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Simulink Model of the Self Controlled Synchronous Motor Drive

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Abstract

The Self Controlled Synchronous Motor (SCSM) is a good solution for variable speed drives at high and very high power ratings . Due to the complexity of the scheme the analytical simulation of this drive system is very difficult .In the paper is shown a new approach based on the Simulink Power System (SPS) library to generate an elegant solution for the simulation model. A SCSM drive system with GTO thyristors was studied and simulated in both steady state and transients showing good performance.

Key words: *Synchronous motor, three phase GTO thyristor converters, position Sensor.*

Introduction

The Self Controlled Synchronous Motor (SCSM) is a good solution for variable speed drives at high and very high power ratings and the characteristics, performances and limitations are well known [1, 2]. In short the main property of this motor is the self synchronising of the rotating field speed with the rotor speed. This operation, done with a rotor position sensor which controls the inverter feeding the SCSM, is similar with the commutation of the current paths of the DC motors armature due to the mechanic commutator.

The simplified scheme of a SCSM drive system is shown in figure 1.

The converter that feeds the SCSM generates the three phased currents with the phase and the frecvency in synchronism with the rotor position. In fact , this means the turning on of the next thyristor of the converter with respect of the rotor position related to the magnetic axis of the following fed phase. The amplitude of these currents is controlled by the mains converter which operates as a phase controlled rectifier. The two converters are linked by a current source intermediary circuit with a filtering inductance Ld which gives the rectangular aspect of the three phase currents. The ideal shapes of the currents are shown in figure 1b.

The inverter that feeds the SCSM operates with forced commutation or is commuted by the synchronous motor. In a normal operating mode the phase induced voltages are commuting the phase currents. The forced commutation is however needed at low rotor speeds (under 10% of the nominal speed).

The inverse circulation of the electric energy, from the motor to mains, is possible. In this regime the SCSM operates in a regenerative braking regime the converter linked to the machine working as rectifier and the one linked to the mains as an inverter.

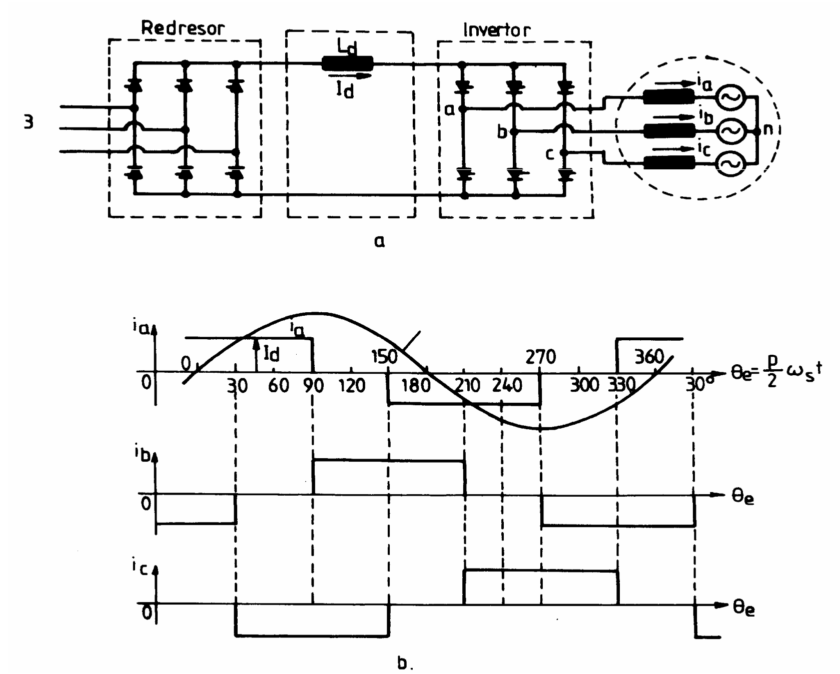

Fig. 1. The SCSM drive system:
a) the simplified scheme; b) the voltage and currents waveforms.

Due to the complexity of the scheme (two static converters, the intermediary circuit and synchronous machine) the analytical simulation of this drive system is very difficult. In the paper is shown a new approach based on the Simulink Power System (SPS) library to generate an elegant solution for the simulation.

The Simulink model of the SCSM drive system

The model shown in figure 2 was build with specific blocks from the SPS library such as GTO thyristors, AC current source, synchronous motor and a reactive circuit element Ld representing the inductance from the intermediary circuit. The three phase converters are both build with GTO thyristors blocks allowing the setting of the thyristor parameters and of the corresponding snubbers.

