SIMULINK LIBRARY OF HIGH SPEED TRAINS CONTROL

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Abstract **– On the mathematical basis and respectively on the structural diagrams of the control of voltage-source inverter fed traction induction motor used in high speed trains, in paper they are presented a SIMULINK library which they permit the working study through simulation. They are described the models associated of those two control types used in the high speed trains: the vector control and Direct Self Control. By means of SIMULINK models, in paper, they are simulated different workings of considered systems.**

Keywords: *high speed train, traction control, SIMULINK library*

1. INTRODUCTION

An important component of the traction control of the high speed trains is the control of the voltage-source inverter – traction induction motor ensemble. This can be:
1) vector control or
2) Direct Self Control (DSC) [1], [2]].
In the vector control case the used solutions are of direct type (Direct Field Orientation - DFO) and/or indirect type (Indirect Field Orientation - IFO). For the simulations from paper it is considered the diagram vector control used in the German ICE high speed train, what combines those two solutions [1], [2].
ABB (ADTRANZ) has implemented the DSC principle successfully through the MICAS microcomputer traction control system utilization [3], [4]. Unlike the vector control, in the implementations case in the high speed trains, the DSC diagram structure like specific feature has three different configurations corresponding to a three stator frequency domains: (0, $f_{sN}/3$], ($f_{sN}/3$, f_{sN}] and (f_{sN}, f_{smax}]. All those three configurations have however like common elements two identical calculus blocks, corresponding to the traction induction motor and the voltage-source inverter.
In order to analysis trough simulation of the control of voltage-source inverter fed traction induction motor used in high speed trains, it was created a SIMULINK library, named "*Control*" (fig.1)". This library contains the blocks corresponding to the vector control, the direct self-control (DSC), 2 blocks what they achieve the PWM modulation within framework of the control structures and the control blocks of the side-line converters.

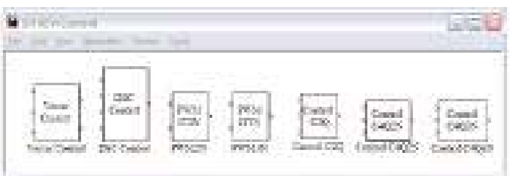


Figure 1: Content of „Control" library

The blocks from this library permit the study through simulation of the electric drives systems control specific to high speed trains, entirely or on components, through easily their coupling.

2. SIMPLIFIED SIMULINK MODEL OF THE VECTOR CONTROL

In order to study the traction induction motor operation, in the vector control case, it is built a simplified SIMULINK model, what take account only of the supply voltage fundamental of the traction induction motor (fig.2). The used model contains two mask blocks:
- *MAS1*, the model corresponding to the traction induction motor [1], [5]
- *Vector control* (fig.3), with the structure achieved in accordance with the vector control diagram used in the ICE high speed train [2].
In this model (fig.1) the used controllers are of the PI anti-windup type the block *sin/cos* calculates the $e^{\pm j\varepsilon}$ expression, and the *Decuplare* block (fig.4) is achieved on the uncoupling equations [2].
Through the feeding of the motor directly with the $\underline{u}_s$ voltage is taken into consideration only the voltage fundamental of the voltage-source inverter and its model becomes useless. Is avoided, thus, the utilization of the complex model in order to study the performances of the control diagram.
By means of the SIMULINK model (fig.2) has been simulated a transient state of the vector controlled traction induction motor, corresponding to a starting, followed of a operation with constant speed and then

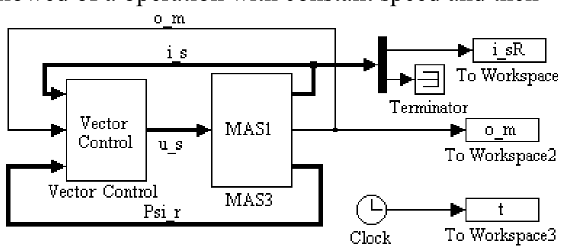


Figure 2: SIMULINK model of the vector control with supply voltage fundamental consideration

