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Control and remote monitoring of the vertical machining center by using the OPC UA protocol

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Abstract. The article discusses the possibilities of using the OPC UA protocol to collect information from CNC machines and graphically represent data about the technological process, according to Industry 4.0 concept. A generalized organization structure of NC kernel with an embedded SoftPLC module, OPC UA server and various types of OPC UA clients has been developed. The mechanism of interaction between the NC kernel and the standalone OPC UA server is proposed. The possibility of developing a remote OPC UA web client based on the Node-red programming tool has been investigated.

1. Introduction

Modern trends in machine-building enterprises development, corresponding "Industry 4.0" concept presuppose that the creation of industrial automation systems with supporting wide communication capabilities to ensure transfer of information to higher levels of enterprise management. Collecting information about the state of production and technological system allows continuous operation's monitoring of equipment, processing and analysis of this information and making decision to adjust equipment's operating modes and improve the efficiency of production processes.

Implementation such monitoring mechanisms can significantly improve the level of organization and service, as well as reducing downtime due to organizational reasons in the enterprise. For example, considering tool's operating time in CNC machines allows to optimize the maintenance process and reduce the percentage of scrap because of the tool by optimizing tool's change time [1-4].

The described trends suggest the use of universal and platform-independent communication mechanism that implements reliable interaction between control systems at production level, and ensures information transfer to higher-level control systems (MES, ERP). One of such mechanisms is the communication technology OPC UA (Open Platform Communication Unified Architecture) [2,5-8], which corresponds to international standard IEC 62541. This technology provides ample opportunities for reliable information transfer from control devices, this information can also be used to monitor the operation process of production facilities [9].

2. Generalized diagram of a control system with an integrated OPC UA mechanism

In recent years, universal machine tools are increasingly being replaced by software-controlled equipment, specifically those equipped with CNC systems. CNC machines allow solving both geometric task (controlling movement of axes and, accordingly, part's shaping) and logical task (controlling machine's electro-automatics) by using embedded software-implemented controllers (SoftPLC) instead of external hardware PLCs. Interaction of SoftPLC with a control object is usually carried out using passive I / O modules that implement logic control functions [3,10].

The presented work describes an approach to operation state monitoring of AxiOMA Control CNC system and its embedded SoftPLC controller using OPC UA technology, which allows collecting data about state and parameters of CNC machine's industrial equipment (figure 1).

