HIERARCHICAL STRUCTURES BASED ON PLC DISTRIBUTED SYSTEMS

LUIGE VLĂDĂREANU, CONSTANTIN ICHIMOAEI, VIORICA BOGDĂNESCU

Abstract. The paper presents a deep study of advanced programming techniques of the automation system based on PLC (Programmable Logical Controllers) such as: index addressing; saving data to Flash EPROM when the power supply drops down and refreshing of status variables when the power is turned on; acquisition and digital processing of analogue signals; complex arithmetic functions; special functions for closed feedback loop adjustment PI-PID; memory allocation, word and double word processing, etc. There is presented a versatile communication network in hierarchical structure integrated through an Advant field bus as a decentralized, safety system in Advant OCS networks. There are included examples of applications for developing top technologies used in food processing industry, petrochemical industry and agriculture. In the end there is shown a hierarchical structure system for automatic management of industrial processes.

Keywords: real time control, SCADA systems, programmable logical controller, distributed and decentralized systems.

1. INTRODUCTION

Top technology applications and advanced technologies require transmitting a massive amount of data, larger communication, control distances and connections with other systems. Most of the complex automation systems and installations try to solve problems such as reducing the volume of cable used, assembly time, design, software programming and certainly the cost [1, 2].

Basic elements in getting these performances are:

- *Distributed intelligence*. The use of decentralized automation technology divides up the processing work on system components their own compact processor. A controller then only defines set point values for these remote processors and ensures that they are correctly executed [3, 4]. The decentralized intelligent simplifies design and assembly, reduces the amount of programming work and also commissioning times. Modifications and the extensions are possible without any problem and the efficient diagnostics fault search times.
- *Making the connection.* The connection between the controller, the input/output modules and decentralized processing modules is made via the

Institute of Solid Mechanics, Romanian Academy

system bus. It creates the conditions for eliminating the complex and fault-vulnerable laying of measurement and control cables, because it replaces the multitude of cable connections and a correspondingly large number of terminals, connectors etc. with a simple two-wire line which serves as the system bus. The controllers also offer the possibility of connection to current and often already existing communications buses (e.g. PDnet, ARCNET, RCOM, MODBUS) for higher-order communication.

- *User-friendly all round*. Intensive and permanent information exchanges with the users form the basis of enhancing the system.
- *Clearly structured*. The higher-order controller can be networked to each other for large configurations [5, 6].

Depending on your requirements, various networks are available for this purpose. This structure allows the user to plan, design, assemble and put into operation the autarkic system components independently of each other. Studies shows that, by using smart decentralized automation systems Advant Controller 31 (AC31), one may reduce to less than 80% of cable, 50% less assembly work, 40% less programming work, 30% less design and commissioning, 30% less equipment costs.

The Advant Controller 31-S is also open to higher-level controllers and networks. It can be integrated via the Advant field bus as a decentralized, safety-orientated system in Advant OCS networks. Other standard interfaces include ARCNET, PDnet, MODBUS, Profibus, RCOM for data teletransmission or an open ASCII protocol.

2. COMPLEX HIERARCHICAL SYSTEM

The PLC automation systems provide versatile communication means (Fig. 1):

Procontic CS31 BUS (CS31 FIELDBUS) is a fast bus which stands as basis of communication for automatic systems in the family CS31 and AC31. It links the MASTER bus and the SLAVE process modules and controls digital signals as well as analogue ones; using this kind of bus a central unit can communicate to up to 31 modules. The bus is of type RS485 on twisted pair cable, specially designed for immunity against powerful noise and for fast data transfer. The two twisted and shielded cables can provide reliable data exchange up to 500 m, and using signal repeaters this distance can be increased to 2.000 m.

PLC Procontic T200 automata – distributed, are automata which allow using smart distributed technique. By connecting them to the CS31 FIELDBUS one can extend them in a decentralized system. Thus, every central unit can command up to 4 CS31 bus systems by means of a line coupler. This coupler is not part of a different project as inputs and outputs are usually controlled by the central unit.

ARCNET network is used in smart decentralized systems for fast connection of the central unit to the network. It allows to transmit the signal up to 300 m and using signal repeaters this distance can be increased do 6 km. High data exchange rate is provided by a communication speed of 2,5 MBPS.

