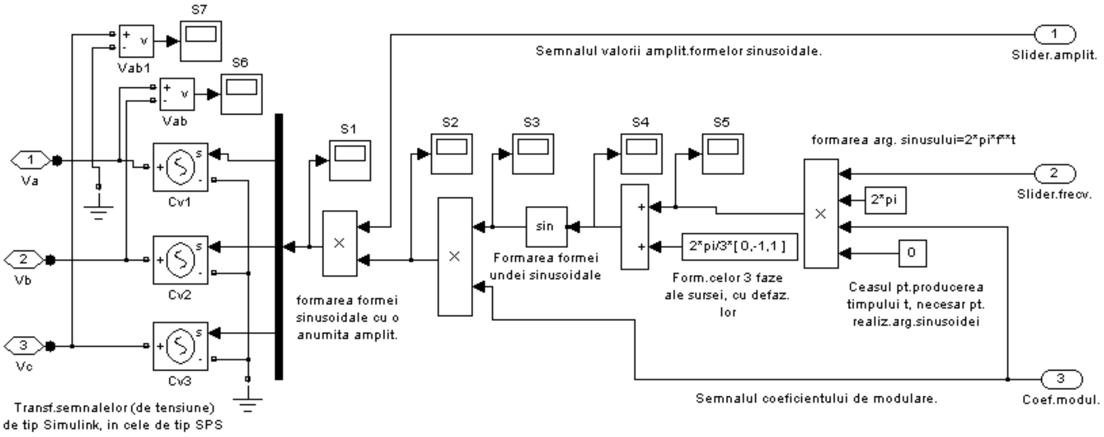


Fig.3 The block diagram of the of the symmetrical three-phased supply voltage subsystem, with the possibility of wide control of the voltage amplitude and frequency.

In this block diagram can be seen the Simulink signal inputs from the subsystem presented in Figure 2, and also the SPS signals from the outputs (Va, Vb, Vc), that represent the supply voltages of the main schema from Figure 1. “The comments” are enough explanation for understanding the diagrams functionality. The following blocks are of note: Cv1, Cv2, Cv3, (available in the SPS library), representing interfaces between Simulink signals and SPS signals. The block diagram of the subsystem includes several Scopes that allows for observing the variation of different measurements that appear during the simulation process of the supply source.

At position C of the diagram from Figure 1 is the measuring block of the voltages/currents in the drive system that supplies the active/reactive power consumption calculation block D; having the instantaneous values of these powers, using the classic formula for determining the power factor, we can determine the instantaneous value of the power factor.

In zone F is the asynchronous motor block with squirrel-cage rotor that has a shaft load is established using the manual switch from G at certain convenient values, prescribed with the help of some constant blocks (switching can be done during simulation, also modifying values of prescribed loads in constant blocks). The asynchronous motor has been picked from the preset options (7.5 kW, 400 V, 50 Hz), with all the necessary parameters from the electrical machine library of SPS.

Zone H from Figure 1 corresponds to the display block of the asynchronous motor's measurements that are obtained during simulation (only the main measurement are displayed, being conveniently selected); in the same zone is the Scope for measuring the speed and electromagnetic torque of the drive engine.

In zones E and J from Figure 1 are Scopes used to display the homopolar component for the supply voltage and for the stator currents of the asynchronous motor: both components are null, meaning that the drive system behaves as a three-phase symmetric system at any time of the simulation. This is proof that the three-phase block for measuring the voltage/current can be used in zone C, or the three-phase block for determining the active/reactive power can be used in zone D. Similarly, the active/reactive power in instantaneous values is measured in zone I from Figure 1 with a PQ block, but considering the currents/voltages in the motor stator in (d, q) coordinates and establishing that the homopolar component of these measurements is null. It is obvious that the active/reactive power instantaneous indications in zone I and zone D (the first established in the (d, q) coordinate system, the second in a three-phase system) are identical.

As such, the whole block diagram in Figure 1 is completely described with its main details.

Presenting Several Main Results.

