MICROPROCESSOR CONTROL SYSTEM OF THE SDMC-103 ELECTRONIC EQUIPMENT FOR DC TROLLEYBUS TRACTION

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REZUMAT. In lucrare se prezintă sistemul de control şi funcțiile echipamentului electronic SDMC-103 de tracțiune al troleibuzului cu motor de curent continuu. Este descrisă structura sistemului de control cu microcontroler AtMega128 al echipamentului de tracțiune pentru un MCC de 110 kW şi 550 V. Sunt aduse schemele şi unele fragmente de program ale algoritmului de control general, cât şi ale regimurilor de frânarea/accelerare. Fiabilitatea şi flexibilitatea sistemului de control este dovedită de utilizarea în trei state a sutelor de echipamente.

Cuvinte cheie: tracțiune, troleibuz, echipament electronic, control, microprocesor, MCC cu excitație mixtă..

ABSTRACT. This paper presents the control system of the SDMC-103 electronic eqiupmet for DC trolleybus traction. The algorithm is presented for a specific case with a DC motor of 110 kW, 500 V and 1500 rpm. The implementation of the algorithm is made writing it down in a C form and writing it into an Atmega128 microcontroller. The practical function modes of the motor are introduced into the algorithm, and their adaptation into the diagram and program explained.
The reability and flexibility of the control system is proven on hundreds modules installed in three countries.

Keywords: *traction, trolleybus, electronic equipment, microprocessor, control algorithm,, compound DC motor.*

1. INTRODUCTION

Although the DC motor loses ground to the AC motors, it still has a vast presence in some domains. For example, in the ex-soviet space, the passenger urban public transport (trolleybus, tramcar), in 90% of the cases use DC motor systems for traction. Most of these DC systems operate for many ears already, but the new ones are being implemented because of elder specialists or for maintaining the operation-repair base in transport administration.

In these conditions the SDMC-103 electronic equipment, a product of the Informbusiness SRL from Chisinau [1], is very much asked for. At present day, over 600 trolleybuses in Moldova, Ukraine, Russia are equipped with this equipment.

The SDMC-103 (fig.1) electronic equipment's purpose is the traction of trolleybuses with compound or series field DC motor with over 200 kW power and supplied from a contact power grid of 500-750 VDC.

The general function structure of the traction system is formed of a compound (or series) field DC motor, the SDMC equipment and a board panel (fig.2). The description, performances, energetic and modeling aspects of the traction systems with the SDMC-103 are presented in papers [2-4].

The SDMC-103 electronic equipment includes a power module with 2 DC/DC converters meant to control the DC traction motor and a microprocessor control system.

This paper presents the microprocessor control system of the SDMC-103 equipment, the structure of the control algorithm and some programming elements of the microprocessor.

