

# ASPECTS OF VARIABLE SPEED CONTROL OF ASYNCHRONOUS MOTORS THROUGH THE TECHNIQUE OF SPACE VECTOR MODULATION

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**Abstract** – Because of development of the power electronics in the branch of frequency converters, the drives with variable speed with asynchronous motors required today a great interest. An almost new technique for speed control of the induction motors is the SVM strategy, which allows the minimizing of the harmonics of current and torque.

The paper presents the simulation in Matlab Simulink of the electric drive with the asynchronous motor for the purpose of speed control, realized through the SVM strategy, using predefined Sim Power System blocks for rectifier, inverter and motor. We present the Simulink model of the speed controller, but the SVM generator will be analyzed in detail in [1]. It will be analyzed the working of the model in a numerical application, noticing the accuracy from which we obtain different electrical and mechanical variables.

**Keywords:** electric drives, SVM, asynchronous motor, simulation.

## 1. INTRODUCTION

Having a simple and robust building, the asynchronous motor is used today, more and more, in electric drives with variable speed. Because of development of the power electronics in the branch of frequency converters and, especially, in the branch of forced commutated electronic switches, the drives with induction motors require today a great interest.

One of the methods for speed control of the asynchronous motor is the vector control method using the SVM (Space Vector Modulation) strategy, an almost new technique of optimal modulation which allows the minimizing of the harmonics of current and torque [2].

In the terms of PWM generation, this technique can directly be controlled within the frame  $\alpha$ - $\beta$ . It is known that a three-phase set of voltages is represented by a space vector of constant magnitude, equal to the amplitude of the voltages and rotating with angular speed  $\omega=2\pi f$ . The eight possible states of an inverter are represented as two null-vectors and six active-state vectors forming a hexagon. SVM approximates the rotating reference vector in each switching cycle by switching between the two nearest active-state vectors and the null-vectors. In order to maintain the effective switching frequency of the

power devices at a minimum, the sequence of toggling between these vectors is organized such that only one leg is affected in every step.

It may be anticipated that the maximum obtainable output voltage is increased with SVM up to 90% of the inverter capability. It is also a relatively easy task to improve this technique in order to reach full inverter capability.

The operating principle of a variable speed electric drive controlled through the space vector modulation is presented in Fig. 1.

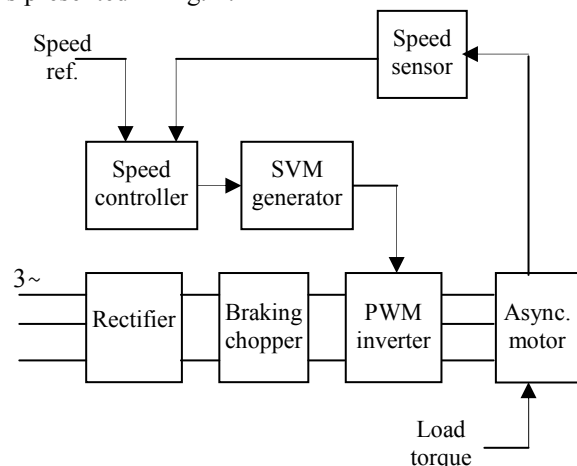


Fig. 1: The operating principle of the electric drive controlled through the SVM strategy

## 2. THE SIMULATION IN MATLAB SIMULINK OF THE ELECTRIC DRIVE SCHEME

To analyze the way in which the principle works, we realize a Matlab Simulink scheme (Fig. 2) which uses both Simulink blocks and Sim Power Systems blocks.

The supply of the asynchronous motor is made from a three phase alternative voltage source with the help of the equipment formed by: three phase rectifier, intermediate D.C. circuit and controlled three phase inverter, elements which are introduced in Simulink scheme through Sim Power Systems pre-definite blocks. The controlled scheme contains two subsystems: the speed controller which we are going to present immediately and the SVM generator (that we have presented in detail in [1]).