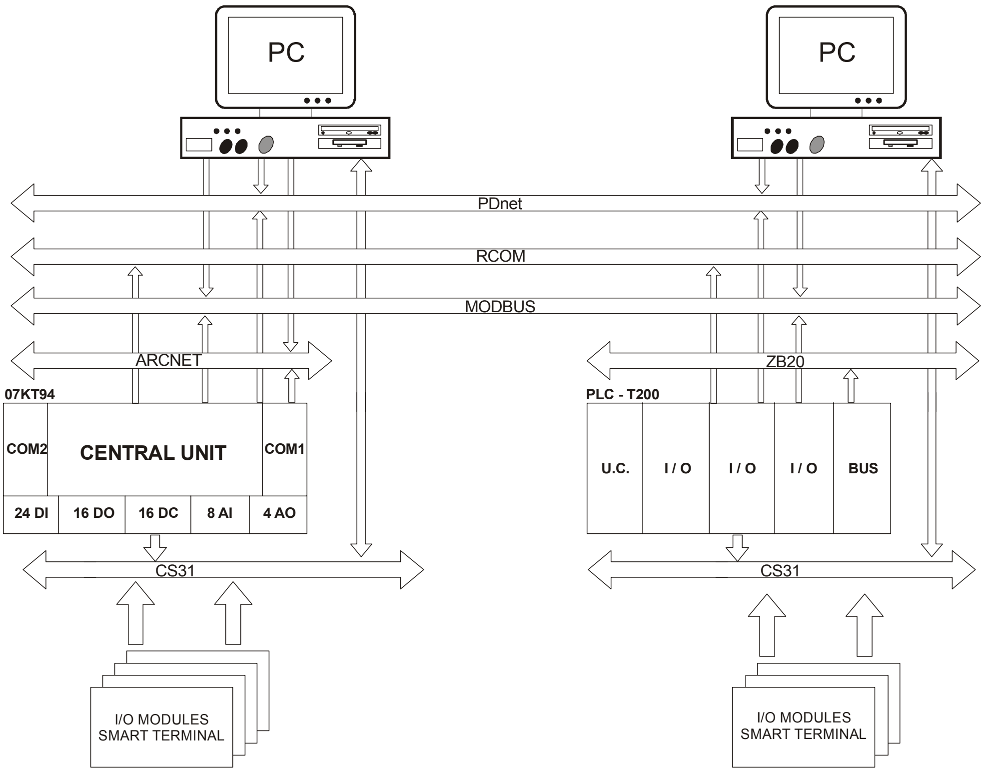

Fig. 1 – Versatile communication network in hierarchical structure.

ZB20 bus is a network specially designed for Procontic T200 providing the highest data transmission rate and easy designing features. All data belonging to the central unit may be accessed using the program instructions without any further design.

MODBUS (RTU), provides, due to higher level processing, possibility to connect to several well-known automation modules, as well as to command terminals and PC stations. The coupler designed for Procontic CS31 and designed for Procontic T200, provide data exchange to a maximum rate of 19,2 kBPS and can work either as MASTER or SLAVE.

RCOM, is a system dedicated to data exchange at distance. This allows sending data to standard networks as well as to radio communication systems. Due to its high flexibility RCOM provides a good response time and can be adapted to other dedicated data transmission networks.

PDnet links together various distributed systems, with PC stations and other communication systems. The PDnet coupler is a configuration device, which rapidly and safely controls data transmission and is independent with respect to any automation module. As for the data exchange rate and distance PDnet has the same advantages as ARCNET.

