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# INTEGRATED SOFTWARE ENVIRONMENT DEDICATED FOR IMPLEMENTATION OF CONTROL SYSTEMS BASED ON PLC CONTROLLERS

**Summary.** Industrial processes' control systems based on PLC controllers play today a very important role in all fields of transport, including also sea transport. Construction of control systems is the field of engineering, which has been continuously evolving towards maximum simplification of system design path. Up to now the time needed for the system construction from the design to commissioning had to be divided into a few stages. A mistake made in an earlier stage caused that in most cases the next stages had to be restarted. Available debugging systems allows defect detection at an early stage of the project implementation. The paper presents general characteristic of integrated software for implementation of complex control systems. The issues related to the software use for programming of the visualisation environment, control computer, selection of transmission medium and transmission protocol as well as PLC controllers' configuration, software and control have been analysed.

# ZINTEGROWANE ŚRODOWISKO PROGRAMOWANIA PRZEZNACZONE DO REALIZACJI SYSTEMÓW STEROWANIA OPARTYCH NA STEROWNIKACH PLC

**Streszczenie.** Systemy sterowania procesami przemysłowymi oparte na sterownikach PLC odgrywają w dniu dzisiejszym bardzo dużą rolę we wszystkich dziedzinach transportu. Budowa systemów sterowania jest dziedziną inżynierii, która ciągle ewoluuje w kierunku maksymalnego uproszczenia ścieżki konstruowania systemu. Czas potrzebny na budowę systemu od projektu po oddanie do eksploatacji do dnia dzisiejszego musiał być podzielony na kilka etapów. Błąd popełniony na wcześniejszym etapie powodował, że kolejne etapy trzeba było w większości przypadków powtarzać. Dostępne systemy debugowania pozwalają na wykrycie usterki we wczesnym stadium realizacji projektu. W artykule przedstawiono ogólną charakterystykę zintegrowanego oprogramowania do realizacji złożonych systemów sterowania. Przeanalizowano zagadnienia dotyczące wykorzystania oprogramowania do programowania środowiska wizualizacji, komputera sterującego, wyboru medium transmisyjnego oraz protokołu transmisji oraz konfiguracji, oprogramowania i sterowania sterownikami PLC.

## 1. INTRODUCTION

The control systems based on PLC controllers find numerous applications both in the industry and in mobile transport means of inland and sea transport. A large field of opportunities entails a broad spectrum of applications of such systems. Possibility of cooperation with the detectors and actuating devices provided with practically any communication interface allows implementation of such systems in the existing solutions without the necessity to modify the system itself, and in many cases also simultaneous use of these elements of the system for the purpose of preliminary safety tests.

Navigation, as a component of the system, provides information about position in the space. This information has to be compared on a current (quasi-continuous) basis with position of units located nearby. It is unacceptable that datas are lost or they are incorrect because of hanging up by the controller or freezing of part or entire picture. Both these situation have to result in transition of the system into a safe condition and ensure an appropriate safety level by warning the personnel and giving them a possibility to control the ship. It is also important that the condition just before the malfunction is restored for the diagnostics purposes and the statuses necessary to restore the equipment behavior in case of malfunction are archived.

## 2. ARCHITECTURE OF CONTROL SYSTEMS BASED ON PLC CONTROLLERS AND INDUSTRIAL COMPUTERS

Architecture of control system is various and depends of the solution applied. It is based upon computer network topology because of a need to cooperate and exchange the information between controllers.

The main features of the system's structure is the use of a central computer that coordinates operation of all controllers or distribution of the logics between the controllers so they become either autonomic or semi-autonomic. An advantage of using a centralized system is the possibility of full archiving with a practically unlimited memory capacity (for the purpose of archiving, we may use disk array, whose safety is greater that the one of a single disk (using RAID array)). A centrally controlled system reduces system readiness, because of a need to ensure a safe condition in the case of communication system malfunction and depending of the assumed safety strategy to shut down all the controllers or only those with broken communication (a controller, when facing loss of communication, should enter into a safe state which may not mean shutting down all the output signals).

Giving autonomy to the controllers in a decentralized system enables performance of certain tasks in spite of loss of communication. It has to be related with a possibility to archive all changes in the controller's memory up to the moment of restoration of communication, when all the archived data in the controller are transferred to the central archive. Data concerning the activities performed have to be time stamped i.e. bear the information about the exact time of occurrence of an event.

