The main technical solutions for the creation of an automated control system for the technological process of thermal vortex enrichment

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Abstract. The main technical solutions for the creation of an automated control system for the technological process of thermal vortex enrichment were adopted for the creation of an integrated resource-saving technology and the organization of high-tech production of nanostructures based on carbon and silicon dioxide to improve the properties of building and structural materials using control digitalization techniques technological processes. The decisions were made taking into account the dependence of the process of obtaining a modifying additive containing nanostructures in the form of spherical silicon dioxide on a large number of interrelated variables, a variety of operating modes of the technological line, and instantaneous changes in parameters. Technical solutions have been developed for the structure, means and methods of communication for information exchange; interconnection with adjacent systems, ensuring its compatibility; modes of operation, diagnostics of system operation; number, qualifications and functions of personnel, modes of their work, the order of interaction. This includes also requirements for ensuring the given consumer characteristics of the system, which determine its quality; the composition of functions, complexes of tasks implemented by the system; a set of technical means, its placement at the facility. Besides, it concerns the composition of information, volume, methods of its organization, types of machine media, input and output documents and messages, information processing sequence and other components; the composition of software, languages of activity.

1. Introduction
The main stream of the science in the future is resource and energy saving technologies [1-4]. A characteristic feature of the process of obtaining a modifying additive containing nanostructures in the form of spherical silicon dioxide is the dependence of its flow on a large number of interrelated variables, a variety of operating modes of the technological line, and instantaneous changes in parameters [1-4].

Ensuring the stability of the technology is achieved by collecting and processing data on the state of the technological process every second. To ensure constant technological control of equipment operation and parameters of the technological process, to ensure its safety, an automated control system for the technological process of obtaining a modifying additive based on silicon dioxide has been developed [5-8]. When creating the system, the following technical solutions were adopted [9-12].
2. Decisions on the structure, means and methods of communication for information exchange

Step The automated control system for the technological process of thermal vortex enrichment has a modular structure with a clear division of functions between its subsystems. The performance of the functions of an automated control system for the technological process of thermal vortex enrichment, as well as access to the data and control structures contained in it, is carried out through specialized components that have mechanisms based on a human-machine interface for interacting with users. In the process of functioning of the automated control system for the technological process of thermal vortex enrichment, the procedures for exchanging data between the subsystems are carried out using software [13-15].

The automated control system for the technological process of thermal vortex enrichment is a set of automated systems of separate departments, which can function both separately, while ensuring at each level the functioning of individual subsystems in full within a separate automated system, and jointly ensuring the functioning of subsystems within the framework of general information interaction [16-19].

The automated control system for the technological process of thermal vortex enrichment includes the following subsystems:

- a subsystem for collecting primary information, processing, generating control actions and data transmission;
- data storage subsystem;
- a subsystem for generating and visualizing reports.

Work on the development of an automated control system for the technological process of thermal vortex enrichment was carried out taking into account the following requirements:

- support of generally accepted technologies for information processing and presentation;
- use of standard sets of tools within the automated control system for the technological process of thermal vortex enrichment;
- openness of data structures;
- focus on reliable equipment;
- building taking into account ease of use for the end user;
- construction of an automated control system for the technological process of thermal vortex enrichment, taking into account safety requirements.

3. Decisions on modes of operation, diagnostics of system operation

The automated control system for the technological process of thermal vortex enrichment is designed to function during the working time set by the Customer, except for cases caused by the occurrence of force majeure circumstances [20-21].

The following operating modes are provided:

1) Normal mode of production operation:

- execution of automated functions of technological process control;
- displaying the parameters of the technological process, technological equipment;
- archiving and backup of technological information;
- administration, management of basic settings.

2) Operation in emergency situations:

- execution of automated functions of technological process control according to the algorithm.

In the event of force majeure circumstances leading to the downtime of the APCS 2, the interaction between the subjects is temporarily suspended until the moment of full restoration of working capacity, while the control systems of individual departments can continue to function in normal modes.
4. Decisions on the number, qualifications and functions of personnel, their modes of operation, the order of interaction

For the technical and system support of the system, to perform the functions of system administration, the creation of a technical support group is required. The recommended number of technical service personnel required to maintain the system is given below.

The following is the requirements for the qualifications and positions of the system technical support group(s).