The control block of the current inverter feeding the synchronous motor is very important for the correct operation of the whole system and includes the rotor position sensor and the six outputs for the GTOs , shown in figure 3.

The rotor position is calculated by integrating the angular speed .The obtained variable, called angle will generate the control signals for the six GTO thyristors by reading a look up table which gives the “On “ (1 binary) or the “Off” (0 binary) with respect of the current angle. The control block called Encoder is a subsystem of the scheme from fig.2 and stores the final position of the rotor at the end of the running time like a real electric motor. This position will be the initial position at the next run. The six control signals are multiplexed and send under the names Pulses+ and Pulses- to T2 , T4 , T6 and T1, T3, T5 respectively.

In figure 4 are shown the essential signals generated in the **Encoder** block. There are two groups of control signals for the T1, T3, T5 and T2, T4, T6 GTOs respectively and the variables wm, tetha and angle. The variable wm is the rotor speed of the SCSM and is the input of this block. Tetha is the continuous angle as result of speed integration and angle is the this angle reduced to a complete turn, angle by this can be between 0 and 6.28 radians.

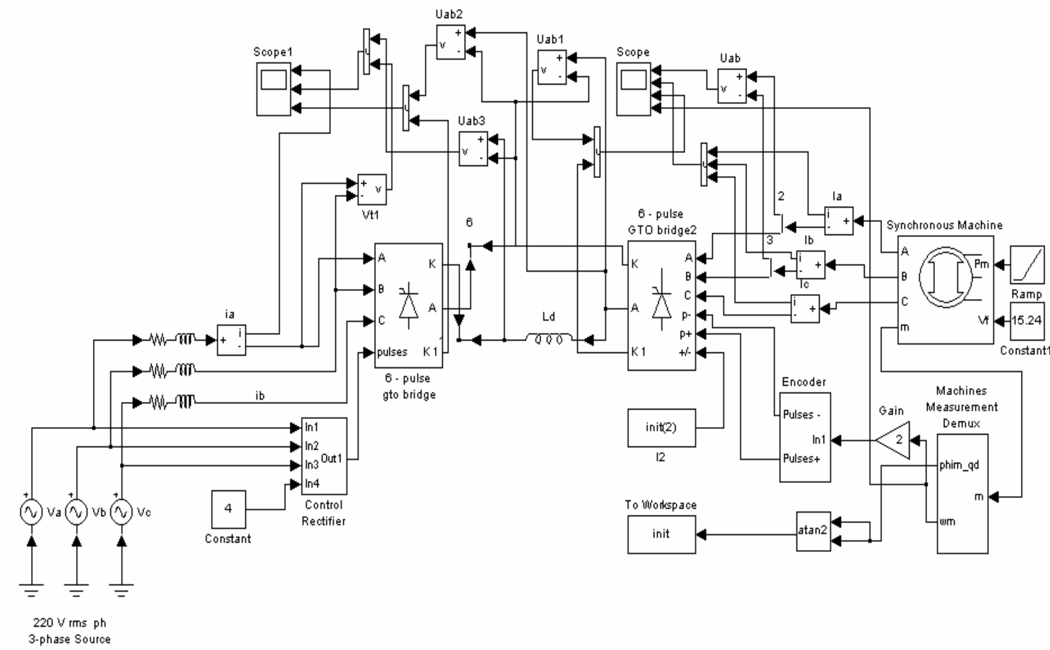

Fig. 2. The Simulink model of the SCSM drive system .

