UDC 62-503.51

The data acquisition and management system for controlling the physical installation

A. E. Kuvakina, A. V.Osipchuk, A. N. Ralo, S. N. Styervoyedov
V.N. Karazin Kharkiv National University, Ukraine

This paper discusses developed and tested systems for the control of accelerator complexes that are unique objects of data collection and management. Testing of the system was conducted on the neutron-activation complex NG-150, the technological process of thermal metal deposition, as well as on the plasma welding control system. The paper briefly shows the developed system architecture and block diagram of the intelligent sensor core. There described the system operation algorithm and operation with system modules. Reviewed the results of the offered technology.

Key words: *information management systems, data acquisition system, control system, technological process.*

В статье рассматриваются разработанные и испытанные системы для управления ускорительными комплексами, которые являются уникальными объектами сбора данных и управления. Тестирование системы проводилось на нейтронно-активационном комплексе НГ-150, на технологическом процессе термического осаждения металлов, а так же на системе управления плазменной сваркой. В статье кратко приведены разработанные архитектура системы и принципиальная схема ядра интеллектуального сенсора. Описаны алгоритм работы системы и работа с модулями системы. Рассмотрены результаты предложенной технологии.

Ключевые слова: *информационно-управляющая система, система сбора данных, система управления, технологический процесс.*

У статті розглядаються розроблені та випробувані системи для управління прискорювальних комплексами , які є унікальними об'єктами збору даних і управління . Тестування системи проводилося на нейтронно- активаційному комплексі НГ- 150 , на технологічному процесі термічного осадження металів , а так само на системі управління плазмової зварюванням. У статті коротко наведені розроблені архітектура системи і принципова схема ядра інтелектуального сенсора. Описано алгоритм роботи системи та робота з модулями системи . Розглянуто результати запропонованої технології.

Ключові слова: *інформаційно-управляюча система, система збору даних, система управління, технологічний процес.*

1. Introduction

The accelerator complexes (AC) are unique objects of data acquisition and control with a fast morally aging hardware and software components of information management systems (IMS) [1].

Distinctive feature of work of IMS AC is continuous operation mode, often 24 hours * 365 days, when significant flows of physical information received and processed in online mode at the same time with a lot of data on technological parameters and operating modes of the accelerator systems. At the same time the notorious "human factor" should be excluded as much as possible. This is necessary to reduce the risk of nonnormal operation of the accelerator, and to obtain objective data from the studied processes [2] .

The majority of developed IMS AC does not meet the requirements of scientific staff and researchers. On the other side the narrow focus of previously developed IMS AC in conjunction with their closeness is not possible to adapt the hardware and software components to changes in the operating conditions of AC. That's why the development of integrated open systems is actual for effective monitoring and management of technological processes of accelerator and for data acquisition with a new ideology on the new hardware and software base.

2. Statement of a problem

According to the classical architecture of the control system the basic concept of the system are sensors and control elements, connected among themselves by physical interface [3]. For the data exchange *are* used different logical protocols. All collected data is stored for further processing and making relevant decision. If necessary, information can be visualized by using custom software.

For realization of information management system AC in order to increase it's reliability, speed and versatility, it was decided of partitioning of this architecture into two relatively independent unit. A data acquisition and primary repository are allocated in the first «Slave» module, and the processing and further work with the data are allocated in the second «Master» module. Figure 1 shows suggested PLC-technology.

