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# Web-based monitoring and control system for industry 4.0

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**Abstract.** Industry is a field that has undergone various stages of development. The advent of modern technologies has led to significant advancements in the realm of industrial process monitoring and control, resulting in enhanced efficiency. These advancements facilitate enhanced accessibility to operational data concerning industrial processes, enabling real-time monitoring. The present paper sets out a methodology for the supervision and regulation of an industrial assembly line through the utilization of web technologies. The present study focuses on the integration of a user interface and the implementation of a system capable of managing and supervising industrial equipment. The programming language employed in the development of the proposed system is JavaScript, which is responsible for the construction of the control and command interface. The component that ensures communication between system elements is Node-RED, a flow-based development tool. The monitoring and control of sensors and equipment along the industrial line are managed through the OPC protocol, which facilitates the connection between the system and the main programmable logic controller (PLC) of the assembly line. The system utilizes the Modbus TCP communication protocol to facilitate the monitoring of the electrical parameters of the industrial line. The data is collected from a SENTRON PAC3200 network analyzer. The system developed and implemented in this paper serves the purpose of managing and supervising data from the industrial line, while also allowing the user to intervene in the process functionality through various control commands.

**Keywords:** OPC, Modbus TCP, Industria 4.0, Node-RED, web technologies, SENTRON PAC 3200.

## 1. Introduction

Digitalization and technological advancement have become pivotal drivers in the evolution of industrial processes. The concept of "industry" is defined by several core elements, namely advanced technologies, process automation and system

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interconnectivity, which enables seamless data exchange between components. The development of industry is commonly described in four major stages. The advent of the First Industrial Revolution was characterized by the emergence of steam engines and hydropower as the predominant sources of mechanical energy. The second stage marked the transition to electricity as the predominant energy source, precipitating a substantial augmentation in production capacity. The third industrial revolution was characterized by the implementation of automation equipment, thereby establishing the foundation for computer-integrated manufacturing. The fourth stage, frequently termed 'Industry 4.0', emphasizes the integration of digital technologies into industrial systems. This encompasses the implementation of smart devices, cyber-physical systems, and the utilization of digital media to enhance process control, efficiency, and adaptability [1–3]. The design and implementation of systems utilized for the monitoring and control of industrial processes necessitates technologies and tools that can communicate with industrial equipment. These technologies are typically represented by web-based solutions [4], which enable the development of systems such as SCADA (Supervisory Control and Data Acquisition) systems [5]. A variety of communication protocols may be employed for the purposes of data exchange and control, including OPC (Open Platform Communications) [6], MQTT (Message Queuing Telemetry Transport) [7], S7comm [8], Modbus [9], TCP/IP (Transmission Control Protocol/Internet Protocol), and HTTP (Hypertext Transfer Protocol) [10]. These technologies empower users to oversee the real-time status of industrial equipment and proactively intervene in the event of operational errors. The objective of this project is to design and implement a system that enables both data monitoring and remote control of an industrial assembly line. The proposed solution is based on web technologies, allowing remote supervision and control of the assembly process. The system has been implemented using the JavaScript programming language. The transfer of data between system components is facilitated by the Node-RED interface. The OPC protocol is employed to control the industrial process and to monitor the status of the line's sensors, while the Modbus TCP protocol is used for managing the electrical parameters of the assembly line. The paper proposes a monitoring and control solution for an industrial assembly line based on web technologies and Node-RED, replacing traditional SCADA systems with web-based interfaces that are easily scalable and remotely accessible without requiring complex infrastructure. The structure of the paper is as follows: The second section of this study presents an overview of the current state of the industry and industrial process automation. The third section of the text provides a detailed description of the system design, while the fourth section outlines the implementation of the system. The fifth section of the paper presents the results and discussions, and the final section concludes with the paper.