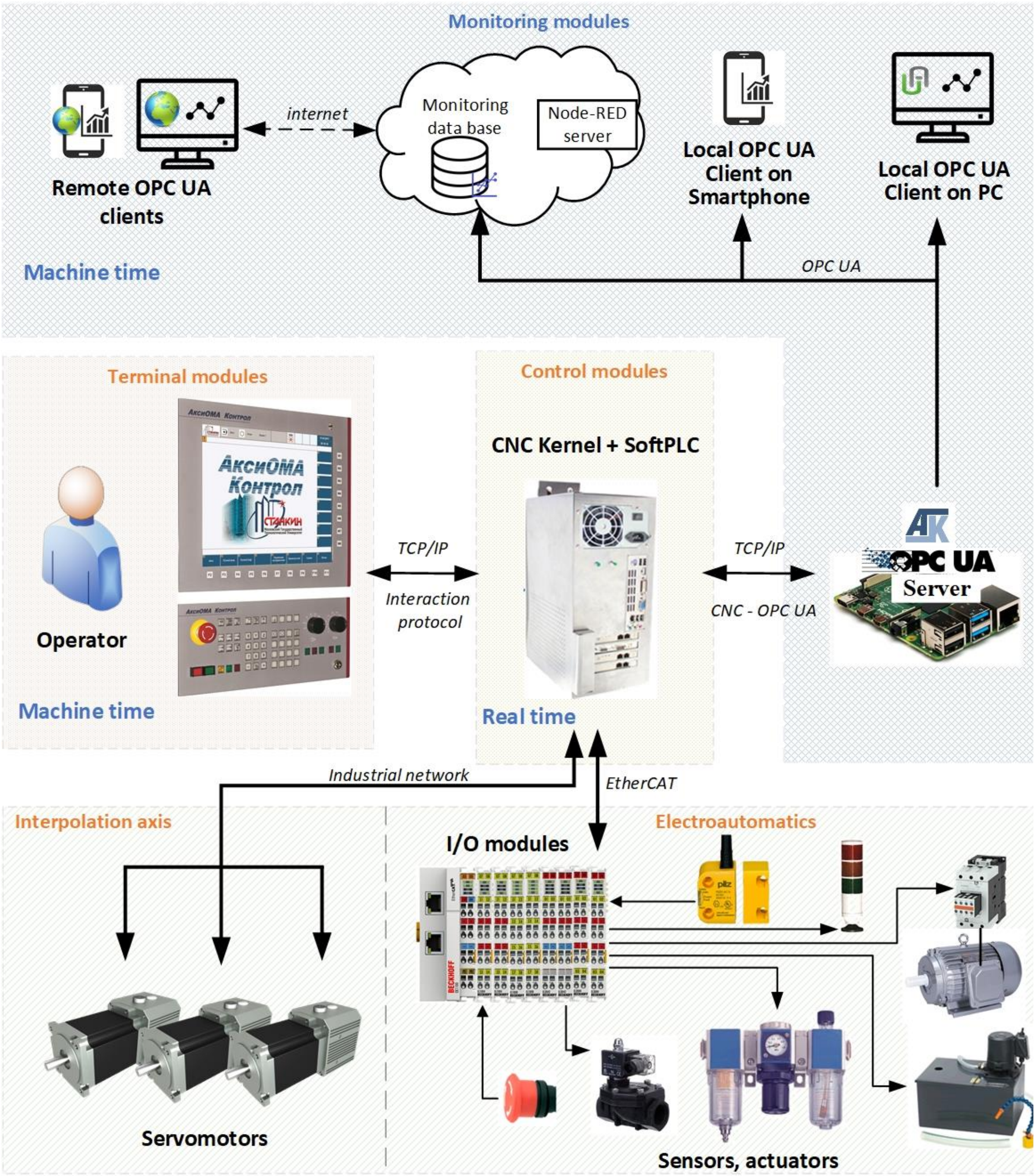

Figure 1. Architecture of building CNC machine tool with embedded SoftPLC module and monitoring the whole system using OPC UA technology.

The main computing module of the system is CNC kernel, which works in real time on an industrial computer, into which the machine operator loads the necessary ISO 7-bit control program to implement axis control function and solve shaping task. Here CNC kernel communicates with axis servo drives using one of industrial protocols (EtherCAT, SERCOS, CAN, etc.). Besides that , in the embedded software-implemented controller, PLC program is executed and the electro-automatic of the machine are controlled. Through bus coupler, SoftPLC communicates with various types of I / O modules via a fieldbus, that allows transmitting control actions to actuators, as well as receiving signals from sensors and built-in terminal objects (buttons, controllers, toggle switches, etc.) [11-13].

To implement OPC UA mechanism and monitoring functions, a server operating on the basis of a Raspberry PI single-board computer is used as a reliable and inexpensive computing platform. The implementation of interaction between OPC UA server and CNC kernel is carried out using additional monitoring software modules that interact with the kernel and its embedded controller. OPC UA server is the main monitoring module, as it contains the controller information model. Communication between OPC UA server and controller is achieved by using the developed OPC UA-CNC interaction interface, which allows converting information about the operation of system kernel and the state of the I / O modules connected to it into data blocks called nodes that contains the current state of physical input / output modules in OPC UA server. The data received from the controller is associated to corresponding OPC UA nodes in server's address space and is grouped by component type in server's information model. The use of the common OPC UA information model provides flexibility and reliability of interaction mechanism. Further, at a request of clients, the server generates standardized messages in the form of an OPC UA packet and sends them to the required addressees. Thus, it is possible to receive, at the request of clients, standardized data packages containing information about the state of CNC system and embedded controller of electro-automatic equipment [5, 14].

Local OPC UA clients are on the same production network with OPC UA server and can request information from him in real time. The information can be used to monitor the controlled processes of CNC machine, as well as analyzing and processing it in real time.

Remote OPC UA clients are web applications that connect to OPC UA server through a cloud database using Node-RED service, which allows to view the address space of OPC UA server, read its attributes, and subscribe to the changes of tracked items. Thus, remote clients can connect to OPC UA server via global Internet and monitor required parameters, for example, using a web browser on mobile devices. This allows monitoring and controlling technological processes regardless of the used hardware platform and operating system.

3. Development interaction mechanism between CNC kernel (with embedded SftPLC module) and OPC UA server

The organization of communication between CNC kernel (with an embedded SoftPLC controller) and OPC UA server presupposes the implementation of additional software modules in each of the components (figure 2).