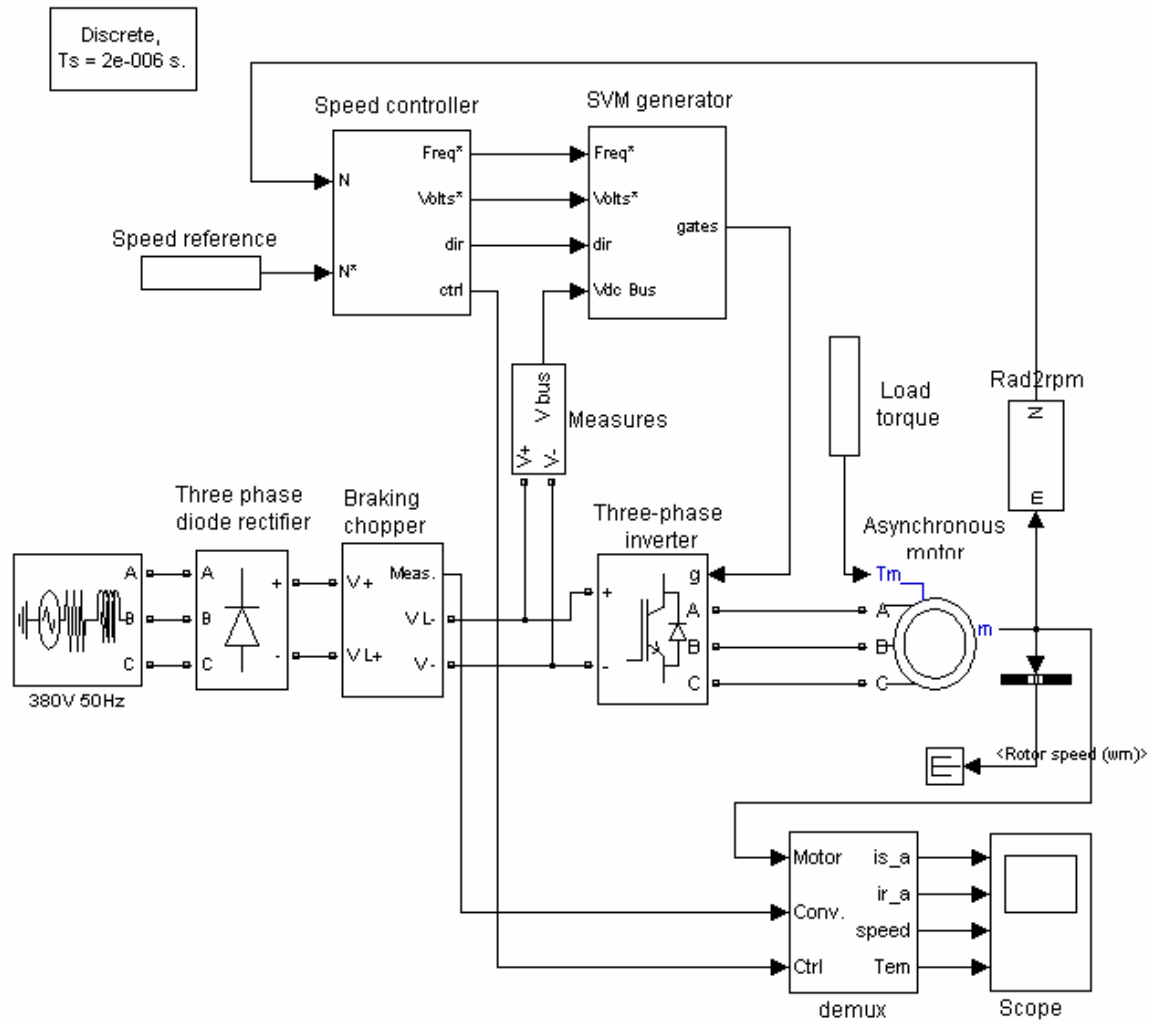


Fig. 2: The Simulink scheme of the electric drive with asynchronous motor controlled by the SVM technique

