

Araştırma Makalesi - Research Article

## Application of Monitoring and Controlling of Water Storage Tanks, Pumps, and pH Value in Industrial Areas Based on Industrial Internet of Things

### Endüstriyel Alanlarda Su Depolarının, Pompaların ve pH Değerinin İzlenmesi ve Kontrol Edilmesine Yönelik Endüstriyel Nesnelere İnterneti Tabanlı Uygulama

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#### ABSTRACT

In this study, the control and monitoring of 110 kW water motors in 4 water wells at different distances from each other, the monitoring of 500-ton water tanks and additionally the monitoring pH value of the rainwater log of a chemical factory have been carried out. In the application, 9 Raspberry Pi 3 embedded system boards based on the Industrial Internet of Things (IIoT) have been utilized. The sensor data have been taken with the developed analog digital converters (ADCs) and collected in the open-source InfluxDB database with embedded system cards. These data have been visualized in a computer setup the open-source supervisory control and data acquisition system (SCADA) Grafana software. Thus, the IIoT application of a large system has been fulfilled cost-effectively by using Raspberry Pi 3 embedded system boards, open-source InfluxDB and Grafana software.

**Keywords-** IIoT, Raspberry Pi, InfluxDB, Grafana, Embedded System

#### ÖZ

Bu çalışmada, birbirinden farklı mesafelerdeki 4 adet su kuyusunda bulunan 110 kW'lık su motorlarının kontrolü ve izlenmesi, 500 tonluk su depolarının izlenmesi ve ayrıca bir kimya fabrikasının yağmur suyu giderinin pH değerinin izlenmesi yapılmıştır. Uygulamada, Endüstriyel Nesnelere İnterneti (IIoT) tabanlı 9 adet Raspberry Pi 3 gömülü sistem kartı kullanılmıştır. Farklı alanlardaki sensör verileri, geliştirilen analog dijital dönüştürücüler (ADC) ile alınmış ve gömülü sistem kartları ile açık kaynaklı InfluxDB veri tabanında toplanmıştır. Bu veriler, açık kaynaklı yönetici kontrol ve veri toplama sistemi (SCADA) Grafana yazılımı olan bir bilgisayar kurulumunda görselleştirilmiştir. Böylece Raspberry Pi 3 gömülü sistem kartları, açık kaynaklı InfluxDB ve Grafana yazılımı kullanılarak büyük bir sistemin IIoT uygulaması maliyet etkin bir şekilde gerçekleştirilmiştir.

**Anahtar Kelimeler-** IIoT, Raspberry Pi, InfluxDB, Grafana, Gömülü Sistem

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## I. INTRODUCTION

The use of water and steam technologies in industry is called Industry 1.0. Later, with the use of electrical energy, people's work became easier, and this was described as Industry 2.0. Industry 3.0 has entered working life with digitalization using information technologies. The spread of these computer technologies in the industry has occurred at a faster pace than other developments. Almost all machines have become computerized, allowing production to be faster, more efficient, and less expensive. A new era has begun with the use of the internet around the world. It has become very easy for people to communicate with each other. The rapid dissemination of news and information has been achieved by creating different platforms and communities. This situation has brought about the transfer of machine and process information in the industry via the internet. Thus, it was possible to intervene in machines and processes from remote locations. This concept is expressed as Industry 4.0.

Transferring the information of machines and processes to the internet using wireless networks has led to the formation of a new concept, the Internet of Things (IoT). If these objects are in an industrial environment, the transfer of their data to the internet and the possibility of remotely intervening in these devices and processes are described as Industrial IoT (IIoT) [1]. IIoT systems include interconnected smart power generation plants, industrial production areas, medical applications, and transportation [2]. In IIoT systems, real-time sensor data is transferred to a cloud environment on the internet. These data can be visualized with the Supervisory Control and data Acquisition System (SCADA) and instantly transmitted to operators, engineers, and factory owners. Since the received data can be stored for a long time, retrospective inferences can be made [3]. In addition, information can be obtained about the behavior of the system. Depending on these, artificial intelligence [4], machine learning algorithms [5], and predictive maintenance operations [6] can be performed. As a result, smart factories, smart processes, and smart machines have emerged [7].

One of the most important elements of IIoT systems is embedded system cards. Embedded systems are cheaper electronic cards in the structure of a computer and contain almost all the units found in a computer. Units from embedded systems are assembled into integrated circuits to make microcontrollers. The fact that microcontrollers can be produced more cheaply than embedded systems has enabled these integrated circuits to be used more widely in IIoT systems [8]. While every microcontroller system can be expressed as an embedded system, not every embedded system can be expressed as a microcontroller system. But each of these can be used for IIoT systems. While the units in microcontrollers are quite limited, the units in embedded systems and computers are quite capable.