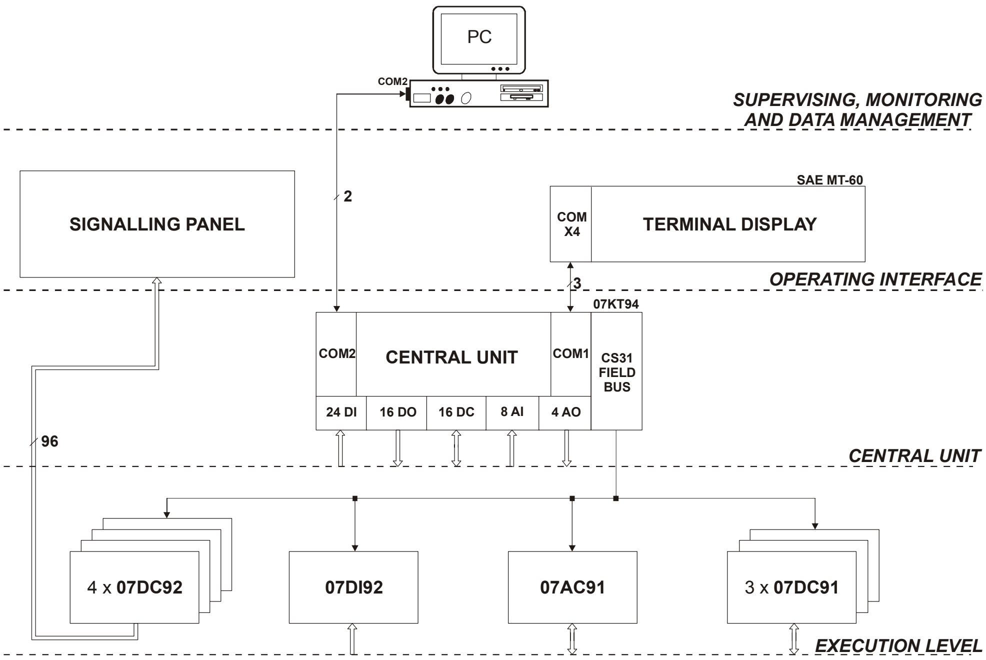

Fig. 2 – Example of hierarchical structure with decentralized PLC.

For a complex hierarchical system, in many applications an important and absolutely necessary feature is the possibility to connect it to other communication systems. Generally there is used MODBUS as processing standard for connection. Higher data transmission rates require PDnet because of the very easy way to mount the coupler and to process the communication program [7].

For connection to other completely different communication systems, which are closed systems (*e.g.* bar code reader), it is mandatory to use specific protocols. By using a communication processor and the development software one can program using C language and communicate using a given protocol.

Development software performance improvement. The continuously developing automation concepts require new programming solutions to be adapted to advance technologies [8, 9]. This implies finding software "user-friendly" in matters related to programming, testing, graphic interface and commissioning of distributed automatic systems. The new programming software represents a new generation with many improved features [10]:

- Five programming languages for PLC: Instruction List (IL), Sequential Function Chart (SFC), Function Block Diagram (FBD), Structured Text (ST), and Ladder Diagram (LD).
- The most powerful programming tools for distributed automation under Windows; it can be used to generate, test and document user programs for the programmable logic controller.

The Windows standard with its familiar advantages: pull-down menus used to choose functions, dialog boxes containing, amongst other things, the directories of equipment, files and modules, menu bar and graphic button bars for even simpler program generation

- Debugging. This allows step-by-step editing of the automation program, including setting break points.
- Offline simulation. The software package allow simulating the program run without connected hardware. This means that all instructions and commands for an external PLC, including operating errors, can be simulated.
- Integrated visualization. Such visualization is elaborated offline with the aid of geometrical elements, which then change their shape or color for instance online as a function of the specific variable values. Ready-to-use pictures and graphics can be integrated.
- Open system structure: interfaces to CAD/CAE systems, interfaces to high-level language programming, interfaces to data teletransmission.

3. INDUSTRIAL PROCESSES CONTROL SYSTEMS IN HIERARCHICAL STRUCTURE

In the following pages there is presented a project completed by the authors which intends to solve the issue of complex and complete automation of tyre vulcanization presses. The automation is accomplished by means of programmable logic controllers (PLCs) that manage the entire vulcanization process performing various tasks such as automatic loading of presses, vulcanization process in active cycle, automatic unloading of presses, as well as monitoring of parameters of the vulcanization.

Within a communication network all PLCs of the presses are linked to a computer which has the tasks of displaying the graphical user interface of the vulcanization process for each press, monitoring of alarms and status of each press in the vulcanization cycle, and plotting graphs and diagrams of technological agents of the vulcanization process (Fig. 2).