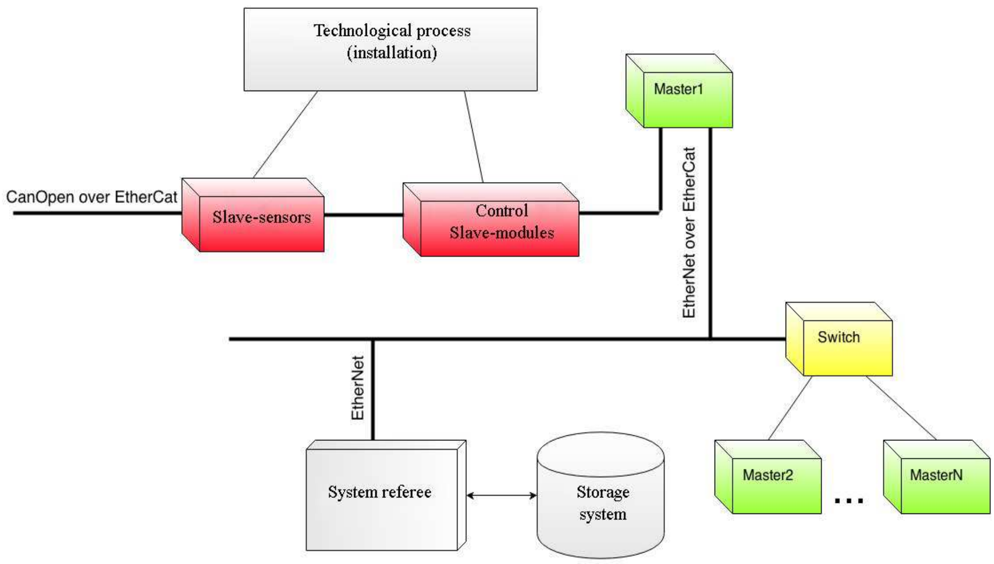

Fig.1. System with split-architecture management - PLC-technology

Thus, the goal of the work was, firstly, the development of the open, easy scalable system for collecting, primary processing and storage of the data, and secondly, the creation of the system of fast decision making on the basis of the obtained data.

2. The system architecture

Figure 1 shows the suggested and developed PLC-technology. Each of the used sensors in the system and control elements is an intelligent device having a unique number. By implementation of the work was used laboratory devices based on PIC 32MX* microcontrollers by Microchip or the final equipment. In the last case, devices were equipped with microcontroller consoles, allowing them to interact in a single system as Slave devices. Thus, the elements of lower type are devices, intelligent enough to communicate with the referee system. These nodes are usually created based on microcontroller devices and programmable logic arrays and include some processing core, the implementation of the protocol stack interaction and signal converters.

While developing each of system control elements and data acquisition, a set of commands that supported by this device are discussed. A command set is specific for each type of equipment. Working with each cell of the system implemented by sending a command or request to a specific address. The controller recognizes its address, read the command and executes the task. This architecture provides the following benefits: Slave-modules after obtaining of the latest commands transfer to the autonomous control, and can store data, or to manage the process until the «Master» referee sends a new command.

The received data from Master is passed back over the network, and picked up by the PC with user software, visualized and transmitted to the data repository analyzer. Next the analyzer filters the information, translates to the required format and stores it in the repository, as well as decide on further work of Master - device.

An analysis of such architectures [4] with a common bus has shown that compared to the topologies, for example, "point to point" has several problems: there is a need for addressing the devices and the organization of queuing. Furthermore, there is a necessity in waiting for release of the bus. Adding an address in each of packages significantly reduces the rate of exchange of information. This is especially noticeable with the predominance of short messages.

The desire to make such universal nodes and the fact that different parameters require different measurement methods, was proposed using of modular solutions, in which the applicability of the node to measure variety of parameters is achieved by creating the node structure on the principle of modularity, both on hardware and on software levels, as well as the using of the CanOpen / EtherCat protocol between Master and Slave devices, as well as between the Master and Master devices.

3. The schematic diagram of the intelligent sensor core

The schematic diagram of the basic module element of data acquisition is presented in Figure 2. On the central board is situated just a basic element - the computing core, and all other functions of the device are realized by external components, connected by connectors. In general, each of the data acquisition and management elements are represents an intelligent device based on the microcontroller and possibly programmable logic arrays, having a physical RS-485 interface for communication with a data transmission medium and a set of provided functions, special for each node. For example and for supporting a high resolution as the core of the system was chosen ADuC 812 microconverter of Analog Device Company with more advanced analog part, compared to other microcontrollers, where the predominant part is digital.