In CNC Kernel, additionally to the main standard modules responsible for shaping task, it is necessary to develop a communication module with OPC UA, which includes a local data server and an OPC UA-CNC data module. This module is designed to form the required data packet, which is sent to OPC server in accordance with the specified structure [15].

Data transferred between CNC kernel (with embedded SoftPLC module) and OPC UA server can be conditionally divided into two main groups: general parameters of the CNC and the status of the SoftPLC I / O. The general parameters of CNC include: CNC mode, version of CNC kernel, the status of the kernel, the state of the servo drives, the current positions along the coordinate axes, the spindle rotation speed, etc. This set of parameters is unchanged and is transferred to the OPC server when controlling any process. Moreover, each of the listed parameters is a read-only parameter, with no possibility to changing their values.

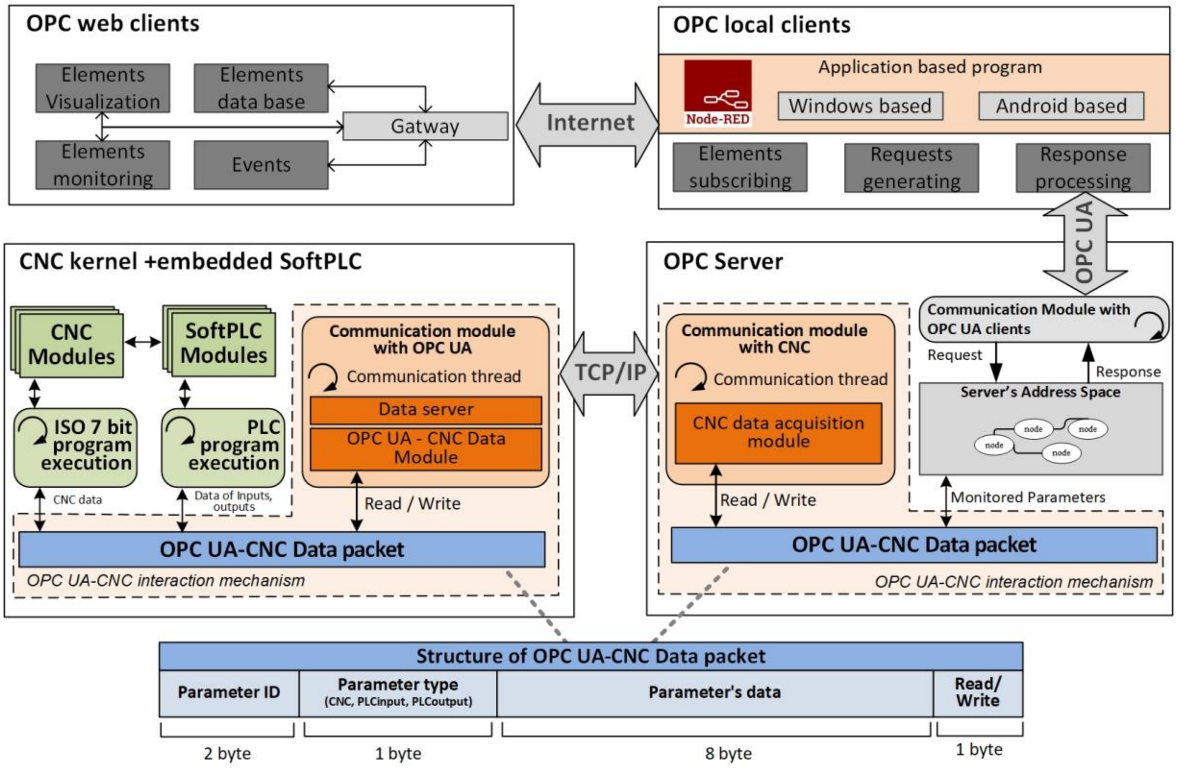

Figure 2. Implementation CNC kernel-OPC UA interaction mechanism.

The main variables of SoftPLC include controller's state, as well as the values of its hardware inputs / outputs. The set of this data may vary depending on the process being controlled. To control and monitor the operation of specific equipment in the controller programming toolkit, it is necessary to form a set of parameters that will be transmitted to OPC UA server for remote monitoring capabilities. It is also important to set the configuration of the parameter indicating whether its change is allowed through OPC UA server, or it is read-only. This will allow separating the parameters necessary for monitoring the process, and the parameters, the change of which will affect the work of controlled object, that is usually used to carry out remote parameterization [18].