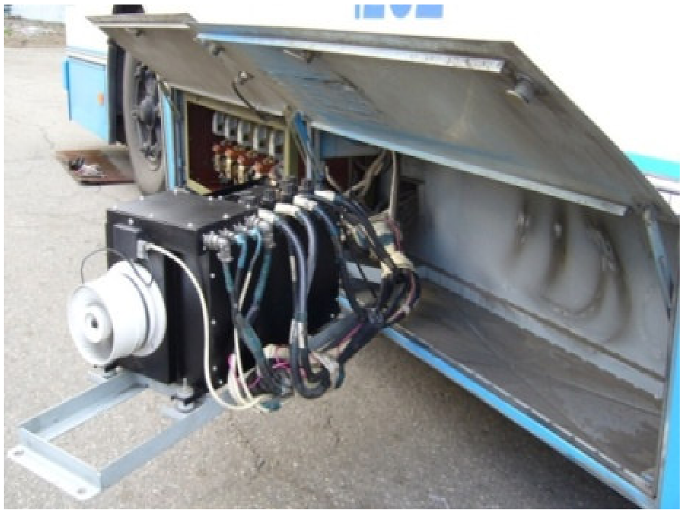

Fig1. General view of the SDMC-103 equipment

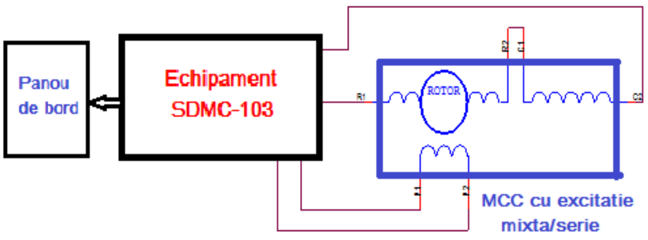

Fig 2. General structure of the traction system with the SDMC-103 equipment and a compound DC motor

2. CONTROL SYSTEM STRUCTURE

The microprocessor control system of the SDMC-103 traction equipment is made in the form of a printed circuit boards placed in the equipment's case. The SDMC-103 command module consists of a microprocessor with incorporated PWM signal generators, power transistor drivers of the DC/DC convertesr, EEPROM memory, I/O ports, etc. There is also a board display to ensure the interaction between the system and user. On the display may be shown the state and conditions of the module and motor.

Depending on necessity, the electronic system can be developed with Atmega128 controller of Atmel company [5], or with MB91F647 of the Fujitsu [6]. Further in the paper we will analyse the mode of the electronic control system developed with Atmega128. The microcontroller has been chosen for its performance and availability on the market. The AtMega has a fast execution speed, a large enough variety of possible operations and a large enough memory capacity. AtMega 128 is an 8 bit controller, with and internal programmable Flash memory of 128 kbytes. The controller includes 32 general use registers, connected directly to the ALU. The 53 general use I/O ports allow the usage of all the modules and functions of the microcontroller, four of which are timers/comparators with PWM, a real time counter, internal clock, 2 bit oriented interface serial channel.

The control system of the SDMC-103 equipment with an Atmega128 controller (fig.3) includes components for generating PWM signals for the field series and parallel windings, voltage and current measurement modules, IGBT transistor drivers, error detection and treatment modules, electrical energy, overload, temperature and speed control modules. The diagram is suggestive considering the connections between external and internal modules of the microcontroller, and their functionality, which is performed by the control algorithm.

Although the internal PWM generator of the processor ensures the real necessities, special PWM circuits have been developed to avoid the signal's deviation from the output pin when the processor is overloaded. To increase the reaction speed analogical error detection modules were created. The protection of motor and transistors is also performed by external specialized circuits.

As peripheral units for the processor, there are sensors and state encoders for the contactors, acceleration and brake pedals; contactor and ventilator command.

