A Novel Monitoring Dashboard And Hardware Implementation Simplifying The Remote Access In Industry

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***Abstract*— In today's world where technology is developing with a great speed, it is getting harder day by day to adapt or include changes on new technology to the processes in facilities. Insisting on using conventional solutions adopted so far in industrial facilities cause problems to compensate the changing fast consumption needs of today. Adopting recent technologies improves the maintenance and troubleshooting processes of the facilities, accelerates the production and increases the quality of production. In this way, technology based smart systems can provide the devices or machines with the skills required for problem solving and system development in the industry. In this study, a remote monitoring and control application is proposed for a frequency inverter which is widely used and critical device for motor driving in industrial facilities is discussed and a novel internet of things (IoT) based communication gateway is developed. In this way, it is intended to improve the problem solving skills of field personnel by contributing with remote support.**

Keywords*— Industrial IoT, Machine-Cloud-Human Interaction, Remote Monitoring and Control, Frequency Inverters, Smart Machines, Smart Factories

I. INTRODUCTION

Industry 4.0, one of the biggest subjects of technological change, makes its presence felt in all work areas and leads new applications for different sectors. Industry 4.0 refers to many developments and innovations from advanced automation techniques to the machine learning that will accelerate developments in industrial production. While increasing productivity and efficiency, it also offers significant opportunities to provide numerous benefits in production facilities by reducing waste and operating costs [1]. The main question here is how industrial facilities that need to keep up with the digital requirements emerging with Industry 4.0 will be affected by this wind of change. Today's revolution, which is also described as the Fourth Industrial Revolution, aims to make life easier and increase the quality of life, like previous revolutions. Industry 4.0 focuses on monitoring and controlling the devices used in the industry with the network infrastructure with IoT [2]. Technological developments have significantly changed the content of the problems and the diversity of solutions in industrial areas. Thanks to Industry 4.0, it is aimed to solve remote access problems by developing a versatile perspective on risk analysis in industrial facilities with this study.

