Training Software Complex "Automated Control System of Enterprise"

Alina A. Gainullina, Rustam K. Nurgaliev, Denis A. Ryjov

Abstract: ***This paper describes the integrated enterprise management system implemented on the basis of the training laboratory "Automation and Process Control Systems" in the Kazan National Research Technological University. It is designed to teach bachelors and masters the principles and standards of design and development of MES class systems.***

Keywords: ***MES-system, integrated production management system, control system, Exaquantum, real-time database, education.***

I. INTRODUCTION

According to ISA 95 [1, 2, 3], the pyramid of integrated enterprise automation is a four-level model and consists of the following levels (Fig. 1):

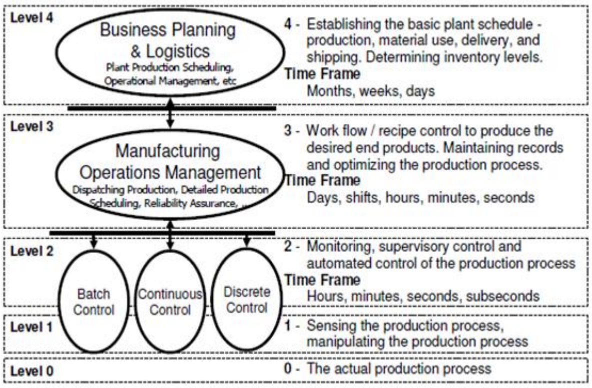

Figure 1 - The hierarchy of enterprise management systems [1]

Level 0 - the level of technological processes.
Level 1 - the level of measuring transducers and actuators.
Level 2 - the level of technological process control systems, programmable logic controllers (PLC), distributed control system (DCS) controllers, automatic emergency protection controllers.
Level 3 - level of production process control systems (MES (Manufacturing execution system) level).
Level 4 - the level of planning and management of enterprise resources, the level of ERP systems (Enterprise Resource Planning).
The levels differ from each other by the time of collecting and processing information, tasks and tools used.

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* Correspondence Author
Alina A. Gainullina, Kazan Federal University, Kazan, Russia
Rustam K. Nurgaliev, Kazan National Research Technological University, Kazan, Russia
Denis A. Ryjov, Kazan National Research Technological University, Kazan, Russia

The first and second levels implement the functions of an automated process control system (APCS), where the tasks of collecting and processing information from instrumentation equipment, generating command signals to actuators, and monitoring and control of technological processes are performed.
The third and fourth levels implement the functions of an automated enterprise management system (AMS), where tasks related to the planning and management of enterprise resources, financial management, supply and sales are solved. Information of the third level is a source of data for ERP systems on actual production capacities, fulfilment of production tasks, and equipment load indicators.
For a long time, APCS and ERP systems developed almost independently and separately from each other. At the same time, the process of transferring information to / from ERP systems was poorly automated. To optimize technological processes, increase productivity and competitiveness of enterprises, the need to integrate the two systems arose. The difficulty was that the data supplied from the process control system to the ERP system must be appropriately prepared and processed, depending on production requirements and the task at hand. The complexity associated with the lack of initial data ready for use in ERP systems has become one of the reasons for the appearance of a kind of connecting link in the form of MES systems. [4-12]
Based on the specifics of the tasks to be solved, at the junction of technological and planning-financial structures of the enterprise, the main functions of MES-systems were formed as follows:

- Improving the quality of products by monitoring and managing the entire production chain.
- Increase in productivity by reducing equipment downtime.
- Reducing the cost of materials and raw materials per unit of output due to the optimization of technological processes.
- Submission of operational information on violations of the production process.
- Visual representation of the production process progress in real time.

The theoretical foundations of production control systems (ACS) or MES systems began to be developed in the second half of the last century. However, their first practical implementation in Russia was at the end of the first - beginning of the second decades of the 21st century. [5, 6, 7]
A rather poor modern pedagogical base for training professional personnel for the construction of such systems is also connected with this.

