ABOUT COMMAND FEATURES OF AN ELECTRIC DRIVING SYSTEM BASED ON ASYNCHRONOUS MOTOR AND INVERTER USED FOR URBAN TRACTION

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***Abstract* – The paper deals with the control features of the electric drives for a trolley-bus. One presents the mains electronic blocks that are included in the electric driving system structure. The main presented results are those concerning the vector control for the asynchronous motor controlled by a voltage source inverter. Based on the operation test results, the advantages are shown, resulting from the introduction of this technical solution, such as energy saving.**

***Keywords*:** *trolley-bus, control inverter, urban traction, industrial electronic*

1. INTRODUCTION

The increase of the specific power demand by present-day urban traction vehicles implies to find reliable technical solution in order to reduce the energy consumption. The electric propulsion gives trolleybuses performance characteristics similar to those of rail modes: powerful traction and fixed alignments. The combination of rubber tires with electric propulsion provides trolleybuses with two excellent qualities: good performance and low negative environmental impact. Their high but smooth acceleration and grade-climbing ability are very much appreciated by passengers.

The developing of public transportation systems in cities is a practice in many European countries. Its purpose is to reduce the transportation jams and intense pollution. In order to get a compatibility of the Romanian urban travelers transportation with its European counterpart, one must consider the environment requirements, the energetic consumptions savings and the adaptation of consumption to the travelers flux.

2. ELECTRIC DRIVING SYSTEM STRUCTURE

The electric driving system (Fig.1) is based on a structure described below. The electronic control block is used to perform: the interface with the power electric circuits, the interface with the vehicle (running conditions), the prescription of electric quantities, the control and regulation, the determination of parameters on the vehicle, the acquisition of numerical signals

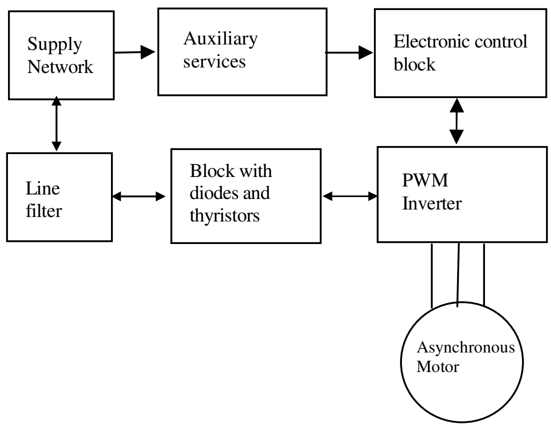

Figure 1: Driving system structure.

and respectively the generation of the signals for the numerical control, diagnosis and protection.

The control equipment provides pulses to the inverter through the driver circuits so as to provide continuous control for 2 quantities: statoric current and rotoric frequency.

3. THE ELECTRONIC CONTROL BLOCK

The electronic control block (figure 2) contains a high speed microcontroller. In the inverter control unit the vector control program is implemented. Figure 3 depicts the control and diagnosis units used on the trolley-bus controlled by a voltage source inverter.

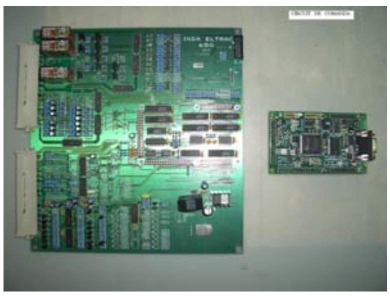

Figure 2: The electronic boards used for the inverter control

The control block performs a correspondence between the mathematical model parameters and the real parameters of the asynchronous motor. This is possible due to a test program capable to find asynchronous motor parameters. The test program of the control block makes possible the determination of the current and voltage regulators' constants. The parameters of the asynchronous motor which are used in the vector control (stator resistance, stator reactance, magnetization reactance) and regulators' constants are displayed on a PC or a Laptop.