IIoT has found application opportunities in many areas, from agriculture [9] to health [10], from health to transportation [11], and from transportation to education [12]. Its usage areas are increasing day by day, with a dizzying acceleration [13]. Monitoring the development of a product [14], determining the maintenance status of all agricultural products in a field with image processing devices [15], detecting humidity and temperature in agricultural areas [16], recording them, and intervening remotely when necessary [17]. Today, IIoT can be easily done in the field of agriculture. With the increase in devices with wearable sensor technologies, continuous monitoring of a person's heart condition [18], remote intervention by the patient's doctor [19], monitoring and recording of chronic diseases [20] stand out as applications of IIoT in the field of healthcare. Remote access to this data is based on taking personal privacy into account [21]. In the field of transportation, it is seen that it is used in determining the locations of general vehicles [22], sharing information about how long it takes to reach the destination [23], how many parking spaces there are in a parking area [24], and communicating the road condition to drivers with smart sensors placed on the roads [25]. Monitoring the chemicals in tanks in a chemical factory and analyzing the received data can be used to identify objects passing through the conveyor belt of an industrial process [26]. In addition, it is preferred to deliver the sensor data used to determine the amount of carbon dioxide coming out of factory chimneys to the necessary inspection organizations without any intervention [27]. IIoT is a very good use case for monitoring the status of large-power asynchronous motors located in critical areas of processes and sending alerts to technicians for predictive maintenance. Thus, there will be no interruption in the process, and product production can continue [28].

Factories located in large organized industrial zones do not want the water they use to be interrupted. They also want the quality of the incoming water to be at a certain value. For this purpose, they obtain the necessary permissions in these regions, open water wells, and build water tanks next to them. In addition, they want to keep tight controls on chemical production factories and constantly monitor pH values to prevent water with high pH levels from mixing with rainwater in their region. When an undesirable situation occurs, they take the necessary precautions to be notified immediately.

In this study, IIoT system design and application of four separate water wells in Manisa Organized Industrial Zone (MOIZ) was carried out. In addition, the pH value of hazardous waters that may mix with the rainwater of a factory was monitored with the IIoT system. The data of a system was taken with sensors and transmitted to Raspberry Pi 3 embedded system cards. With these cards, the data was transmitted to the InfluxDB

database and visualized with Grafana to create an IIoT system application. The presentation of the study is made as follows: After a general introduction, "Material" is explained in the second part of the study. "Method" is given in the third section, and "Results" are explained in the fourth section. Finally, "Conclusions" are stated in the fifth chapter.

## II. MATERIAL

It is possible to divide the designed and developed IIoT system into several parts. The first of these is a set of nine Raspberry Pi 3 embedded system boards that can work like minicomputers. The second is the analog digital converter (ADC) sensor and relay cards used in receiving and controlling the data of the system developed for the Raspberry Pi 3. Another one is the water pump panel used to control water pumps. The last one is the InfluxDB database, where the data from Raspberry Pi 3 cards are collected, and the Grafana software, which can be called a SCADA, makes the data meaningful and adds visuality to the system.

### A. Raspberry Pi 3 embedded system card

The Raspberry Pi has been developed by the Raspberry Pi Foundation to realize minicomputer functions and be used in system controls. It was first used in 2009 to achieve student education purposes and is an open-source embedded system board. Almost all Input/Output (I/O) units installed on a computer can be installed on this controller card. These are I/O systems such as monitors, keyboards, mouse, cameras, and Ethernet lines. With these control cards, image processing can be done precisely thanks to the high-resolution multimedia interface. It contains connectors for Universal Serial Bus (USB) connections. If there is a Wi-Fi network around, this communication makes it possible to send any information to the internet environment [29].

By using the Ethernet port, it is possible to connect to the internet or a different network environment and exchange data. Programming can be done with the C and Python languages, which are embedded system programming languages. At the same time, Linux and Windows operating systems can be installed and run on this card. These operating systems require a micro-static disk (micro-SD) to be used. With the general purpose I/O (GPIO) pins on the Raspberry Pi 3 board, an intermediate integrated circuit (I<sup>2</sup>C), universal asynchronous receiver-transmitter (UART), and serial peripheral interface (SPI) communication protocols are possible. It allows both power and data connections to be made via the Ethernet line [30]. In addition, a computer with the Windows operating system can be accessed via a Raspberry Pi main screen monitor with a known Internet Protocol (IP) address by using the Virtual Network Computing (VNC) program.