## 2. State of the art

The field of industry is one that is subject to constant evolution. The technologies that define modern industry include the following: the Internet of Things (IoT), web platforms, monitoring and control systems, mixed reality, and virtual reality [11-12]. The paper [13] presents an IoT system designed for the monitoring and control of industrial equipment. A variety of communication protocols can be utilized for the purpose of transferring data and information. One such protocol is OPC. The paper [14] describes an interface that enables monitoring and control of an industrial process. The system has been developed to facilitate the remote supervision of equipment, the programming of RFID tags, and the establishment of network communication, thereby enabling the acquisition of real-time data and information. A further method for the transmission of operational data pertaining to industrial equipment is through cloud computing systems. These systems facilitate remote access to data and information by users [15]. A different type of system used for monitoring and controlling industrial processes is the SCADA system. A SCADA system of this nature is outlined in paper [16], wherein data transmission is facilitated by the MQTT communication protocol. The MQTT broker constitutes the central component of the system, with implementation undertaken using the Python programming language. Web technologies also offer an alternative implementation approach. These devices can be utilized to simulate and test a variety of manufacturing processes. A significant benefit of web technologies is their capacity to facilitate the development of prototypes for industrial processes. These technologies have the potential to replace traditional SCADA systems. These systems possess the capacity to calculate operational parameters, collect data, and control industrial processes. Paper [17] presents the structure and implementation method of a SCADA system that utilizes web technologies. This system facilitates real-time monitoring of operational parameters. Another system developed using web technologies is described in paper [18], which allows for the assessment of operating parameter states and detection of malfunctions. The evaluation of technological process parameters can be facilitated by the utilization of designated devices, with network analyzers such as the SENTRON PAC-3200 [19] being particularly effective in this regard. A few additional technologies are available for implementation in the development of monitoring and control systems, including augmented reality (AR) and virtual reality (VR). According to paper [20], augmented reality is defined as a technology that enables users to visualize and interact with various virtual tools while simultaneously operating physical equipment. This is achieved by overlaying virtual elements onto the real-world environment. Paper [21] introduces a system that simulates a robotic arm. This system is designed to help users understand the functioning of an industrial robot by providing control over each of its components. Another example of an augmented reality application is presented in paper [22], where the implemented system allows users to interact simultaneously with multiple virtual objects to control physical equipment. Paper [23] presents a system that uses augmented reality to interact with a robotic arm. It is posited that this system enables the user to engage with virtual tools and control physical equipment. An additional feature of this system is the user's ability to receive haptic feedback through an end effector. The fourth industrial revolution, otherwise known as Industry 4.0, is predicated upon the integration of a variety of technologies and devices with a view to the monitoring and control of industrial processes. One software tool that can be used for this purpose is the Node-RED interface. As stated in paper [24], Node-RED is a system that facilitates visual programming for its users. The components utilized within this interface are designated as nodes. The constituent components of this interface are designated as nodes. It is evident that Node-RED can be deployed across a multitude of platforms. The programming language that is customarily utilized within these nodes is JavaScript. The potential applications of this technology are manifold, spanning diverse domains and a wide range of tasks. Paper [25] presents the structure of a system designed for remote monitoring. The Node-RED programming environment was utilized to develop and implement a control interface, enabling the monitoring of variables such as temperature and humidity. The transmission of this data to an ESP8266 microcontroller, which is responsible for the management of data acquisition, is a subsequent process. The collected data are then integrated through the Node-RED environment, utilizing a range of predefined virtual tools. Another application of the Node-RED interface is described in paper [26]. The following paper presents an IoT system that collects and processes data related to energy consumption and environmental conditions within a technological installation. A control panel developed using the Node-RED interface enables users to monitor data gathered from temperature and humidity sensors. The implementation of these technologies and devices is contingent on various programming languages, in addition to diverse communication protocols, which are essential for ensuring proper data transmission and system integration. OPC (Open Platform Communications) is a communication protocol that is frequently utilized in industrial processes to facilitate interaction between devices and equipment. This protocol has been established as the standard for facilitating communication between different types of equipment and devices [27]. The OPC facilitates the integration of multiple technologies within the domain of industrial automation. It is regarded as a fundamental component within the domain of IoT technologies [28]. Another platform that can be used in conjunction with the OPC protocol is Node-RED, which facilitates the development of various SCADA interfaces. The utilization of these technologies enables the design and implementation of systems with the capacity to collect and control a variety of industrial processes. The integration of these tools with various communication protocols has resulted in the development of systems that ensure both security and accessibility. The concept of Industry 4.0 facilitates the integration and interoperability of industrial systems, thereby enabling the automation that is imperative for optimizing and enhancing the reliability of industrial processes.