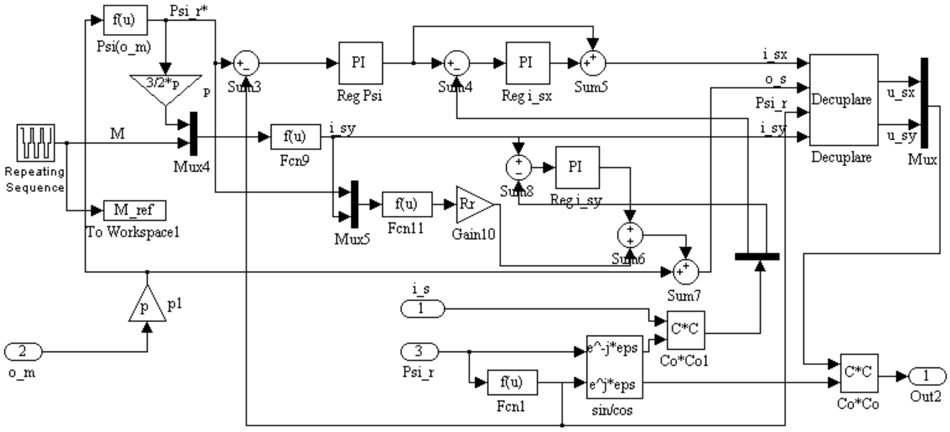


Figure 3: Content of the „Vector control” mask block

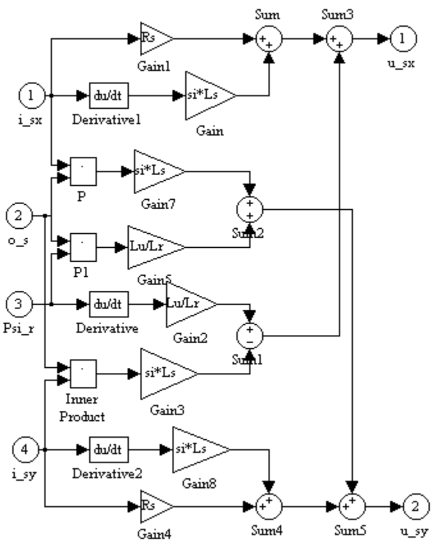


Figure 4: Content of the „Decuplare” block mask

of a braking of a high speed train. They have obtained, for these regimes, the variation in time of the M_{ref} reference torque, of the M electromagnetic torque, of the Ω_m angular speed and of the i_{sR} stator current on the R phase (fig.5).

For a step input of the M_{ref} reference torque, the M electromagnetic torque of the motor achieves the imposed values after approximately 1,5 s later; follows a prewriting of the reference torque at the static torque level, which corresponds it's the operation at constant speed of the traction induction motor; and in the end, the motor is braked through the prewriting of a negative torque.

It is obtained a good answer of the system, specifically the vector control, fact what confirms the worked out model correctness.

This model, because of its simplicity, is useful in analysis, through simulation, of a specific phenomenen of the high speed trains, how would be the anti-slip control, the inequality influence of the motor wheels diameters etc.. Also, in the IGBT utilization case, this model has an alike behaviour for high switching frequencies.

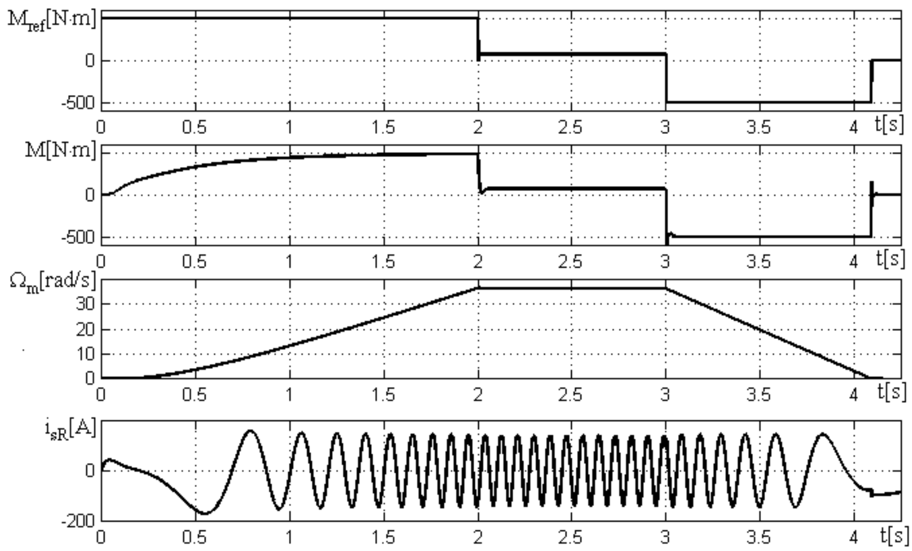


Figure 5: Wave of the principal quantities what characterized the vector control of the traction induction motor at supply voltage fundamental consideration