Decentralizing of the system realized during completely independent activities brings advantages in the form of lack of communication problems, although renders difficult or impossible to perform a central control of a distributed system because of problems that may occur with the safe transmission. Full decentralizing enforces also a guaranteed full archiving of the controller's operation in its memory. Thus, the capacity of archive memory has to be adapted to the average number of activities performed by the controller in the time period required for keeping entries.

Communication between particular system components may be effected in many ways. Transmission media being used may be split up into two basic categories: open standards and private standards. As per today, because of a dynamic development of computer network and also availability of Ethernet standard based equipment (10Base-TX, 100Base-TX, 1000BASE-T, etc.) based on TCP/IP protocol, more and more actuating devices has such interface implemented. This enables, of course with a proper data protection technique (such as CRC) to use this medium for control of equipment, while maintaining guaranteed transmission safety (using a non-safe transmission medium). Methods of

digital cryptography based on long keys that are available today could enable to use an open Internet network for data transmission over long distances and access to the equipment from any place on Earth. Anyhow, small possibility to influence the availability of Internet providers' net results in the fact that public networks are rarely used for control of these devices.

Protection of the system against access of unauthorized persons requires implementation of not only access system for computers, but also such organization of internal network as to separate it completely from the public network. Various solutions may be used for this purpose. One of them is creation of a gate server allowing the access of authorized (verified) persons to the separated zone of system diagnostics and control.

The above solutions allows to establish a system organization diagram taking into account the communication layer, which is shown on Fig. 1.
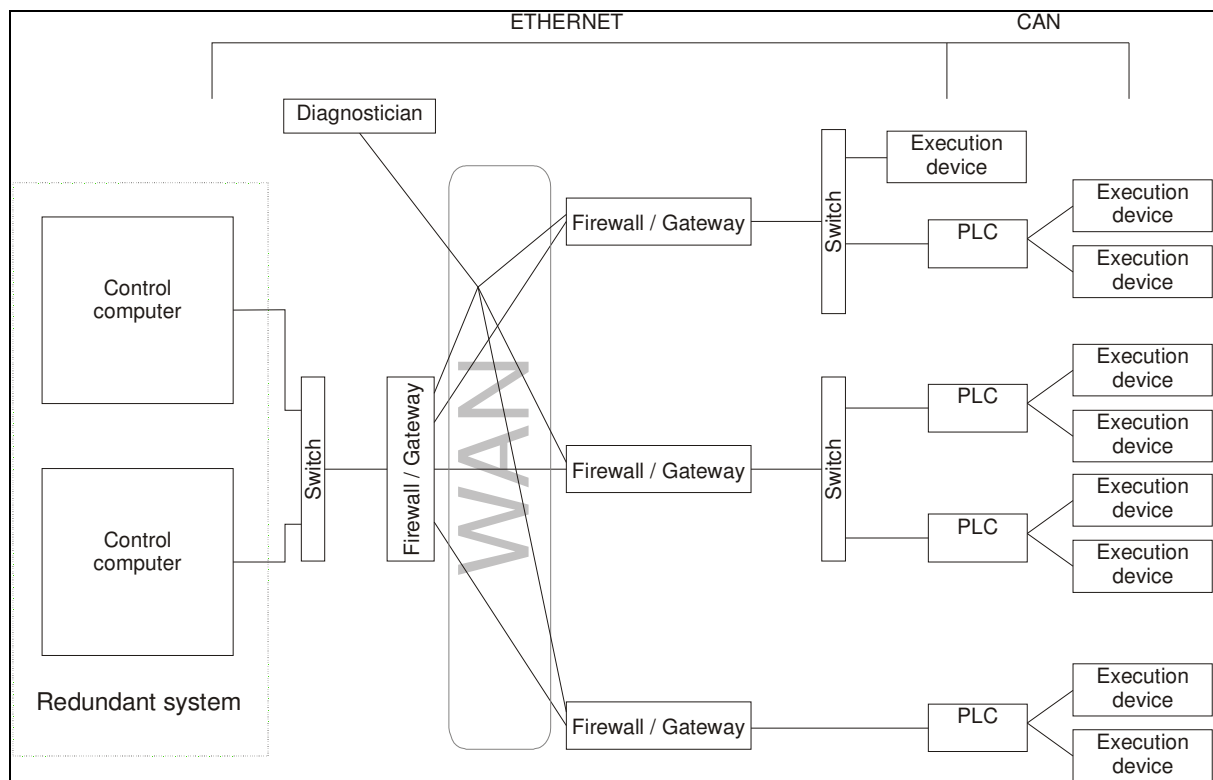


Fig. 1. Construction of a system with devices, protecting against access of unauthorized persons
Rys. 1. Konstrukcja system z ochroną urządzeń przed dostępem osób nieuprawnionych

## 3. TYPICAL SOLUTIONS OF SOFTWARE STRUCTURE FOR THE CONTROL SYSTEMS BASED UPON THE PLC CONTROLLERS

### 3.1. STRUCTURE OF SOFTWARE

Software for the control systems consists of several basic layers:
− visualization;
− communication;
− control;
− decision.