The PLC also controls a “mechanical arm” (manipulator) for loading/unloading of the press and replaces the classical cycle programmer KENT-TAYLOR as well as BRISTOLL recorder. The goal of the proposed project is to determine, based on research activity, the technical solution for building an automatic system for controlling tyre vulcanization processes.

Advanced programming techniques of the PLC automation system. The PLC software provides a wide-ranging, integrated library from which a large number of complex function modules can be called up quickly. On-line documentation also gives you information about these modules at the press of a button. The library can be extended with individually created logic elements (CE) from function modules and instructions.

In order to reduce the number of used variables, modules and, consequently, of the memory reserved for the application software, in programming the PLC system for automation of vulcanization presses there were used several types of advanced programming methods and instructions such as: index addressing, saving data to Flash EPROM when the power supply drops down and refreshing of status variables when the power is turned on, acquisition and digital processing of analogue signals, complex arithmetic functions, special functions for close feedback loop adjustment PI-PID, memory allocation, word and double word processing, etc.

Index Addressing. Index addressing consists in reading/writing a value from/to a fixed address given by the sum between a reference base and a variable, which represents the index. Value multiplexing can be achieved using the IDSm instruction, while demultiplexing is performed by means of IDLm instruction. IDSm (Write Word Variable, Indexed). When the block is enabled, the value of the source variable is read and allocated to the target variable. The target variable is defined by indexing the basic variable. IDLm (Read Word Variable, Indexed). The source variable to be read is obtained from indexing the basic variable. The value of the source variable read is allocated to the target variable. As it can be seen in Fig. 3 first IDSm instruction allows removing from program 16 multiplexes of 48 inputs each which corresponds to reducing the number of variables by at least 3.136 and the pace reserved for instructions by 3 kbytes. The relation gives Index: $INDEX = 3\times(NN-1)\times16 + (MM-1)$, where: NN stands for one of the 16 types of tyres. MM is one of the 48 parameters corresponding to a tyre type. Parameter value is written by using a terminal display (SAE) for accessing the PLC. Since reading the tyre parameters processed by SAE device must be made from a pre-defined memory zone it is necessary demultiplexing the memory zone corresponding to processed tyre from the PLC's RAM and then pass the value to a temporary variable (MW 49,07).

The value from this address is multiplexed by repeated increment of the index with one unit maintaining a fixed base MW07,00. In this way values read from stable addresses MD07,00 to MD09,15 can be read by SAE and they represents processed tyre parameters. Almost similar there can be obtained a memory zone in the PLC containing the parameters the user wants to visualize simultaneously with the processing operation of another tyre type. Moreover, by this method one can modify the parameters of every tyre with the exception of the processed tyre. Finally, the number of the variables may be reduced by 9.406 and the space allowed for storing the instructions by kbytes.