3.VECTOR CONTROL FOR THE VOLTAGE-SOURCE INVERTER WITH TWO LEVELS

In order to study the operation of the voltage-source inverter with two levels – traction induction motor ensemble in the vector control case is built the adequate SIMULINK model (fig.6). This model (fig.6) contains moreover given the precedent (fig.1) the *PWM IT2N block* (fig.7), of which structure is achieved on the model basis of the voltage-source inverter with two levels [1], [5]. It is modelled thus the operation of the traction induction motor fed from the voltage-source inverter with two levels, what is working in PWM regime, after the vector control strategy presented previously.

By means of the model (fig.6) has been simulated the same regimes succession, for the same variation of the reference torque, like in the consideration case only of the voltage supply fundamental of the motor. They have been visualized, following the simulation, the forms of the variation in time of the Ω_m angular speed, of the u_{sR} stator voltage on the R phase and of the i_{sR} current on the R phase (fig.7). The speed variation is alike with the precedent case (fig.5), the voltage and current on the R phase being characteristic of the PWM. Like in the precedent case it is established stable behaviour of the model without convergence problems of the integration method.

4. SIMPLIFIED SIMULINK MODEL OF THE INDIRECT SELF CONTROL (ISC)

On the mathematical models basis associated with the DSC [1], [4] can be created SIMULINK models, having the same topology structure. Through adequate completions or simplifications can be achieved models which they permit the study through simulation of the different phenomenon specific to the high speed trains.

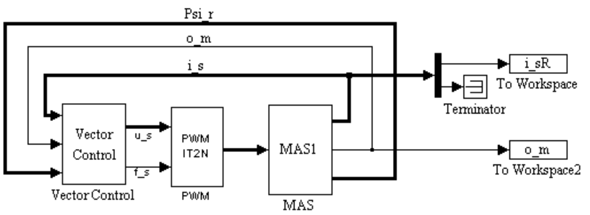


Figure 6: SIMULINK model of the vector control of the traction induction motor fed from a voltage-source inverter with two levels

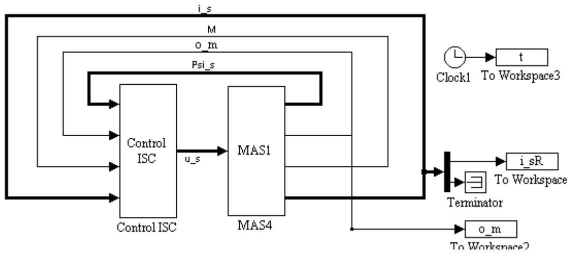


Figure 9: ISC SIMULINK model without consideration of voltage-source inverter model

