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THE ELECTRIC LOCOMOTIVES LE 5100 KW CONTROL USING A PARALLEL, DISTRIBUTED COMPUTING SYSTEM

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Abstract: starting from the necessity of the railway vehicles modernization in our country, the increase of their reliability and for a better quality of the services offered by the railway transportation system, in this paper is presented the architecture of a parallel, distributed computing system which performs the control and supervising functions of the locomotives, system which was implemented, with some adaptation for the LE 5100 kW electric locomotives modernization.

Key words: multicomputer system, electric locomotives control

1. Introduction

Analyzing the electric diagram of an electric locomotive LE 5100 kW, made by S.C. ELECTROPUTERE Craiova [1] and based by the results obtained after the implemented since 2000 of some stand alone equipment in the electric locomotives [4], [5], I proposed the implementation of a computing system with a parallel, distributed architecture composed of some equipment interconnected by serial busses.

2. A short description of the computing system

The bloc electric diagram of the computing system for the control and supervise of the electric locomotives is presented in figure 1.

The computing system is composed of the following equipment:

- the signalling and protection equipment – supervises and indicates to the locomotive driver all the abnormal functional states and if it is necessary command the brake-down of the main electric circuit and command the step-down of the tap-changer to the first step
- the tap-changer drive equipment – receive commands from the driver controller and drive adequately the tap-changer motor, supplying the traction motors with varied voltages from the outputs of the 25 kV transformer
- the slip and slide protection equipment – detect the axes which slip or slide when vehicle accelerates, indicates to the driver the apparition of the phenomena and command the stop of the tap-changer step-up and it's step-down until the phenomena disappear

- the equipment for protection and control of the auxiliary services is composed of 4 static converters which supply the compressor of the pneumatic installation, the ventilators of the brake resistors, the ventilators of the main transformer and the oil pump and the two groups of ventilators for the traction motors
- the equipment for vehicle speed measure, record and control
- the display equipment and interface with the locomotive driver, placed on the driver desk