The Raspberry Pi 3 embedded system board has a Cortex-A53, 1.4 GHz, quad-core, 64-bit supported central processing unit (CPU). Ethernet access is possible with Gigabit Ethernet, 300 MBit/s (USB 2.0). Wi-Fi communication is carried out in 802.11ac, 2.4 GHz, and 5 GHz dual-band. It has 2.0 Bluetooth communication with BLE support. The camera connection is made via a CSI port. The number of GPIOs is 40. There is 1 GB of LPDDR2 SD RAM space. The number of USB ports is 4 and has 2.0 speed. Micro SD can be installed as a storage unit. Due to these mentioned features, using the Raspberry Pi 3 embedded system boards in the IIoT system has provided great convenience.

### B. Analog digital convertor

The signals of the transducers used to convert the levels of four 500-ton water tanks into electrical signals are 0.5-4.5 V DC. The output of the pH sensor used to know the pH value of the liquid that is likely to mix with the rainwater of the chemical plant is 4-20 mA. ADC processing is required for the Raspberry Pi 3 embedded system board to process these analog signals. For this reason, the MCP3008 I/P ADC integrated by Microchip has been preferred in the analog sensor card. This integrated circuit requires 2.7-5.5 V DC supply voltage. It can transmit ADC values to the Raspberry Pi 3 card via SPI communication. It has a sampling rate of 200 kSPS with a 10-bit resolution. This integrated circuit has four differential inputs. These differential inputs can be used as 8 analog inputs. It draws 5 nA of current from the power supply when used in low-current mode and 300 µA of current when active. The operating temperature range is between -40°C and +80°C.

### C. Liquid pressure sensor

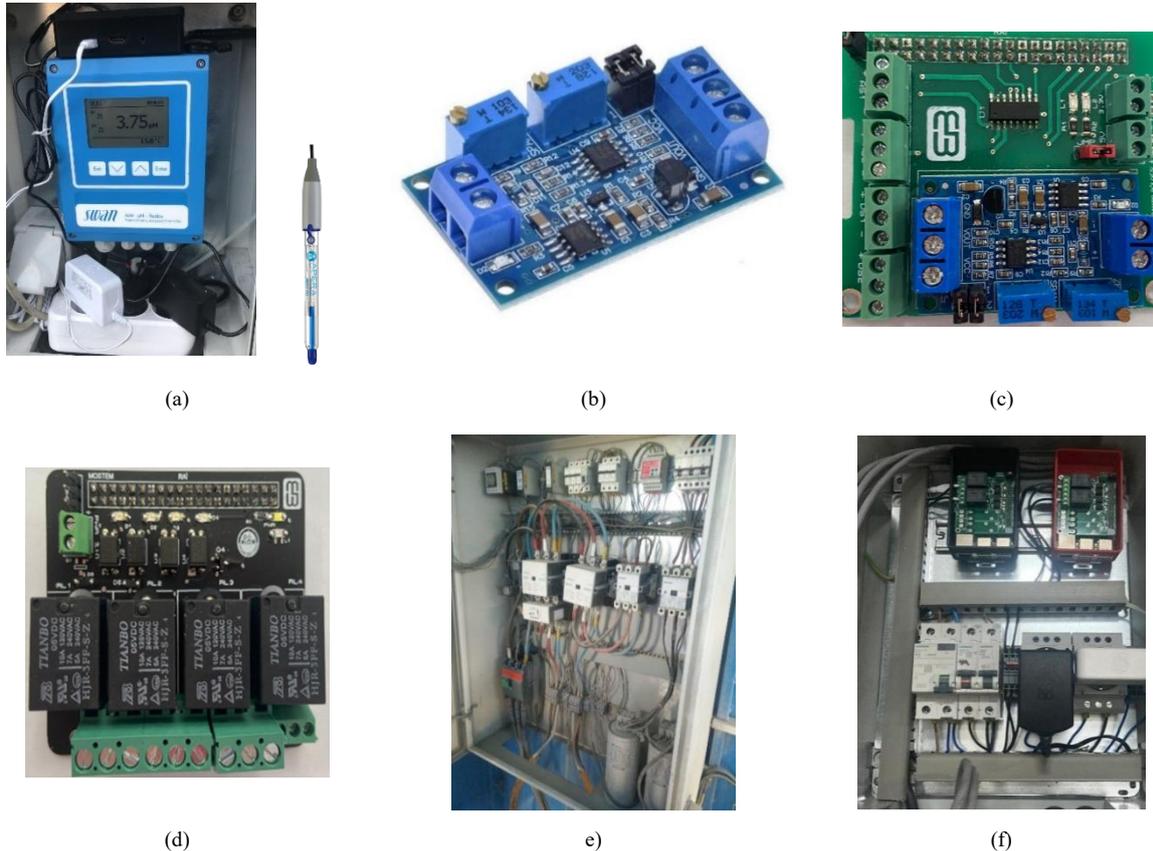
5V G1/4 0-1.2 MPa Hydraulic Water/Oil/Gas DN10 pressure sensors, which can be used in non-corrosive liquids, have been used to determine the levels of four 500-ton water tanks. Their operating voltage is 5.0 V DC. It can be used in the 0-1.6 MPa value range and provides linear output in the 0.5-4.5 V DC range. It has an operating temperature between 0°C and +85°C. It can withstand up to a maximum of 2.4 MPa. The output voltage value is given by the following equation:

$$V_{out} = V_{cc} \times (0.75 \times Pressure + 0.1) \quad (1)$$

Where,  $V_{out}$  is the output voltage, and  $V_{cc}$  is the supply voltage of the sensor.

