Description of software for an automated control system for the technological process of thermal vortex enrichment

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Abstract. The software description of the automated system for controlling the technological process of thermal vortex enrichment was carried out as part of a project to create a comprehensive resource-saving technology and organize high-tech production of carbon and silicon dioxide nanostructures to improve the properties of building and structural materials. The description of the software hardware complex consists of a description of its structure, a description of the software parts and their functions, methods and software development tools, the selected operating system, and tools that expand the capabilities of the application operating system. The composition and structure of software support the requirements of technical, informational and mathematical software.

1. Introduction
When developing software for an automated process control system for thermal vortex enrichment, designed to control and control the process of thermal vortex enrichment to obtain a modifying additive based on silicon dioxide (MD1), the following documents are guided [1-4]:

   Technical support:
   - description of automated functions;
   - description of the complex of technical means;

   Information Support:
   - description of information support;
   - description of the organization of the information base;

   Mathematical and algorithmic support:
   - description of algorithms.

2. Software structure
Figure 1 shows the software structure of an automated process control system for thermal vortex enrichment.
Figure 1. Software structure of an automated process control system for thermal vortex enrichment.

3. Functions of software parts

3.1. Step 7
Step 7 - Siemens software for the development of automation systems based on programmable logic controllers. Included in the TIA Portal v.13 package. Includes:
- High level programming languages.
- Graphic languages for technology professionals.
- Related software for diagnosis, simulation, remote maintenance, development of factory documentation, etc.

With the help of this program, a set of works is carried out to create and maintain automation systems based on programmable logic controllers Simatic S7-1200, S7-1500, S7-300 and Simatic S7-400 from Siemens. First of all, these are work on programming controllers.

Step 7 allows you to configure programmable logic controllers and networks. During the configuration process, the composition of the equipment as a whole, the division into modules, connection methods, used networks are determined, settings for the used modules are selected.

The system verifies the correct use and connection of individual components. The programming of the controllers is carried out by the program editor, which ensures the writing of programs in three languages:
- LAD - language of relay-contact logic;
- FBD - functional block diagram language;
- STL is the language of the instruction list.

In addition to the three main languages, four additional languages, available separately, can be added:
- SCL is a structured control language similar in syntax to Pascal;
- GRAPH 7 - language for managing sequential processes;
- HiGraph 7 - control language based on the system state graph;
- SFC is a state diagram language.

3.2. Features Step 7
Parameter setting tools:
- block diagram: provides visibility and simplifies the process of selecting controller settings. Individual functions can be activated or transferred to a passive state using program keys;
- test functions with the display of the cycle and curves of parameter changes: they allow you to set up the controller with recording and displaying graphs of changes of four parameters;
- optimization of the regulatory process: allows you to follow all the steps to optimize the regulatory process with the presentation of all the information necessary for this purpose. The
function allows you to quickly optimize the regulatory process even in cases where the user does not have the skills to perform such work;

- dynamic tuning: the frequency of sampling the values of the current parameters can be set such that in dynamic operating modes the deviation of the adjustable parameter from the set value will not exceed 10%. If necessary, adjusting the controller can be performed so that deviations of the adjustable parameter will not occur (aperiodic approximation to the set value);
- dead zones: for each regulator dead zones can be set, which allow maintaining adjustable parameters with a certain degree of accuracy. If this is not necessary, then dead zones may not be established;
- context-sensitive help functions: at any point in the program, the necessary help can be received.

3.3. Standard Function Blocks Step 7

Standard functional blocks ensure the execution of specified control algorithms and control the corresponding data structures. When configuring using software switches, the following settings of functional blocks can be activated or put into a passive state:

- processing of setpoints using a task generator, a timer, normalization, function call (FC), an adjustable sawtooth signal generator, limiting the rate of change of tasks and their limit values.
- processing of current values of adjustable parameters with performing operations of scaling, smoothing, calculating rms values, calling functions (FC), comparing with sawtooth signals, checking boundary conditions and controlling deviations.
- deviation processing taking into account the dead band and checking boundary conditions.
- step-by-step PID control with or without feedback.
- processing control actions with their manual or automatic correction, using the FC functions, normalizing, scaling, checking boundary values and the rate of change.

The program consists of logical blocks and data blocks. Logical blocks are: organizational (OB), functional (FB) and functions (FC).

The operating system makes the following data available:

- peripheral inputs and outputs;
- overview of the process at the inputs and outputs;
- markers;
- counters;
- timers.

Only one-character table is created for the S7 controller program, regardless of which programming language was selected. The types of data that Step7 works with are shown in Table 1.

**Table 1.** The data types that the Step7 controller works with.

| Data Type | Description |
|-----------|-------------|
| BOOL      | Data of this type are bit combinations. From 1 bit (type BOOL) to 32 bits (DWORD). |
| BYTE      | Data of this type occupies exactly one character from the ASCII character set. |
| WORD      | This data is available for processing numerical values (for example, for calculating arithmetic expressions). |
| DWORD     | This type of data represents different time and date values within STEP 7 (for example, to set a date or enter a time value for a timer). |
3.4. WinCC

WinCC is a modular system. The main components are Configuration Software (CS) and Runtime Software (RT) [Execution System].

Simatic WinCC - software for creating a human-machine interface, part of the Simatic family of automation systems manufactured by Siemens AG.

Designed to solve the complex tasks of the human-machine interface: from designing a single operator panel to developing powerful human-machine interface systems with a client / server architecture.

Key features of WinCC:

The process visualization is based on parameterization of graphic objects, design of graphic structures:

- numeric and alphanumeric input / output fields;
- static display of text and graphics, vector graphics;
- dynamic graphics from the HMI symbol library;
- graphics of straight, curved lines; zoom function;
- signal-dependent text lists and graphic lists;
- buttons and switches for process maintenance;
- editable fields for process values (signals);
- analog display, regulators;
- designed compositions from the main objects of the system;
- graphics of standard formats, for example, BMP, JPEG, WMF.