The electronic system performs a non-stop diagnosis

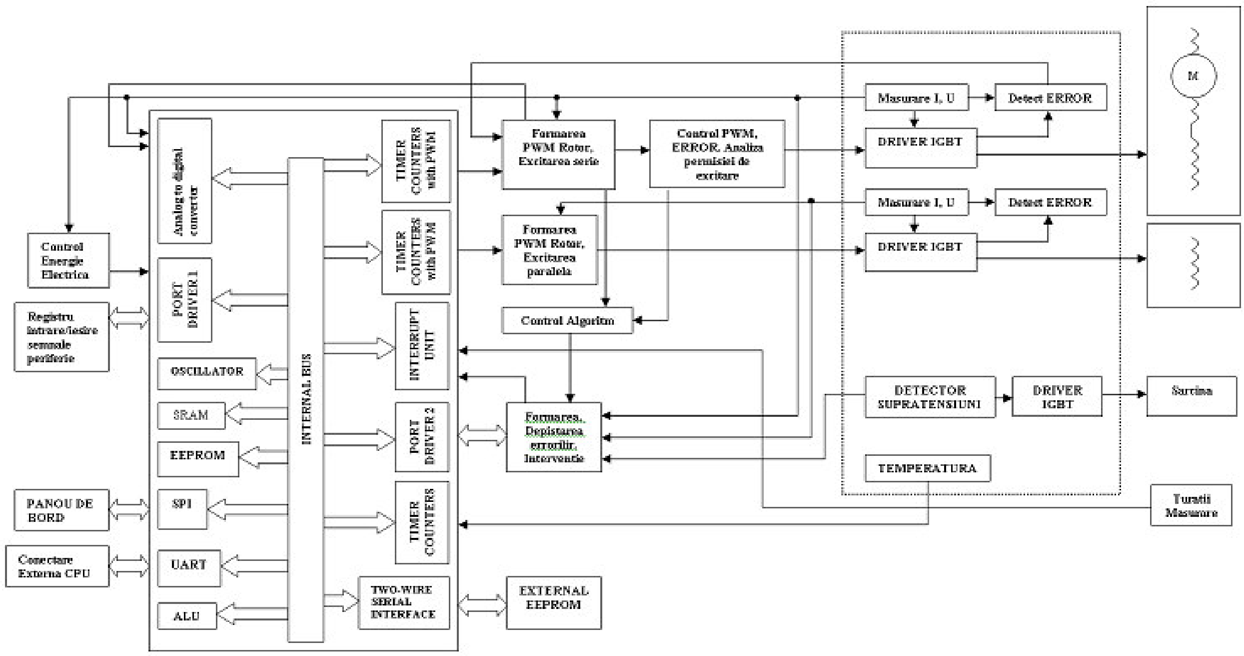

Fig3. General structure of the SDMC-103 equipment's control system

electronic module analyses the system in real time and having found an error, the error code is displayed on the panel board. Thus major damage of the motor as well as the electronic equipment of control is prevented. The module protects the motor in any state of work and from any defect cause, including overheating. The heating problem is solved through a chain of sensor – module – ventiloar+radiator. On the construction of the radiator has been much experimented on for finding an optimal solution for cooling the system.

The SDMC-103-01 module was programmed to account for important external conditions for efficient function and lowering the energetic expenses. Thus factors like the topology of the trolleybus' route, climatic conditions and the load of the trolley, are important variables for the control algorithm of the DC motor.

Considering ulterior changes and improvement of the algorithms, diagrams and work characteristics of the DC motor, the SDMC-103-01 system has been provided with a RS-232 interface module. For the protection against unauthorized access into the program, the module is protected with an electronic key.

3. CONTROL SYSTEM FUNCTIONS

The functions of the SDMC equipment are determined by field conditions. Their aim is to enhance the energetic efficiency and the lifespan of motor. The analysis of the motor's performance has determined the need of the independent control of current on the field parallel winding. Thus implementing into the algorithm the state of field-weakening into the DC motor's work.

The module's functions are divided in main and secondary functions. The main function is the control and command of the DC motor. Most of the secondary functions are bound to the diagnosis and monitoring of the electric system. The diagnosis of the system's currents and voltages function is executed non-stop, be it at the display, power or peripheral modules. Each measured voltage and current can be viewd on the board panel.

The control algorithm develops function diagrams and technical characteristic for DC motor's control, but the variables are set for each kind of motor in particular. The main input variables for the algorithm are the levels of brake and acceleration pedals, the output of the algorithm being voltages and currents. For acceleration, four modes of work have been chosen, thus four levels of pedal angle. The brake algorithm is easier, having found only two necessary levels. In these levels of brake and acceleration, special work modes of the motor have been implemented. Get started, start of movement, stationary mode, field weakening and dynamic brake are the special modes that help achieve a soft work diagram for the motor and reduce the consume. The four steps of acceleration are: A, C1, C2, C3 (fig.4). Besides the previous operating modes, variables from external factors are introduced into the algorithm. The climatic conditions, the load of the trolley and the route's topology are some of the external factors that influence the motor's performance thus are being considered in the control algorithm.