To overcome this gap and a perform more detailed and visual study of the methods and principles of constructing MES class systems at the Kazan National Technological University, a training program complex "Automated enterprise management system" (training program complex AMS) was developed on the basis of the training laboratory "Automation process control systems” (APCS). The training program complex AMS is an integrated laboratory management system based on the Exaquantum system.

II. METHODS

Consider the composition and purpose of the AMS laboratory.
The AMS laboratory consists of four separate laboratories:
- Instrumentation Laboratory;
- The control and computing systems Laboratory
- Laboratory with facilities simulating metering units for heat, liquid and gaseous products;
- Computer class with systems for computer modelling of chemical-engineering processes.

The instrumentation laboratory (Fig. 2) consists of eight stands for the study of devices, principles of operation and the procedure for conducting metrological maintenance of instrumentation.

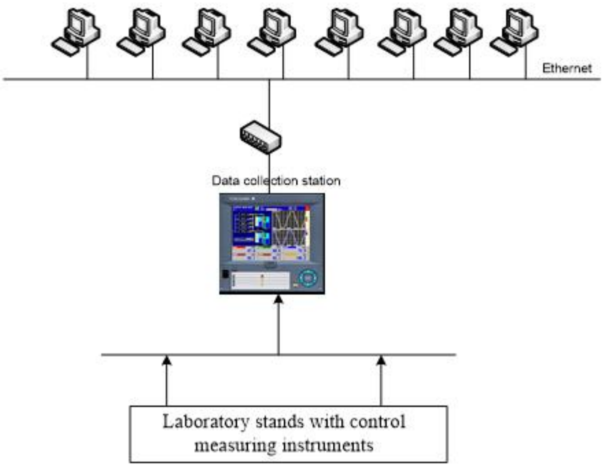

Figure 2 - Block diagram of the instrumentation laboratory

The laboratory is equipped with modern measuring instruments and automation equipment. The personal computers in the stands are integrated into the local Ethernet network, and the measurement information from each stand is sent to a common data collection station (DCS).
The control computer system laboratory is intended for laboratory and practical studies with bachelors and undergraduates with the aim of:
a) Acquisition of practical knowledge on the building-up, composition, hardware and software principles, methods of functioning of modern software and hardware systems for process control systems of the industry;
b) In-depth study of hardware and software interfaces and means of communication of concentrated and distributed process control systems;
c) Training in modern technologies of information exchange in process control systems;
d) Learning how to use standard interfaces and industrial networks in modern automation systems;
e) Gaining skills in configuring and setting the communication ports of process control devices for implementing data exchange through industrial networks.
The laboratory complex (Fig. 3) represents a combination of software and hardware based on the STARDOM FCN network controller and six personal computers connected via an Ethernet local network.

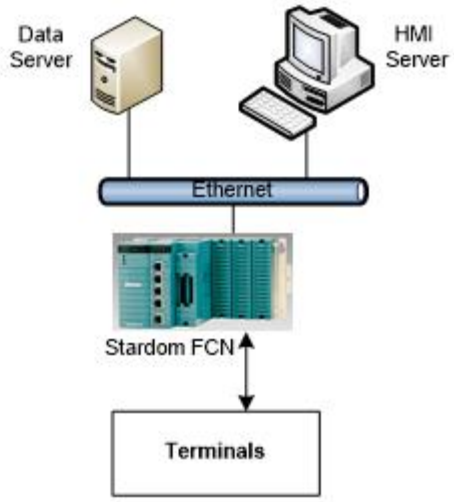

Figure 3 - Structural diagram of the control computing system laboratory

A laboratory with facilities that simulate metering units for heat, liquid and gaseous products is designed to study the composition and principles of construction of process control systems, to study methods for setting up and configuring devices and their interfacing with control and protection controllers. In addition, it is intended for studying the software and hardware of programmable logic controllers (PLCs), distributed control system (DCS) controllers, emergency automatic protection (EAP) controllers, studying a human-machine interface for implementing control algorithms and visualizing technological processes, studying of data transfer interfaces. [8-10-15]
These installations are operating autonomous systems that simulate with a reduced scale the configuration and operation of automated accounting units of the corresponding purpose and incorporate a functionally complete set of technological equipment and the most modern technical means of automation and field level.
All installations are located in a separate room and connected to a common automated system for processing measurement information and control, implemented on the basis of the Centum VP distributed system controller, Prosafe RS automatic emergency protection controller, and Stardom FCN / FCJ programmable logic controllers.