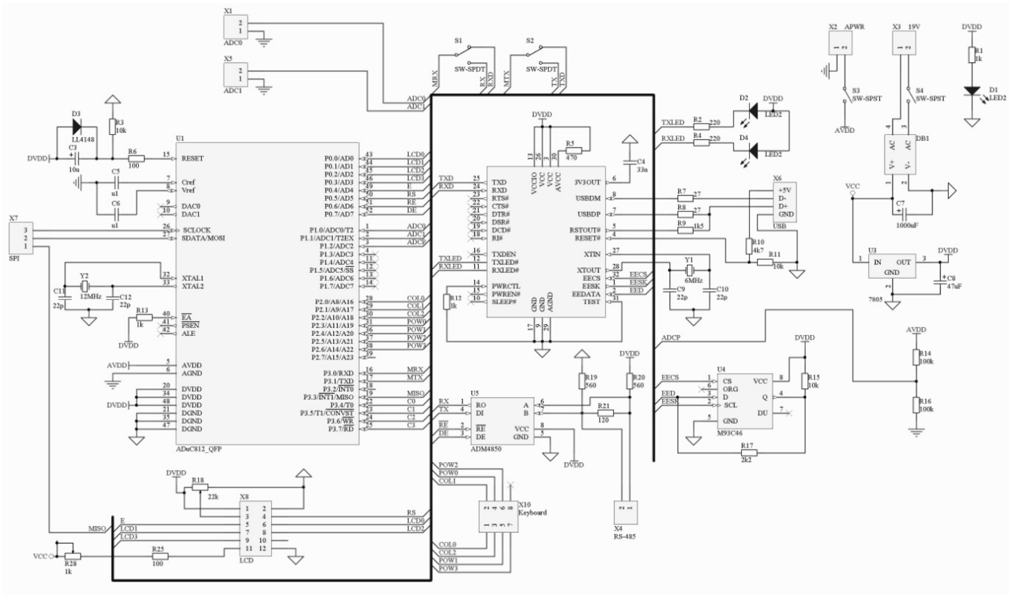

Fig.2. Schematic diagram of the intelligent sensor core

One of the system nodes is personal computer that controls the operation of the system. The connecting part of the data acquisition system was realized based on the most commonly used protocols of lower and upper levels. So, as a data transmission medium has been selected a twisted pair, and for the logical protocol are used Ethernet and RS-485 interface, the use of which is one of the most common solutions for similar problems. Herewith the data conversion, moving from one environment to another, reduced only to changes on the physical level and CanOpen/EtherCat protocol implementation. Based on the simulation for the different formats of transmitted messages the choice was made in favor of the format shown in Fig. 3.

4. The system operation algorithm

The system operation algorithm can be described as follows: control computer and Master connected via TCP / IP connection and in Real-time mode transmits data about the system and its separate nodes in general, managing the computer initiates the transmission of data to the network by sending a frame, that contains as recipient address a sensor number from which you want to get more detailed information; Master receives the message and checks the frame structure, because the bus is shared, but each Slave module knows the address of the Master module that allows to provide the uniqueness and speed of exchanging packets with Master-Slave devices, each of the Slave devices on the bus detects the signal and compares the contents Master address field, and after that, the contents of the address field with its own number, with a match is found Slave module sends the requested data back to Master, and controls elements perform a dispatched instruction, picking up obtained data, Master makes their intermediate storage. Since the described actions are standard for data acquisition and management, module that performs them, as mentioned above, was decided to allocate in a separate block, associated with upper level software using open functions, i.e. it was suggested to create an intermediate node, that allows to abstract from the physical environment and processes the data transmission occurring in it, which also allows you to trace the working capacity of the system and its individual sections, depending on the algorithm supplied. Figure 3 shows the most successful frame structure used for exchanging packets between Master-Slave devices.

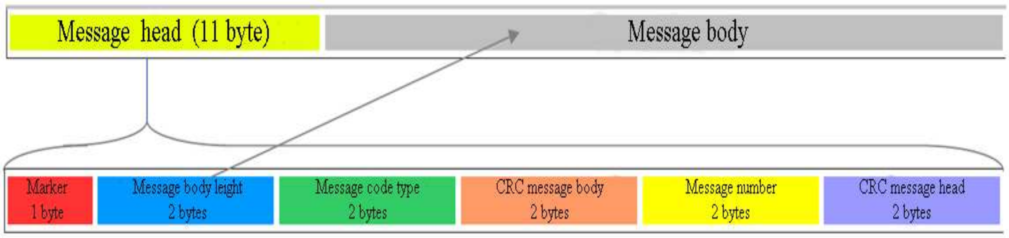

Fig. 3. The frame structure.