The block diagram from Figure 1 is equipped with many scopes, as well as its subsystems, to better highlight some measurements/parameters obtained during simulation, in several variants of the supply voltage, of the supply voltage frequency and the load applied at the drive motor's shaft. As an example, in Figure 4 is presented the motor speed variation and the electromagnetic torque, while the load applied at the motor shaft is 35 [Nm] (the nominal torque of the motor is ~50 [Nm]), the supply voltage is nominal and the supply voltage frequency is established by the Timer block program in the subsystem in Figure 2, connected to port 3 of the Multiport Switch; this program has been fixed at [0 1 3 4 6] seconds of simulation time (the total simulation time is 7.5 seconds), with the frequency values [10 30 50 35 50] Hz.

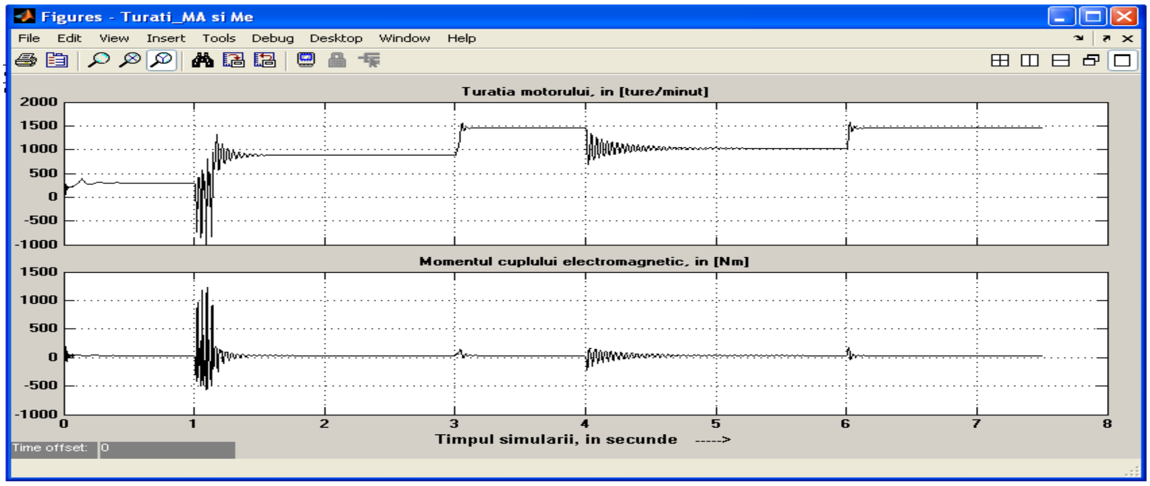


Fig. 4. Speed and electromagnetic torque variation for the drive motor while a certain load is applied to the motor shaft and a variation of the supply voltage frequency.

In Figure 4, the pronounced response of the motor speed can be observed (the synchronous motor speed is 1500 [rotations/minute]), also the less pronounced responses of the electromagnetic torque (the load is constant) to the supply voltage frequency variation, considering the drive system inertia (especially the mechanical inertia). Similar behaviors of these measurements can be obtained by modifying the supply voltage in a certain range (with the help of the respective slider) and maintaining a constant supply voltage frequency during the same simulation cycle, eventually making a comparison between the different behaviors of the drive system.

The block diagram allows the scoping of instantaneous values for the active/reactive powers in different variations of supply or drive system loads. In Figure 5 is presented one such variation of the instantaneous values of the active/reactive powers.

