An approach of developing solution for monitoring the status and parameters of technological equipment for the implementation of Industry 4.0

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An approach of developing solution for monitoring the status and parameters of technological equipment for the implementation of Industry 4.0

P A Nikishechkin*, N Yu Chervonnova and A N Nikich

MSTU STANKIN, department of Computer Control Systems, 127055 Vadkovsky per 3a, Moscow, Russia

*pnikishechkin@gmail.com

Abstract. The article is devoted to the study of trends in the construction of «smart» industries and the theoretical aspects of developing a system for the implementation of continuous control and monitoring of technological processes in industrial enterprises. The requirements for the developed system, its functionality and basic principles of construction are formulated. The main data blocks that need to be obtained and timely monitored during the technological process, as well as methods for obtaining them, are systematized

1. Introduction

The main factor affecting the competitiveness of engineering enterprises, is the quality of manufactured products. The quality of products depends on many factors at all stages of the production cycle, including: quality of design work, raw materials and supplies, technology and organization of production, technical condition of equipment, qualification of production and management staff, quality control of the processing process, as well as control already manufactured product. The implementation of continuous monitoring of the technological process at all its stages allows you to organize feedback, forming information about the real state of production, in particular, the technological processes of manufacturing engineering parts, as well as decide on the necessary adjustments [1].

At the same time, modern enterprises have a global transition from the concept aimed at automating individual machines and processes to the «Industry 4.0» concept, which is based on a multi-level, complex, global technological and organizational system that involves integration into a single information space of individuals. operations and their accompanying processes [2-3]. The hierarchical structure of a modern digital engineering production consists of several levels, each of which contains automated information and control systems that solve various tasks (process control, monitoring systems, production preparation, financial, staffing systems, top-level control systems) that interact between themselves and allow you to implement the effective functioning of the enterprise [4].

At the same time, domestic enterprises often experience the problem of combining all equipment and control systems into a single system, which consists in the fact that the totality of heterogeneous technological equipment from different manufacturers, having different interaction protocols, complicates the monitoring of their operation and makes it difficult to implement the aggregation of all information and its transfer to higher levels of production [5]. When using heterogeneous technological equipment, differences in standards and data exchange protocols make it difficult to fully synchronize

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equipment collaboration, and sometimes even make it impossible. This greatly complicates the solution of the problem of building flexible production systems consisting of heterogeneous technological equipment. Technological process monitoring systems available on the market, such as InTouch (Wonderware) USA, WinCC (Siemens) Germany, AIS Dispatcher (Stankoservice) Russia, Citect (CI Technology) Australia, are also not able to fully solve this problem, since most of them are closed solutions, functioning with a limited number of industrial protocols, and intended mainly for monitoring the operation of equipment from a single manufacturer, for working with complete solutions [6-7].

Thus, to ensure product quality and production efficiency at enterprises, it is necessary to introduce additional automated quality control systems, one of the most important elements of which are monitoring systems of the technological process and equipment that perform feedback functions [8]. To do this, it is necessary to implement intermediate synchronization and scheduling of data flows from various process control systems operating on the basis of heterogeneous industrial communication protocols, and to create an intermediate system implementing data collection from heterogeneous process equipment and its transfer to higher levels of enterprise management [9].

2. An approach to building a process monitoring system

In the course of the study, the main data blocks were systematized, which need to be obtained and timely monitored to implement a complete monitoring of technological processes and increasing their efficiency (table 1).

Table 1. Data required for technological process control and monitoring.