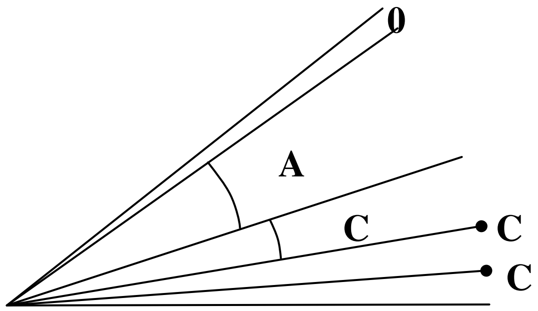

Fig.4 Levels of the acceleration pedal

- The A operating mode is for the first phase of the pedal's press, in which the motor gets started and departs of place. The rotor is commanded through PWM to an average current of 280A (for the described earlier motor). Both the series and parallel fields are commanded through PWM, in the parallel one the current being brought up to 4,5A.
- C1 : The rotor is being connected directly to source with a 310A current, parallel field winding's current decreases up to 0,7A and the series field winding PWM with a filling factor of 100%
- C2 : The rotor's current increases up to 330A, and the field series winding's PWM filling factor decreases with 20%, the field parallel winding is disconnected
- C3 : Rotor's current reaches 400A and the field series winding's current weakens by 50%

Having only two steps (fig.5), the brake algorithm is much simpler, and has only two functioning modes. As a third work mode for brake, if the current on the rotor decreases to less than 30A for more than 5sec then the electric brake is disconnected and the mechanical brake is being used, all of these happening when the brake pedal is pressed. The electrical conditions for mechanic brake's usage are matched to 5 km/h

- F1 : The rotor is disconnected from source and switched on a brake resistance, the field parallel winding's current is set to 4,5 A.
- F2 : The current through the field parallel winding is set to its max

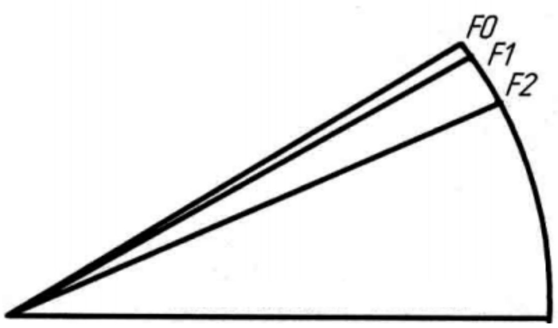

Fig.5 Levels of the brake pedal

The secondary functions are some utilities secondary to the motor's performance, but which contribute to the motor's longer lifespan and welfare. The system's diagnosis and error tracking are two objectives for most of the secondary functions. The power system and the peripheral one are always monitored, in case of errors; the motor's work is stopped. One of the more eye-catching objectives of the SDMC module is energetic efficiency, the power consumtion can be shown on display. For safety reasons and as a start condition in the function algorithm of the motor, the brake pressure is checked. If the pressure is too low the processer does not allow the start of trolleybus. The described secondary functions may be accessed at the board panel, and the errors are shown on appearance to the driver's attention.

4. GENERAL CONTROL ALGORITHM

The elaborated algorithm must be optimum for the motor's performance, from the power efficiency stand point as well as from the stand point of the passengers. Thus, prior to allowing the start of the motor, the SDMC system checks these vital conditions: the press on the acceleration pedal, the state of the power transistor drives, the module's temperature, the input voltage for power system of 600V and the 28V for low power system (board panel), the brake system's pressure and the state of all the contactors in the control system. When the motor is in function there are 3 types of commands executed by the SDMC-103 equipment: start, command level, stop.

All the voltages, currents and time values are taken for an elaborated example for the earlier specified motor. These variables and values are modified for each case in part.

The general control algorithm of the SDMC-103 is shown as a block diagram in fig.6.

The first steps of the algorithm are for initialization of registers, after which takes place the interaction with the external signal from the pedal. After the work permission is given by the processor and lack of errors the command for start is given and the necessary contactors are activated for supplying the motor. The level at which the acceleration pedal is pressed is requested and the PWM is initialized to supply the necessary current to the motor. Meanwhile the processor reads what current is given to the rotor and rectifies the levels of filling of the PWM signal. The error monitoring works through the whole process, and if errors are found the stop command is given.