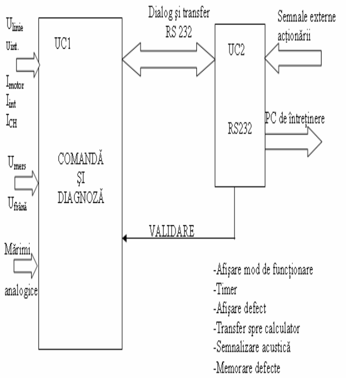

Figure 3: The control and diagnosis blocks.

The control block has 16 numerical signal inputs, 12 analogical signal inputs, one input for speed sensor, 16 PWM signal outputs and 12 outputs. All input and output signals are optically isolated. Software configuration of inputs and outputs permitted to realize control dedicated structures according to the scope of electrical drives.

The control equipment generates pulses to the inverter through the driver circuits so as to provide continuous control for two quantities: statoric current and rotoric frequency. In figure 4 a block diagram of a IGBT driver is presented [1].

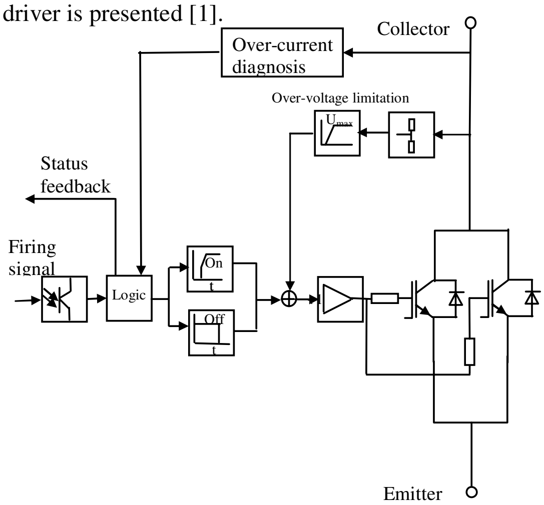

Figure 4: Block diagram of IGBT driver.

The function spectrum of these circuits mostly comprises:

- gate voltage generator;
- input for V_{CEsat}- monitoring, sometimes also input for shunt or sense-emitter;
- monitoring of too low supply voltage;
- error memory and error feedback output ;
- adjustable dead time generation of the TOP-driver.

These standard drivers do not provide a real potential isolation. For some variants, the control input may be configured for connection of opto-couplers or pulse transformers. Moreover, progress is being made in the development of fast optic couplers with power driver output which have already integrate supply under voltage- and V_{CEsat}- or V_{DS} (on)-monitoring. To achieve simple driver units, DC/DC-converter and few passive components merely have to be added. With the growing variety of function and protection parameters in driver circuits, the assemblies necessary on the primary side also have to meet more sophisticated requirements, for example, input signal logic, short-pulse suppression, dead time generation, error memory and error evaluation and drive of the pulse transformers. During turn-on, switching speed is limited by a ramping up of the control voltage, which allows a good compromise between soft recovery and low turn-on losses. During turn-off, a feedback-control of the collector voltage will provide a safeguard against a too high voltage. A voltage divider in combination with an analogue amplifier which is coupled to the gate-control voltage is used here. For the short-circuit protection the collector voltage is compared to a reference voltage [2].

4. THE DIAGNOSIS BLOCK

The electric signals for the entire system are analyzed by the UC_2 control unit. After that this unit transmitted the signals to the unit UC_1 for validation. If one of the conditions is not realized, the validation signal becomes inactive and the default is displayed. Between both units with microcontroller there is a permanent dialog, the information regarding the default state having the highest priority [3]. The diagnosis structure performs functions in two states:

- "automatic work state": the units are mutually influenced (this is the normal state when all the signals (internal or external) are active);

- "manual work state": one or more external signals (doors, pressure) are out of operational ranges, allowing the trolley-bus to function for a limited period. When an event or a default state appears, the inverter is stopped and a default message appears on the display. The reset of the default state is made by a double press of the treadle. When the fault protection appears repetitively, the circuit breaker is open. The entire system is reset after the supplying of the control circuits. In normal conditions, the data and local hour appears on the first line on board, the second line presents information regarding the working state and the current value absorbed by the motor in running regime or the current given in breaking regime. The major defaults and events are stored and can be downloaded on a PC or a Laptop.

