SIMULATION OF THE ELECTRIC DRIVE WITH ASYNCHRONOUS MOTORS OF THE BELT CONVEYORS IN ORDER TO INCREASE THEIR EFFICIENCY

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Abstract: In open pit mining coal, it is necessary to develop high transport capacities and adapted to the requirements of consumers. In the paper, a study of the coal transport system with high capacity belt conveyors is carried out. The conveyor system is presented, the structure of these conveyors and an evaluation of the performance of such a conveyor is performed. The belt conveyor has a drive which is based on an asynchronous cage motor. There are also options for traction schemes with static voltage and frequency converters and groups of asynchronous cage motors. Finally, a Simulation Model of the static converter - asynchronous motor drive assembly is presented in the Simulink - SimPowerSystems extensions. And a series of simulations are made for the transient processes of starting, speed adjustment, braking. Making mathematical models and numerical simulation on them is very useful in complex actuating equipment such as assemblies consisting of static voltage and frequency converters and groups of electric motors.

Keywords: open pit, belt conveyors, asynchronous motor, Simulink – SimPowerSystems, voltage and frequency converters.

1. INTRODUCTION

Mining transport represents a productive link of the mining technological process, which decisively influences the technical-economic indicators throughout the mine, even the quality of the product [3].

In mining industry belt conveyors are the most widely used equipment for the continuous transport of material [4].

A high-capacity conveyor is made mainly of a conveyor belt that runs on support rollers and is driven by drive drums, figure 1. The operation of the conveyor with belt must ensure the smooth start of the conveyor with the progressive increase of the speed,

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adjusting the speed of the conveyor belt until the working parameters imposed by the process computer are reached.

Fig 1. Belt conveyor for coal

The traction force in the conveyor belt is realized by means of drums driven by one or more electric motors. The drive system is located at one end of the conveyor, figure 2.

Fig 2. Power electromechanical drive for belt conveyor

2. VARIABLE SPEED ELECTRIC DRIVE SYSTEMS FOR BELT CONVEYORS

2.1. Overview

With the advent of electronic power devices has led to the development of electronic force schemes that have solved to a certain extent the drive problems imposed by asynchronous motors [8].

In order to solve the starting problems and adjust the speed of the asynchronous motors, equipment encountered under the name of static converters were made [5]. The use of power converters based on semiconductor power devices with high technical parameters, of the high-performance control electronics has led to remarkable results in ensuring optimum traction conditions [1].

The static voltage and frequency converter ensures the supply of electrical energy, with variable parameters, to the asynchronous traction motor. Typically, this consists of a three-phase bridge rectifier followed by an intermediate type LC filter circuit and a voltage or current inverters [7].

Figure 3 shows a general structure of an asynchronous motor drive system with the short-circuit rotor.

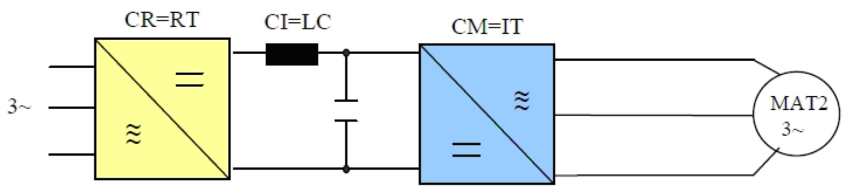

Fig 3. General structure of the static converter - motor drive system

The asynchronous motor with the rotor in short circuit is very good in electric traction because it is robust and easy to maintain. The energy exchange between the stator and the rotor is realized without mechanical parts in contact so that there are no limitations regarding the power and speed, from this point of view. This type of electric traction motors can also reach MW power.

Figure 4. shows the torque - power characteristics according to the speed, in the case of an asynchronous motor with the short - circuit rotor.