#### D. pH sensor

In the IIoT system, the pH value of the liquid that may mix with the rainwater of the chemical factory has been determined. Rainwater that is likely to combine with other rainwater and end up in clean water basins can be identified by measuring its acidic or basic values using Swan Company's AMI pH redox potentiometric analyzer controller. This device has a pH sensor and was installed in the factory in the area where rainwater goes. Accessing the device allowed for the acquisition of the previously measured values. The device can transmit the measured pH value to other devices at 4-20 mA with the help of its two pins. These two pins have been used in the realized IIoT system. The sensor and device used, and the Raspberry Pi 3 used to send this data to the Influx DB database, are shown in Figure 1a.



**Figure 1.** a) Swan AMI pH – Redox potentiometric analyzer – controller device, b) current voltage converter card, c) analog digital converter card for Raspberry Pi 3, d) relay card designed for Raspberry Pi 3, e) well pump control panel and f) Raspberry Pi 3 - Raspberry Pi 3 relay board

The pH value of rainwater is around 5.6. This value normally varies between 0 and 14, depending on the acidity and alkalinity of the liquid. The pH value in drinking water is in the range of 6-9. This value indicates that the liquid is neutral when  $\text{pH} = 7$ , acidic when  $\text{pH} < 7$ , and basic when  $\text{pH} > 7$ .

#### E. Current-voltage converter

The outputs from which pH information is obtained from the Swan pH measuring device are 4-20 mA. For this value to be entered into the Raspberry Pi 3 embedded system controller, it must first be converted to a voltage value and then to digital data. Using the developed card in Figure 1b, 4-20 mA has been first converted to 0-5 V DC and then converted to digital with the MCP3008 I/P ADC integrated on it and sent to the Raspberry Pi 3 card. The size of the designed card is  $40 \times 25 \times 12$  mm. The operating voltage has been kept between  $-10^\circ\text{C}$  and  $60^\circ\text{C}$ . These values are quite suitable for the weather conditions of the water tanks at the MOIZ site. The operating voltage of the card is 5-30 V DC with the linear voltage integrated circuit used.

#### F. Analog digital converter board for Raspberry Pi 3

It is not possible to directly connect the output voltages of the pressure sensors used to determine the level of four 500-ton water tanks to the General Purpose I/O (GPIO) pins of the Raspberry Pi 3 card. GPIO pins only read digital data. For this purpose, the analog digital converter card was designed, produced, and then used in the system. The current-voltage converter card has been mounted on this card. Figure 1c shows the analog digital converter board designed for the Raspberry Pi 3. This card has been used by placing it on each Raspberry Pi 3 card

on which the IIoT design of the system has been made. This board has 3 analog inputs, two digital signal inputs, and two 5 V DC and two 3.3 V DC supply inputs. To determine the system status, two blue and white light-emitting diodes (LEDs) are placed on it. A jump pin has been added so that the card can receive the supply voltage from the Raspberry Pi 3 card or externally. Thus, high-current feeds can be made by a different source.

### ***G. Relay card for Raspberry Pi 3***

The designed and produced relay card has been developed to be mounted on Raspberry Pi 3. Figure 1d shows the relay card developed for Raspberry Pi 3. Four relays have been placed on top of this. These relays have two open and two closed contacts. Optical isolation of Raspberry Pi 3 has been made with PC817 optocouplers. Two of these relays have been used to receive signals from Raspberry Pi 3 and the other two have been utilized to give output from Raspberry Pi 3. The coil voltages of the two relays used to receive signals coming from outside are 220 V AC. The operating information of the 110 kW asynchronous motors in the well is transmitted to the Raspberry Pi 3 card with the help of these relays. Relays activated by MMBT3904 transistors, which send information to the system from the Raspberry Pi 3 card, send the status of the water pump in the well to the operator via a signal lamp. These motors could be controlled with the Grafana SCADA software in the IIoT system. 220 V AC and 5 V DC relays are placed on the card as redundant. Additionally, four signal LEDs have been used for the on/off states of these relays.