Data block	Functions implemented in the developed system
Information about the technological processes route	• dispatching the passage of the part along the technological route using QR-code technologies; • analysis of the execution time of technological stages and the possibility of their optimization.
Equipment performance	• counting the time of active work of the equipment (work not in idle mode); • calculation of equipment downtime; • analysis of the total workload of the equipment during the implementation of the technological process; • analysis of opportunities to optimize equipment operation.
General condition of the equipment	• collection of data on the current modes and the state of operation of process control systems; • determination of the correctness of performance of the planned tasks on the process equipment; • a visual representation of the picture of the work of an individual machine, workshop, and/or the entire production by building its own control and monitoring terminals; • environmental monitoring of equipment (temperature, humidity, dustiness, etc.).
Operator's work and actions	• fixing the work of a specific operator with specific equipment; • analysis of operator performance; • analysis of erroneous operator actions.
Diagnostics of complex and critical equipment operation nodes	• diagnostics of the cutting tool condition and prediction of its residual durability; • the ability to install additional sensors and sensors to monitor the operation of individual machine components; • determination of the state of operation of technological equipment equipped with closed control systems; • determination of the state of operation of the main components of the equipment by manual control - universal machines and other machines; • determination of indicators exceeding the permissible norms to determine the emergency situation in the equipment operation.
The quality of manufactured products	• storing data on metrological measurements; • analysis of the repeatability of the deviations found in the manufacture of similar products; • analysis of the impact of changes in the process on the quality of finished products.

Figure 1 shows the options for the interaction of the data collection system with heterogeneous technological equipment within the production site or workshop from which data should be collected and processed.

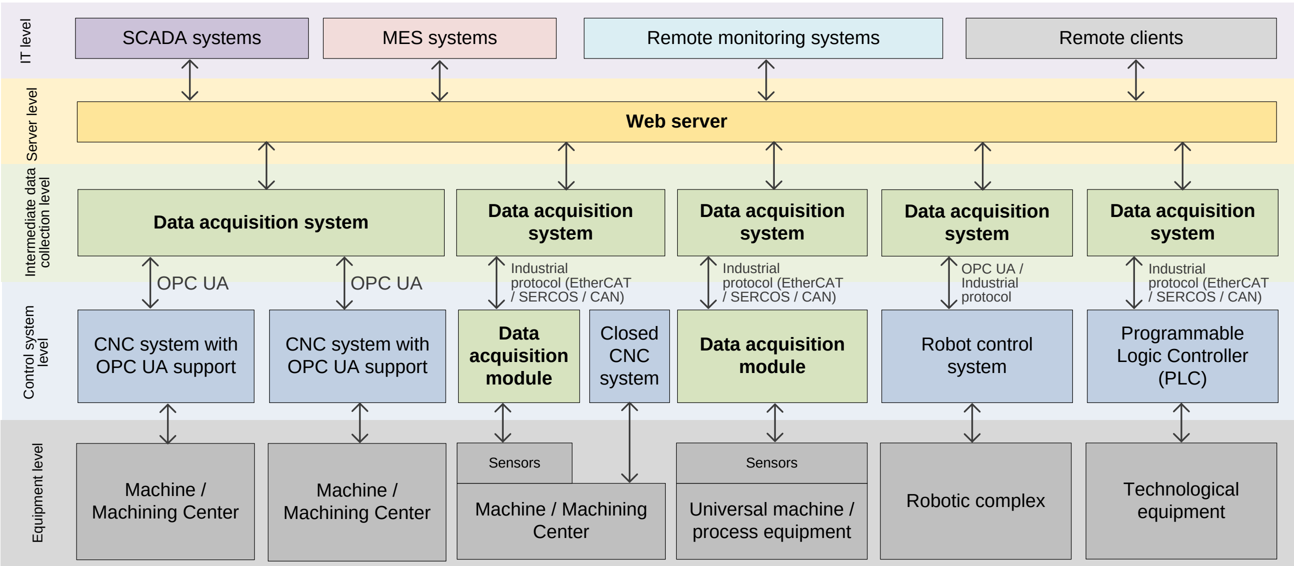

Figure 1. Approach to building a monitoring system of technological processes within a production site with different equipment variations

As can be seen from the figure, the complex can collect data from the process equipment in three ways:

• using the OPC UA standard, if one is supported by the CNC system or other control system;

• by connecting the data acquisition system to the industrial network used by the equipment using one of several industrial protocols (EtherCAT, SERCOS, CAN).

• using an additional hardware data acquisition module that receives information from sensors that need to be equipped with equipment for monitoring its operation status. A similar option is used to control equipment that uses closed control systems, or there is no control system at all (universal machines).

At the same time, the complex has some restrictions on the amount of data transmitted and processed, therefore the number of such solutions for collecting data from the production site may vary, depending on the complexity of the equipment [13-14].