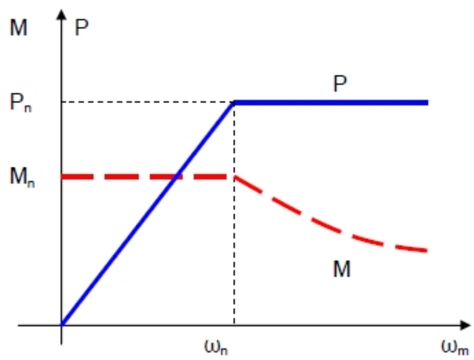

Fig 4. Torque - power characteristics according to speed for an asynchronous motor

2.2. Static voltage and frequency converter

Static AC power converters are complex electronic equipment and have high power and high voltage electronic devices. In recent years the electronic devices in the power circuits are the GTO thyristors or IGBT transistors.

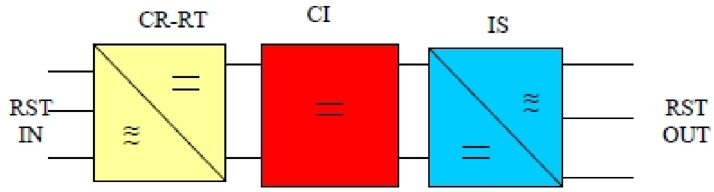

Fig 5. Electronic diagram of static voltage and frequency converter

A general structure of a static voltage and frequency converter is shown in Figure 5. As can be seen we have the basic elements:

- a network converter which is a three phase rectifier, rectifier bridge type, CR - RT;
- an intermediate circuit that adapts the network converter to the static inverter, CI;
- static voltage or current inverter, IS.

In the case of belt conveyors, voltage inverters are used, with intermediate voltage circuits, of type LC filters, for which the capacitive character is predominant. In the literature we find two types of voltage inverters, namely:

- Voltage inverter with 2-level switching;
- Voltage inverter with 3-level switching.

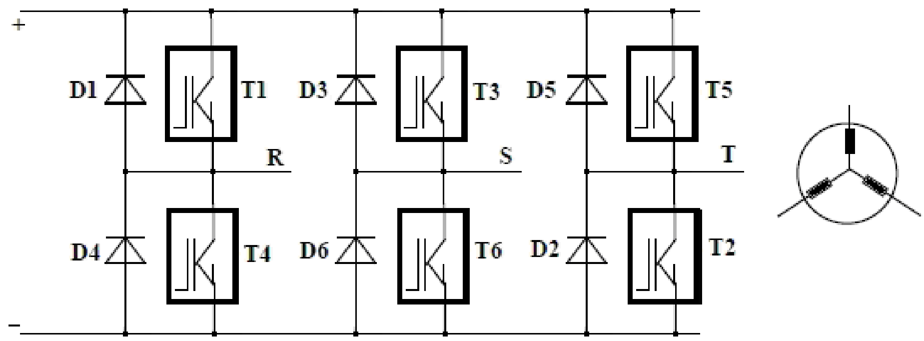

Fig 6. Voltage inverter with 2-level switching

Next, we will discuss only about the 2-level switching voltage inverter, as it is very well suited for drives with asynchronous motors and allows a sinusoidal PWM type modulation [6]. A voltage inverter with 2-level switching (fig.6.) is based on a three-phase bridge constructed of semiconductor devices of the type of bipolar transistors (IGBT), (T1-T6), which in parallel have fast power diodes (D1-D6). Under these conditions the current can flow in both directions, freely through diodes D1-D6, but controlled by the semiconductor devices of force, the transistors IGBT, T1-T6.

Figure 7. shows the basic electrical diagram of the electric drive system used on the belt conveyors with asynchronous traction motors with the short-circuit rotor, MA, which ensures the regulation of the asynchronous motor speed and implicitly the adjustment of the conveyor belt.