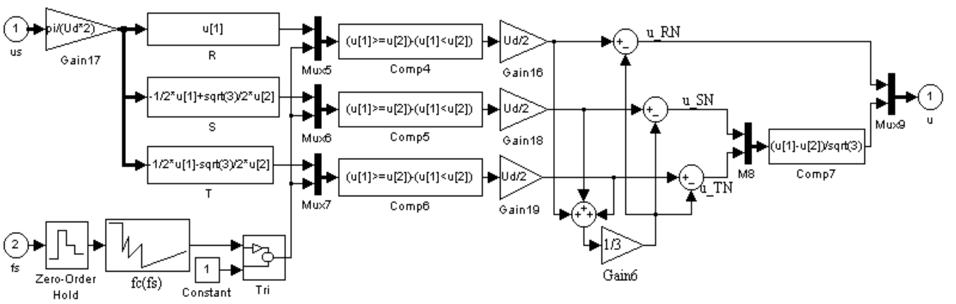


Figure 7: Content of the „PWM IT2N" mask block

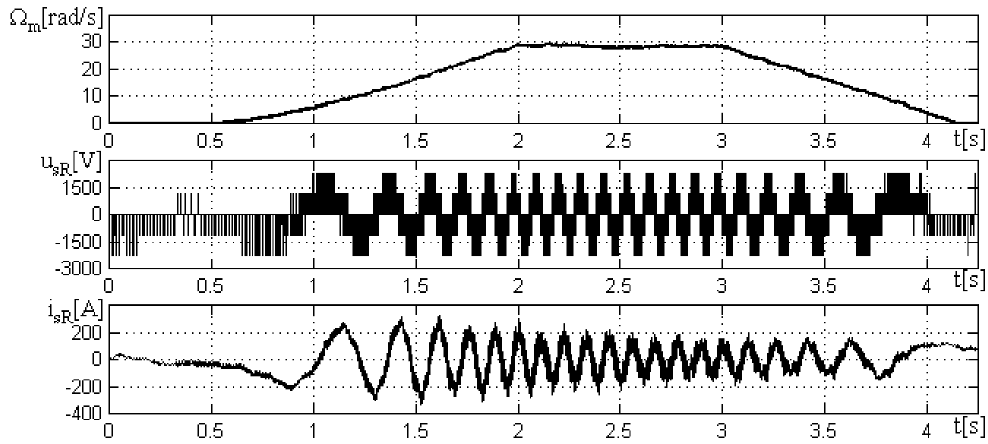


Figure 8: Waveforms of the Ω_m, angular speed, of the u_{sR} stator voltage on the R phase and of the i_{sR} current on the R phase at vector control of the traction induction motor fed from a voltage-sou with two levels

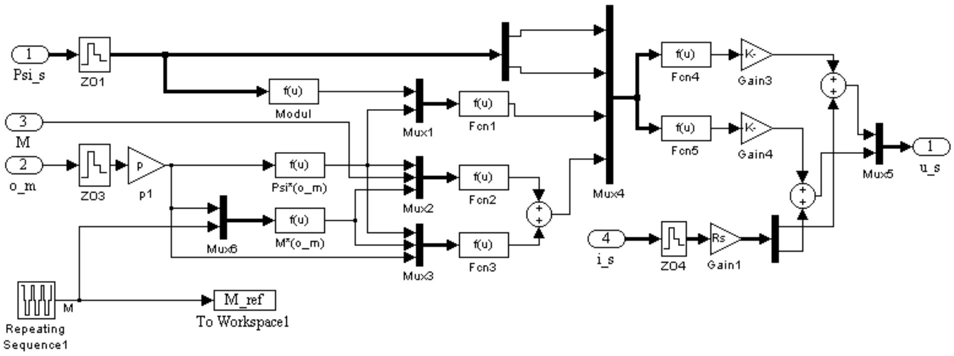


Figure 10: Structure of Control-ISC mask block from fig.9

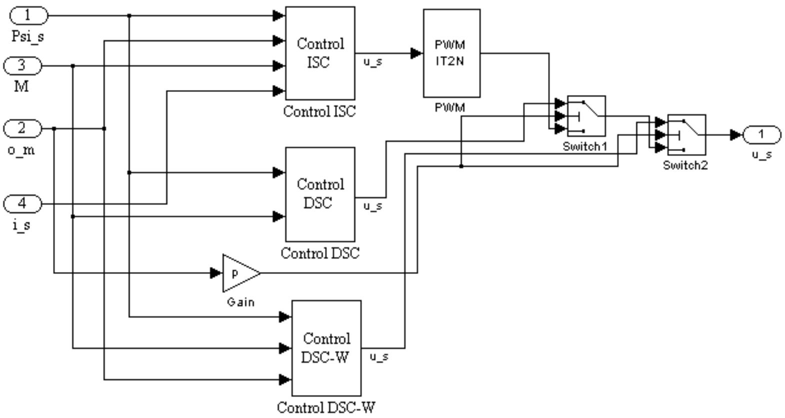


Figure 11: Structure of Control-DSC block

In order to working study of the traction induction motor in the ISC case, without the consideration of the voltage-source inverter model, it is built its SIMULINK model (fig.9).The used model contains two mask blocks:

- *MAS1*, the model corresponding to the traction induction motor [5];
- *Control-ISC* (fig.10), which it has the structure achieved in accordance with the ISC diagram [1], [4].