From OPC UA server side, a communication module with the CNC kernel has been developed, which sends requests to get the necessary information from communication module of controller. The response data packets contain information about the requested parameters, namely, the current value of the kernel parameters corresponding to SoftPLC inputs / outputs.

Cyclic data exchange is implemented on the base of TCP / IP protocol, and thus OPC UA server receives a full set of monitored parameters, which it loads into its address space as nodes attribute. To perform monitoring tasks, the simplest way to exchange data between the client and the server is to use OPC UA read and write services, which allow any OPC UA client to read and write one or more node attributes (request / response mechanism) supported in OPC UA server address space. Thus, clients get access to the necessary data based on the mechanism of subscriptions or queries, which is a necessary feature for clients that need to cyclically update their variables values [20].

4. Example of using OPC UA mechanism for remote monitoring the work of vertical machining center Quaser MV184P

Vertical milling machining centers equipped with a CNC system are the most common milling equipment used in modern machine-building enterprises due to a combination of high reliability, versatility and flexibility in control. Also, vertical milling machining centers can be easily integrated into automated production lines.

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The Quaser MV184P vertical milling multipurpose machining center, controlled by the AxiOMA Control CNC system, contains three linear interpolated axes (X, Y, Z) and a spindle unit S. Movement along X and Y axes is carried out by moving the work table along machine bed guides. Moving spindle headstock along the vertical axis realizes movement along Z axis (figure 3).

Figure 3. Vertical milling multipurpose machining center Quaser MV184P.

In addition to shaping task and controlling the movement of axes, the vertical milling machining center contains a large number of electro-automatic units (control of circuits and power supplies, processing of auxiliary M-functions, supply of cutting fluid (coolant), automatic lubrication of axis guides, controlling chip removal mechanisms, controlling safety guards, automatic tool change), which require about 114 digital inputs and 67 digital outputs to control and monitor. The electroautomatics control of machining center is carried out using a software controller embedded into the kernel of AxiOMA Control CNC system. Monitoring machining center state includes of monitoring the operation of CNC system, as well as monitoring the operation of electroautomatics devices[10,21-24].

The developed information model of the OPC UA server, corresponds to the hierarchy of the internal structure of CNC objects, allowing to have complete and structured information about the operation of the vertical milling machining center MV184 by monitoring and controlling its operation. To test the developed OPC UA server, there are many ready-made OPC UA clients on the market, such as UaExpert OPC UA Client, Matrikon OPC UA Explorer, Siemens OPC UA client, Prosys OPC UA Browser, etc., which connect to CNC kernel via OPC UA server. to receive the necessary data from it and transmit corresponding commands. UaExpert client was chosen as a tool for testing the created OPC UA server.

UaExpert project tree displays developed OPC UA server's nodes, such as Parameters CNC kernel, Parameters SoftPLC (inputs) and Parameters SoftPLC (outputs), that require monitoring. The list of monitored nodes and the frequency of data polling can be changed and configured for specific tasks (figure 4).