### ***H. Water pump control panel***

In the IIoT system, four well pump control panels have been used to control four 110 kW water pumps that enable the filling of 500 tons of water tanks. These control panels have been set up and manufactured previously. These have been used before the IIoT conversion of the system. These are shown in Figure 1e. The well pump control panels are installed approximately 10 m away from the water tanks. The control circuit operates with 220 V AC. Two Raspberry Pi 3 control cards and IIoT control panels with Raspberry Pi 3 relay cards installed on the sides of four well pump control panels, all of which are in different sites, have been designed and produced. Figure 1f shows the Raspberry Pi 3 - Raspberry Pi 3 relay board. This board contains two Raspberry Pi 3 supply adapters, two 10 A fuses, an overcurrent relay, and two Raspberry Pi 3 and two Raspberry Pi 3 relay boards. The Raspberry Pi 3 relay board has been attached to the GPIO pins of the Raspberry Pi 3. These have been placed in boxes designed with SolidWorks and produced with a 3D printer. The 220 V AC relays on the relay board are at the top of the board, and the 5 V DC relays are at the bottom of the board.

### ***İ. InfluxDB data platform and Grafana***

This database has been used in the IIoT system to store and analyze the levels and pH values of four water wells. InfluxDB is an open-source database and written in Go. It is designed to capture and record real-time data from the field. InfluxDB software uses InfluxQL, a query language like Structured Query Language (SQL). It supports the Hypertext Transfer Protocol Application Programming Interface (HTTP API) for data retrieval. Additionally, there are various visual supports for displaying the data. This software is generally preferred with SCADA-type software such as Grafana [31]. Another feature of this software is that it can handle increased data by adding more machines to a cluster. It facilitates sending data to the database via HTTP. It allows access to old data and deletion at any time.

Grafana is open-source visualization and monitoring software. The implemented IIoT system, it has been used to visualize and monitor the data received with InfluxDB. With this, it can be used with Graphite and Elasticsearch database software. This software offers its users various tools, such as tables for data, graphs, and heat maps. It allows warnings to be placed on certain values of the received data. These warnings can be sent via e-mail [32]. Several users can be determined to log in to the program, and different security levels can be defined for their intervention in the system. Using these features, messages have been sent to system technicians.

## **III. METHOD**

The information flow of the designed and implemented IIoT system and the method used are shown in Figure 2. In the IIoT system, four 110 kW asynchronous motors serve as water pumps and provide water pumping into water wells. Contactors on the pump control panel provide power to water motors. These water pumps have been worked by the IIoT system, with four Raspberry Pi 3 cards used for each water pump. The contactors have been operated with information coming from the Grafana interface to the relays on these Raspberry Pi 3 cards. Information about whether the water pumps are running or stopping has been transmitted to InfluxDB and visualized in the Grafana interface.

Four 500-ton water tanks loaded with water pumps have been positioned across the MOIZ area. These water tanks have been monitored by the IIoT system, with four Raspberry Pi 3 cards used for each water tank. Figure 3 shows the location of the water tanks taken from the interface of the Grafana program. When this figure is examined, there appear to be three water tanks in total. There are two water tanks where the red sign is located.