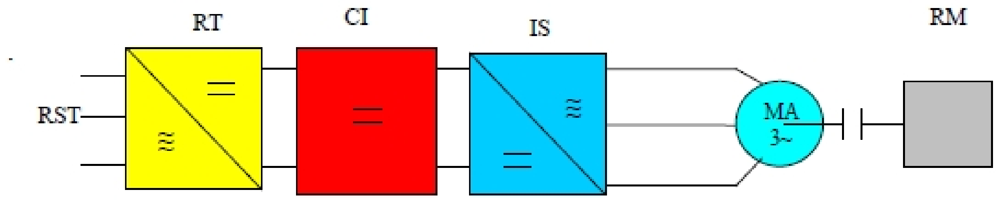

Fig 7. Speed control of asynchronous motor with rotor in short circuit

2.3. Types of traction schemes with static converters and asynchronous motors

Taking into account the requirements imposed by the specific traction parameters of the belt conveyors, on such a conveyor we can have a multiple number of asynchronous motors with the short-circuit rotor which are mechanically coupled to the same conveyor belt. Thus we can have a series of options of traction schemes with static voltage and frequency converters and asynchronous motors, schemes that allow the adjustment of the speed of the asynchronous motors and therefore the speed of the conveyor belt. Here are the following options for traction schemes:

- a static converter which supplies 6 traction motors;
- two static converters which supply 3 traction motors each;
- three static converters that power two traction motors each, (fig.8.);
- six static converters that each power a traction motor.

Analyzing the variants of the drive schemes, it was necessary to choose the variant with three static converters, which supply two traction motors each.

3. MODELING AND SIMULATION OF THE ELECTRICAL DRIVES OF THE BELT CONVEYORS

3.1. Overview

Considering the widespread use of continuous belt conveyor systems in open pit, it is necessary for the electric drive systems of these transport systems to describe their behavior in stationary regime, in transient starting regime, as well as in the case of the speed control regime, under prescribed conditions, severe disturbances. For this reason, it is required that, based on measurements made on physical models that mimic their behavior, we obtain mathematical models with a high degree of generality [2].

Based on the mathematical model we can proceed to the next stage of its numerical simulation. Some kind of mathematical model can be generated and simulated numerically using the MATLAB utility. What we want to generate is the mathematical model of operating a continuous conveyor system with electrical drive based on an assembly consisting of a static voltage and frequency converter and a group of electric traction motors coupled to the static converter (figure 8).