4. THE TRANSMISSION DATA BLOCK

4.1. The Pulses Transmission for IGBT and the Control Unit

The transmission of information (electric signals between the system elements) is realized with copper wires and optical fibers. The transmission of impulses from the control unit to the driver is realized with optical fibers. The de-saturation signals from drivers are transmitted through optical fibers to the control unit [4]. There are 3 optical fibers for the IGBT control and 3 for the de-saturation signals (stop signal, stop pulses) to the control unit. For the data transmission from the central unit to drivers, the optical transmitter is in the control unit and the receiver is mounted in the driver circuit. If the de-saturation signals are transmitted, the place of transmitter and receiver are exchanged.

4.2. The Information Transmission between the Control Unit's Microcontroller and the Trolley-Bus Board's Microcontroller

The information transmission is realized with 3 copper wires. The information taken from the control unit's microcontroller and respectively from the trolley-bus board's microcontroller are computed and displyed. The LCD displays two lines, each of 16 alpha-numerical characters.

5. THE VECTOR CONTROL

The vector control is the most popular control technique of the AC induction motors. In special in the reference frames, the expression for the electromagnetic torque of the smooth-air-gap machine is similar to the expression for the torque of the separately excited DC machine [5]. At the induction machines, the control is usually performed in the reference frame (d-q) attached to the rotor flux space vector. Therefore the vector control's implementation requires information on the modulus and the space angle (position) of the rotor flux space vector. The stator currents of the induction machine are separated into components that produce flux and respectively torque through the use of the transformation to the d-q coordinate system, whose direct axis (d) is aligned to the rotor flux space vector. That means that the q-axis component of the rotor flux space vector is always zero:

$$\Psi_{rq} = 0 \text{ and } \frac{d\Psi_{rq}}{dt} = 0 \qquad (1)$$

To perform vector control, the following steps must be made:
• the motor quantities (phase voltages and currents) are measured
• they are transformed into the 2-phase system (α ,β) using a Clarke transformation

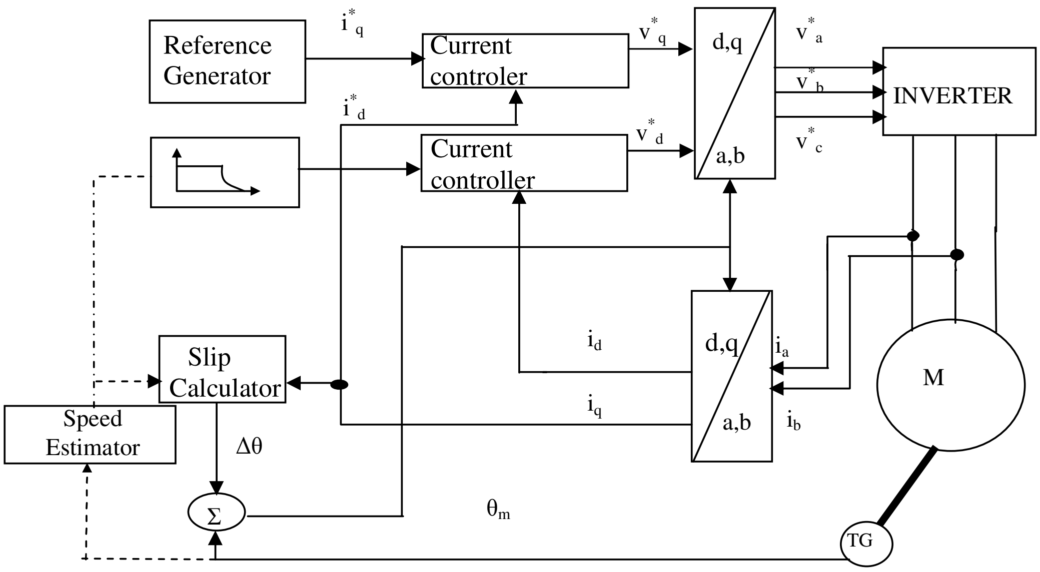

Figure 5: Complete block diagram of Vector Control.