By means of this model (fig.9) it has been simulated a transient state like in the vector control case, obtaining similar variations of the visualized quantities.

5. SIMULINK MODEL OF THE DSC

In order to study the operation of the two levels voltage-source inverter – traction induction motor ensemble in the DSC case it is built its SIMULINK model. From physical viewpoint, this has the same structure with the ISC model (fig.8) with the substitution specification of the *ISC* block through the *DSC* block. The structure and the content of DSC are illustrated in fig.10.

The *Control-DSC* block (fig.11) contains all those three components of the DSC [1], [4]:

- the ISC, in the low speeds domain, modelled by the *Control-ISC* block (fig.10) and followed of the *PWM-IT2N* block, which take thus account of the voltage-source inverter operation;
- the DSC, in the medium speeds domain, modelled by the *Control-DSC* block (fig.12) and
- the DSC-W, in the high speeds domain, modelled by the *Control DSC-W* block (fig.13).

Like in the case of SIMULINK model corresponding

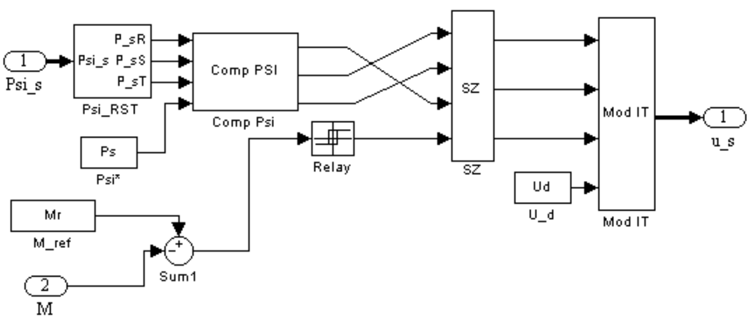


Figure 12: Structure of Co C block from fig. 11

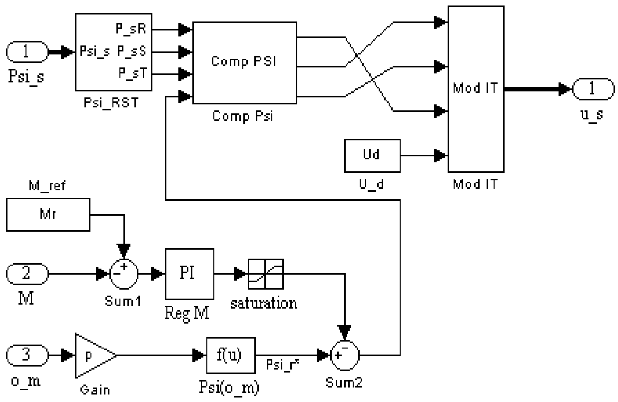


Figure 13: Structure of Control-DSC-W block from fig.11

to the ISC, too, the composition of the *Control-DSC* and *Control-DSC-W* blocks is given by the corresponding diagrams presented in [1], [4].
The selection of one among those three control types is made depending on the speed of traction induction motor (fig.11).
In order to simulation the operation of voltage-source inverter, after the *Control-ISC* block has been inserted the *PWM-IT2N* block. The other two DSC blocks contain each a such *Mod-IT* block of generation of the voltage pulse.
By means of the DSC model has been simulated the starting regime of system based on the DSC for the reference torque by 6000 N·m. They have been visualized the forms of the variation in time of the M electromagnetic torque, of the Ω_m speed, of the voltage and current on the R phase, u_{sR} and respectively i_{sR} (fig.14).
The appeared modifications in the torque variation are established at the passing from a control type to another. For the medium values domain the λ variation width of the torque can easily modify by means the *Relay* block (fig.12).
supplementary validation of the models correctness used for DSC it can make by means of the experimental results presented in [4]. In this sense it is used the DSC model, at which the initialization it is made with the dates of another traction motor [4].
Further on, they are presented comparatively the obtained dates experimental way with those obtained through simulation. In the last case, it appears not the voltage variation from the intermediate circuit, too, which it has been considered in simulation, like being constant. The comparisons are given graphically, through the alike diagrams juxtaposition.
They have been compared the torque and current variations on phase of the traction induction motor at the passing from the ISC to the DSC (fig.15).