The control system hardware complex has a hierarchical structure and consists of three levels (Fig. 4).

The first level of the hardware complex includes:

- Primary measuring transducers (sensors);
- Local indicating instruments and controls placed on technological equipment.

The second level of the hardware complex includes directly the DCS and emergency automatic protection controllers. The third level includes:

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- Automated workplaces (AWP) of operators (training places),
- Engineering station (teacher's workplace).

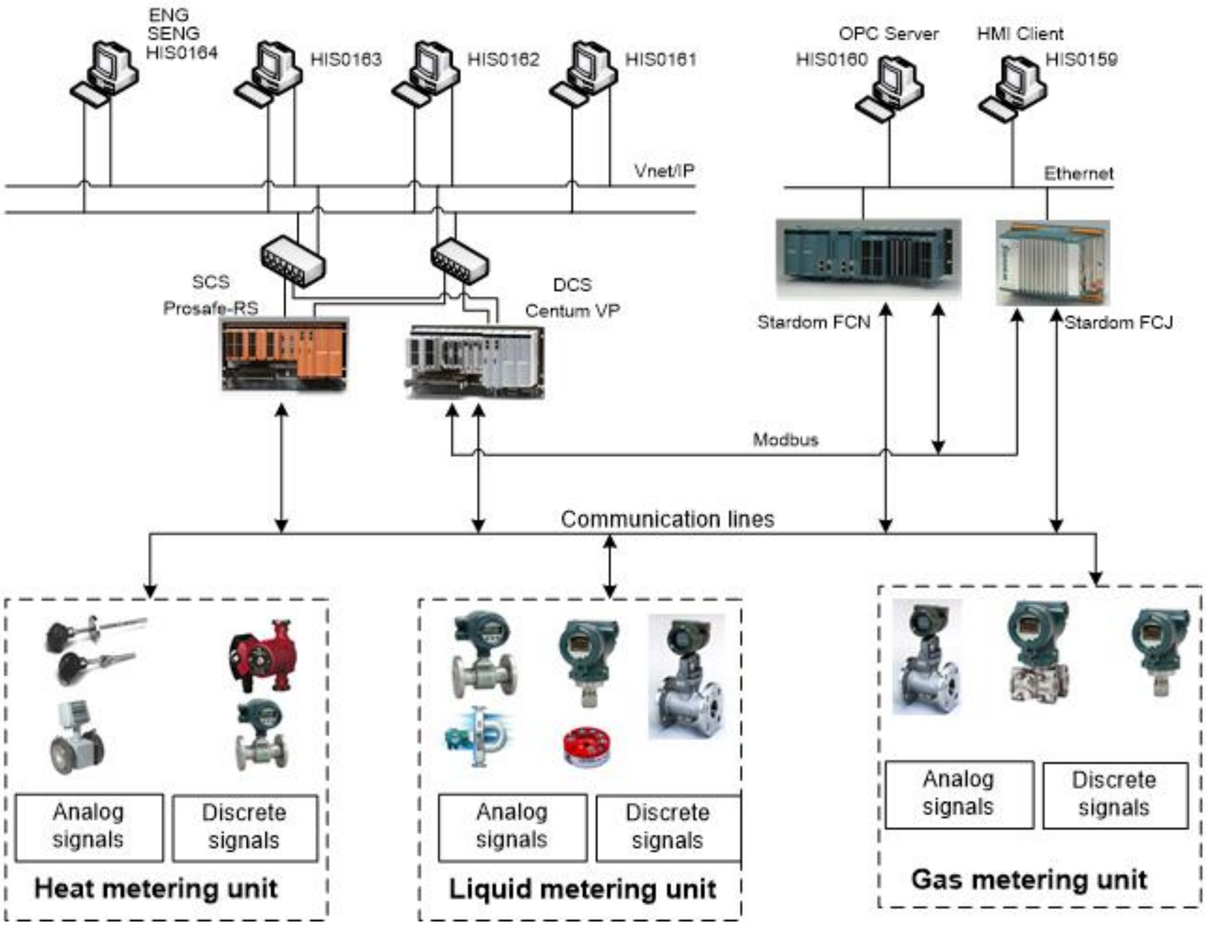

Figure 4 - Structural diagram of the laboratory with installations that simulate the operation of metering stations