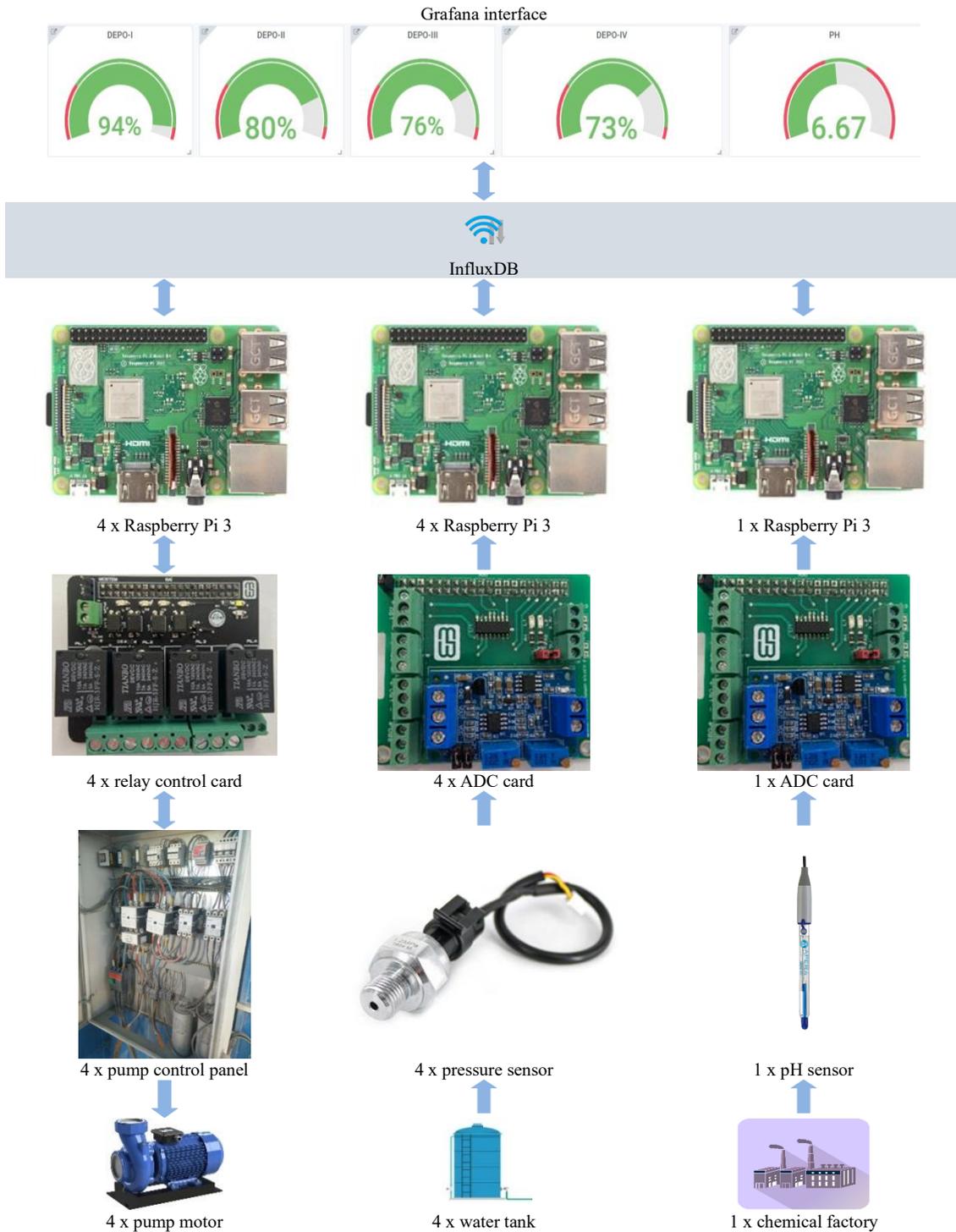


Figure 2. Developed IIoT system data flow



Figure 3. Locations of four different 500-ton water tanks

Level information for four tanks has been obtained analogously from pressure sensors. This analog information has been converted into digital information for the Raspberry Pi 3 to process with the ADC card designed and produced. Afterward, this information has been transferred to the InfluxDB database and visualized with Grafana.

A Raspberry Pi 3 has been used to measure the pH level and transfer it to the IIoT system to determine the chemical rates that are likely to be mixed with the rainwater channels of a chemical production factory. The pH level of the factory has been taken from the 4-20 mA current output of the Swan brand pH analyzer. The value of this analog current signal has been first converted into a voltage signal and a 0-5 V DC signal with a current-voltage converter card. Then, this converted signal has been converted to eight-bit digital with the ADC card and transmitted to the Raspberry Pi 3. So, this pH level has an 8-bit resolution.

The pH data has been made meaningful through a program written in Python. These pH values have been recorded on a Raspberry Pi 3 every minute and sent to the database from there. These pH data have been first transmitted to InfluxDB with the program written on the Raspberry Pi 3. This is visualized with Grafana software that communicates with InfluxDB. In addition, data has been saved to the Raspberry Pi 3 when there was no internet access, so no data loss occurred. When internet access has been restored, this data has been first transmitted to the InfluxDB database and from there to Grafana and visualized.

There are problems with internet access in areas where Raspberry Pi 3 cards are installed, in other words, in areas where water wells are located. This problem had to be solved because field data can be transmitted to InfluxDB via Ethernet cable or Wi-Fi connection. Since there is internet infrastructure in the area where the four Raspberry Pi 3 cards are located, the data here could be transferred to the internet via Wi-Fi. Since there was no internet infrastructure in the other four regions, four USM 3G modem providing devices have been used. Again, since there is no internet infrastructure in the region where the chemical production factory is located, a USB 3G modem device was used here.

The data stored in InfluxDB has been tested with Docker software, which is a storage area and works like a virtual machine. InfluxDB data has been transmitted to Docker software via the HTTP protocol, thanks to open protocol support [33]. The InfluxDB package software has been embedded into the card with Python to transmit the data processed on the Raspberry Pi 3 to the InfluxDB software. Thanks to the free software offered by InfluxDB, data could be easily transferred to the database.

Grafana has built-in support for the InfluxDB data source. Thus, Grafana and InfluxDB data could be visualized via an internet server. Data from the Raspberry Pi 3 was stored in the InfluxDB database. First, InfluxDB was installed after the Debian operating system was installed on the Raspberry Pi 3. Then, InfluxDB was updated. Afterward, a user was created in InfluxDB. Grafana plug-ins were then installed on the Raspberry Pi 3 and the program was updated. Afterward, "http://<ipaddress>:3000" was typed into a browser, and the username and password have been determined for Grafana from the resulting interface. Again, from the same interface, http://<ipaddress>:8086 has been typed, and the previously determined username and password have been entered into the interface. As a result, InfluxDB is connected to Grafana.