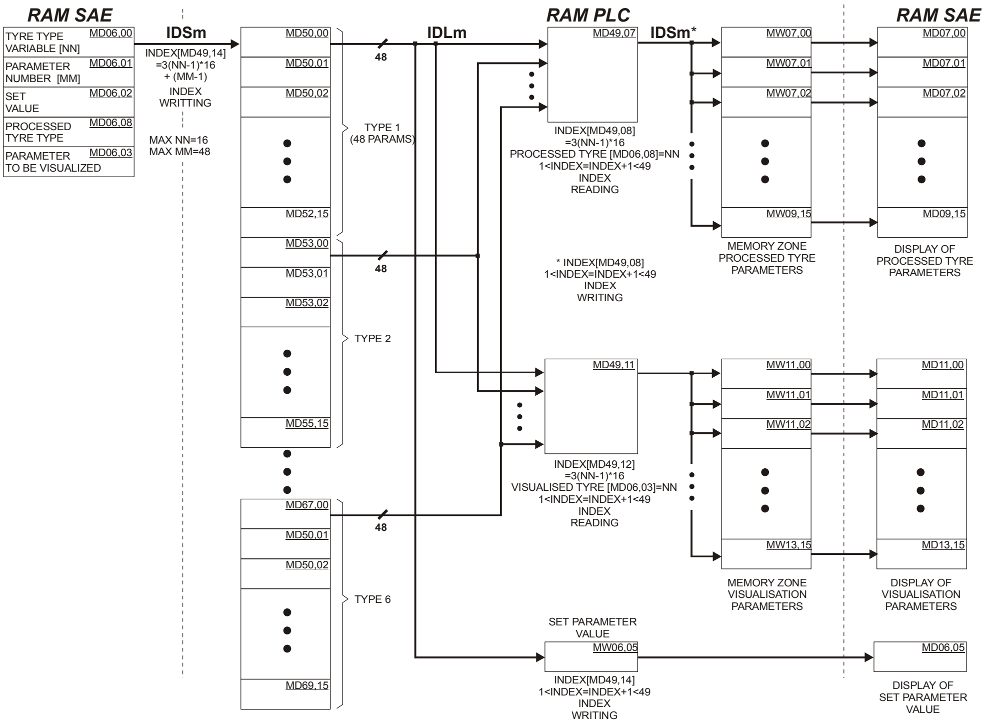

Fig. 3 – Index addressing for interactive interface with a smart display terminal.

5. COMPLEX AUTOMATIONS FOR RADIO-MODEM MONITORING OF DISTRIBUTED SYSTEMS

Next will be presented a complex automation for monitoring distributed water supply systems (Fig. 4). The control and command of 31 submersible pumps with debit meters and 7 re-circulation pumps putted on 4 different zones located at distances from several hundred meters to several kilometers is insured [11].

Controlled systems are distributed as following:

- water pumping station with AAR (PT7) controls 13 submersible pumps, 7 re-circulation pumps out of which 4 NDS14 of 250 kW and 3 NDS18 of 200 kW, having 4 ultrasonic traducers for automated control of the water level. It insures a complex automation through control of the 176/32 binary input/output, 40/4 analogical input/output; data transmission to the supervising system through Wobiscom modem with high communication speed and high dates flux.

- water pumping station (PT-ACC) controls 11 submersible pumps with programmable automates in a structure with 96/16 binary inputs/outputs, 24/4 analogical inputs/outputs, data transmission to supervising system through R380 ERICSSON GSM radio-modem with hard interface between modem and PLC.
- central zone pumping station (PT-CANT) controls 5 submersible pumps with programmable automate in a structure with 64/16 binary inputs/outputs and 8/4 analogical inputs/outputs; data transmission to supervising system through 9600 bauds standard modem through PLC generated telegrams.
- central water pumping station ENERGO (PT-CET) with direct transmission through RS232 communication to supervising system and control of 32/16 binary inputs/outputs and 8/4 analogical inputs/outputs.

The system is projected regarding both the automated leading of the supplying flux and water carrying and for engaging motors and execution elements.

System status and alarms are displayed on the synoptic panel. An intelligent display terminal is used to input and visualize process data.