The next laboratory is a training class of computer systems for modelling chemical and technological processes, on the basis of which a computer training complex (CTC) is implemented. A computer training complex is designed to teach students the basics of process control and management, as well as the development and configuration of application software for managing various processes. [11-13-14]

The software of the computer simulator includes a dynamic model of a crude oil distillation plant ELOU AT, an automated process control system and its emulation in a simulation environment.

The plant model includes 3 main process units:

- Crude oil preparation unit: oil heating, desalting and dehydration;
- Crude oil distillation unit, including columns for topping and atmospheric distillation of oil;
- Kiln unit.

To fully simulate the process control system, the model was integrated with the CENTUM VP DCS station. Signals to this station come from the mathematical model of the plant, allowing the trainee to monitor the progress of the process, control adjustable parameters and control actuators. Control signals set by the trainee influence on the mathematical model of the process through the control system in a similar way.

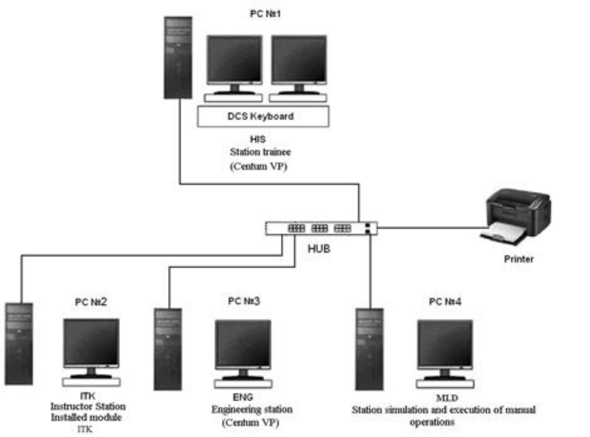

Figure 5 - Block diagram of a computer training complex

This training complex allows us to solve the following tasks in the framework of the training course:

- The study of the relationship between technological processes within the framework of petrochemical production.
- The study of causal relationships of chemical technology processes.
- Studying the influence of changes in the dynamic characteristics of objects on the control system and PID controller performance.

- Calculation of regulator settings.
- Acquisition of practical and theoretical skills in tuning control loops.
- Studying the principles of safe process control in various modes and emergency situations.
- Acquisition of practical skills for the prevention, localization and liquidation of emergency situations;
- The study of software packages for the simulation of technological processes.

The authors were faced with the task of developing an integrated data management system that collects data from all laboratories, processes those data, stores and transfers them to the workstation so that the trainee has the ability to monitor, issue a summary and analyse data for all laboratories in real time.

This system will increase the efficiency of using the existing material and technical base of the control system, provide an opportunity to implement the educational process not only to study the main elements of the control system, but also on the production management system as a whole and provide a practical study of the interaction between individual elements of control systems and their impact on the operation of the system generally.

III. RESULTS AND DISCUSSION

The training software system AMS is implemented on the basis of the Exaquantum integrated enterprise management system (IEMS). It is a factory production data management system combined with a user interface. The main functions of the system are the collection, storage and aggregation of process data and other production data.

Integrated enterprise management system Exaquantum consists of three main components:

- The real-time database is a real-time operated, high-performance repository for process data, this system which also provides flexible, user-defined calculations and obtaining aggregated values for different time periods.

- The Historical Database “Historian” provides efficient storage of the archived volume of factory data for a long time and their quick retrieval as needed. In addition to archiving data, “Historian” calculates “aggregated values”, average values, tracks maximum / minimum values, calculates rms values, and sums values over user-defined times.