Each level features its individual safety class that has to be ensured to classify this system as a safe one. The lowest safety requirements apply to the visualization level because it is not responsible for

decision-making that might influence the safety, and each command issued through an interface is verified several times, which enables elimination of interface and transmission errors in the control commands bypassing the decision logic (the error would have to appear several times in different telegrams while not causing changes in redundancy code of each of these telegrams).

The communication layer safety depends of the assumed solution. If we use a safe medium, it is required that such medium has very strict parameters in terms of quality and resistance to the interferences so the transmission over this medium is not distorted. The simplest solution that fulfills such requirement is optic cable. This medium is not vulnerable to the electromagnetic interferences.

The Ethernet standard used in the communication layer contains 4-byte redundancy code (CRC) for the purpose of transmission correctness control. A package with CRC code that was calculated in the transmitter and stored in the frame being sent and that differs from the code calculated in the receiver will be ignored and a request will be sent to the transmitter to repeat the transmission. Application of such a transmission protection method results in the fact that we may use medium with less strict parameters, because the transmission is protected against errors by verification of redundancy code (CRC).

The control layer covers actuating systems such as PLC controllers and end devices (pumps Motors) if their control takes place with bypassing of PLC controllers (this is possible when they are provided with an appropriate interface – such as Ethernet). These devices may be current or voltage controlled by the controllers but if they are provided with the communication interfaces and diagnostic electronics, it is possible to perform a current analysis of equipment condition i.e. continuous diagnostics that may detect not only two states – operating – non-operating but also discover worn-out or damaged bearing based upon the vibrations or certain components of vibration that are characteristic to specific malfunctions.

Decision layers contains most frequently the interlocking computers that supervise the total control process and issue commands to the controllers and devices. They are provided with one or several communication standards and enable cooperation with many system elements, such as redundant computers, PLC controllers or actuating equipment. These computers fulfill also function of archive servers for the entire system.

The control and decision layer have to supervise the communication layer and one another. If one of the layers is damaged entirely or in part the system has to work out a safe situation that would guarantee elimination of possible hazard to human health or life and further also material losses.

## 3.2. CREATION OF PROGRAMS IN A MODERN SOFTWARE FOR CONTROL SYSTEMS CONSTRUCTION

Changes that took place during the last several years in the creation of programs for each system layer dramatically changed the system construction method. This had an advantageous impact upon the costs of the system and time of its construction, fig. 1 shows the evolution of software with time.