## 3. Proposed system

The following sections of this paper propose a methodology for the monitoring and control of an industrial assembly line. The system has been developed for the purpose of assembling components based on a selected configuration. As illustrated in Figure 1, the component is assembled by the industrial line.

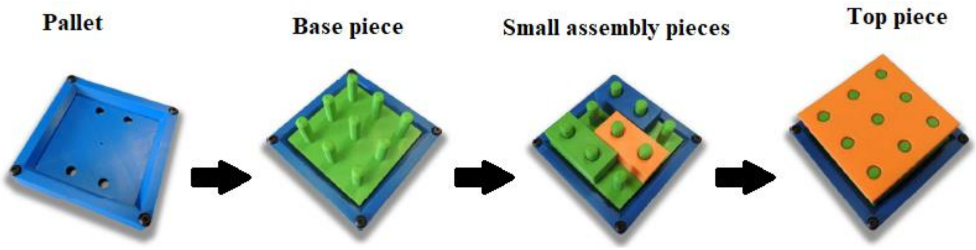


Fig. 1. Part assembled by the industrial line.

The industrial line comprises a series of stations. These stations facilitate the transfer of data and communicate with each other using the Profinet protocol. The stations can be configured by the user to operate to achieve a specific configuration of the final product. It is also possible to utilize the five stations of the industrial line as standalone entities for the execution of specific processes. As illustrated in Figure 2, the industrial assembly line is composed of several distinct components.

Fig. 2. Industrial assembly line.

As demonstrated in Figure 2, the industrial line comprises multiple components that facilitate automation. These include programmable logic controllers (PLCs) from the S7-1500 and S7-1200 series, the TP1500 Comfort human-machine interface (HMI), SINAMICS G120 frequency converters, and RFID modules. Pneumatic actuation systems are utilized for the purpose of releasing parts from storage. The position of the parts is determined by means of multiple capacitive, inductive and optical sensors. The storage units housing the components are equipped with optical sensors that detect their availability or depletion. A capacitive sensor is utilized for the purpose of detecting parts that have been released from storage and activating the conveyor belt. The conveyor belt is driven by an asynchronous motor, which is controlled by the programmable logic controller (PLC) via the frequency converter. This functionality is consistent across all stations. The programming of the industrial line is performed using the TIA Portal software, with SCL and Ladder programming languages. As illustrated in Figure 3, the component architecture within the TIA Portal software is comprised of several distinct components.

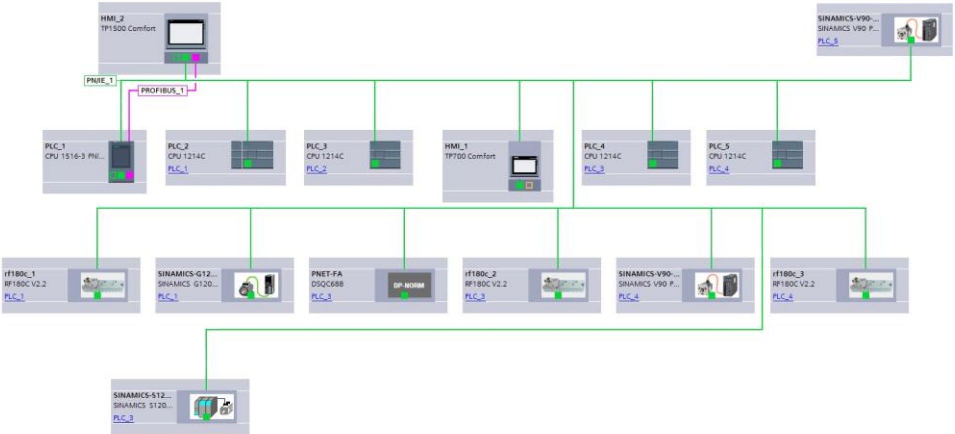

Fig. 3. Component architecture within the TIA Portal software

The system under discussion employs a variety of hardware and software components for the purposes of data and information collection and management. The collated data can be viewed by users in real time, thus enabling them to make informed decisions and issue appropriate commands. To track the evolution of the data over time, a variety of data and information storage elements are employed. As illustrated in Figure 4, the components employed within the system architecture are structured and interconnected in a specific manner.

