Approach to the construction of logical control systems for technological equipment for the implementation of the concept «Industry 4.0»

R. A. Nezhmetdinov
MSTU STANKIN
Moscow, Russia
neramil@gmail.com

Petr A. Nikishechkin
MSTU STANKIN
Moscow, Russia
pnikishechkin@gmail.com

Anatolii N. Nikich
MSTU STANKIN
Moscow, Russia
a.nikich@stankin.ru

***Abstract* — In work actual tendencies of development of modern industrial enterprises are investigated, the analysis of conformity of available principles of construction of systems of logic management of the concept «Industry 4.0» is spent. The principles of constructing a logical control system are described and its architectural model is proposed with the possibility of its integration into digital engineering industries. An example of solving the task of synchronizing the work of machine and robotic equipment with the application of the described approach to the construction of a logical control system as well as the possibility of transferring diagnostic information to higher control levels is given.**

***Keywords* — logical control, controller, CNC, PLC, technological process, Industry 4.0, «smart» production.**

I. Introduction

Today's stage of development of society is attributed to the post-industrial, the basis of which is information, as a means and object of production. In this environment, the means for collecting, processing and transmitting information have changed: more and more people use mobile devices to work with information resources, and to access large amounts of data, they use a global network and cloud technologies [1]. These changes are reflected in industrial technologies that have shifted from the concept aimed at automating individual machines and processes to the concept «Industry 4.0», which provides for the digital representation of all physical assets with subsequent integration into the digital global system, built in conjunction with partners participating in the value chain. The new concept is based on a multilevel, complex, global technological and organizational system that implies the integration of physical operations and the accompanying processes into a single information space.

The concept «Industry 4.0» includes 6 aspects, each of which influences the technological system as a whole: product life-cycle management, work with large volumes of data, organization of «smart production», organization of cyber-physical systems, «Internet of things», Interoperability of system elements [2, 3].

To date, the most common automation of machine-building production is PLC-based logic control systems, while modern automation tools such as SoftPLC and PAC (programmable automation controllers) are becoming increasingly popular, but none of them fully corresponds to all aspects of the concept «Industry 4.0» (Table 1).

The system of logical control implemented with the support of the "Industry 4.0" concept should: have a channel of interaction with product lifecycle management systems, which will allow the operative transfer of information on the state of the material and technical base of individual production units and sites; support work with large amounts of data (including through cloud technologies), which are collected directly from the objects of management; have the opportunity to work in the structure of digital engineering production, including in the framework of virtual production corporations; to support the main industrial and network protocols for the possibility of interaction within the network of the enterprise; have an Internet connection with support for the transmission of control commands and specified information about the operation status of the control object.

II. The approach to building a logical management system for integration into digital engineering industries

Figure 1 shows the hierarchical structure of digital engineering production with a dedicated logical control system. At the lower level of the structure are located sensors and actuators, which include: feeders and main motion drives, hardware I /O modules, measuring devices, etc.

The control systems of technological equipment (CNC, RobotControl, PLC, etc.), located on the level above, unite the sensors and actuators on the basis of specialized industrial protocols of interaction. At the level of control systems, SCADA systems also operate, which receive data on the operation of process equipment and present them to operators in a form convenient for analysis [4, 5].

The combination of a large number of technological equipment from different manufacturers makes it difficult to monitor their functioning and complicates the process of transferring technological information to higher production levels (MES, ERP). There is a need to synchronize and dispatch data flows from control systems of technological

Table 1. Analysis of the correspondence of the logical control systems of the concept «Industry 4.0»