The automation engineer performs the following tasks:

- ensuring the operability of technical means and software of automated information and measuring systems (AIIS) and automated control systems (ACS) in technological shops and departments, operation of systems for the protection of technological equipment;
- ensuring the uninterrupted functioning and maintenance of systems transferred to industrial operation in accordance with the requirements and rules set out in the technical documentation;
- metrological support of the automated control system for the technological process of thermal vortex enrichment;
- implementing production control over compliance with industrial safety requirements in the sector;
- coordinating and directing the work of the engineering and technical personnel of the sector on maintenance and modernization of software, on the development and correction of working documentation for software. Control the timeliness of making all necessary changes and additions to the programs and work instructions;
- coordinating the work of the department of the automated control system for the technological process of thermal vortex enrichment with the technological department;
- constantly improving their qualifications and qualifications of personnel, organize the study and implementation of advanced methods in work. Organize in the sector and conduct work on training and preparation for independent work of young specialists newly entering the sector, as well as those transferred from other workshops in accordance with the rules and regulations in force in the association.

Persons with a higher technical education in the specialty "Automation of technological processes and production", work experience of at least five years are appointed to the position of an automation engineer.

The instrumentation and control locksmith on duty performs the following tasks:

- repair, adjustment, installation of automatic and electronic equipment;
- check of electrical measuring instruments of all types and systems;
- check and adjustment of automation units, control units on automatic machines with programmed control;
- identification and elimination of equipment malfunctions;
- determination of the degree of wear of parts and assemblies;
- commissioning and comprehensive testing of control schemes and automation of technological equipment;
- assembly of circuits for testing automation devices;
- mathematical processing of measurement results and registration of the necessary materials.

Persons with higher professional engineering and technical or secondary vocational education are appointed to the position of the duty mechanic of instrumentation and automation.

The required number of personnel for the technical support group is shown in Table 1.
Table 1. Required number of technical support staff.

| Personnel name | Quantity |
|----------------|----------|
| Automation engineer | 1        |
| Locksmith on duty for instrumentation and automation | 3        |

The functions of personnel (operator, shift supervisor) working with an automated control system for the technological process of thermal vortex enrichment include:

- remote control and monitoring of the technological process, presented on mnemonic diagrams;
- prompt notification of service personnel about pre-emergency process situations and malfunctions of technical automation equipment.

5. Information on ensuring the specified consumer characteristics of the system that determine its quality

Ensuring the compliance of the developed automated control system for the technological process of thermal vortex enrichment with the technical requirements is carried out through the following measures:

- automatic interrogation of sensors and devices, processing of input signals is achieved by using a distributed data collection system, built on the USO of Siemens, which interact with each other via Ethernet;
- control of technological processes and equipment is carried out by the control of the burner, smoke exhauster, screw feeder motor and air supply damper to the cooling zone.

Requirements for the organization of input data are provided:

- using sensors and devices with an output analog signal (4-20 mA);
- using sensors, instruments and devices in a discrete format (dry contact, 24 V);
- using a digital communication channel Ethernet for communication between distributed input-output systems, controllers, AWPs and operator panels, frequency converters;
- using automated workstations, as well as operator panels to ensure the input of user commands.

The requirements for the organization of the output are provided by:

- using discrete signal output modules (24V);
- using a digital communication channel (Ethernet, etc.) for communication between distributed input-output systems, controllers, workstation and operator panels, frequency converters;
- using automated workstations, as well as operator panels for displaying graphic information.

Timing requirements are provided by using 1/O modules with a polling time of less than 2 s;

Requirements for the composition and parameters of technical means are provided by the use of an appropriate set of technical means.

Siemens programmable logic controllers, Simatic S7-1214C with parameters:
- operation time is no more than 2.3 μs;
- the number of channels in the local input-output system is not more than:
  - discrete input -146;
  - discrete output-142;
  - analog input - 67;
  - analog output -33.
  - built-in interfaces - Ethernet;
  - loadable memory (MMC) not less than 4MB.

Personal computer must be with the following parameters:

- processor with a clock speed of at least 3.0 GHz;
- RAM of at least 4 GB;
6. The composition of functions, complexes of tasks (tasks) implemented by the system
The system consists of the following subsystems and tasks.

The system includes the following functional subsystems:

- subsystem for collecting primary information, processing, generating control actions and data transmission, designed to implement the processes of collecting primary information about the course of a technological process, bringing this information to a form convenient for program processing in accordance with algorithms, generating control actions, and so the same for data exchange via digital communication lines;
- subsystem for generating and visualizing reports, designed to generate information about the progress of the technological process, archived data in tabular and graphical form.

7. Solutions for a set of technical means, its placement at the facility
A distributed control system was chosen as the structure of the automated control system for the technological process of thermal vortex enrichment. This structure provides independent control functions for each of the 5 thermal vortex enrichment lines. If the equipment of the adjacent departments fails, the rest continue to function normally. The same situation occurs when the integrity of the network cable is violated.