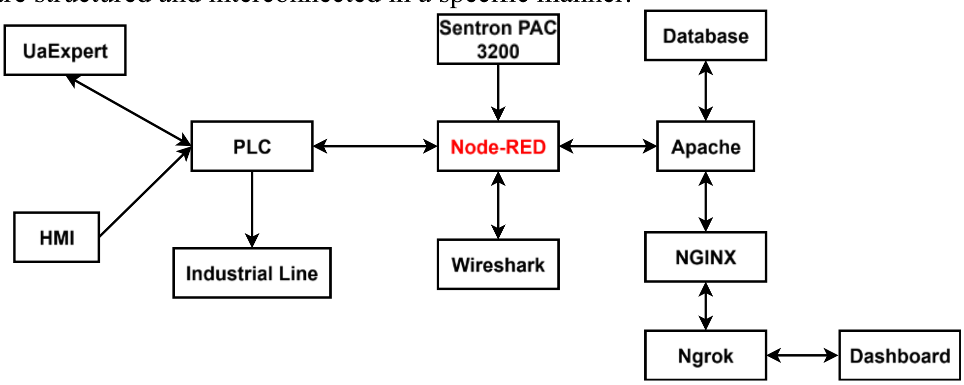

Fig. 4. Architecture of the monitoring and control system

As demonstrated in Figure 4, the Node-RED interface constitutes the core component of the designed system. This interface facilitates data and information exchange between the other components. The system is responsible for the management of information pertaining to the electrical parameters of the industrial line, the status of sensors, and user commands. To exercise control over the industrial line and to monitor the sensor states, the Node-RED interface communicates with the main programmable logic controller (PLC). The Programmable Logic Controller (PLC) is responsible for the oversight of the industrial line and the assembly process. The device is connected to an HMI (Human-Machine Interface), which provides local monitoring and control capabilities.

The communication infrastructure encompasses the utilization of the OPC communication protocol, facilitating seamless interaction between the web interface and the Programmable Logic Controller (PLC). The UaExpert software is utilized for the identification of potential communication errors. UaExpert facilitates the visualization of data that has been shared via the OPC protocol, the identification of the data tags, and the monitoring of the connection status.

## 4. System implementation

The implemented system is designed to monitor and control an industrial assembly line. To achieve this objective, a range of hardware and software components are utilized. The developed system endows users with the capacity to oversee the electrical parameters and sensor statuses of the assembly line. As illustrated in Figure 5, the web interface for monitoring and control has been designed to consist of the following components.


Fig. 5. Structure of the web interface for monitoring and controlling the industrial line.

As demonstrated in Figure 5, the system comprises control elements that facilitate the initiation or cessation of system operations, in conjunction with multiple graphical components employed for the monitoring of operational parameters, the provision of detailed information regarding the line's mode of operation, and the presentation of its prevailing status. The collection of all this data is facilitated by the Node-RED interface. The software utilizes two communication protocols to facilitate data transfer. The initial protocol employed is Modbus, which oversees data pertaining to the status of electrical parameters. As illustrated in Figure 6, the nodes employed for the transfer of this data have been delineated.

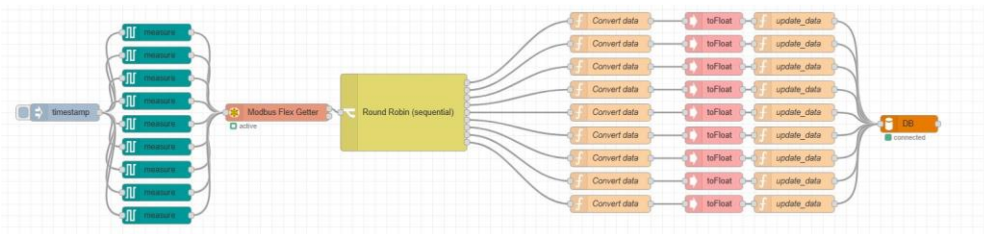


Fig. 6. Reading data using the Modbus communication protocol.