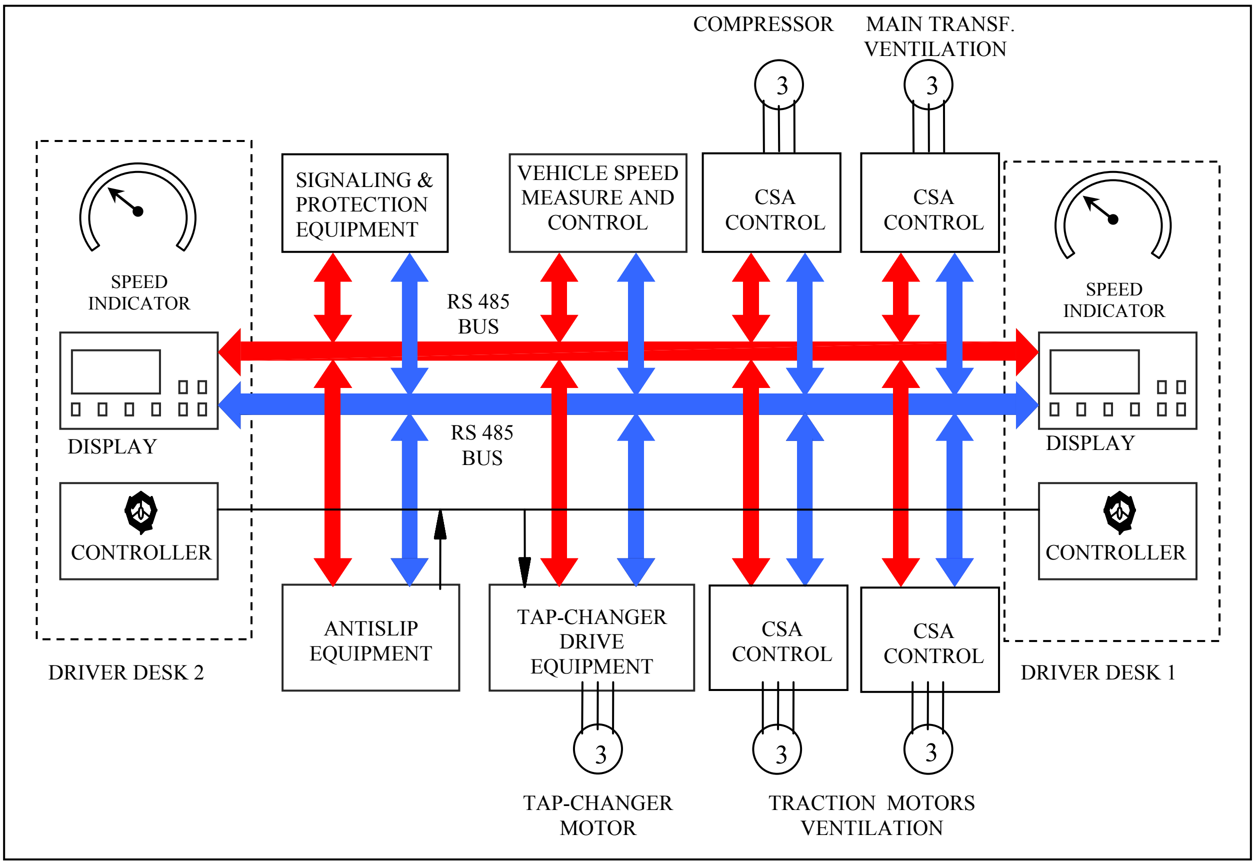

Figure 1. The bloc diagram of the computing system for control and supervise of the electric locomotives

3. The communication network

The presented computing system has a multi-computers architecture [2]. Such a system is made from a number of autonomous computers, which can be geographical dispersed; therefore they are also called weak connected systems. These computers communicate according with an interface and a communication protocol. Each processor in a multicomputer system has its own I/O devices and local memory, like in figure 2. These systems are proper for jobs which can be divided in relative independent tasks which are executed with a small amount of information exchange. The equipment which composed the computing system are interconnected to exchange information through a communication network. From reliability reasons, to obtain a high reliable network, the equipment are interconnected through two data buses. At once, only one of them is used for data transfers and the communication on the other one is made only when the communication on the first one is interrupted. Also, periodically test information are exchange on the reserved bus to detect an eventually fault on it.

In the case of the parallel, distributed system for electric locomotives control I used data links with a **bus** topology. Every node can hear all the message packets which are transmitted on the network. Every node checks the destination node address which is included in the packet to detect if that pack is for it. When the signal reach the end of the bus, an electrical terminator absorbs the packet energy to keep it from reflecting back again along the bus cable, possibly interfering with the other messages already on the bus.

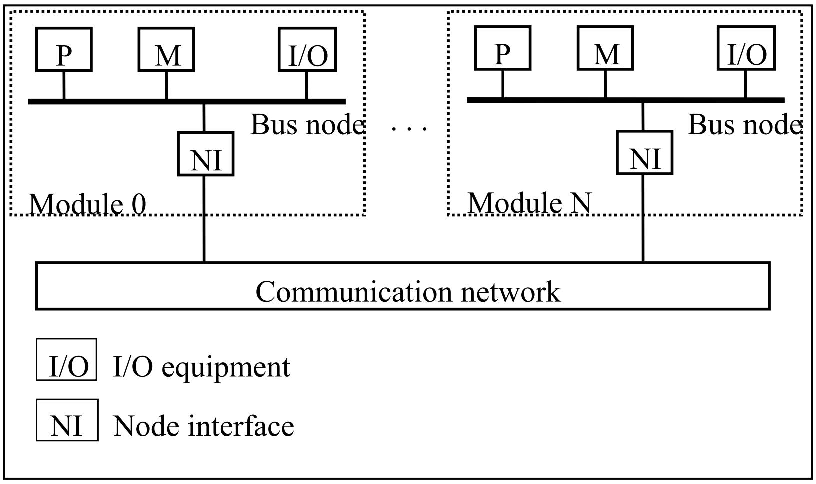

Figure 2. The electric diagram of a multicomputers computing system

The access to the bus is made using "**token**" method – the access is made in a increasing order of the addresses assigned to every node, so eliminating the collisions between the messages.

The communication protocol is **HDLC** (High Level Data Link Control), a bit oriented protocol and the messages are treated as strings of bits.