	PLC	PAC	Soft PLC	Controller in the concept «Industry 4.0»
Product lifecycle management	Communication with PLM systems with the use of an intermediate hardware and software link for the collection and processing of information			Communication with PLM systems directly
Working with large data	–	Depends on the specific software implementation		Resources for working with large amounts of data
«Smart» Production	Supported by individual flagship models	Depends on the specific hardware and software implementation		Implement the concept of smart production
Cyber-physical systems	Capable to work in a uniform network space of the enterprise if it is realized with support of standards of the concrete manufacturer of the equipment			Work in a single enterprise network space
«Internet of Things»	Supported by individual flagship models	Have access to the global network	Depends on hardware platform	Have access to the global network
The possibility of linking the equipment of different manufacturers into a single system	Only at the level of hardware signals			Implements a full synchronization, based on multi-protocol
Interoperability	Support for a specific standard and communication protocol (depending on the manufacturer)			Support for all the most common standards

equipment operating on the basis of heterogeneous industrial communication protocols.

The existing process monitoring systems, such as InTouch (Wonderware, USA), WinCC (Siemens, Germany), Citect (CI Technology, Australia), are closed solutions operating with a limited number of industrial protocols and intended primarily for monitoring the operation of equipment from a single manufacturer, i.e. work with complete solutions.

To solve this problem, it is proposed to organize an additional level on which a specialized logical control system is located, the main functions of which are: communication with top-level management systems and dispatching of information transfer between technological equipment. This will allow to combine diverse equipment of different manufacturers into a single network and organize information exchange between automated cells [6].

Figure 2 shows the architectural model of a logical control system. The most important feature of the proposed approach is the implementation of cross-platform functions, both at the system and hardware levels. This allows to use several hardware platforms (x86 / ARM), with one of the supported real-time operating systems installed on it (Windows RTX, Windows CE, Linux RT) [7]. The implementation of hardware support of several platforms provides an opportunity to build a logical management system both on the basis of personal computers and on the basis of single-board computers and create independent compact devices for automation of technological processes, with the possibility of remote control and access to data, which is one of the most important principles the basis of building «smart» productions.

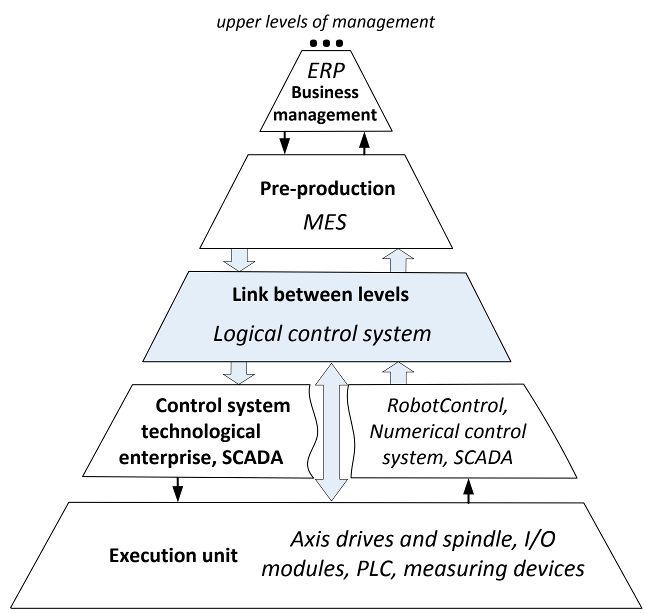

Fig. 1. The structure of digital engineering production with the separation of the logical control system

Figure 2 shows the architectural model of the developed logical control system. At the level of the operating system, there is a division into user space intended for visualization tasks and interaction with top-level management systems, and kernel space responsible for performing management tasks and interacting with hardware devices.