- Configuration Tools: A set of easy-to-use configurators is provided to create, use and manage Exaquantum environment. These tools include Exaquantum / Explorer and Exaquantum / Web applications.

Exaquantum / Explorer (Explorer) is a client application (client) for working with data that can be installed on a user PC. This environment provides the possibility of flexible analysis and reporting, with which production information can be presented in the form of graphical displays and reports.

Exaquantum / Explorer present mimics similar to those used in automated process control systems such as HMI and SCADA. The mimic diagram is a static schematic representation of a manufacturing process. The mnemonic is superimposed with data in the form of histograms, updated text values, etc., which reflect the current state of the process.

Exaquantum / Web allow users to use a client terminal (thin client) within the Internet / Intranet networks.

The block diagram of the developed training software for automated control system based on the Exaquantum system is presented in Fig.6.

The training software system of the automated control system consists of four levels. The first and second levels (Level 1, 2) include the whole range of laboratory equipment, control and protection system controllers (DCS Centum VP, automatic emergency protection Prosafe RS, PLC Stardom FCN / FCJ), as well as engineering stations with OPC servers. The third and fourth levels respectively host the Exaquantum server, which collects data from OPC servers of the second level and Exaquantum clients equipped with a user interface, report generation functions and tools for developing visualization of technological data.

This complex performs the following functions:

- Collection and archiving data obtained from controllers of a distributed control system (DCS), automatic emergency protection system, programmable logic controller (PLC);

- Presentation of information to employees being trained;

- Providing data exchange with other software packages;

- Settlement

- Presentation of summaries, trends and operation schedules.

Raw process data is collected from the automated process control system (Level 1 and 2 Fig. 6), through OPC servers, to the Exaquantum server real-time database. Here they are combined and used in real-time calculations. The result of this processing is derivative information of a higher level.

The received data is archived (placed in the historical database), which provides the ability to access them over a long time using the Historian Historical Database.

Archived and aggregated real-time information is transmitted to the trainee’s workstation through the Exaquantum / Explorer program.