Beginning Flag	**Address**	**Control**	**Information**	**Frame check**	**Ending Flag**
01111110	8 bits	8 bits	Any number of bits	16 bits	01111110

Each block of the frame is called a field and the start and end called flag field consisting of 01111110b. The packets have a cyclic redundancy check (CRC) frame, 16 bits length, generated using the polynomial generator:

$x^{16} + x^{12} + x^{5} + 1$

One of the industry's most widely used balanced transmission-line standard is ANSI/TIA/EIA-485-A (referred as **RS 485**) [3]. Transmission takes place via a two-wire bus, formed by a twisted-pair and ground wire with an overall shield. On a RS 485 bus the signalling rate can be up to 50 Mbit/s, the length of the bus can be up 1200 meters and to the bus can be connected up to 32 users. The communication is half-duplex, only a transmitter can be active at once. Because the electro-magnetically noise on the locomotive can seriously affect the integrity of data transfer I used a galvanic isolation between drivers and receivers [6]. Galvanic isolation removes the ground-loop currents from data lines, and the impressed noise voltage that affects the signal are also eliminated. Common-mode noise effects can be removed completely and many forms of radiated noise can be reduced to negligible using this technique. When an adjacent electric motor starts up, a momentary difference in ground potential at the data logger and the computer may occur due to a surge in current. The electric diagram of the galvanic isolation for a system's node is presented in figure 3.

Two exchange information between the system components I used, how I presented, the HDLC protocol. To use the same program modules on all equipment I used packets with a fixed length of 32 bytes, length which is covered for the information acquired by the equipment from the system (analogical information represented voltages values, currents, the state of the numerical inputs, the state of the relays, etc.). Together with the beginning and ending flags, the address, control and frame check bytes will result a packet of 38 bytes length.