• the instantaneous flux angle ρ_r is calculated by the motor flux model
• the stator currents are transformed into the d-q coordinate system using a Park transformation
• the stator current torque- (i_{sq}) and flux- (i_{sd}) producing components are separately controlled
• the output stator voltage space vector is calculated using the decoupling block
• an inverse Park transformation transforms the stator voltage space vector back from the d-q coordinate system to the 2-phase system fixed with the stator
• using the space vector modulation, the output 3-phase voltage is generated.

The components $i_{s\alpha}$ and $i_{s\beta}$, calculated with a Clarke transformation, are attached to the stator reference frame α, β. In the vector control, all quantities must be expressed in the same reference frame. The stator reference frame is not suitable for the control process. The space vector *is* is rotating at a rate equal to the angular frequency of the phase currents. The components $i_{s\alpha}$ and $i_{s\beta}$ depend on time and speed. These components can be transformed from the stator reference frame to the d-q reference frame rotating with an angular frequency identical to that of the phase currents [6]. Consequently the i_{sd} and i_{sq} components do not depend on time and speed. The component i_{sd} is called the direct axis component (the flux-producing component) and i_{sq} is called the quadrature axis component (the torque-producing component). They are time invariant; flux and torque control with them is easy. Knowledge of the rotor flux space vector magnitude and position is key information for ac induction motor vector control. With the rotor magnetic flux space vector, the rotational coordinate system (d-q) can be established [7].

Figure 6 depicts the following signals: the red signal (waveform 1) represents the variation of the current through the motor reported to the q axis (the active current) and the blue (waveform 2) one represents the reference value of the current reported to the q axis.

Then current i_{sq} is direct proportional to the torque developed by the motor and is limited through the program to a value admitted by the motor.

The current raises linear to the maximum value so as to overcome the resistant torque and to make the motor's axis to rotate with a prescribed speed.

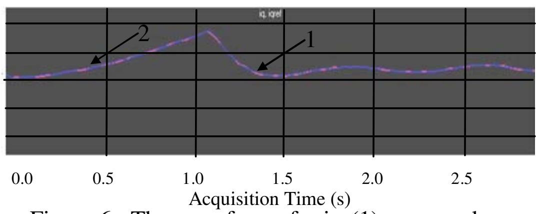

Figure 6: The waveforms for i_{sq} (1) measured current and i_{sq} (2) reference current.

Both graphics almost coincide and thus indicate the motor's normal operation all over the rotation speed range.

Since the rotor currents cannot be measured with cage motors, this current is replaced by an equivalent quantity described in a rotating system coordinates called d,q and following the rotor flux [8].

Between the stator currents i_{sd} and i_{sq} in the d,q rotating reference frame components and the stationary reference frame components $i_{s\alpha}$ and $i_{s\beta}$ there is the next relation:

$$\begin{bmatrix} i_{sd} \\ i_{sq} \end{bmatrix} = \begin{bmatrix} \cos\rho_r & \sin\rho_r \\ -\sin\rho_r & \cos\rho_r \end{bmatrix} \cdot \begin{bmatrix} i_{s\alpha} \\ i_{s\beta} \end{bmatrix} \quad (2)$$

where ρ_r is the instantaneous flux angle obtained by the motor flux model.

4. CONCLUSIONS

The performed tests revealed a good operation of the control and diagnosis parts. Each unit was separately tested on the stand. The transmission of signals from the microcontroller to the drivers and in the reverse sense was performed through the optical fiber. Therefore one gets a good galvanic insulation, noise immunity (that is insensibility to electromagnetic parasites), small attenuation and information security.

The driving system presents a superior energetic efficiency (the electric braking might be regenerative until stop and the energy dissipation over the braking resistances is no longer present); the asynchronous motor has identical characteristics for both regimes: operating as motor and during braking; the asynchronous motor exhibits insignificant losses and no thermal problems; the recovered braking energy can used by auxiliary services when no other consumers are present on the line.

Such a system creates practical possibilities to introduce trolleybus traction into Craiova city.

Acknowledgments

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