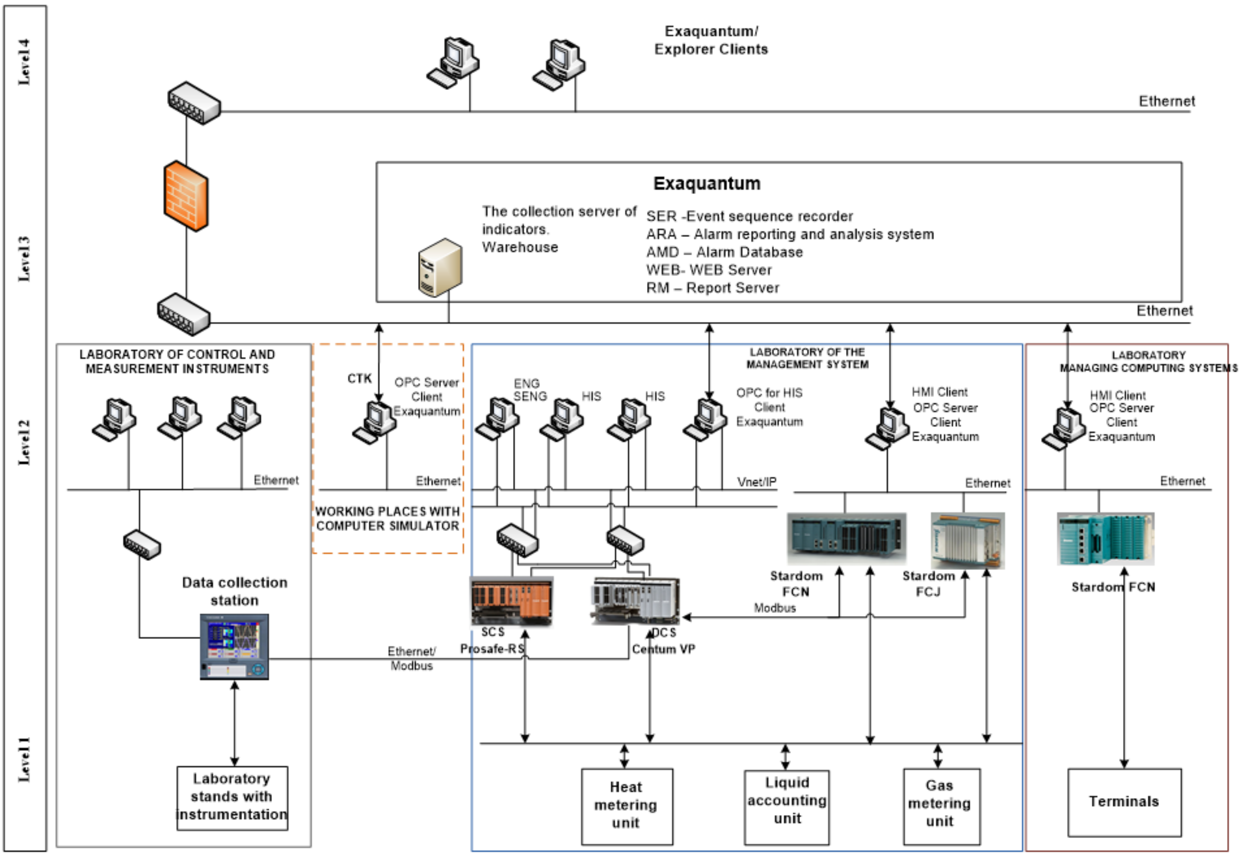

Figure 6 - Structural diagram of the training software system ACS

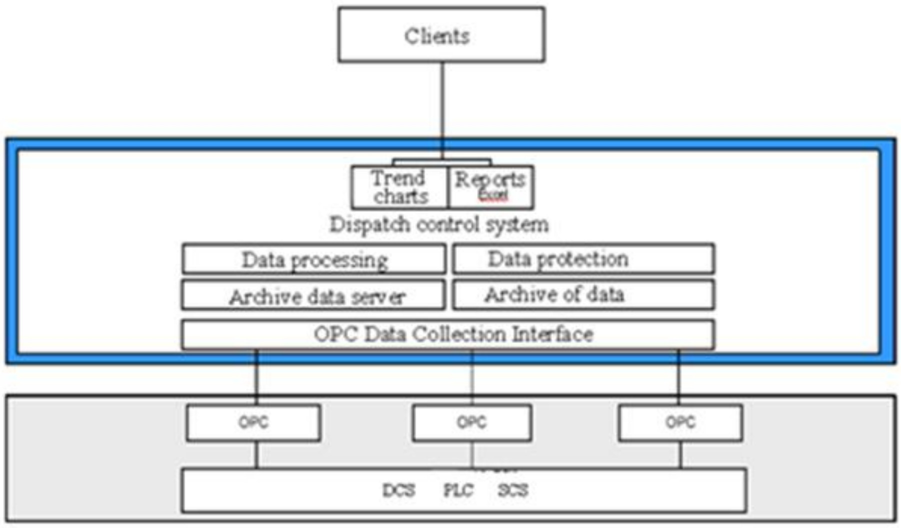

Figure 7 - The structure of the applications for the Exaquantum training software complex ACS

The training software package of the automated control system has a multi-level architecture with OPC servers and consists of the following levels:

- Interface for data collection from DCS, emergency protection, PLC via OPC server;

- Archived data storages that manage the main storage of production data;

- Data archive, which is an extended data warehouse;

- An information processing layer comprising internal algorithms for processing the obtained production data, for example, aggregation calculation processing;

- Data protection is an application module responsible for providing client applications that have access to production data in archive storage.

- Supervisory control module - a module responsible for providing production data to client applications.

IV. CONCLUSION

The training program complex AMS covers almost all the basic levels of the complex automation pyramid of an enterprise, providing training in conditions close to real in industrial enterprises. It allows us to clearly teach trainees the methods and principles of building automated enterprise management systems.

The organization of the educational process on the basis of this complex will allow trainees to gain knowledge and acquire practical skills in the field of integration of enterprise management systems, skills in working with software and hardware used at various levels of automation, and as a result, will provide a deep understanding of the essence of the studied disciplines.

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