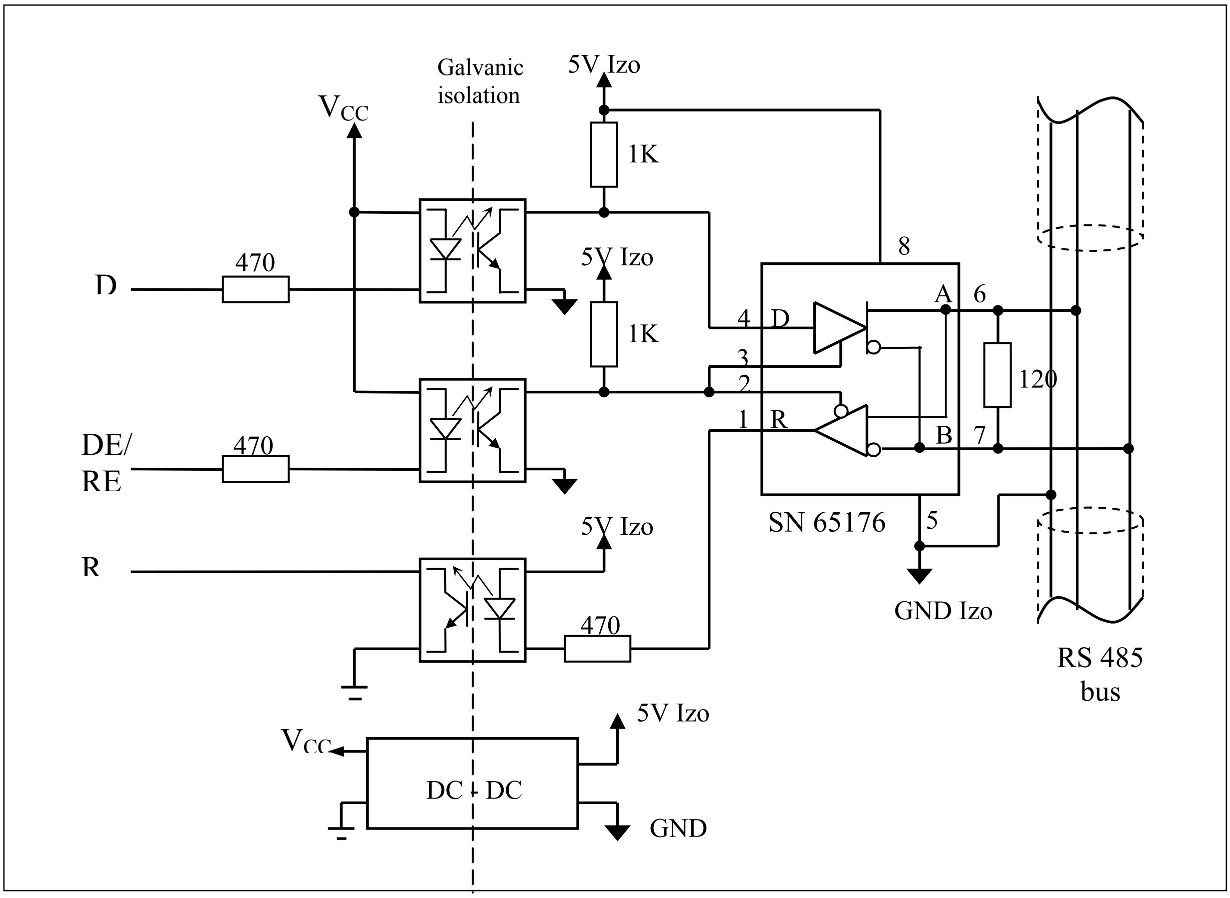

Figure 3. The electric diagram of the galvanic isolation for a system's node

The equipments from the system have a specified address, in an increasing order starting with the display equipment, which it is assumed to be in any implementation of the system on any types of the locomotives. The computing system being a dedicated one, the number and the types of the equipment is specified from the beginning and it is not modified later. But, for detecting new equipment connected to the communication network (from redundancy reasons, for example, it is possible the ulterior connection of some converters modules for the auxiliary services), when the computing system is powered on the display equipment will initiate a searching routine for the equipment which are connected to the network.

The data packets are transmitted on the bus at a speed of 256 kBauds. Computing a pause between the packets of 8 bytes will result that the information packets will be exchange between the equipment at:

$$46 \times 8 \times 1/256000 = 1.4 \text{ ms}$$

In the most unfavourable case, when every equipment in the system (in number of 10) has to transmit new information toward all the other equipment at a moment of time, will result that the necessary time for communication will be:

$$9 \times 9 \times 1.4 = 113.4 \text{ ms}$$

The period of an information exchange cycle between equipment affect especially the refreshing rate of the information displayed on the screen placed on the driver desk because there aren't information related to the safe function of the locomotive which must be exchanged between the computing system components. A refreshing rate of the displayed information of about 100 ms is sufficient, according to the fact that the human eyes discern about 10 images in a second. Because, usually, there aren't information exchanges between all equipment, unexisting simultaneous changes of all parameters and state signals of the locomotive, the refreshing rate of the displayed information is in reality bigger.

4. Conclusions

A parallel, distributed computing system for electric locomotives' supervising and control has a number of advantages compared with the solution of using a central computer system:

- the control units are dispersed along the locomotive and placed close to the equipment which they control and the using of the serial data buses replace a large amount of traditional cables, decreasing the costs
- new units can be added easily, with minimal costs for the supplementary hardware necessary for connection to the serial busses
- the control units are dedicated to an application, and this leads to an efficient use of their resources. Their main job is the equipment's control and supervise, and the amount of information exchange with the other control units being reduced at minimum
- every equipment can be tested and verified individually on test banks, following that when the equipment is mounted on the locomotive to be verified only the interconnections between them
- it can be used different driving equipment, controlled by different control units, the only imposed condition for integrating in the system being to respect the communication protocol and the information's structure transmitted to the other units
- for redundancy there are two serial vehicle's buses RS 485. When the communication between the display equipment and interface with the locomotive driver and one of the other system's module is interrupted, the communication channel will be commute on the other serial bus and the locomotive driver will be notice
- a distributed computing system offer the advantage that at the apparition of a fault at one of its components, only some of the locomotive's equipment to be

affected, opposed to a central computing system where a fault affects the entire locomotive function

- a central computing system which must to coordinate the entire function of the locomotive need a high computing power and the elaboration and writing of the application's program is difficult. Also the extension of such a system needs major interventions both in its structure and also in the application programmes, could affects the function of the entire system
- the computing system include a locomotive diagnostic system designated to increase the availability of the vehicle as well as to decrease the maintenance costs. The diagnostic system execute the events recording, recording of relevant signals just before, during and just after a fault occurs

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