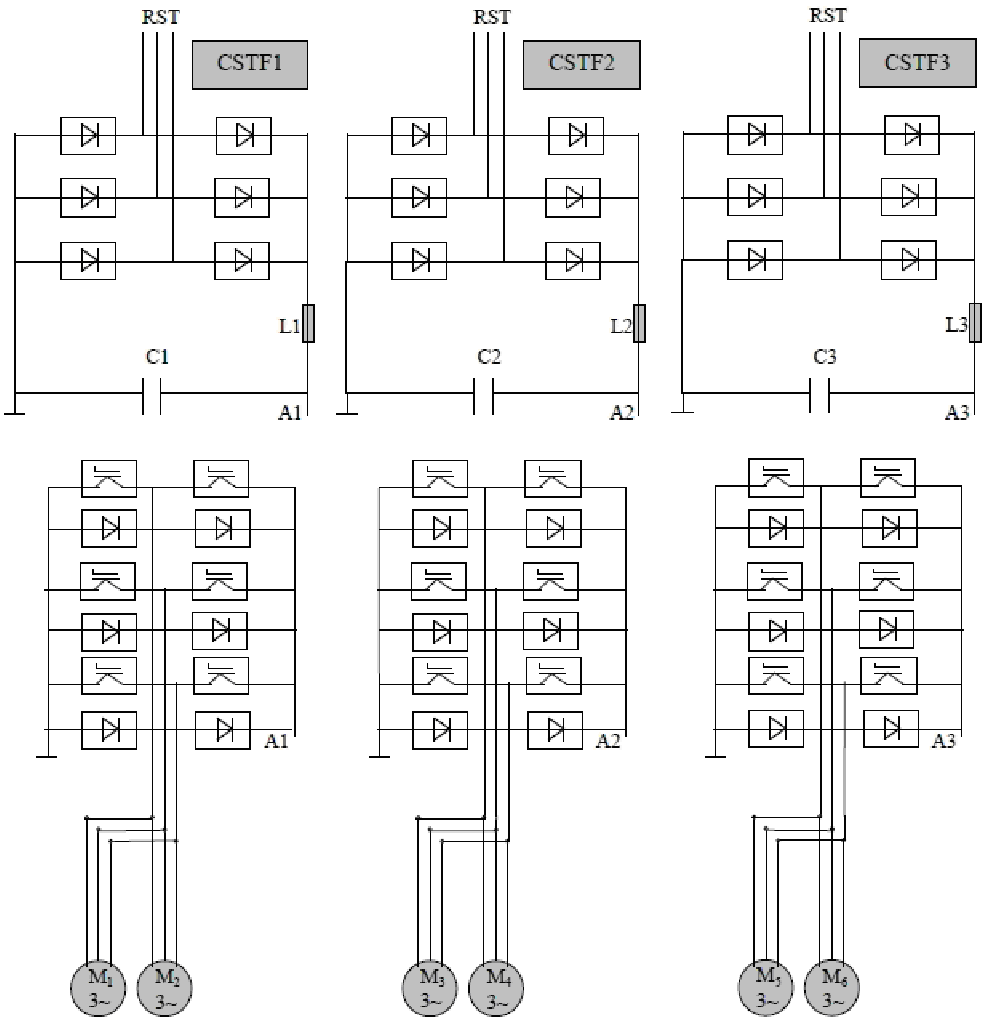

Fig 8. Operating principle diagram with three static converters and two asynchronous motors on each converter

3.2. Simulation model of static converter drive system - asynchronous motor with cage using Simulink - SimPowerSystems

In order to perform the simulations, the model of figure 9. was used in which on the power bars of the static converter were coupled a number of 2 three-phase asynchronous motors. The technical characteristics of the asynchronous motor are: Rated power. – 50 kW, Rated voltage – 560 V, Rated current – 62,5 A, Start-up current – 975 A, Rated speed – 1455 rot/min, Nominal couple – 328,5 Nm.

Figure 9. shows a model based on SIMULINK –SimPowerSystems extensions. This model allows the simulation of the drive system for static converters - asynchronous motors in dynamic regimes such as controlled starts, speed adjustments. Simulation on such a model is made simple by activating the running command of the simulation

program. Based on the blocks of type Speed step, Torquw step we can make the modification of the mechanical sizes such as angular speed and mechanical torque.