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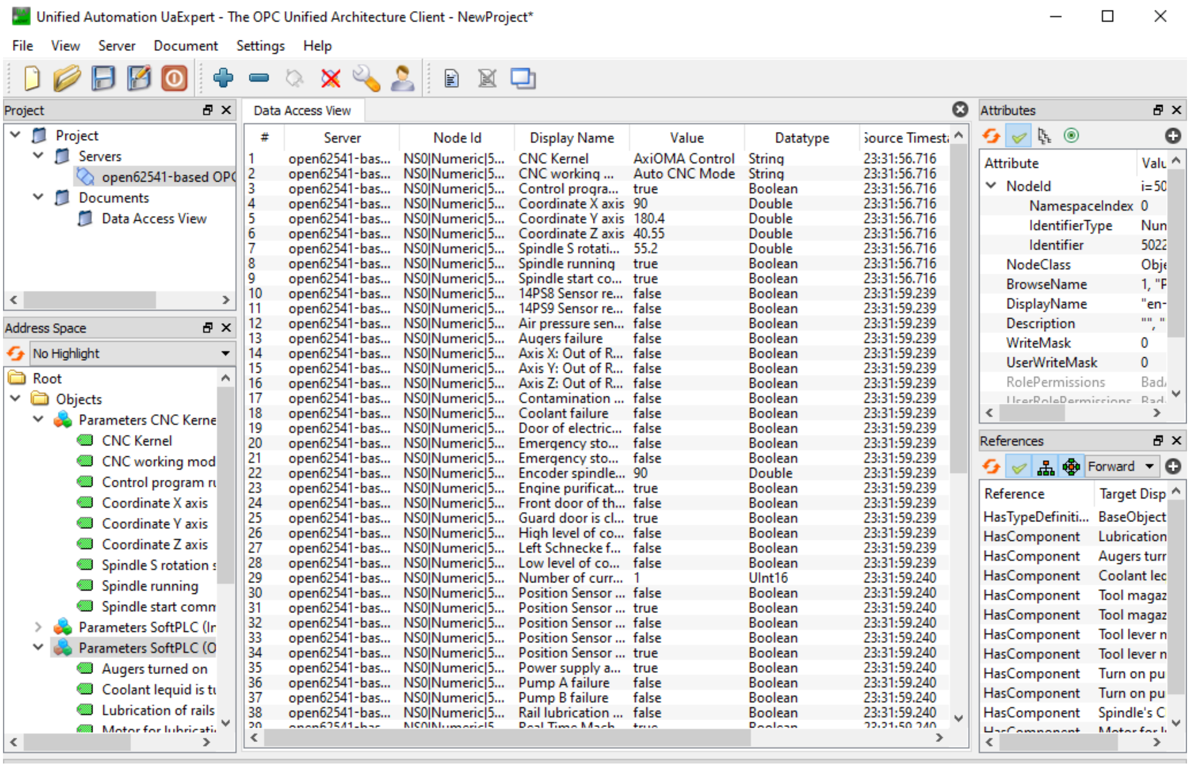

Figure 4. Using local OPC UA Unified Automation UaExpert client for monitoring the operation of CNC machine tool (Quaser MV184P).

5. Development of OPC UA web client

The functionality of OPC UA web client was implemented using Node-RED tool for programming and linking hardware devices, APIs, and online services. Node-RED is browser-based editor that simplifies development procedures of OPC UA web client with a wide variety of different nodes and capabilities [3,7,21].

The developed OPC UA web client can remotely connect to OPC UA servers and allows to view the server's address space, read / write node values, create subscriptions and access historical data through any web browser. Node-RED communicates with the OPC UA protocol through the Node-opcua toolbox, which is an implementation of OPC UA stack written entirely in javascript. The OPC Ua-client node tool from the Node-opcua package is used to connect OPC UA web client to OPC UA server. In this tool, it’s necessary to specify the exact URL of the OPC UA server, hostname, port and OPCUA endpoint, and specify the required action (read, write, view, etc.).

Corresponding to OPC UA server’s address space, OPC UA node should be defined in OPC Ua-item node tool referring to the ID, name of each node and its data type (int, double, char, etc.). to update status of each node from OPC server, inject node tool runs at regular time intervals. An example of developing a CNC remote user terminal based on OPC UA web client using Node-RED tool is shown in figure 5.

The Node-RED tool allows to create dashboards, providing many widgets for reading, writing and viewing live data in the web client (buttons, charts, gauges, text input, etc.).

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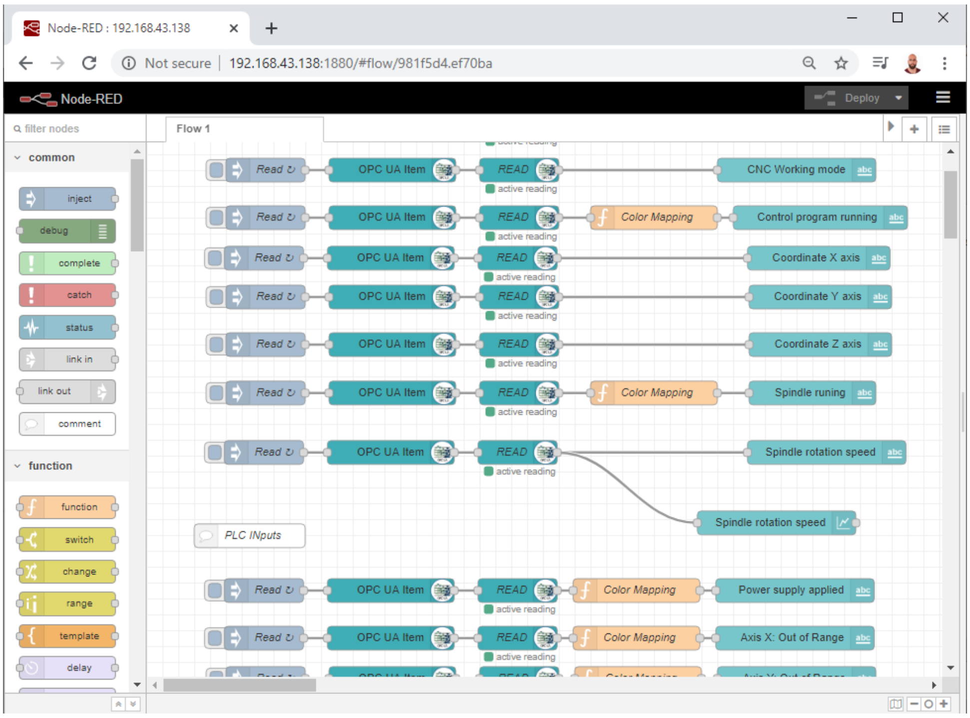