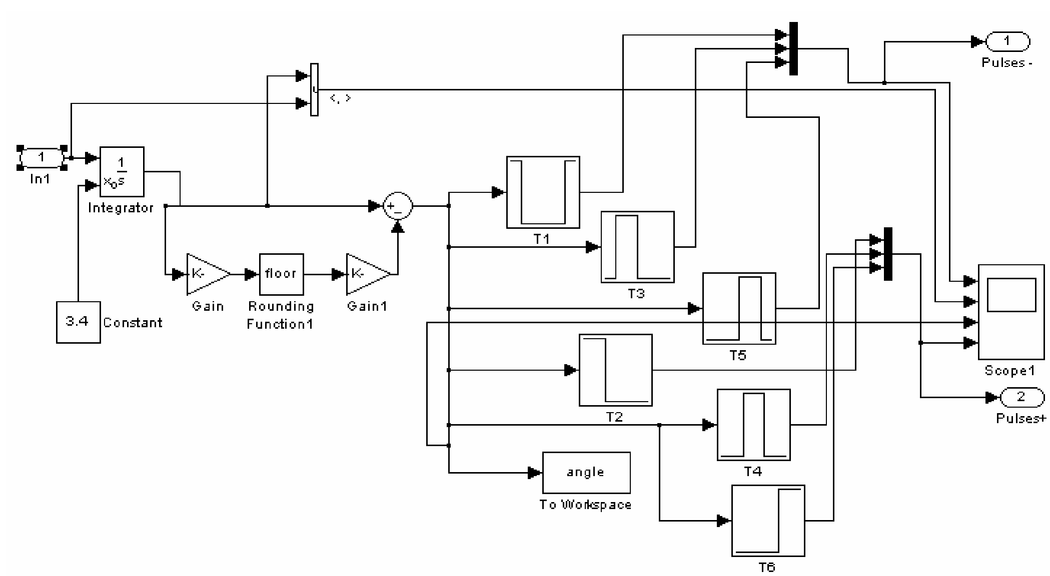

Fig. 3. The Simulink scheme of the control block of the inverter.

The synchronous motor is a block from the SPS library with S = 111kVA and p=2. The other electric and mechanic parameters are shown inside the block .The electric parameters are in d , q coordinates system and are set according the Matlab Simulink documentation [4]. The machine Block has a specific block for the motor variables called **Machine Measurement Demux**, see fig.2. In this Simulink scheme, for an efficient solution, only the wm output was used being useful for the rest of the elements of the scheme. The currents and the voltages were obtained with measurement blocks.

Simulation results

The good operation of the simulation scheme is shown by starting the SCSM drive system from stand still applying a step up signal at the rectifier's control block . The specific signals of the SCSM are shown in figure 5.

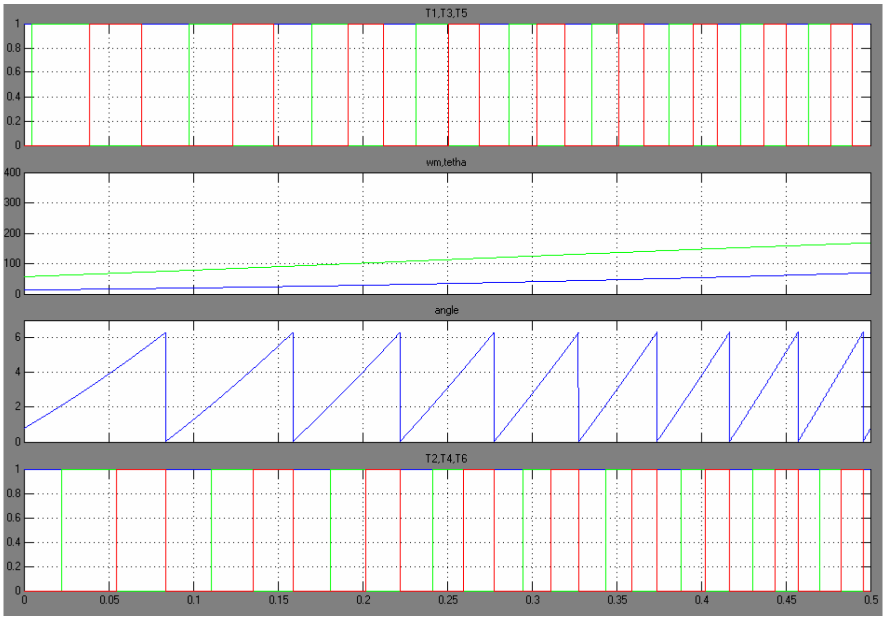

Fig. 4. Specific waveforms for the Encoder block.