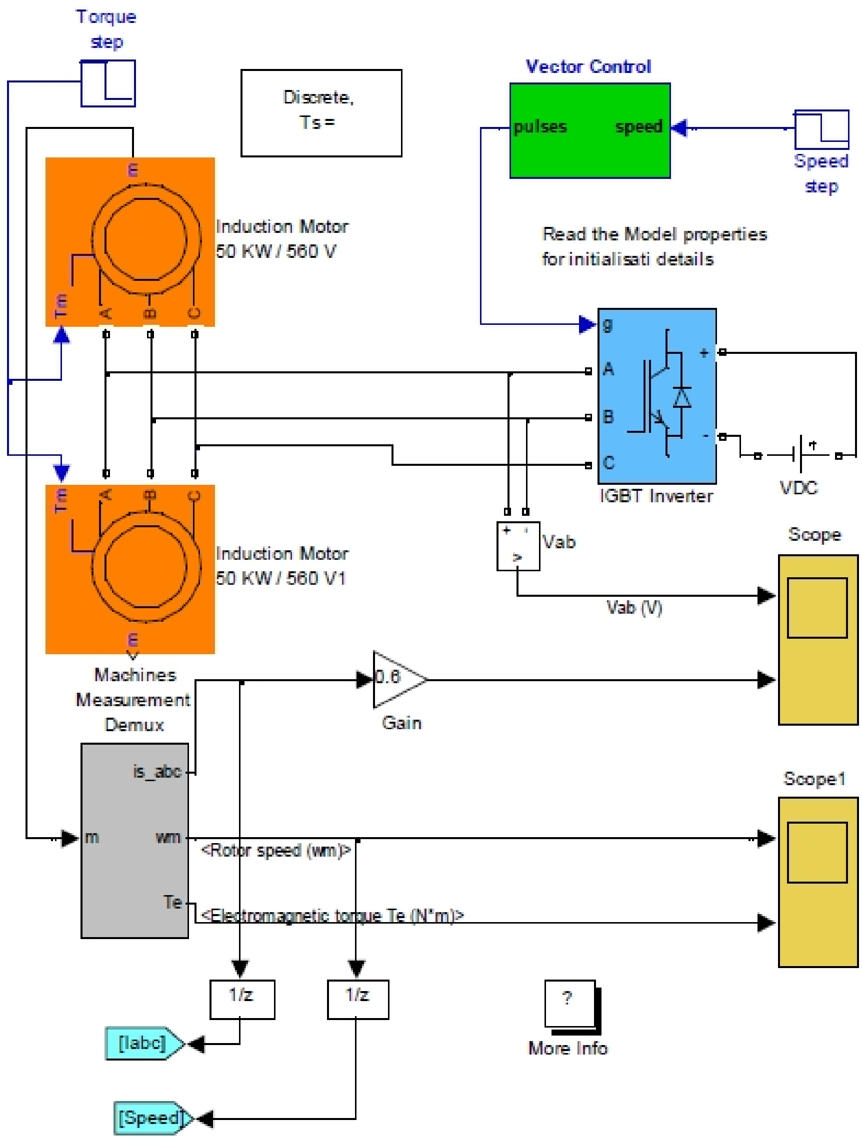

Fig 9. Simulation model drive system static converter - asynchronous motor

Different transient regimes have been simulated for the static converter system - asynchronous motor, by prescribing different values for speed and mechanical torque.

The simulation results are presented in the following figures (figures 10 to 15):

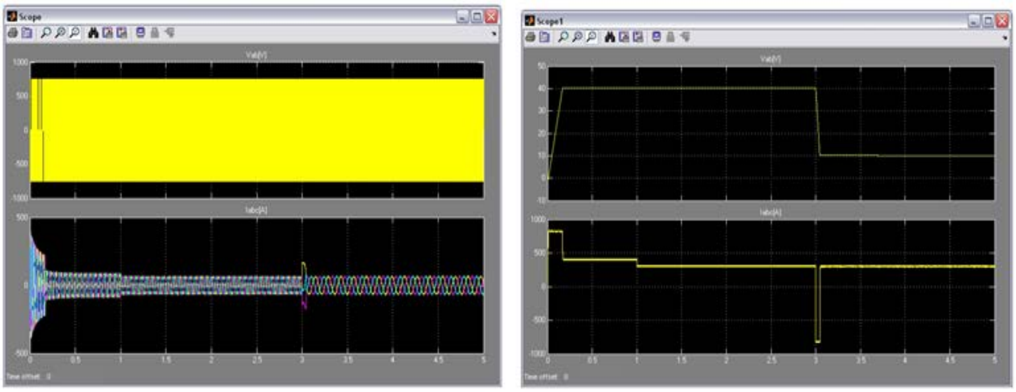

Fig 10. Transient speed of the traction motor, when changing the prescribed sizes:
- t=0 min we have ω*=0 rad/s; - t=0,2 min we have ω*=40 rad/s; Mr*=400 Nm;
- t=3,05 min we have ω*=10 rad/s; Mr*=300 Nm