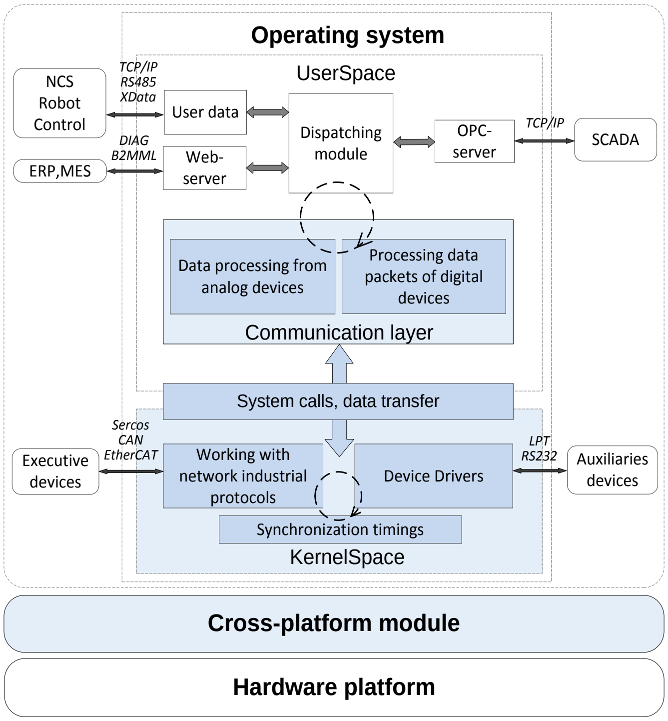

Fig. 2. Architectural model of the logical control system

The transfer of data between the spaces is organized using the mechanism of system calls, through which data comes from the kernel space into the communication layer of the user space. The parsing of data packets in the communication layer is performed depending on the type of signals: analog or digital, then data verification is carried out, which is realized in the corresponding module. To transfer information to the systems: the top-level management and remote diagnostics and configuration, the dispatching module is used. At the same time, the ability to work with various equipment is achieved by implementing: a modular approach, the invariance of the application of various industrial communication protocols. This allows the logical control system to retrieve data from the CNC system about the position of the machine axes via the high-speed communication protocol (for example, SERCOS) and transmit them to the industrial robot control system for synchronization with the operating element, while the robot control system can be organized using a different industrial protocol than the CNC system. The logical control system also has an OPC UA server, which allows you to organize the transfer of information about the progress of the process in SCADA.

III. Practical Implementation

Consider the solution of the task of synchronizing the work of the milling machining center with the CNC and the robotic complex (RTC). The Logic Controller acts as a dispatcher between the robot control system and the machine's CNC system, thereby synchronizing the process control processes of the process equipment, regardless of the protocols used.

The controller monitors the operation status of both systems and is connected to the emergency shutdown hardware circuit of each technological unit, allowing to prevent errors and emergencies.

Figure 4 shows the program of logical control of the machine and the RTC with synchronization of their actions among themselves, developed in the language of function blocks (FBD).

In the presented program there are special function blocks for processing signals about the status of the machine (iChannel) and robot (RobotState), both received from the hardware part and their digital control systems. The program of logical control determines the completion of the workpiece processing, blocks the work of the machine and sends a signal to change the workpiece, if any. After that, the enabling signal for processing a new workpiece is fed. During the processing process, the operation of the RTC is blocked to prevent emergency situations [9-10].

The result of the program is control commands and generated error signals, which are then displayed to the operator in the SCADA system. In the presence of critical errors, emergency shutdown of the main power circuits is performed.

Fig. 3. Remote control and monitoring of technological processes

The controller has the ability to transmit information about the controlled process to the upper levels of production: in specialized SCADA systems, through which the operator can monitor the status of work and emergent emergency situations, as well as higher-level systems (ACS).

The controller has remote control functions and monitoring of controlled processes, including using smart devices (tablets, mobile phones, laptops).