When using the control system, a line of Siemens controllers of the Simatic S7 1200 series was chosen.

Rittal modular cabinetry was chosen to accommodate the control systems.

The following primary technical means were selected to control the technological process:

- measuring the temperature of the air entering the combustion chamber, the temperature of the air at the exit from the combustion chamber, the temperature of the air flow at the beginning and end of the vortex enrichment tube, the temperature in the cooling gas duct, the temperature of the air entering the cooling gas duct, the temperature in the bag filter hopper - thermal converter with unified output signal Metran 2700;
- signaling the presence of material in the pipeline after the feeder - microwave sensor for the presence / absence of flow of solid bulk materials MWS-DP-3;
- speed control for blower M1-1, smoke exhauster M2-1, screw feeder M3-1 - Schneider Electric Altivar Process ATV600 frequency converters;
- vibration level switch VEGAWAVE 61 for signaling the upper and lower levels in the raw material hopper and the bag filter hopper;
- controlling the gas flow rate in the combustion chamber - vortex flowmeter Rosemount 8800;
- measuring the pressure of compressed air in the main, gas pressure in the main, pressure at the beginning of the vortex enrichment pipe, pressure at the end of the vortex enrichment pipe, pressure in the cooling gas duct, pressure in the clean and dirty chambers of the bag filter - pressure sensors of the Metran 55 series;
- valves for supplying compressed air for bag filter regeneration - SMC solenoid valves for cleaning bag filters of the VXF2 series.

All primary converters are located on process pipelines, equipment in such a way as to ensure ease of maintenance, as well as to fulfill the requirements for the installation of devices specified in the operating manuals.
The power supply for the control cabinets envisaged in this project is carried out from the existing power supply boards. Power supply for the lower level of automation is provided from control cabinets.

8. Decisions on the composition of information, volume, methods of its organization, types of machine media, input and output documents and messages, information processing sequence and other components

The information consists of data coming from the following sources:

- sensors and primary converters;
- buttons and switches;
- automated workstations (AWP);
- operator panels;
- personal computers (PC).

By volume, the information is divided into:

- small (sensors and primary converters);
- medium (operator panels, remote data collection stations);
- large (AWP, PC).

Organization method:

- analog (two-three-wire single-point: current loop, resistance);
- digital (two-wire, multipoint: RS-485);
- digital (multi-wire, multipoint: Ethernet).

Types of media:

- flash memory of the controller, operator panel;
- hard drive AWP, PC.

Output documents and messages:

- process trends;
- logs of emergency messages.

The sequence of information processing:

- raw information from sensors, instruments and devices enters the PLC via analog or digital communication channels;
- brought to real values, check for validation of raw information from sensors, bringing it to real values with processing of pre-alarm and emergency limits. Saving data in the PLC memory;
- processed data are used in control algorithms and form data for controlling devices and mechanisms. And they also enter the upper levels via digital communication channels: operator panels, AWP and PC;
- information received from the lower level is displayed on mnemonic diagrams of AWP.

9. Decisions on the composition of software, languages of activity

The delivery set of the automated control system for the technological process of thermal vortex enrichment includes the developed software (hereinafter referred to as the program) for the PLC and PC.

The PLC program is a project developed in Siemens Simatic Step7 environment.

The PC program (SCADA) is a project developed in the Siemens TIA Portal environment.

To develop an automated control system for the technological process of thermal vortex enrichment, the following programming languages, queries, representations, visual modeling are used:

- standard IEC 61131-3 (LD, FBD);
- STL (IL IEC 61131-3 modified by Siemens Simatic Step7);
- ANSI C.

For the functioning of the automated control system for the technological process of thermal vortex enrichment at the AWP, Microsoft Windows 8.1 (OS) software is required.
10. Conclusion
The main technical solutions for the creation of an automated control system for the technological process of thermal vortex enrichment were adopted according to:

- structure, means and methods of communication for information exchange;
- interconnection with related systems, ensuring its compatibility;
- modes of operation, diagnostics of system operation;
- number, qualifications and functions of personnel, modes of their work, the order of interaction;
- requirements for ensuring the specified consumer characteristics of the system, which determine its quality;
- composition of functions, complexes of tasks implemented by the system;
- set of technical means, its placement at the facility;
- composition of information, volume, methods of its organization, types of machine media, input and output documents and messages, sequence of information processing and other components;
- composition of software, languages of activity.

The main technical solutions for creating an automated control system for the technological process of thermal vortex enrichment are necessary and sufficient to achieve the goal of creating an automated control system for the technological process of thermal vortex enrichment.

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