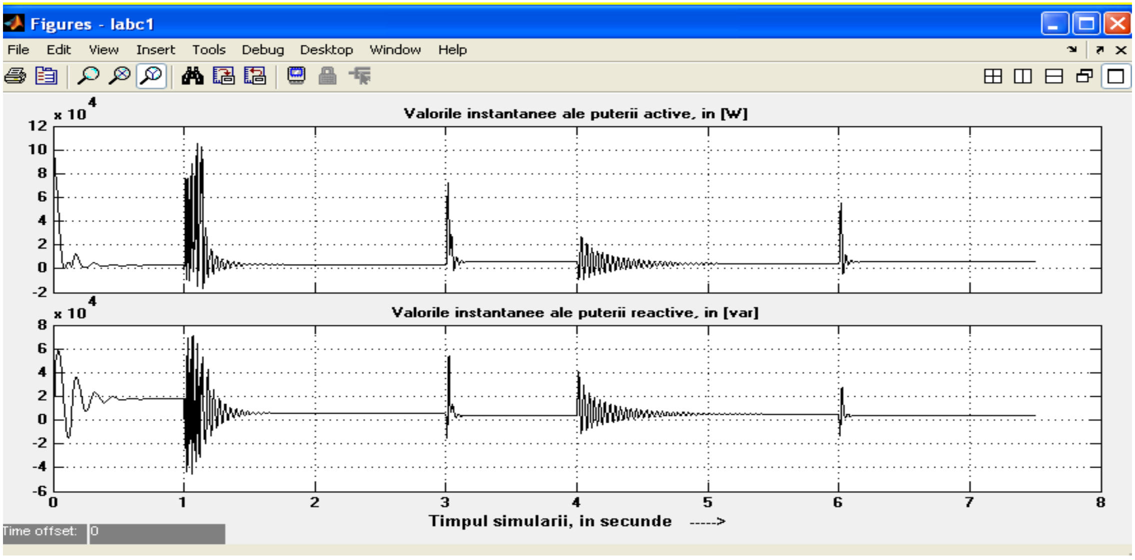


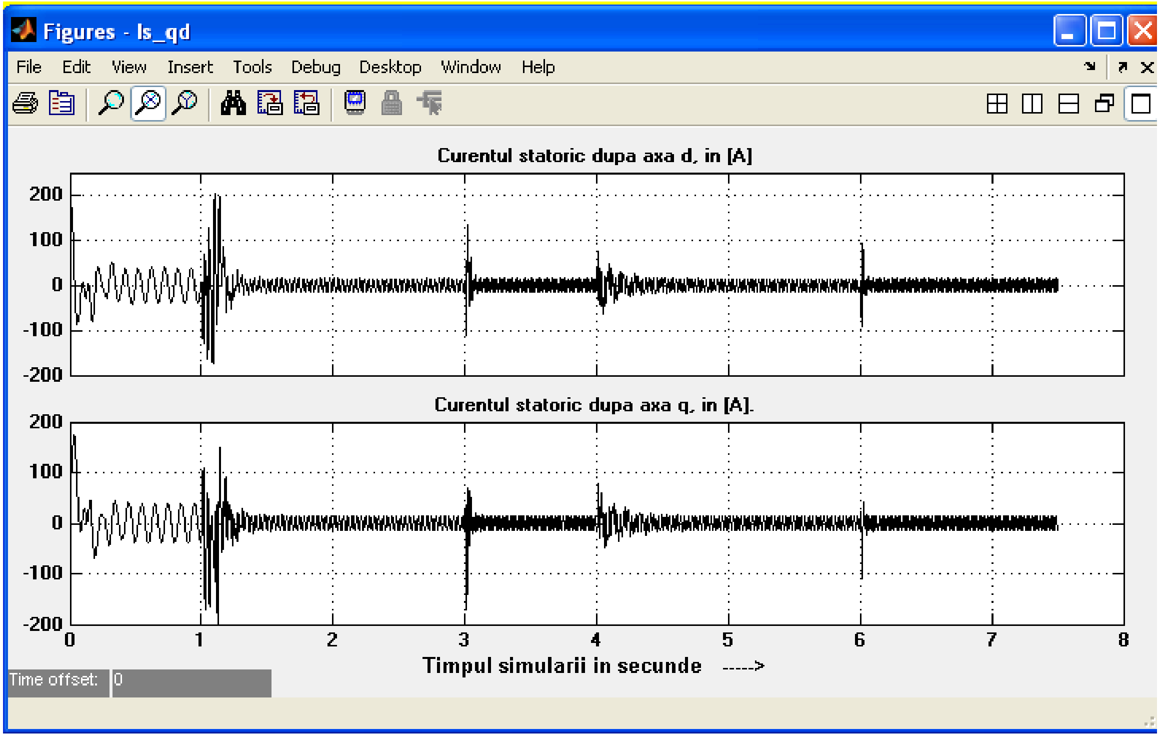
Fig. 5. Variation graphs for the active/reactive power during the simulation of a drive system.