### 3. THE SIMULATION OF THE SPEED CONTROLLER

The speed controller (Fig.3) has as inputs:

- the reference speed  $N^*$  which is given by the Speed reference block,
- the speed  $N$  obtained from the asynchronous motor, and as outputs the signals:
  - $Freq^*$  (the reference frequency),
  - $Volts^*$  (the reference voltage),
  - $dir$  (shows the sign of the prescribed speed  $N^*$  at the output from the speed ramps),
  - $Ctrl$ , which includes the signals:  $Volts^*$ ,  $Freq^*$ ,  $Error$  and reference speed  $N^*$ .

The first three output signals go to the SVM generator subsystem and the last one to visualization at Scope. The speed controller is based on a proportional integrator (PI) regulator which controls the motor slip. As we can see on the scheme, the slip value calculated by the PI regulator is added to the motor speed in order to produce the demanded

inverter frequency. This frequency is also used to generate the demanded inverter voltage in order to maintain the motor  $U/f$  ratio constant.

### 4. THE SVM GENERATOR

The SVM generator, whose operating principle is presented in Fig. 4, contains seven blocks with the following functions:

- the three-phase generator is used to produce three sine waves with variable frequency and amplitude; the three signals are out of phase with each other by  $120^\circ$ .
- the low-pass bus filter is used to remove fast transients from the DC bus voltage measurement; this measure is used to compute the voltage vector applied to the motor.
- the  $\alpha\beta$  transformation converts variables from the three-phase system to the two-phase  $\alpha\beta$  system
- the  $\alpha\beta$  vector sector is used to find the sector of the  $\alpha\beta$  plane in which the voltage vector lies; this plane is divided into six different sectors spaced by  $60^\circ$ .

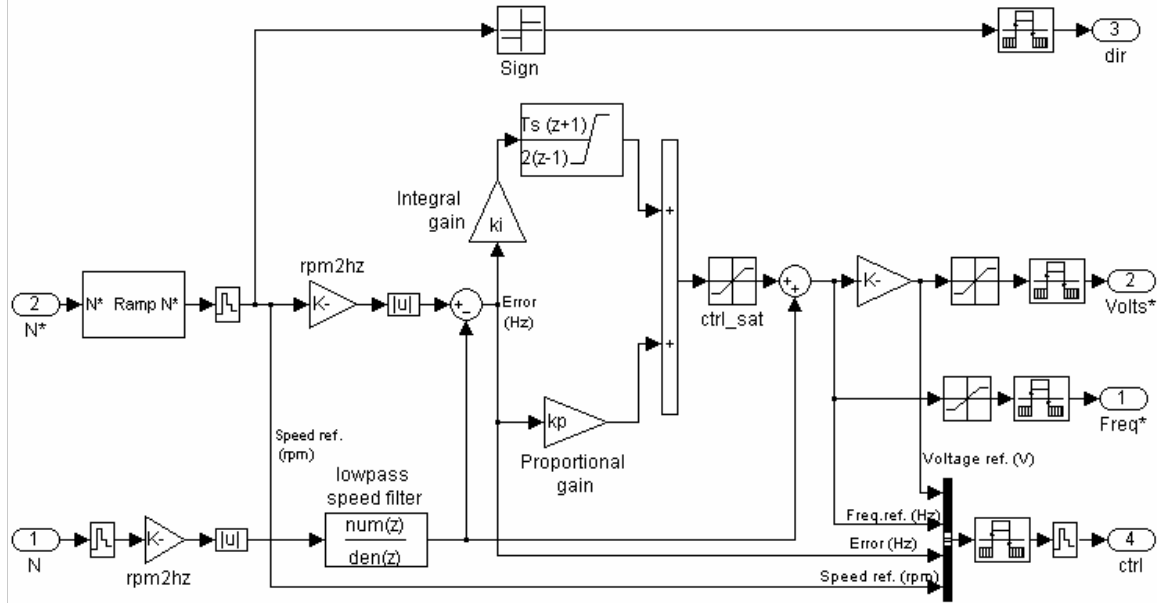


Fig. 3: The Simulink scheme of the speed controller

-the ramp generator is used to produce a unitary ramp at the PWM switching frequency; this ramp is used as a time base for the switching sequence.