The works with the frame:

1. Start marker of the telegram (byte)
   equal to the number 10011001 in binary or 153 in decimal or 0x99 in hex
2. The length of the message body (unsigned short int)
   each message has its unique message type code
3. The message type (unsigned short int)
   each message has its unique message type code
4. CRC of the message body (unsigned short int)
   uses an algorithm CCITT CRC-16 for calculation
5. The message number (unsigned short int)
   perforating message serial number (regardless of type)
   when reaching 65536 cyclically reset to 0
6. Header CRC (unsigned short int)
   uses an algorithm CCITT CRC-16 for calculation
   considered by the first 9 bytes of the header
   CRC data at the moment of calculations have to be calculated.

5. Work with the system modules

The module was divided into two parts: the management system driver that has maximum privileges when working with the ports of host PC and a dynamic library. Work with the I/O ports implemented in the driver, and the library is used for communication with the upper level software responsible for the interface part. Owing to orientation of the system to the cross-platform, the library was realized as a dll-, and so- form. The upper level user software [4] provides a number of functions, allowing both to receive state data of the system in real-time and get access to the historical data, that are contained in the repository. In total there was developed 4 functions for reading and writing, working with sensors or repository. An example can be the most commonly used function read_data (byte bAddress, string sName), to which are transmitted address as parameters of the relevant device in a data transmission network , and the name of the node that is necessary for the proper conduct of history values removed from the same sensor . The called function implements the layout package necessary format. The obtained package is copied into RAM area, an open to access it from other processes. Changes in RAM fixed by service software, that is presents the driver, which is one of the most accessible methods of implementing of the real time mode as drivers are allowed to be running at a relatively high priority. The driver sends the detected frame to the network, either through USB-, or Ethernet-port. In case of working with Master (PLC), expects corresponding response frame that puts back into the general memory area. Further, the above described function in the dynamic library verifies the integrity of the package produces it's decrypts and sends the extracted data as a result of the function and maintains into a specialized repository for further processing. So the storage concept was chosen, since they are allows to handle heterogeneous data compactly save them and record the history. In our case, the storage system was created based on a dynamic multidimensional array [5], created by GMM + + library [6].

For writing the upper level software, that using developed API, was selected development environment for SCADA IMS LabView, that has a great set of visual components, and provides the ability to quickly develop interactive programs that supports parallelism of work for individual parts of the upper level software, shown in Figure 4.