The active/reactive power graphs from Figure 5 were obtained in the same load, supply voltage and supply voltage frequency variation conditions from Figure 4. In Figure 5 are presented the same reactions of the active/reactive powers to the modification of the supply voltage, the shocks being quite pronounced, especially in the case of more pronounced variations of the frequency. Also observable is that at low operational frequencies (so at relatively low speeds of the asynchronous motor), the reactive power consumption is higher (at a constant load) than at hifher frequencies (but lower than the nominal frequency), which implies a corresponding lowering of the power factor. It is remarked that there is a pronounced fluctuation of powers, even more powerful than at the drive starting, when there is a switch from a frequency to another, especially when the frequency difference is higher. The observation can be drawn that the power variation is relatively low when the drive starting is made with lower frequencies, but the power shock at starting remains high, considering that the starting load torque is very high.

In Figure 6 are rendered the current variations (in (d, g) coordinate system) in the simulation conditions stated previously.

From Figure 6 is observed that the starting current shocks are very high, because they depend on the step type load applied at the motor shaft, but very high shocks (as high as the starting shocks) appear when a pronounced modification of the supply voltage frequency; outside of the inertial periods of these modifications, the current variations are normal, but dependent of the motor shaft load.

Making a relatively simple subsystem out of Simulink blocks, as the one from Figure 7, with 2 inputs (for the active power and reactive power, respectively) and an output for the power factor, it can trace the instantaneous values graphs for the power factor during the simulation of a functioning drive system, observing the variation of this electrical parameter in different drive variations.



Time offset: 0

Fig. 6 The variation graphs of the stator currents in (d, q) coordinate system during the drive simulation.

If the preset motor losses were known for the motor used in the drive system, it could be possible to trace the efficiency variation for the drive, accurately and in different work variations.

Generally, however, determining the efficiency can be done taking into account the absorbed active power (in figure 1 it appears as being delivered by the PQ block from zone D) and the power outputted by the motor through the shaft, as being the product between the electromagnetic torque and the angular velocity of the motor (both parameters are found in zone H in figure 1).

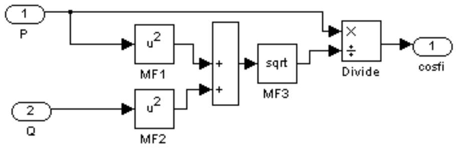


Fig. 7. A subsystem alternative for measuring the power factor

Conclusions

In this paper, the main concern is the way to obtain, during a simulation in the Simulink-MATLAB environment, the main electrical parameters (active/reactive power, power factor and efficiency), while there is the possibility to modify the supply voltage amplitude and the supply voltage frequency, in large ranges, even the load being variable. It has been considered the drive realized with an asynchronous motor with squirrel-cage rotor, the entire drive system and the supply source system being considered three-phase and symmetric. It has not been considered if the proposed solutions, for the block diagram, for the realization of the supply source regarding the voltage amplitude modification and the of the supply voltage frequency, if they are feasible from a practical execution stand-point; this can eventually be another stage of study. In principle, they are valid from a simulation stand-point in the considered environment, using a block diagram equipped accordingly; the diagram itself isn't too difficult, using subsystems (presented previously) to simplify the main block diagram.

The graphs presented are self-evident regarding the operation of the drive system in different variants (there could have been even more variants, but the most important and significant were used), and their processing has been done in the MATLAB environment (so it can be published in black/white) because the signals outputted by the scopes from the diagram use different colors on a black background.

The main conclusion of this paper is that a convenient block diagram can be built, with different work variants and possibilities to obtain the electrical parameters in the case of a three-phased symmetrical drive with an asynchronous motor.

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Asupra unor aspecte privind măsurarea parametrilor electroenergetici în cazul simulării în regimul continuu a acţionărilor electrice cu motoare asincrone

Rezumat

Lucrarea se ocupă cu posibilităţile de obţinere a parametrilor electroenergetici principali, în cadrul unei simulări în mediul Simulink-SPS, a acţionării electrice cu motor asincron, în condiţiile modificării în limite largi a amplitudinii tensiunii, respectiv a frecvenţei tensiuninii de alimentare, fìnd admisă şi variaţii ale sarcinii de la arborele motorului. Sistemul de acţionare, respectiv sistemul de alimentare se consideră ca sisteme trifazate simetrice, iar tensiunea de alimentare este sinusoidală.