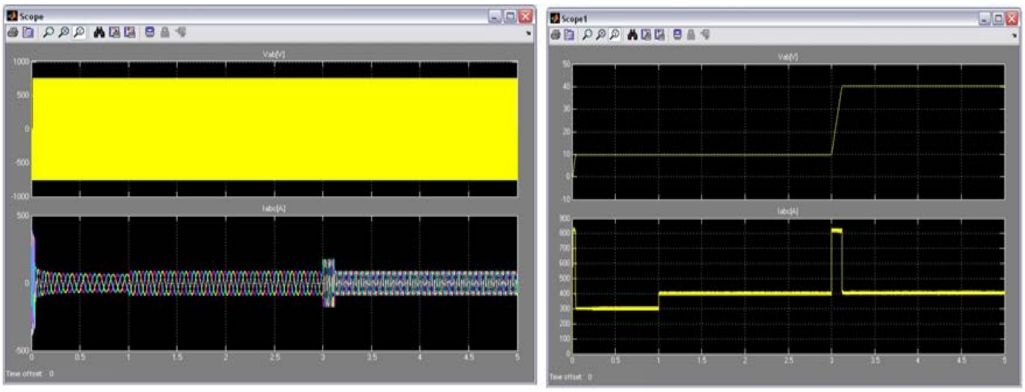

Fig 11. Transient speed of the traction motor, when changing the prescribed sizes:
- t=0 min we have ω*=0 rad/s;- t=0,05 min we have ω*=40 rad/s; Mr*=400 Nm;
- t=3,1 min we have ω*= 10 rad/s; Mr*=300 Nm

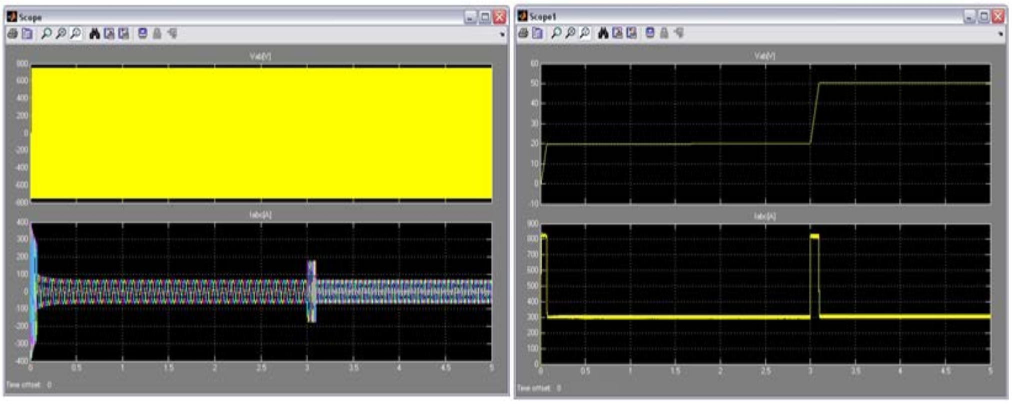

Fig 12. Transient speed of the traction motor, when changing the prescribed sizes:
- t=0 min we have ω*=0 rad/s; - t=0,1 min we have ω*=20 rad/s; Mr*=300 Nm;
- t=3,15 min we have ω*= 50 rad/s; Mr*=300 Nm

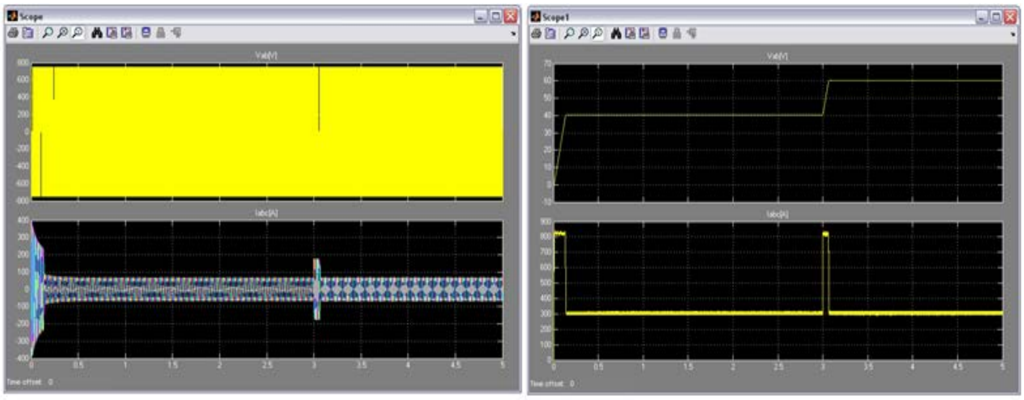

Fig 13. Transient speed of the traction motor, when changing the prescribed sizes:
- t=0 min we have ω*=0 rad/s;- t=0,2 min we have ω*=40 rad/s; Mr*=300 Nm;
- t=3,1 min we have ω*= 60 rad/s; Mr*=300 Nm