As demonstrated in Figure 6, a variety of nodes are employed to oversee the electrical parameters of the industrial assembly line. To facilitate the transmission of data at specific time intervals, a timestamp node is employed, which is configured to transmit data at a rate of 150 milliseconds. The subsequent node, designated as 'measure', is employed for the selection of the electrical parameter to be measured. It is important to note that all these nodes are connected to the Modbus server, as illustrated by the Modbus Flex Getter node. The utilization of a round robin node is imperative for the effective dissemination of information. This node has been developed to facilitate the configuration process by obviating the necessity for multiple nodes to specify the Modbus server. The following nodes are utilized for the purpose of processing the data obtained from the power analyzer. The values obtained from the analyzer are transmitted via two registers. The two values are then concatenated and converted into a float format. After the acquisition of the ultimate value, an alternative function is utilized for the selection of the database and table in which the information is stored. The OPC communication protocol is utilized for the purpose of controlling the industrial process and ascertaining the sensor states on the assembly line. The protocol facilitates the transfer of sensor data and the execution of commands from the web interface to the PLC. As illustrated in Figure 7, the nodes employed for the purpose of data inscription into the PLC are utilized in conjunction with the OPC communication protocol.

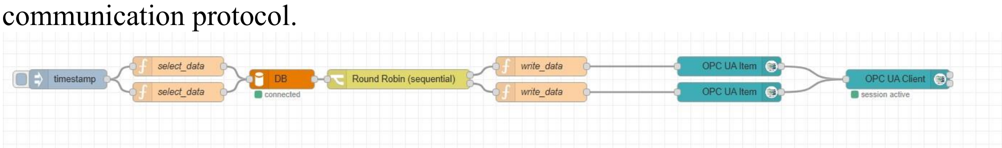


Fig. 7. Writing data using the OPC communication protocol.

The data that is written to the programmable logic controller (PLC) originates from commands that are issued via the web interface. The initial transfer of these commands occurs from the web interface to a database. Within the Node-RED framework, specific functions are utilized for each value that requires transmission to the PLC. The purpose of these functions is to retrieve the corresponding value from the database, pass it to another function that extracts only the numeric value from the query result, and then send this value to the OPC item node. In the OPC item node, the variable in the PLC whose state is to be modified is selected. The appropriate variable is identified by means of its corresponding identifiers. In a similar manner, data pertaining to the sensor statuses and the parameters of the industrial assembly line is accessed by the nodes. These nodes are configured to select the desired values using their respective identifiers, to set up the OPC server, and finally to send the data to the designated location in the database. As illustrated in Figure 8, the nodes employed for the transmission of data from the PLC to the web interface via the intermediary database are delineated.

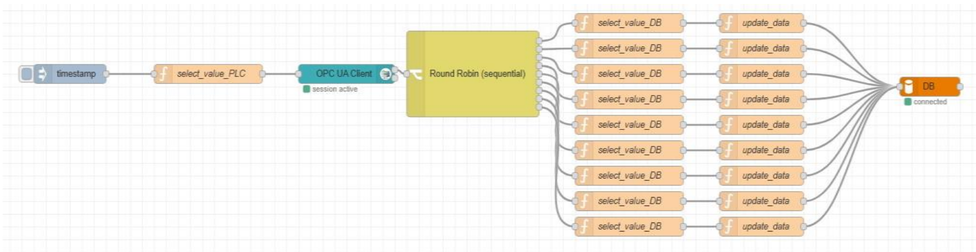


Fig. 8. Reading data using the OPC communication protocol

The operation of this system is comprised of several distinct stages. The initial stage of the process involves the establishment of connections to two servers, OPC and Modbus. The subsequent stage in the sequence of events is the transmission of data to the Node-RED interface, where data processing takes place. Subsequently, the data is transmitted to the web interface. It is possible to initiate a series of commands via the web interface, which are then transmitted to the programmable logic controller (PLC). This results in the restarting of the operation cycle from the second stage. In the event of a disconnection from either the OPC or Modbus server, system operation is interrupted and awaits reconnection. It is important to note that, upon reconnection of the servers, the process cycle will be recommended. As illustrated in Figure 9, the process is comprised of a series of interconnected stages.