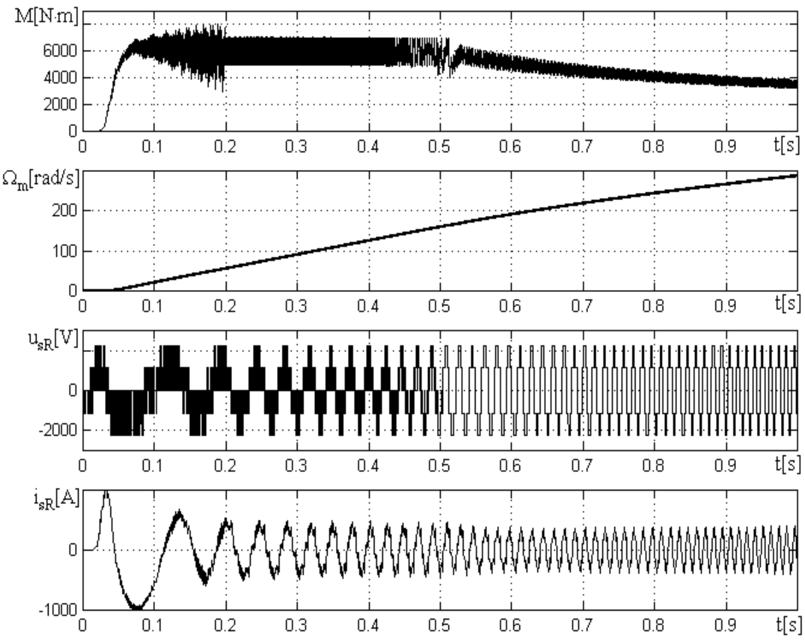
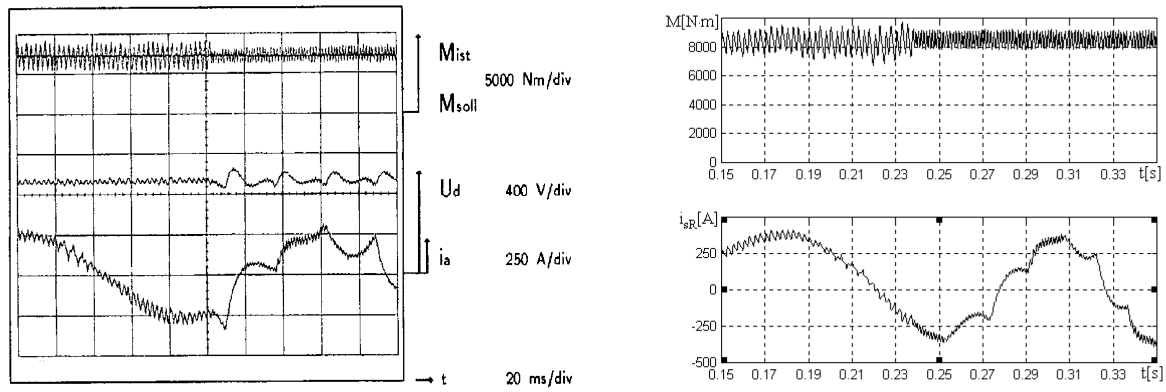


Figure 14: Waveforms of principal quantities that characterize DSC



a) experimental [4] b) simulation

Figure: 15 Torque and phase current of traction induction motor at passing from ISC to DSC

The comparative analysis it underlines the elaboration correctness of the DSC specific models.

6. CONCLUSIONS

By means of these models from presented SIMULINK library they have achieved simulations which they have been praised the specific features of this control type used in electrical traction. Through the comparison with experimental results it has been validated the used models achievement correctness.

The presented SIMULINK models can be usefully within the framework of simulations by hardware-in-the-loop type, too, permitting the study through simulation of a new control strategies how they would be those based on the ISC [2],[4].

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