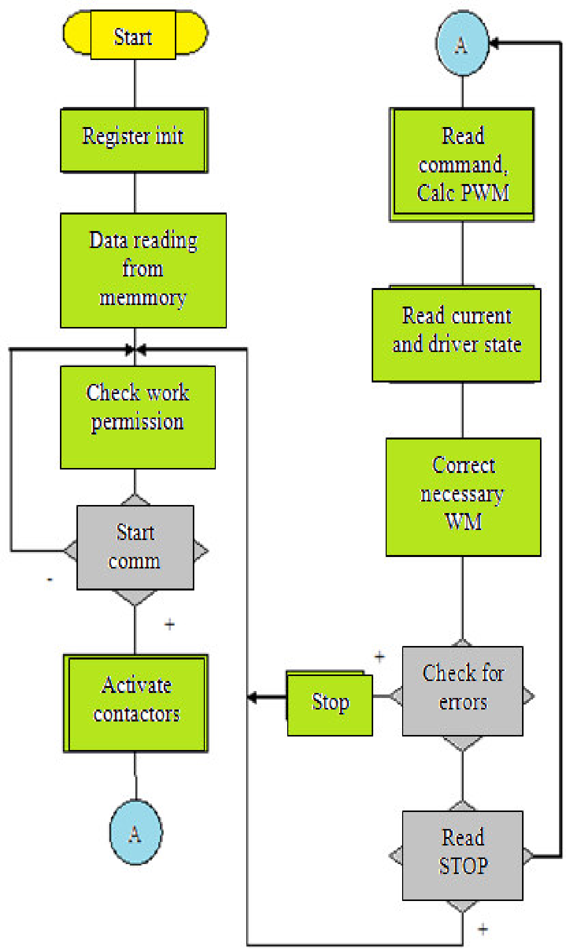

Fig.6 Block diagram of the general control algorithm

The control algorithm for acceleration depends only on the level of the pedal. There are four determined work cycles for each work mode. Further the block diagram is shown in fig. 7, the pedal's positions are displayed in fig.4:

- **1** – pressing the acceleration pedal until level A
- **2** – start of mode "A" function of the motor
- **Steps 3-5** are the same for changing the work modes in the "C" region. The first step (3, 6, 9, 12) consists in pressing the pedal to a minimal level and maintaining the rotor's current level at 220A for at least 1,6 sec. The second step (4,

7,10,13) is the transition to the respective work mode. The last step (5,8,11, 14) consists in bringing and maintaining the current amplitude scheduled.