-the switching time calculator is used to calculate the timing of the voltage vector applied to the motor.

-the gates logic compares the ramp and the gate timing signals to activate the inverter switches at the proper time.

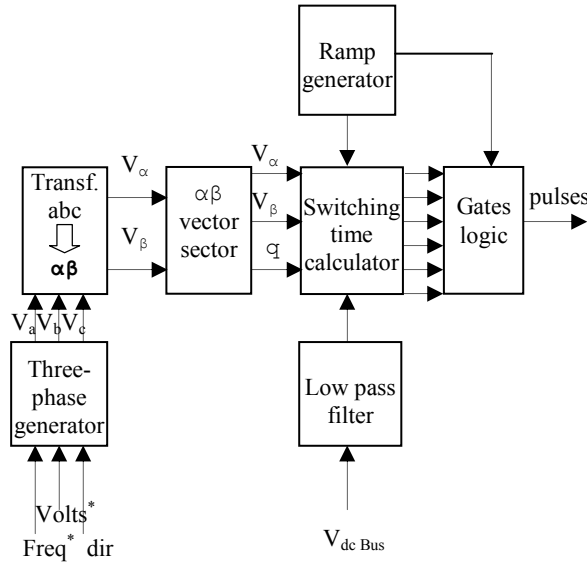


Fig. 4: The operating principle of the SVM generator

The presentation in detail with the simulation of the component blocks in Matlab Simulink and the analyzing of the main signals is done in [1].

## 5. THE RESULTS OF THE SIMULATION

We make simulation for an asynchronous motor tip HXUR 265A2 with the following nominal dates:

$P_n = 5.5 \text{ kW}$	$R_s = 0.894 \Omega$
$U_n = 380 \text{ V}$	$R_r = 0.85 \Omega$
$p = 2$	$L_{ss} = 0.006 \text{ H}$
$J = 0.035 \text{ kgm}^2$	$L_{rs} = 0.007 \text{ H}$
$\cos \phi = 0.79$	$L_m = 0.112 \text{ H}$

We consider:

-the speed reference prescribed to (800; 1400) rpm at  $t = (0; 1.3) \text{ s}$ ,

-the load torque prescribed to (0; 12) Nm at  $t = (0; 0.5) \text{ s}$  with step variation.

We obtain the variations in time of the main electrical and mechanical variables, specific to the presented drive (the stator current  $i_{sa}$ , the rotor current  $i_{ra}$ , the rotor speed  $N$  and the electromagnetic torque  $T_{em}$ ) and we represent them in Fig. 5.

From the graph we notice that:

- the motor speed follows with accuracy the speed reference both on the horizontal portions and on the acceleration ramps (considered here at 1800 rpm/s) which begin at the moments  $t = 0$ , when  $N^* = 800 \text{ rpm}$  and  $t = 1.3 \text{ s}$ , when  $N^* = 1400 \text{ rpm}$ .

-the motor responds to the load torque variation from the moment  $t = 0.5 \text{ s}$  through the electromagnetic torque variation which is stabilized almost quickly to the reference value; the torque is grown also on the periods of the acceleration ramps.