Figure 5. Development of remote OPC UA web client using Node-RED tool.

The developed OPC UA web client for monitoring the operation of vertical milling machining center MV184 is shown in figure 6.

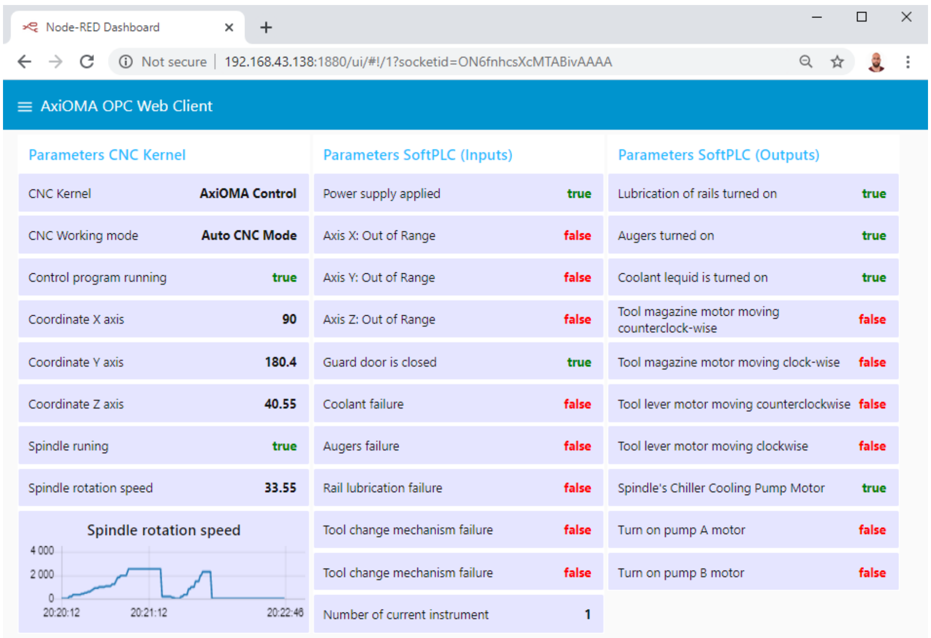

Figure 6. OPC UA web client for monitoring the operation of vertical milling multipurpose machining center Quaser MV184P.

As it is seen from the figure, the developed client allows visual monitoring of the functioning of AxiOMA Control CNC system and its embedded controller that controls the machine's electro-automatics.

6. Conclusions

The task considered in this work by building technological processes' monitoring system using OPC UA technology is relevant for building modern enterprises that meet "Industry 4.0" concept. The implemented OPC UA server provides a standardized, flexible and efficient mechanism for data exchange between AxiOMA Control CNC system and various types of OPC UA clients (local and remote). This allows solving the problem of monitoring equipment's operation and controlled processes, as well as ensuring the transfer of the necessary production information to higher levels of enterprise management [2,5,25-27].

The considered example of transmission equipment parameters using OPC UA for monitoring the operation of a vertical milling machining center, confirms the correctness of the chosen approach and proves the prospects of implementing a monitoring system. The implementation of the presented mechanisms and their use at local enterprises will expand the capabilities of monitoring and control technological processes, respond promptly to emergency situations and It will contribute to build multi-level organizational and production process control systems [11,13,28,29].

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