Monitoring and managing the systems remotely has many benefits, from reducing operating costs to improving the experience for system users. For example, when a remote facility does not have a local support team to handle issues or perform checks, remote connectivity is not only valuable but necessary in many situations. That's why, in many studies, it has been aimed to make remote data sharing easier and simpler for the relevant field personnel as indicated in [3]. The remote monitoring and control of the induction motors which are used in agricultural area is investigated in [4] with various methods. It was stated that many parameters should be continuously monitored in all kinds of application areas in order to ensure reliable, flexible, error-free and efficient operation. In this study, it is also mentioned the importance of IoT-based monitoring and control in order to eliminate the negative impact of power cuts on production [4]. Additionally, it is emphasized in [5] that, thanks to the IoT-based monitoring, maintenance or replacement of defective devices can be carried out with the least possible disruption, without interrupting the production process. An application that includes reading and real-time monitoring of the current values of a three-phase motor is discussed over a wireless network in [6]. Thanks to this system, data can be recorded and monitored and then transferred to cloud storage for monitoring. It is reported that IoT technology is advantageous for monitoring the condition of machine parts in the proposed study [7]. It is also declared in the same study that an IoT-based condition monitoring system can support increase in production throughput, reduce maintenance-related costs, and help decision-making. It is emphasized the importance of electric motors in the industry and mentioned that unexpected failures in equipment working with electric motors can lead to high economic losses in [8]. So, equipment maintenance may become mandatory. The design, implementation and testing phases of an industrial IoT system is demonstrated in order to monitor electric motors in real time. And it is also mentioned that this system can be used to detect operating anomalies and will be a leading study for predictive maintenance models [8]. As stated in earlier studies given, it is also emphasized the importance of monitoring the condition of the motors in [9]. In the study, it is demonstrated that motor operating parameters such as temperature, current, voltage and vibration can be accessed wirelessly and all these parameters can be analysed by the user from anywhere by using IoT technology. The system can send a warning message to the user in case of any malfunction. In addition, it was also mentioned that when the IoT is combined with machine learning, it can help to classify and predict machine errors [9]. A solution is proposed to solve the road safety problem providing a good night-vision for drivers by illuminating intersections in rural areas where the road is typically dangerous and where fatal accidents occur frequently in [10]. In addition, an economic analysis was carried out to show how this application beneficial, which was designed to bring together all the new technologies existing in the market and to monitor the system through the website, is more suitable than the old technology. It is presented an IoT application project that aims to collect, manage and process technical and consumption data of public lighting system in [11]. An IoT system is proposed in which local road condition data is transmitted to the aircraft in order to increase the effectiveness of the braking effect on the wheels of a UAV and to enable the UAV to stop in relatively limited areas during landing in [12]. With a different perspective, beside the advantages, some risks in IoT systems are emphasized in [13], and it is focused on considering the number of devices in a network as a factor in order to calculate the risk in IoT systems to increase security and reduce the impact of the risk. It is argued that while innovations known as smart manufacturing and industry 4.0 for predictive maintenance for modern businesses, necessary technologies such as the industrial internet of things (IIoT) should be provided in [14]. It is stated that with the development of web-based applications and mobile devices, remote control applications and diagnosis of agricultural irrigation systems has been adopted more and more, and they have reduced operating management time and other resource expenditures such as transportation to agricultural areas in [15]. A software and hardware solution are proposed in [16] for cloud connected industrial devices and an alternative approach is presented to SCADA solutions with a prototype called an industrial IoT gateway. With the scope of smart factory concept, an adapting application to the existing installed mechatronic systems is discussed in [17] and the real-time monitoring and control of the states of the sensors and actuators are realized with a communication network from anywhere in the world. It is studied in [18] how plant efficiency can be handled and which improvements can be achieved by monitoring the measured or calculated values directly related to energy consumption such as current, electrical power, motor torque and speed, etc. It is demonstrated how the application of IoT-based measurement helps to reduce energy consumption in an industrial facility in [19]. It is also stated that by using IoT and including more data to the energy management system enables facility managers to use energy more efficiently. It is emphasized the importance of an IoT-based smart irrigation system in agriculture for saving time, water and labor power in [20]. A predictive monitoring system is proposed in [21] for pump equipment. Sensors are integrated into a pumping system and operation data is streamed to the internet to allow remote monitoring. In addition, system alerts or maintenance requests can be sent when needed.

Enabling 24/7 real-time remote machine condition monitoring is a best practice for responding to unplanned downtime and can also increase equipment efficiency. Remote access technologies have a positive contribution to analysis and testing costs, as they provide early warning about the system or device as stated in [2, 4, 7, 9, 19, 20].

It can be seen that the reviewed studies about IoT applications focus on agriculture, defense, production facilities and public areas. And most of these studies mentioned that it provides lots of advantages with security risks. It is clear from existing studies that, remote monitoring and control applications reduce plant downtime, especially unplanned downtime, and accelerating problem resolution in the event of a critical failure are an important part of increasing productivity, minimizing losses and improving equipment efficiency. Nowadays, how to ensure the smooth operation of the machines is the primary concern for the manufacturers. In fact, manually checking the status of each machine is possible but it is costly and open to human errors. And more importantly, it can cause longer delays. All remote monitoring and cloud management application carried out were aimed to facilitate the elimination of such shortcomings.

In previous studies, it was seen that the remote access and control of frequency inverters were not focused enough. Considering the importance of such devices in the industry, positive impact of this study is obvious. For this reason, this study focuses on remote monitoring and management of frequency inverters for the industrial facilities. Internet of Things (IoT) has an increasing impact on industrial operations, and this technology, when coupled with the capabilities of frequency inverters, is thought to have a positive impact on realizing day-to-day operations in industrial facilities.

Based on the earlier studies, in this study, a lean IoT gateway solution has been discussed to monitor and control a frequency inverter in a factory via a cloud server over a local network. It can be easily configured by user for different type of devices. Frequency inverters are one of the industrial equipment that provide the best management in terms of motor driving technology in a factory, it is also an essential part of many industrial operations and provides a number of benefits that reduce the time and resources required to perform operations, increase the safety of equipment and users in the region, lower electricity costs and extend the life of motors.