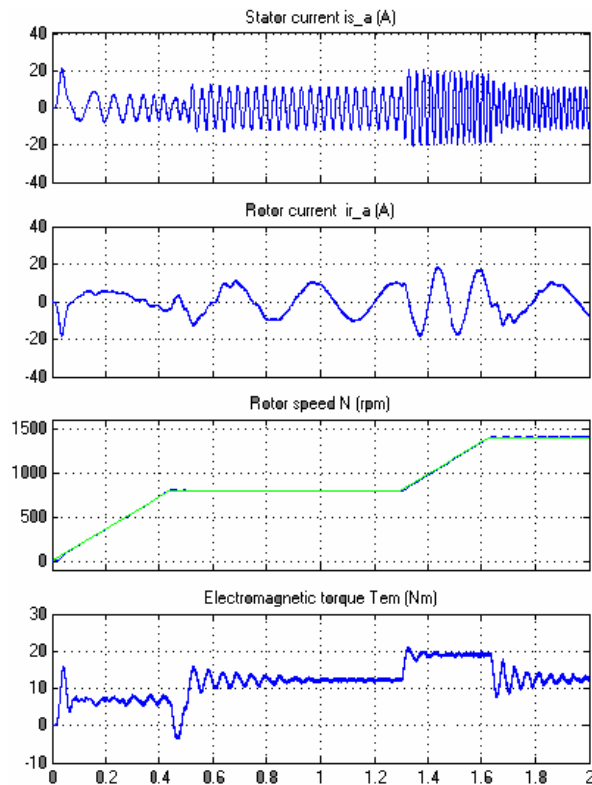


Fig. 5: The waveforms of the main variables to the simulation on the HXUR 265A2 async. motor

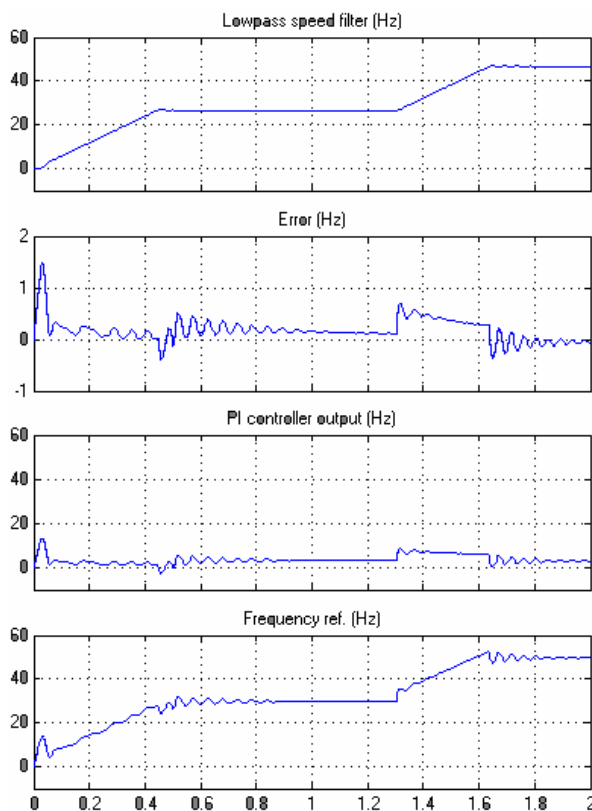


Fig. 6: The waveforms at speed controller

We also present in Fig. 6 the intermediate signals of the speed controller (the output of the low pass filter, the error of the speed, the output of the PI regulator) and the output signal of this (frequency).

We notice:

- the error, which shows the difference between  $N^*$  and  $N$ , multiplied with  $p/60$ , is smaller than 1 Hz.
- the frequency signal at the output of the speed controller, which represents the sum between  $PI$  output and  $pN^*/60$  follows the reference speed variations at  $t=0$  and  $t=1.3$  s.

## 5. CONCLUSIONS

The paper presents the simulation in Matlab Simulink of the electric drive with asynchronous motor for the purpose of variable speed control, realized through the SVM strategy, using Simulink and Sim Power System blocks.

We analyze the working of the model in a numerical application and we obtain, with accuracy, different electrical and mechanical variables.

We present the Simulink model of the speed controller as well as the waveforms of the input, intermediate and output signals of this.

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