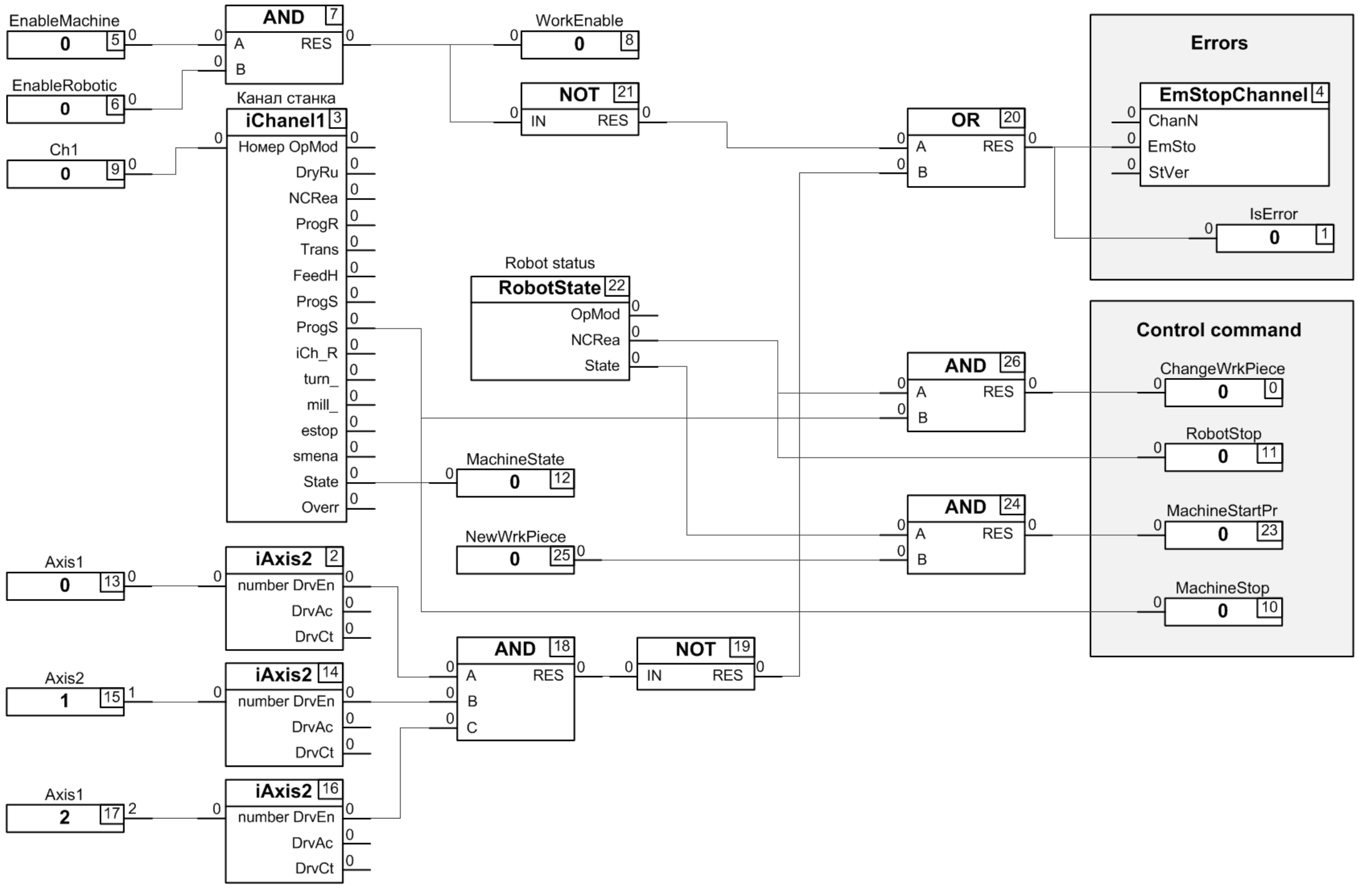

Fig. 4. The program of logical control for the implementation of synchronization functions of machine and robotic equipment

IV. Conclusion

The advantages of the solution proposed in the work include: the ability to manage heterogeneous equipment in accordance with the principles of multi-protocol, synchronize the operation of this equipment, as well as the rapid transfer of information to higher production levels due to the high level of network interaction, which is an important factor in building modern production facilities, corresponding to the concept of «Industry 4.0».

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