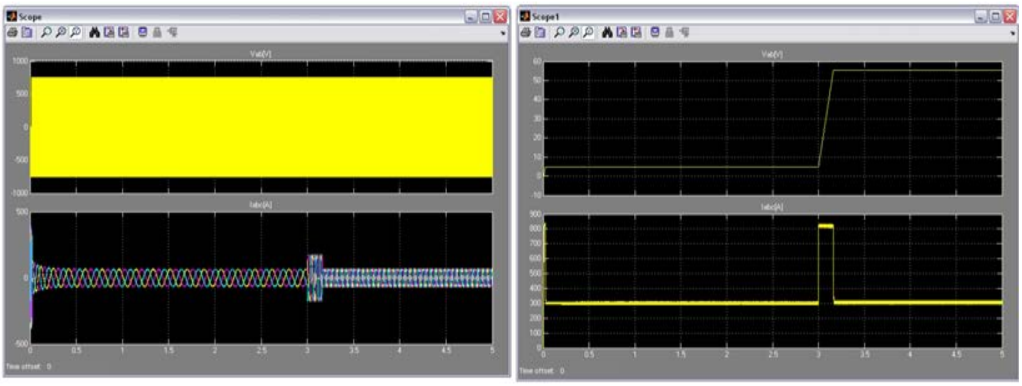

Fig 14. Transient speed of the traction motor, when changing the prescribed sizes:
- t=0 min we have ω*=0 rad/s; - t=0,05 min we have ω*=5 rad/s; Mr*=300 Nm;
- t=3,2 min we have ω*= 55 rad/s; Mr*=300 Nm

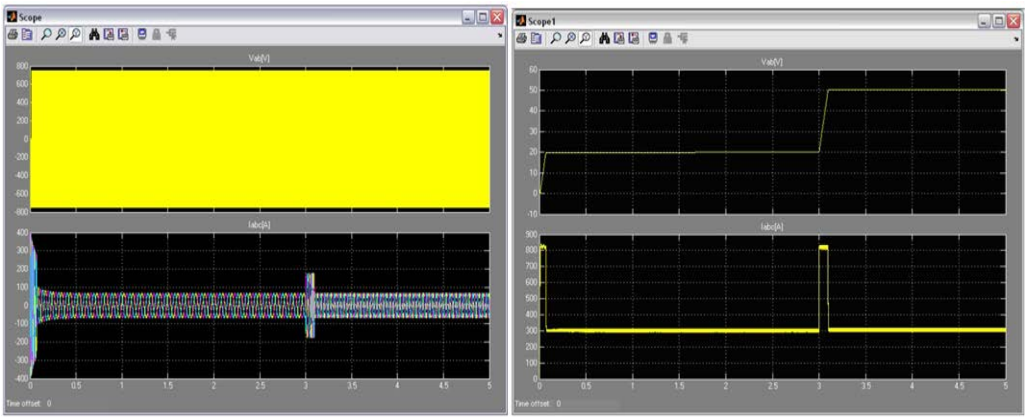

Fig 15. Transient speed of the traction motor, when changing the prescribed sizes:
- t=0 min we have ω*=0 rad/s;- t=0,15 min we have ω*=20 rad/s; Mr*=300 Nm;
- t=3,2 min we have ω*= 50 rad/s; Mr*=300 Nm

4. CONCLUSIONS

Finally, one can conclude:

- the drive systems with static voltage and frequency converters made in IGBT technology are required in the high capacity belt conveyor systems;
- the drive systems as static converters - asynchronous motors can be modeled and simulated numerically by using the MATLAB utility and its extensions SIMULINK and SimPowerSystems;
- based on the numerical simulations, valid conclusions can be drawn regarding the dynamic and static behavior of such relatively high power drive systems;
- the analysis of the operation of the actuation systems with static converters and asynchronous motors, in the field of continuous conveyor belt, with the MATLAB utility and its extensions SIMULINK and SimPowerSystems, offers spectacular results with an acceptable degree of generality.

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