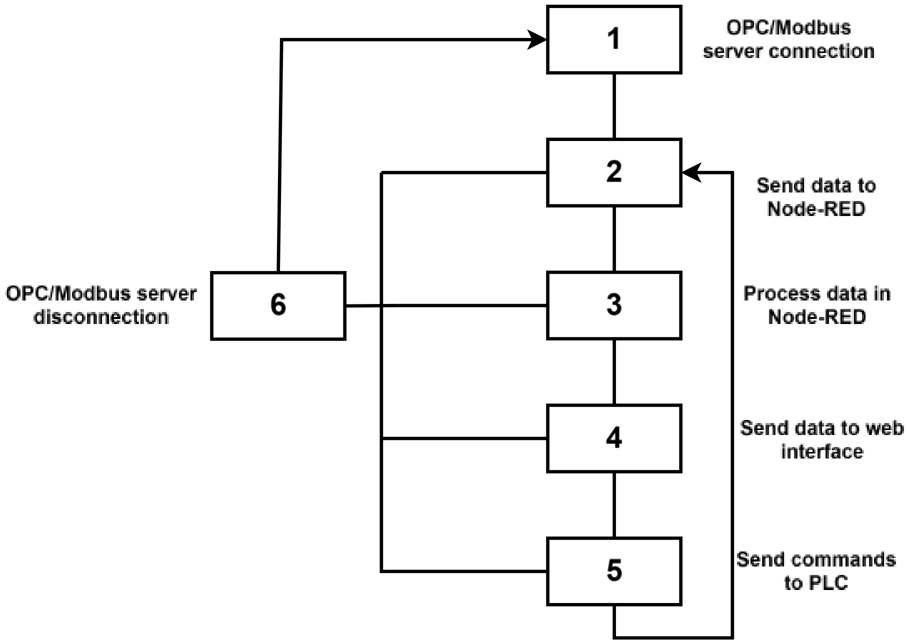


Fig. 9. Operating diagram.

## 5. Results and discussions

The implemented system facilitates the monitoring and determination of the status of the industrial line's parameters. The industrial line is capable of operating in a variety of modes, with the parameter states differing depending on the selected mode. It is important to note that all these parameters are influenced by the operating mode of the equipment. As illustrated in Figure 10, the industrial assembly line is operational, and all automation equipment is fully functional.

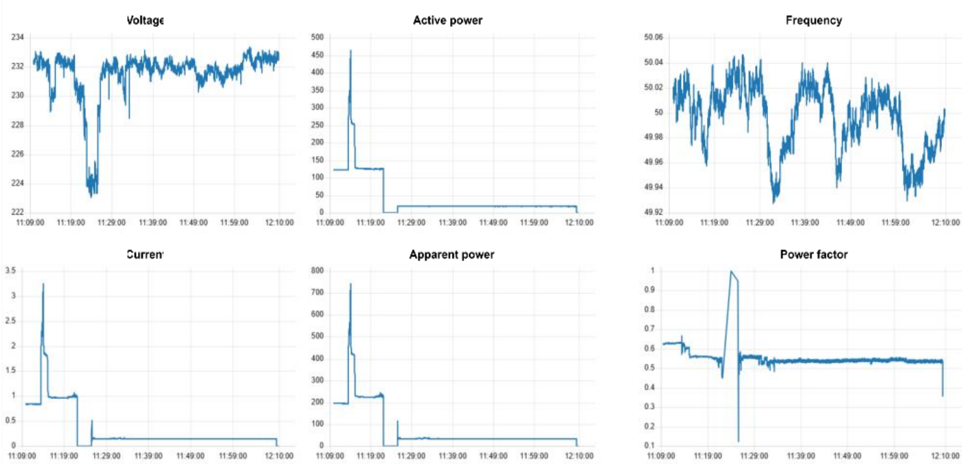


Fig. 10. Status of electrical parameters at process start-up.

As demonstrated in Figure 10, there is a tendency for the electrical parameters to increase when the industrial assembly line is initiated. This is attributable to the equipment requiring a greater quantity of energy until it is configured and ready to perform various tasks. As illustrated in Figure 11, the state of the electrical parameters is depicted once the assembly line equipment has been fully configured.