Start/stop operations of 110 kW water pumps have been provided through written programs. The panels of the 110 kW water pumps in the system have been previously manufactured. Before this work began, the operator could control these manually using the panel. With this study, the remote starting and stopping of the pumps and the start/stop information of the pumps could be observed remotely with the IIoT system.

The open and closed contacts of the designed relay card have been connected to the place where the start/stop buttons of the previously built panel have been located, thus providing a structure that allows remote control of the pumps. In addition, with the relay contacts on the other relay card, the start/stop information of the pumps could be received from the operator's location by the information transmitted to the GPIO terminals of the Raspberry Pi 3.

Analog data between 0.5-4.5 V DC taken from the pressure sensors in four 500-ton water tanks has been transmitted to the Raspberry Pi 3 thanks to the designed ADC card. Incoming 0.5 V DC information indicates that the tank is 0% full, and in 4.5 V DC information, the tank is defined as 100% full. With the Raspberry Pi 3, this level of information is written in a 10-bit resolution. Therefore, the resolution of the level information is 1024. This information has been transmitted directly to InfluxDB, and from there, it has been visualized in Grafana, which communicates with InfluxDB.

The level of information has been continuously transferred to the Raspberry Pi 3. The Raspberry Pi 3 recorded this data every minute. Thus, when the internet communication between InfluxDB and the Raspberry Pi 3 was interrupted, this data was stored on the Raspberry Pi 3. When internet access became available, this data has been retrospectively transferred to InfluxDB, and retrospective data visualization could be done with Grafana.

#### IV. RESULTS AND DISCUSSION

To obtain information and control the 110 kW water pumps in the fields where there are four water wells within MOIZ, the data has been imported into the InfluxDB database with a Raspberry Pi 3-based IIoT system and then visualized with the Grafana interface. Their controls can be made with the graphics and buttons placed in the Grafana interface. With this, the level information data of four 500-ton water wells could be transmitted to InfluxDB with the four Raspberry Pi 3 cards used and other developed ADC cards and visualized with Grafana. A page of the designed Grafana screen is given in Figure 4.