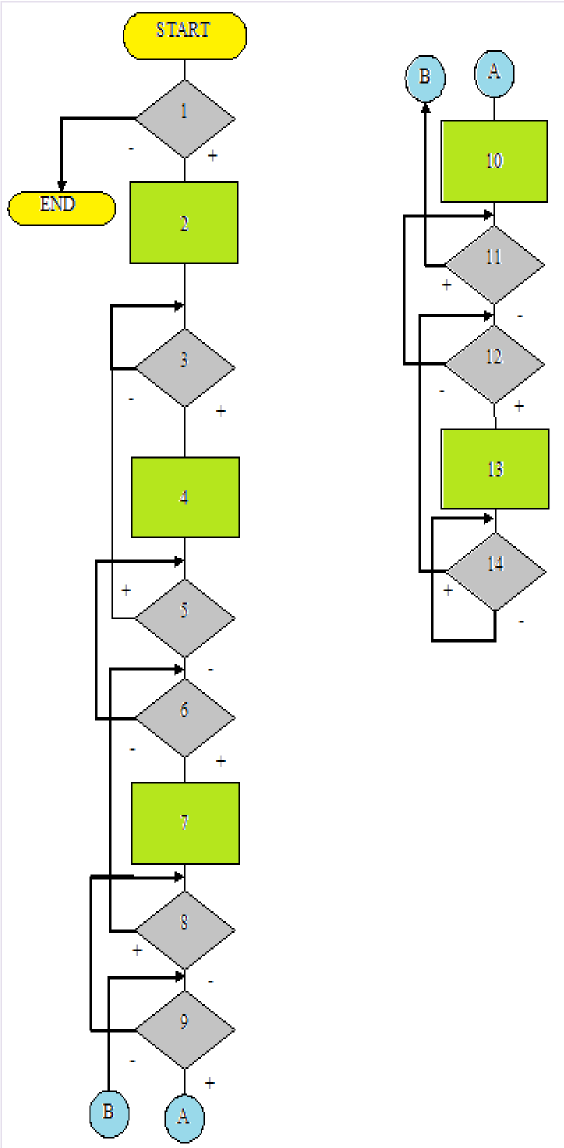

Fig.7. Block diagram for acceleration

In the algorithm the brake is set to having priority over acceleration. If both pedals are pressed simultaneously, the acceleration command is cancelled and the brake algorithm starts being executed. To maximize the power efficiency the brake is executed in the mode of dynamic brake, changing the electric machine into generator mode. The brake algorithm (fig.8) has only two pedal levels (fig.5) and two major work modes.

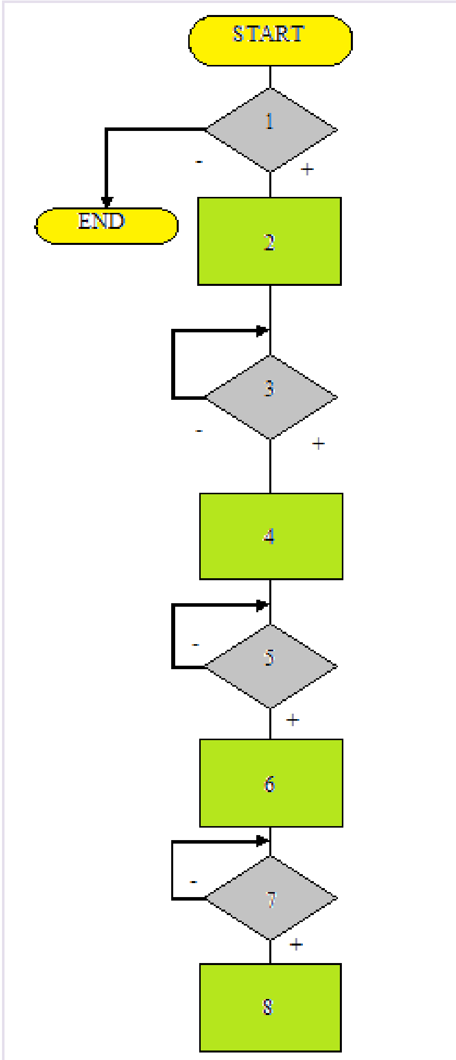

Fig.8. Block diagram for brake

- **1** – the pressing of brake pedal and getting to level ”F1”
- **2** – Disconnecting the rotor from supply and switching it to a brake resistance. The current in the field parallel winding is set to 4,5 A
- **3** – getting the pedal to reach level “F2”
- **4** – Increasing the current through the field parallel winding to max
- **5** – Reading the speed of the trolleybus from an encoder, if the speed is lower than 5 km/h, which is equivalent to having less than 30A for more than 5sec in the rotor
- **6** – Disconnecting the field parallel winding and transitioning to a mechanical brake mode ”F0”.

The diagnosis of the SDMC-103 control system is executed non-stop from the time of supplying the module. If an error has been spotted in the time of acceleration work mode, the module goes back to functioning in the previous working mode. If the error appears before the acceleration pedal has been pressed the module does not supply the motor. In both cases the error codes are displayed on the board panel.

5. CONCLUSION

The control algorithm elaborated for the SDMC-103 electronic equipment is proven to be efficient through it's many uses. Over 600 electronic modules are being used in R. Moldova, Ukraine and Russian Federation.

The program integrated into the microprocessor ensures flexibility in modifying, through software, the parameters for the trolleybus' dynamic of movement.

The control algorithm and respective program of the SDMC equipment ensure all the practical functions, monitoring and protection of the traction system as a whole.

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