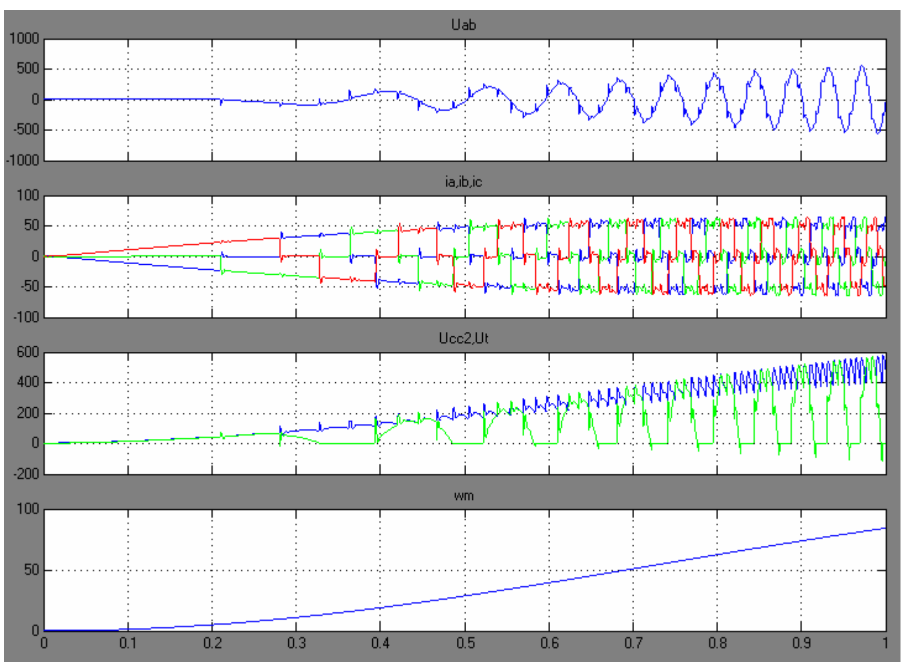

Fig. 5. Starting transients: Uab –the line voltage of the SCSM: ia, ib, ic- the SCSM currens; Ucc2-the DC voltage at the input of the current inverter; Ut – GTO thyristor voltage; wm – the SCSM rotor speed.

The constant excited SCSM transients are shown for 1 sec .The machine speeds up till near 90 rad/sec. The starting was done with a mechanical power ramp, i.e. quasi constant load torque .This way of loading the synchronous motor during the start up was done according the SPS block documentation.

In figure 6. are shown specific waveforms for the controlled rectifier voltage at the input of the current inverter; Ut- GTo thyristor voltage specific to the controlled rectifier.

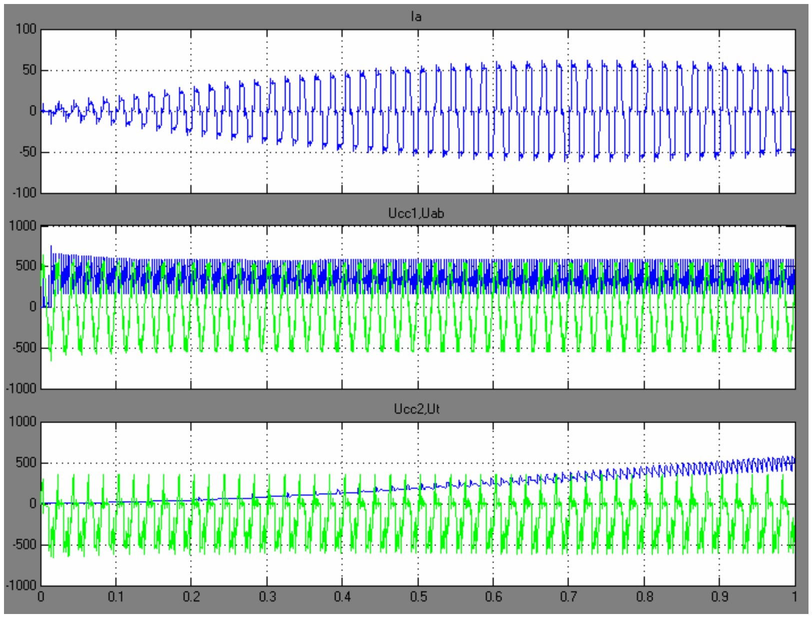

Fig. 6. Specific transients for the controlled rectifier :Ia- the AC mains current;Ucc1- the DC voltage at the rectifier output ;Uab-AC line voltage at the rectifier input;Ucc2- the DC voltage at the inverter input.

The voltage and current waveforms are specific for a six pulses controlled rectifier .It can be seen the step variation of the DC voltage Ucc2 at the begining.

Conclusions

A SCSM drive system with GTO thyristors was studied and simulated in both steady state and transients.The Simulink model showed good performance and flexibility. The original control block **Encoder** works very good with original SPS blocks and similar precision models for other drive systems are in tests.

References

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Modelarea cu Simulink a maşinii sincrone autopilotate

Rezumat

Maşina sincronă autopilotată este o soluţie utilizată pentru acţionările electrice de mare putere ce necesită viteză variabilă.Datorită complexităţii schemei o simulare bazată pe ecuaţiile de funcţionare aeste foarte dificilă.In lucrare se arată o abordare nouă, bazată pe elementele din biblioteca Simulink Power Systems(SPS), ce permite o soluţie elegantă pentru modelul destinat simulării. S-a studiat un sistem de acţionare cu o maşină sincronă autopilotată şi convertoare cu tiristoare GTO în regim staţionar şi tranzitoriu, cu menţionarea unor rezultate în urma simulării.