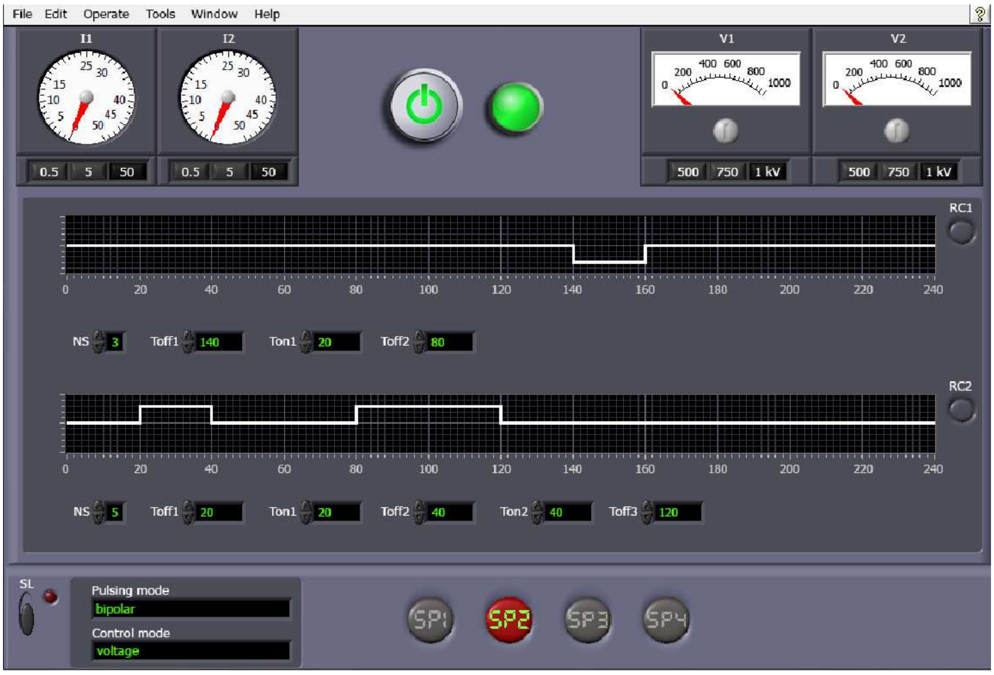

Fig.4. The management subsystem of AC pulsed ion source

The existing software components are aimed at creating normal elements of control and displaying that not always visible. For this, their basic set has been expanded. There were created the components of thermometers, pressure gauges, encoders, etc. Each of the components requires little setup, defining element of the real address of data acquisition in the network, its name, the limit values, type of scale, etc. To reach the desired value called the provided function read, which causes above described function read_data from the library dll, passing as parameters its own name and address. In addition were used non-visual components, designed for sending commands to control elements, as well as to collect data about the overall working capacity of the system. For such components the main called function is write (byte bCommand), which causes the corresponding command write_data.

6. Discussion of results of the offered technology

The proposed architecture increases the number of the hardware nodes, which of course is its disadvantage. On the other hand, as shown by the results of the research, the use of such PLC-technology significantly increases the speed of control and accuracy of the received data. The system allows substantially faster make decisions based on the obtained data .

The data gathering corresponding to the normal state of the system and the processes and events are common occurrence in the management of any technological process. Data refresh rate via the fieldbus is usually lies in the best case in the range of 10-100 Hz. However, for certain applications, as well as for fault searching are necessary a much higher frequency of data acquisition. Manufacturers of microcontroller systems are often connected of data acquisition tools directly to the service port of the microcontroller for diagnostic and fine tuning. There are cases of using very expensive data acquisition connected devices with the built-in memory to detect trends and conservation, etc. This is another advantage of the network EtherCAT it is allows collecting data with frequency up to 20 kHz, without interfering with the work of other slower devices in the same network. Moreover, neither faster nor slower devices no need to develop specially in terms of compatibility with EtherCAT. In fact, the internal circuits of fast devices should be fast enough to keep up to generate new data with such speeds.

7. Conclusion

The successful development of such PLC-technologies, especially in recent years, that is proved by stable operation of the systems in already realized projects, allow confidently consider that PLC-technologies have good prospects to incorporate it into intelligent automated systems of the data acquisition and management. With the improvement of PLC-technologies for solving of many yet existing problems, this technology may become dominant in the implementation of large-scale intelligent networks.

During operation was created an integrated, easily extensible visualization, monitoring and management system of physical units of any complexity. Easiness of creation of upper level application with qualitative interface allows using of the product by specialists that are not directly associated with programming. The system was tested on the neutron-activation complex NG-150, on the technological process of thermal deposition of metals, as well as on the control system of plasma welding. The system has showed the high performance and ease of use.

REFERENCES

1. O. V. Vozniy and G. Y. Yeom. High-energy negative ion beam obtained from pulsed inductively coupled plasma for charge-free etching process. Appl. Phys. Lett. 94, 231502 (2009)
2. A.Derevyanko Constructing empirical models for the control of complex technological processes. / A.Derevyanko // Bulletin of KhNU. Ser. Mathematical modelling. Information technology. Automated management system. – 2009. - Issue 12, №863 – p.101 – 110.
3. Modeling, Algorithms and Implementation of the Microcontroller Control System for the Ion Beam Forming Process for Nanostructures Etching. Andrii Derevianko, Aleksandr Kropotov, Aleksandr Ralo, Sergiy Styervoyedov, Oleksiy Vozniy. ICTERI 2013 Proceedings of the 9th International Conference on ICT in Education, Research and Industrial Applications: Integration, Harmonization and Knowledge Transfer. Kherson, Ukraine, June 19-22, 2013.p.30-37
4. A.Derevyanko, A. Novikov, A.Ralo. Data Acquisitions Systems and visualization to control physical processes. Modern physics and chemistry problems in transport and constraction. - Kharkiv: KhNADU, 2008, с.93-95
5. A.Derevyanko. The concept of data stores in a control system of nanotechnological processes. Information processing systems. Issue 2(83) – Kharkiv, 2010. – p.78-83.
6. Academic Product Bundles. National Instruments. http://sine.ni.com/nips/cds/view/p/lang/en/nid/13134.
7. EtherCAT Technology Group, http://www.ethercat.org.

Надійшла у першій редакції 01.05.2010, в останній - 01.06.2010.