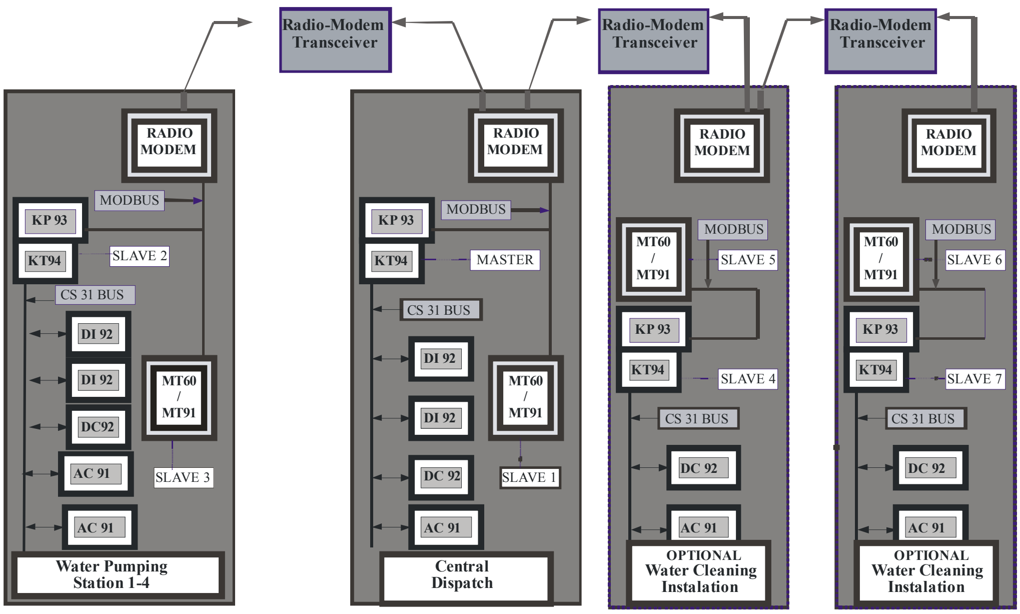

Fig. 4 – Complex automations for monitoring of distributed system.

Based on the implementation of a modern solution by applying high tech engineering, it insures through a hierarchical and distributed architecture, the connection between field elements (traducers, frequency converters, servomotors, intelligent terminals) and programmable automates respectively PC which is on a superior level of monitoring and supervising. Communication is realized, depending upon distance, directly through the CS31 type RS485 specific bus, modem and radio-modem with GSM (Fig. 5).

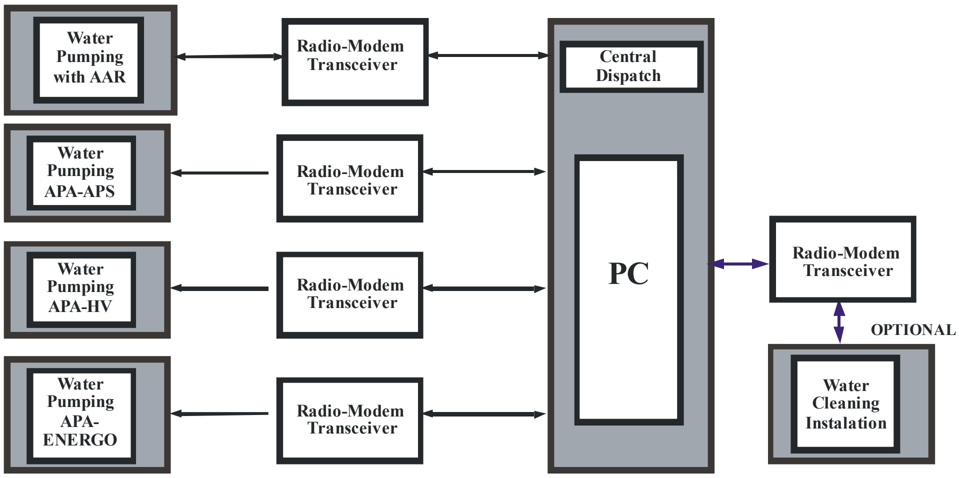

Fig. 5 – Implementation of hierarchical systems for supervision of the water supply distributed processes.

For implementation, there were used 4 central units of KT94 series CS31programmable automates with 8 DC/DI 92 binary input/output modules and 3 AC/AI 91analogical input/output modules bonded in a decentralized and distributed structure which insures control of 368 binary inputs, 80 binary outputs, 80 analogical inputs and 16 analogical outputs.

The **application PLC soft** for each central unit is dedicated to the 4 technological processes which it controls through input/output modules of programmable automates in a distributed and decentralized structure and communicates with the supervising system through PT7 and PT-CANT standard modem, PT-ACC GSM radio-modem, and PT-CET direct link.

The **communication soft** between the supervising PC and the PLCs of the distributed system of command and control is realized through Visual Basic programming which requires 38 Mb with an execution time below 0,1ms and an interactive communication with pumping stations. A PC-operator graphical interface is shown in over 50 “Windows” interactive frames taking into account the accurate placing of the pumps and water circuit highlight: fire water, hot water and technological water. PLC application soft allows control for each pumping station through serial communication with the PC using DRUCK and EMAS telegrams which allows central monitoring. System allows coupling to an ARCNET or MODBUS network with an upper limit of 255 such systems to participate in the network and reach up to over 50 000 monitored process parameters.

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