Today, due to the modern software integrating all layers and reducing the construction of a program to combine the entire system of blocks representing specific devices that mostly are repeatable and at the same time enabling design of entirely new elements (devices) with their own interlocking systems, the complete construction of the system may take place quicker and at the same time with minimum requirements concerning the knowledge of programming languages by the designer. The process itself consists in connection of blocks with inputs or outputs of the controllers or communication bus. The blocks are programmed by a person with broader knowledge and extensive information enables their implementation by a person with minimum programming knowledge. Configuration of specific system elements based on the blocks may be performed by assigning input constants and description of units such that they have unique identification in the system.
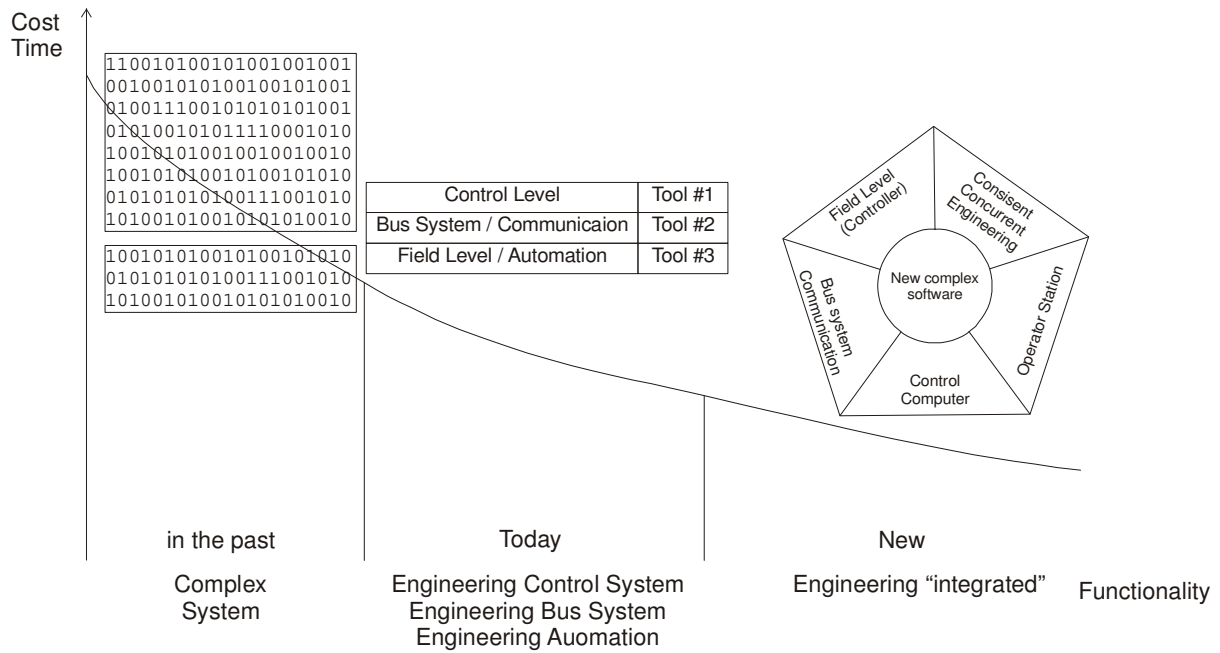
Fig. 2. Evolution of programming methods in the control systems based on PLC controllers
Rys. 2. Ewolucja metod programowania w systemach bazujących na kontrolerach PLC

Exchange of information between system components takes place based upon global variables predefined in the system, similarly as in the older software. However, here we do not have to deal with necessity to know how to define – the interface is intuitive, enabling to decide which variable has to be put for reading outside the controller – without going deeper into the structure of the program. Communication between the controllers may be time-depending i.e. when the attempt to read does not take place or readout of variable fails, the controller has to react in an appropriate way. Besides this there is also the possibility to couple the controllers into a redundant system increasing the readiness of the system (2oo3) or/and its safety (2oo2).

Exchange of information between the actuating devices and controllers is as important as visualization of the process for the service. Hitherto it was an element requiring large programming knowledge especially when the program itself was written in the lower level language (assembler) now is based on a graphic editor. Embedded animated elements representing the statuses of devices or informing the service about their operation (also operation of the entire system) are represented as hyper-macros that issue, as output function, a function that subsequently is used for control of the visualization of the given element used anywhere in the system (regardless whether the logic of visualized component is located in the controller or in the controlling computer).

The time of system construction based upon predefined blocks is considerably shorter. The only element that requires working out in the project is logic of its operation. The construction is the longest part of designing. It has to contain all acceptable variants and protect the system against human errors as much as possible, as well as allow for automatic operation of the system in certain assumed situations based upon the date written in the memory and containing information about the given procedures (such as control of distance between two ships, supervision of entry to the port with location device data taken into account and compared with the stored land parameters with selection of an optimum route which may be displayed to the navigator or take the decision immediately by controlling the operation of onboard devices).

## 4. CONCLUSIONS

Time and cost of the system construction largely depend of the expenditures necessary for creation of part of the system program. Shortening of programming time by its simplification enables saving in terms both of time and money due to the possibility of system operation simulation already at the stage of programming.

Use of an intuitive interface of programming environment renders possible to work on the system not only for IT engineers – programmers but also suitably trained engineers having more knowledge about the system being designed and constructed.

Modern software allows not only for a complete construction of programming for all control levels but also to carry out the full diagnostics of the system being started up and already existing, due to the implemented libraries.

Use of integrated programming environment cooperating with a database where all information is collected about the changes of system status, allows quick determination of the occurring problem, its diagnostics and working out of procedures to prevent the existing situation in  future based upon analysis of  data, current diagnostics and entries concerning similar system conditions written in the database.

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