Alarms and Messages:

- messages from bits and analog signals, as well as an alarm telegram from Simatic S7;
- Freely definable message classes for acknowledgment and display.

SIEMENS SIMATIC WinCC remains a process visualization system for production management with the ability to build both single-user and multi-user solutions and as a platform for integrating IT and business.

SIEMENS SIMATIC WinCC Runtime Runtime Software:

- modular PC-based solution for single-user systems at the machine level;
- works under Windows;
- the basic package provides a cost-effective solution for visualization, signaling and archiving. It can be expanded with optional packages;
- flexible expansion using VB scripts and custom ActiveX elements (requires Open Platform Program);
- can be integrated into automation solutions based on TCP / IP networks;
- extended service concept with remote management, diagnostics and administration via the Internet / Intranet, as well as e-mail communication (using optional packages);
- centralized user management using the SIMATIC Logon option.

SIMATIC WinCC process visualization software:

- an operator system for visualizing and managing processes, product flows, machines and industries in all industries - from a simple single-user system to a distributed multi-user system with redundant servers and remote Web clients. At the same time, WinCC is a hub for vertical integration across the company (process management and platform for integration with the world of IT and business);
- designed for universal use thanks to solutions in all areas (for example, FDA 21 CFR Part 11 compliance) and many languages for use around the world;
- all the basic industry-standard functions are built-in: alarm and acknowledgment of events, archiving of messages and measured values, recording of all process data, configuration, user administration and visualization;
- easy and efficient configuration, thanks to object libraries, modularity, tools for processing data arrays and the ability to upload changes online;
- flexible corporate client-server structures with operator stations on the Web, distributed servers and data integrity due to redundancy;
- easy integrability, thanks to standardized interfaces, such as OPC (OLE for Process Control), WinCC OLE-DB, VBA (Visual Basic for Applications), VB script, C-API (ODK);
- a platform for integration into the company thanks to the Historian functionality built into WinCC and based on Microsoft SQL Server, standard programming interfaces and analysis clients;
- modular extension with options and additions along with individual extensions thanks to VB Script, Visual Basic for Applications, C-API (ODK) and ActiveX control integration;
- totally Integrated Automation (TIA) Integrated Component: Increases productivity, minimizes design costs, and reduces life cycle costs.

The execution system (Runtime software) allows the user to monitor and control the process. The execution system is mainly used to solve the following tasks:
- reading data stored in the CS database;
- displaying process frames on the screen;
- interaction with the automation system;
- archiving current process data, for example, process values and event messages;
- process control, for example, by the operator entering the settings, switching On / OFF.

4. Methods and tools for software development
When developing low-level controller programs, use the method of modular and top-down design using the Siemens Simatic development tools Step 7. To write complex routines, use the STL language, the simple program use LAD or FBD languages.

When developing top-level programs (human-machine), apply the method of object-oriented, modular and top-down design using the Siemens Simatic WinCC development tools. To write scripts use C.

5. Windows operating system
The Siemens Simatic Step 7 and WinCC development tools work only under the control of the Windows operating systems.

Currently, Windows is installed on 90% of personal computers and workstations.

The architecture of the Windows and Windows Server operating systems is modular. Structurally, it can be divided into two parts.

The first part runs in kernel mode and is called the Windows executive system. Kernel-mode components have the following features:
- have access to equipment;
- have direct access to all types of computer memory;
- they are not uploaded to the hard disk in the swap file;
- have a higher priority than user mode processes.

The second part works in the so-called user mode (user mode). This part is made up of protected OS subsystems. Features of the user mode processes:
- do not have direct access to equipment; all requests for the use of hardware resources must be resolved by the kernel mode component;
- limited by the size of the allocated address space, this restriction is established by the allocation of fixed addresses to the process;
- can be unloaded from physical memory to virtual on the hard drive;
- the priority of processes of this type is lower than the priority of processes of the kernel mode, this prevents the OS from reducing performance or delays.
The Windows operating system is selected as the main one, it has support for all versions of Siemens Simatic Step 7 and WinCC, it has all the device drivers and is considered the most stable and secure.

6. Tools that extend the capabilities of the application operating system

Message Queuing Services (MSMQ) is a service that is standard on Microsoft Windows Server. Using MSMQ, applications running at different times can communicate through heterogeneous networks and systems that can temporarily work autonomously. Applications send MSMQ messages and use MSMQ queues - this ensures that the message will reach its destination sooner or later. MSMQ provides guaranteed message delivery, intelligent routing, protection and priority-based messaging.

Using MSMQ, end users can communicate through autonomous networks and systems, regardless of the current state of applications and systems that are communicating. With the help of MSMQ, developers can focus on programming business logic rather than solve network problems, because MSMQ provides guaranteed delivery. System administrators using MSMQ can efficiently manage large, complex message queuing networks.

Software products with such capabilities are often referred to as message queuing support software, intermediate storage software, or message-oriented middleware (MOM, Message-Oriented Middleware).

The MSMQ service is a prerequisite of Windows for the operation of Siemens Simatic WinCC and must be installed in advance.

7. Conclusion

The software description of the automated system for controlling the technological process of thermal vortex enrichment consists of a description of its structure, a description of the parts of the software and their functions, methods and software development tools, the selected operating system, and tools that expand the capabilities of the application operating system.

The composition and structure of the software comply with the technical requirements set forth in the documents:

- description of automated functions;
- description of the complex of technical means;
- description of information support;
- description of the organization of the information base;
- description of algorithms.

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