It may be noted the main advantages of the developed solution over the analogues available on the market:

• simple data exchange between production and IT levels, including MES systems, analysis applications, database applications and cloud applications;

• universality of use, almost regardless of the type of equipment and control systems available;

• no interference with the equipment operation program due to the parallel launch of the data collection function and machine control;

• the possibility of building your own control terminals.

3. Practical implementation and testing of the basic version of the monitoring system

The main part of the complex being developed will be a software and computing module that allows interaction with various types of equipment using industrial communication protocols EtherCAT, SERCOS, CAN, OPC UA standard, and the ability to read data from additional sensors installed on process equipment [15]. The information is then aggregated in a centralized repository on a server, from where it can be transferred to higher levels of production management (SCADA, MES, ERP, OLAP) or provided to remote clients upon request. The solution architecture also allows you to process and configure at the request of operators, installers, etc. the exact data set that is most important and necessary at a given time.

As an example of the application of the basic version of the developed solution, two training and demonstration stands were chosen that simulate the operation of heterogeneous technological equipment. The first stand is equipped with the CNC system «AxiOMA Control» and simulates the control process of a milling machine. At the second stand, the conveyor control is simulated using a software-implemented controller [16-17]. At the same time, the task was to collect and visualize basic information on the operation of the process equipment, namely: information on the type of equipment, operator, status of work, as well as basic technological parameters.

Information was collected using the approaches described above, shown in Figure 1. Information was collected from the CNC system using the OPC UA protocol: information about the system operation status, its continuous operation time, equipment downtime, information about the control program and the number of parts processed during the last shift. Also, information about the equipment and the operator who works with it, as well as the unique identifier assigned to it, was recorded in the database.

The process of collecting information from the stand, simulating the process of sorting parts on a conveyor belt, controlled by a software-implemented controller, was implemented using an approach in which information is read directly from the controller [18]. Thus, information about the state of the main inputs / outputs of the controller and internal variables is transmitted to the collection system: process status, number of parts, type of part, and errors.

Thus, an independent collection of information from heterogeneous equipment and its storage on a single server, with the ability to access it from other systems.

As one of the solutions for the visualization of information collected from heterogeneous technological equipment, augmented reality (AR) technology was used (Figure 2).

Figure 2. Application of augmented reality technology for visualization of information collected from heterogeneous technological equipment

Each technological equipment involved in the technological process, which is monitored, is assigned a QR code, which stores the unique identifier of this equipment. The database on the server stores information about this equipment, as well as data read from it using the developed monitoring system.

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In this case, the data necessary for visualization can be flexibly configured. Thus, the operator, or the foreman, has the ability to quickly obtain all the information he needs about the work of the process equipment in a particular area, by reading the QR code of the equipment, and see with the help of augmented reality glasses up-to-date information about the work of this equipment, updated in real time. The presented capabilities allow us to provide opportunities for operational monitoring and control over the implementation of the entire technological process, in particular for the work of operators and the state of technological equipment, both at the shop level and in higher-level control systems.

4. Conclusion

The task of building a process monitoring system based on reading basic information about the operation of process equipment involved in the process, the work of operators, the stages of manufacturing the final product and other auxiliary processes considered in this paper is relevant for building modern enterprises that meet the requirements of the Industry 4.0 concept.

The paper proposes an approach to reading and aggregating data from heterogeneous process equipment having different levels of automation and control systems from different manufacturers. The presented approach will allow to combine dissimilar equipment into a single network and transfer to the higher levels of enterprise management the most complete picture of the controlled technological process.

The considered example of monitoring the operation of process equipment controlled by the CNC system and equipment controlled by the PLC confirms the correctness of the chosen approach and the basic implementation of the monitoring system. In addition, the paper describes one of the promising ways of presenting read technological information using augmented reality technology (AR), which expands the possibilities and enhances the convenience of monitoring the technological process at the shop level.

The implementation of the presented technologies and their introduction into domestic enterprises will significantly expand the possibilities of monitoring technological processes, reduce the scrap rate, respond more quickly to emergency situations, and will contribute to the successful building of multi-level technological and organizational production management systems.

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