II. Remote Access Model In Industry

Today, many industrial devices have Ethernet ports together with industrial communication infrastructures. However, in order to access these devices remotely, some software and hardware parameters must be set on the internet provider modem. In order to make such settings, expert IT knowledge is required, and in case of opening the internet ports, the security level must be increased in order not to be exposed to cyber-attacks at this time. For all these reasons, the access of industrial devices to the internet is either not desired or remote access of the devices is restricted due to the security. In cases of raising security level by the IT department, it causes many other problems. Thanks to the application developed at this study, it is aimed to prevent these difficulties and to establish both an easy access and a secure communication infrastructure.

An important feature of the developed product is its ability to communicate with field equipment and systems through industrial communication options. Modbus TCP as an industrial communication protocol is widely used to monitor, acquire and control the equipment in the field. The data obtained from the field can be regularly transferred to the cloud by providing continuous communication between the field devices and cloud server which are located in different locations. In this way, an ideal database for real-time monitoring and predictive maintenance can be created.

The proposed product, which will be used as an IoT gateway, acquires data from industrial equipment on the field and uploads it to the cloud, where this information can be monitored via the web.

III. Proposed IoT Gateway Solution

In this study, it was aimed to create a product that can allow to control of a specific device for a specific application, which is frequently used in the industry, rather than a product equivalent to the existing IoT gateway devices. Here, a brand- and device-independent solution has been tried to developed. Thanks to the flexibility of the design, the integration of different brands or models into the platform is provided to the user. All the definition related with different devices can be implemented by user via the web interface.

To integrate the proposed application into the cloud server is possible with a free account created on the Microsoft Azure portal. IoT hub that is provided on the cloud server is needed to be implemented on the server, and for each device created in the IoT hub, device-specific identity data is generated. This identity data can be changed if desired. In order for the device in the field to provide secure access to the IoT hub, the device-specific identification data provided by the system is used [23]. In this way, only the device defined in the system can access the IoT hub thanks to the developed application.

MQTT protocol is commonly used to connect an IoT device to an IoT hub. The MQTT implementation requires minimal code with little effort during the operations applied for data transmission. The MQTT protocol also has built-in features to securely communicate with multiple IoT devices. For this reason, using the MQTT protocol, a secure and fast connection can be established with many devices in IoT applications. When connecting over a low-bandwidth, high-latency, unreliable cellular network, MQTT reduces the time it takes for IoT devices to reconnect to the cloud and enables secure connectivity with different levels of security services.

The block diagram of the application is shown in Fig. 1, multiple frequency inverters (or any other devices) can be connected to the IoT device via ethernet. Data from multiple devices connected to Raspberry Pi, which is developed as an IoT communication gateway, is transmitted to the cloud and the data in the cloud can be displayed on the web application.

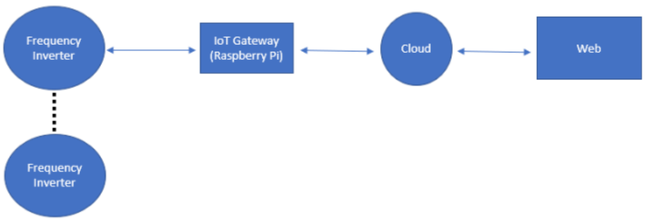

Fig. 1. Block diagram of the proposed application

The frequency inverters placed in the field communicate with the IoT communication gateway with Modbus TCP protocol via Ethernet port and the IoT communication gateway communicates with cloud server over on the internet as shown in Fig. 2. When using this communication method, the IoT communication gateway will be the master and the frequency inverter will be a slave in the field. Communication will always be initiated by the IoT communication gateway, and the frequency inverter will respond as appropriate for the corresponding request.

Every frequency inverter may have different parameter numbers with a unique Modbus TCP register address which can be accessed from the communication or application manual of the related specific device [22]. All the parameters which are desired to be accessed such as motor current, motor frequency, temperature etc. shown in Fig. 3, can be configured on the web interface of the proposed product. Those parameters are acquired continuously within the specified time interval and sent to the cloud server via the internet provider modem.