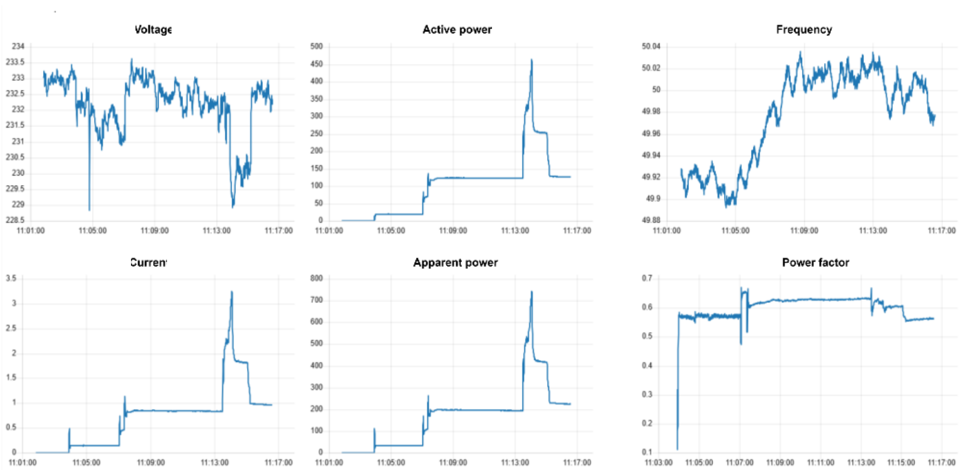


Fig. 11. Status of electrical parameters in standby mode.

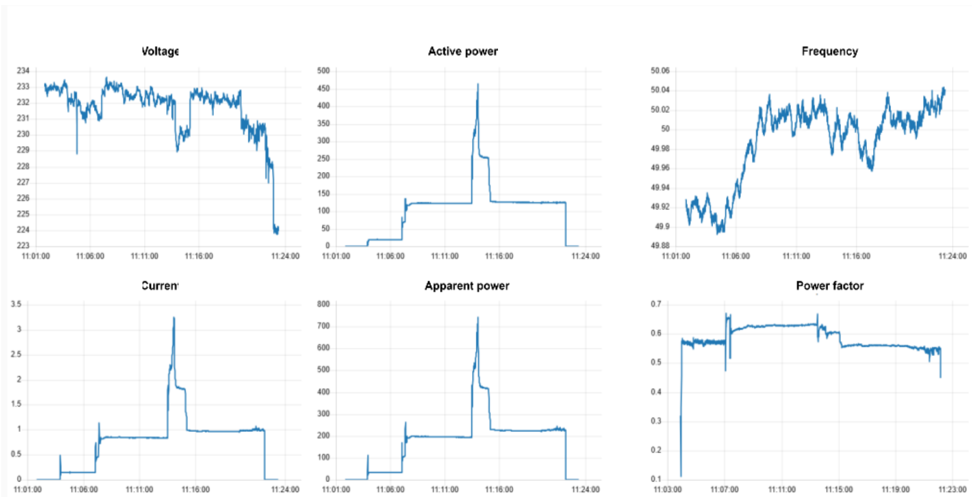


Fig. 12. Electrical parameters during the shutdown of the industrial line.

As demonstrated in Figure 11, in standby mode the system maintains a minimal consumption rate, thus ensuring the support of all the basic functions of the equipment on the industrial assembly line. This is characterized by values that exhibit a propensity to stabilize over time. The cessation of industrial assembly line operations has been observed to result in a precipitous decline in electrical parameter values. Consequently, the behavior of the electrical parameters can be observed during the various operating phases of the assembly line. As illustrated in Figure 12, the state of the electrical parameters now the assembly line is halted is shown.

## 6. Conclusions

The present paper sets out the design and implementation of a system for the monitoring and control of an industrial assembly line for parts. The system has been constructed utilizing web technologies, with JavaScript serving as the designated programming language. The communication protocols employed for data transfer are OPC and Modbus. It is evident that the system under discussion enables users to monitor the status of the industrial line and control the assembly process. The enabling of remote access is facilitated by the utilization of Ngrok and NGINX technologies.

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