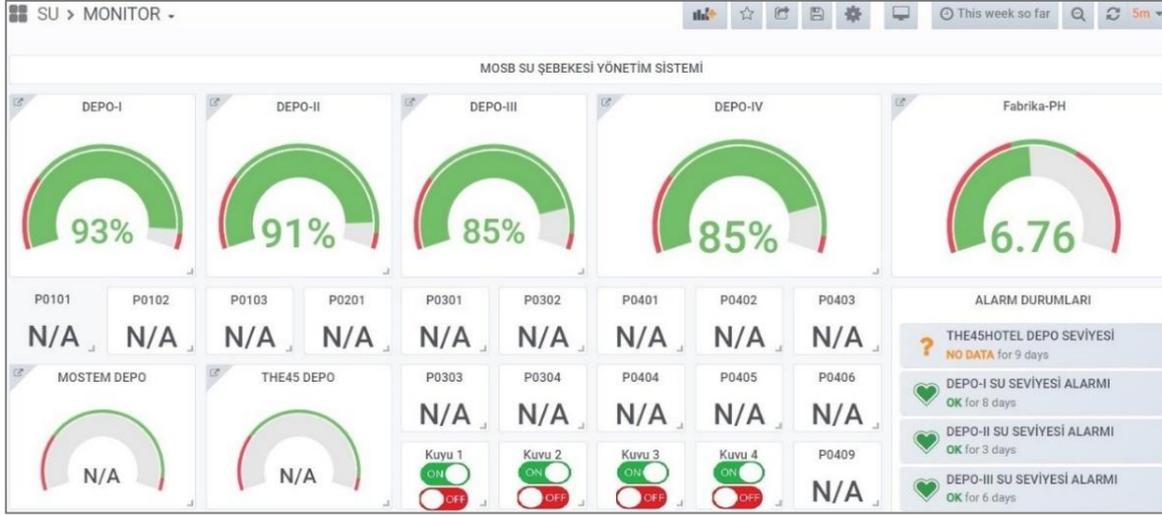


Figure 4. Designed Grafana screen

The start/stop status of 110 kW water pumps could be monitored with 220 V AC relays placed on Raspberry Pi 3 cards, which are activated when the pumps start. These are seen as "Kuyu 1", "Kuyu 2", "Kuyu 3" and "Kuyu 4". When the technicians responsible for the water tanks pressed the start/stop button on the control panel, the 220 V AC relay worked with the motor. With the contact of the relay, the information that this motor is running has been transmitted by sending Logic-1 to the Raspberry Pi 3 GPIO pin. Again, when the technician pressed the start/stop button again to stop the pump on the control panel, the pump stopped, and the 220 V AC relay coil was de-energized, and Logic-0 has been sent to the Raspberry Pi 3 GPIO pin with its relevant contact. These data are shown as pump start/stop in the Grafana interface. To remotely start and stop water well pumps with the IIoT system, Logic - 1 and Logic -0 have been sent to the Raspberry Pi 3 GPIO pin. When Logic-1 has been sent to start the pump, a 5 V DC relay has been operated with a transistor isolated from the control card with optocoupler isolation. 220 V AC is supplied to the middle end of the contacts of this relay. The operation of the relay and the operability of the water pumps have been demonstrated to the authorities by connecting a lamp to this contact.

On the designed Grafana screen, four percentile graphs of "DEPO-I", "DEPO -II", "DEPO-III" and "DEPO-IV" have been placed for the levels of water tanks. The occupancy values of these water tanks are stated as a percentage. When you look at them in order, you can instantly see that there are different occupancy values. The advantage of this is that the occupancy rate of four water tanks can be monitored and recorded with the IIoT system developed from a center, and the water pumps can be intervened with when necessary. The fields are left blank for the "MOSTEM DEPO" and "THE45 DEPO" graphs, which are planned to be included in this developed IIoT system later.

The pH value of the chemical plant, which is likely to mix with rainwater, has been monitored using "Fabrika-PH" in the Grafana interface. Its values are constantly recorded. Under this indicator, the alarms, and warnings section for the status of the pumps in the water wells, changes in the levels of water tanks, and changes in pH levels have been successfully operated, and information is conveyed to the operators when necessary. The sections marked N/A on this screen are areas reserved for sensors that are planned to be added to the software interface later. By clicking on the graphs with the mouse, historical information can be accessed. Historical "DEPO-I", "DEPO-II", "DEPO-III" and "DEPO-IV" graphs are given in Figure 5.

Using this graphical interface, it is possible to see all water level data since the operation of the system. When the mouse is brought closer to this data, it is possible to enlarge the Grafana screen with a magnifying glass. Although the data have been taken for a long time, an average value calculation has not been made. These data are evaluated as maximum and minimum values. But by using all these historical values, it will be possible to have

detailed information about the behavior of the system. With the feature added to the Grafana interface, the indicators of the water tank levels turn red when the levels exceed 97% and fall below 25%, and green in other cases. When you go to the "Fabrika-PH" of the chemical plant, historical data can be viewed graphically. The average "Fabrika-PH" data taken in 2022 is shown in Table 1.



Figure 5. Historical data of a) "DEPO-I", b) "DEPO-II", c) "DEPO-III" and d) "DEPO-IV"

Table 1. "Fabrika-PH" data for 2022

Months	Minimum	Maximum	Average
January	2.98	10.66	6.25
February	3.74	7.64	5.95
March	5.32	7.33	5.88
April	2.59	7.40	6.01
May	1.35	7.65	6.42
June	0.07	6.61	2.86
July	0.06	8.26	7.49
August	4.25	8.00	7.16
September	2.44	8.08	7.48
October	2.36	7.93	6.91
November	2.69	8.14	5.77
December	2.08	8.19	3.23

## V. CONCLUSIONS

In this IIoT application, the controlling and monitoring of 110 kW water pumps in four water wells, the monitoring of levels of 500-ton tanks, and the monitoring of pH value of a chemical plant that is likely to mix with rainwater within MOIZ have been carried out by means of 9 Raspberry Pi 3 embedded system cards. Owing to the implemented IIoT system, one-year data obtained from these cards have been kept in the InfluxDB database. Thus, a retrospective analysis of processes could be made. User interfaces have been carried out by visualizing the processes with Grafana software that can communicate with InfluxDB. Water overflows in tanks that previously occurred have been prevented with the developed IIoT application. In addition, by preventing the personnel working here from moving from field to field, it has been possible to monitor the status of the systems in different fields from a single center in a more comfortable way and to intervene in them remotely. During that time, in the

database, the highest water level of 500-ton water tanks has been measured at 99.9%. With the alarm added to the IIoT system, alerts have been sent to technicians' mobile devices as an e-mail. In this way, they have conducted system interventions. Approximately one year of data have been taken to monitor the pH level of the chemical plant that is likely to mix with rainwater. When these data have been examined carefully, there is no excess compared to the determined levels. All these collected data have been keeping in MOIZ's database, enabling retrospective research to be conducted. Ultimately, the low-cost monitoring and controlling IIoT system shows that the future of these IIoT systems is quite open in the industrial field and can be used in many more areas.

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