The ratings of frequency inverter used for testing purposes during the development of the application are given in Table 1. Although they are basically similar, two different frequency inverter models, which have different usage areas and different parameters, were chosen for the test phases of the application.

TABLE I. Frequency Inverter Ratings

Model	Power	Output Current	Mains Voltage	Output Frequency
DM1	1,1 kW	4,8 A	200-240 VAC	0-400 Hz
DG1	1,1 kW	3,3 A	380-500 VAC	0-400 Hz

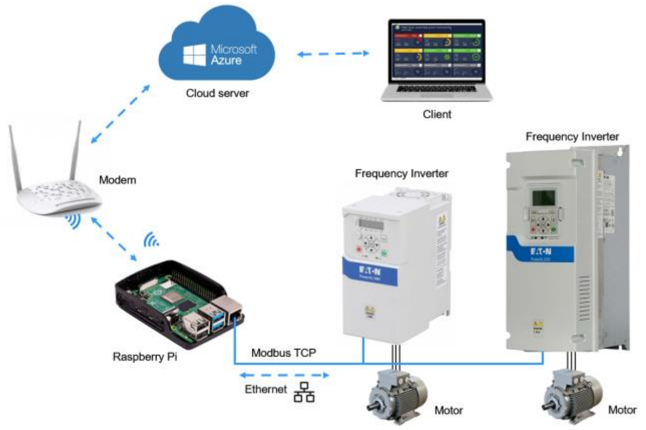

Fig. 2. System structure of the proposed application

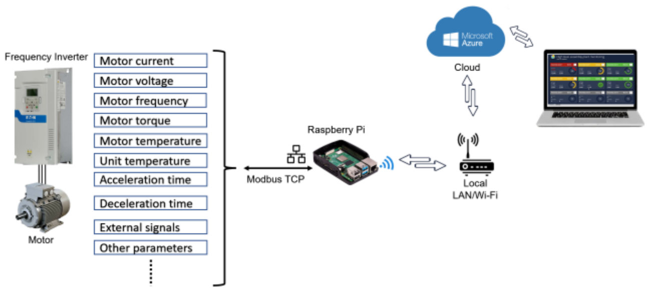

Fig. 3. Data communication between industrial field equipment and proposed application

Here is the method for a device to connect with the proposed product via Ethernet:

To ensure efficient communication between devices, it is needed to be set up a small network as illustrated in Fig. 4. The IP addresses used here are just an example. The important thing is that each device must be assigned with its own unique IP address.

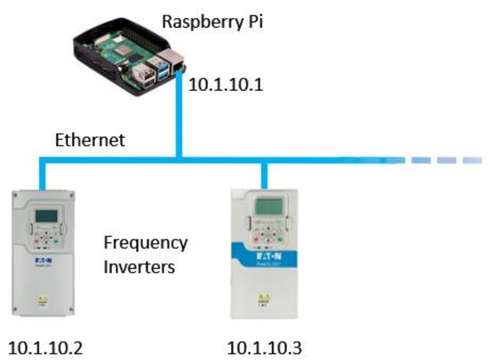

Fig. 4. Communication via Ethernet between devices

During the connection between developed product (Raspberry Pi) and frequency inverter via cable over the internal Ethernet ports, connection status and the parameters can be tested over the web interface of proposed product. Manual connect feature on the web page can be used to make sure every network node of frequency inverter can be reached or not. After typing the necessary information in the relevant boxes, it is only required to press "Connect" button to see the connection status as shown in Fig. 5.

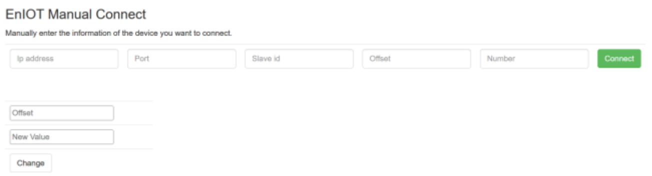

Fig. 5. Manual connection test for every network node

If connection is working properly, frequency inverter responds to proposed product, and the text on the "*Connect*" button turns into "*Disconnect*", additionally data of the frequency inverter is displayed on the web interface as in Fig. 6.

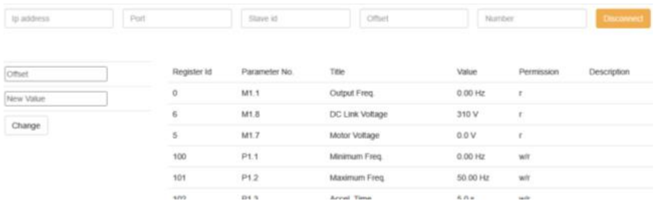

Fig. 6. Manual connection test and data monitoring of frequency inverter

After testing connection, in case of successful connection established, as many as inverter connection as desired are defined on the parameters page of web interface and these are saved on the cloud. Then, when the defined inverter connection is selected on the page, cloud connection becomes active and all parameters' values of the selected inverter are displayed instantly on the web interface as shown in Fig. 7. In addition, the instantaneous values of the parameters can be monitored from the local interface or device own display as shown in Fig. 8. This feature is useful especially for testing. In this way, it can be easily confirmed whether the developed application reads the correct values or not.

The application software running on the IoT communication gateway firstly sends all the parameters, which are read from the frequency inverter, to the IoT hub. All data reaching the IoT hub is instantly displayed on the web interface of the application. The Modbus register ID number, Parameter No, Parameter description (Title) and the instant values of the parameters are displayed in the corresponding columns as shown in Fig. 7. The instantaneous values of the parameters are refreshed every 3 seconds as default due to the network density.

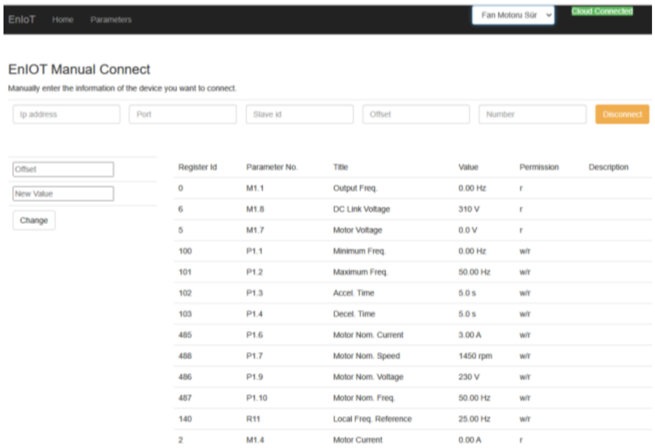

Fig. 7. Web interface of the proposed application

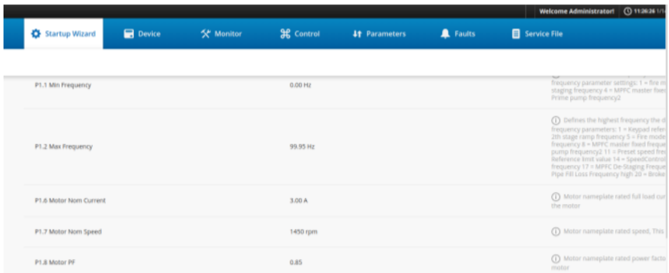

Fig. 8. Embedded web interface of frequency inverter

IV. Conclusion

In this study, remote monitoring and control of a frequency inverter, which is required for motor driving in industrial facilities, has been carried out. Thanks to remote access to devices in the industrial field, users can monitor the status of machinery and equipment from anywhere. This allows expert technical teams to be alerted earlier, which means they can respond quickly to issues and find solutions without time-consuming delays. With the developed application, it will be possible to access data and devices over multiple access points. Also, shift changes, task sharing and team operations in the factory will become more fluid. Thanks to the remote support, it will be easier to access the specialist personnel needed especially in night shifts. With real-time monitoring over internet-connected devices, the technical team will always have the latest data available. This can help manufacturers implement more efficient processes while reducing delays in recording and sharing information.

While this study forms the basis for many projects currently being worked on, we believe that it will also be a source of inspiration for the creation of new projects.

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