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Design and Implementation of Monitoring System for Power Stations Based on IOT

Aseel Yousif Mohammed
PG Scholar, College of Engineering,
Department of Computer Engineering, Mosul University, Iraq
Email: aseel.enp81@student.uomosul.edu.iq

Rabee Moafaq Hagem
Assistant Professor, College of Engineering,
Department of Computer Engineering, Mosul University, Iraq
Email: rabeehagem@uomosul.edu.iq, rabee.hagem@griffithuni.edu.au

Abstract: *Monitoring power transmission stations in terms of energy efficiency, diagnosing faults and monitoring deterioration in metrics affecting energy quality has a long been neglected due to the inability of current energy monitoring systems to obtain energy data in real time. In this research, an initial system was designed to monitor the important factors in determining power quality based on the Internet of Things, by using a microcontroller (ESP32S), sensor (PZEM - 004T) to measure voltage, current, frequency, power as well as power factor, temperature sensor (max6675), and any load to provide us with current and (Power Supply) to obtain variable voltages. This system can provide data to help prevent power outages by relying on engineers who have a thorough electrical system analysis. The proposed system is ready for testing in any actual power station.*

Keyword: *Please provide four to six keywords or phrases in alphabetical order, separated by semicolon (;)*

1. INTRODUCTION

Substations are an important part of the electrical power system. These stations convert the voltage level from high voltage to low voltage using (transducer). The substation transfers power from transmission lines to distribution stations [1].

Systematic electrical substation inspection is crucial to detecting faults, because if left unchecked, small and undetected electrical issues may lead to far-reaching consequences. These failures not only cause excessive energy losses, but they also cause unnecessary energy losses. It can also lead to expensive unplanned outages, serious technician injuries or a fire. Therefore, reliable, precise and regular inspections are important to ensure secure long-term operation, the integrity, protection and overall reliability of this type of industrial installation [2].

At present, the electric power infrastructure is considered weak against problems that negatively affect the general performance and the stability of the network, although the fault indicators technology has provided a way to identify faults, but the technical staff still has to make a manual effort and inspect the devices for longer hours to discover and determine the fault in the power stations, IoT technology provides an easy way to monitor problems at power stations without spending extra time [3].

Internet of Things is a network connects objects that uniquely identifiable to the Internet, things are linked to sensors and can be programmed. The goal of the Internet of Things is to connect all things and achieve communication between the user and the object, the Internet of Things can be applied in every aspect of the electrical power network (from generation to the customer), implementing IoT in power grids and access to data in real time allows engineering or technical staff to monitor and analyze the system and make decisions in real time, which improves the efficiency and reliability of the system [1].

Yu Tia, Zhenjiang Pang, and others proposed a substation monitoring system to monitor the station's equipment and operating environment in real time. The system consisted of three parts, the first part is (hardware), divided into (UHF) (Ultra High Frequency) temperature monitoring subsystem to monitor equipment, and substation environmental monitoring subsystem to monitor the operating environment using temperature, humidity, gas and smoke sensors, and the wireless repeater, responsible for sending the sensor data to the communication protocol (IEC60870-101104 protocol), the second part is (network) using (Zigbee) technology, the third part is (software), the

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data is received via the communication protocol (IEC101 or IEC104) and the data is processed and sent to the monitoring substation [4]. Mrs. Asha John, Richu Varghese, and others proposed an automation system for a power substation using built-in processors of Raspberry-pi to automate a substation (11kv) [5]. Rohit R. Pawar, Priyanka A. Wagh, and others, have designed a system for monitoring various gauges in power distribution transformers. The proposed system consists of two parts, Hardware, consisting of a (PIC18F4550) controller and various sensors, a current sensor, a temperature sensor, an oil level sensor, a vibration sensor, and a humidity sensor, software part depend on SQL (Structured Query Language) [6]. NA Hidayatullah, AC Kurniawan, and others have proposed a transmission line monitoring system based on (WSN) (Wireless Sensor Network) and (GPRS) (General Packet Radio Services) to be used in remote areas where 3G and 4G networks are not available [7].

Hassan Jamal, M. Faisal Nadeem Khan, Ayesha Anjum, and others, have proposed a distribution transformer monitoring and protection system, based on the Internet of Things. The proposed system is divided into two units, a (RTU) (Remote Terminal Unit), and a control unit, (RTU) consists of a microcontroller (ESP8266-E12) (Wi-Fi), current sensor, temperature and humidity sensor (DHT22), which collects data continuously and sends it to the monitoring unit that uses the (Thingspeak) platform for real-time monitoring [8]. Dragan Mlakić, Srete Nikolovski, and others have designed a "smart meter" to measure voltages and current in low voltage networks using Arduino UNO R3 controller, voltage sensors, and current sensors [9].

The analysis of the literature detects that a majority of the substations monitoring systems depend on expensive microcontrollers and differ in terms of the type of microcontroller, and the type of sensor used to simulate the practical circuit. Most of the studies used the microcontroller (Arduino) and (WSN) (Wireless Sensor Network), (GPRS) (General Packet Radio Services), and (Zigbee) technology, and used a many sensor to measure the important parameters in the substations.

This paper describes how to apply IoT to the electrical power grid environment, accessing and monitoring the substation data at real time, leading to improve substation reliability, performance and efficiency.

The proposed system is characterized by low cost and few used devices compared with previous studies. It aims to measure all important parameters in substations simultaneously, these parameters include (current, voltage, power, power factor, frequency and temperature) using a microcontroller (ESP32S), (PZEM-004T) and (MAX6675) sensor.

Section 2 explains the proposed framework. In Section3, architecture and working principles. The execution of the project is discussed in section 4. The results in section 5. Section 6 contains the conclusions and future works.

2. SYSTEM DESCRIPTION

3. 2.1 Components

The prototype of the proposed system consists of several components. Node MCU (ESP32S) for controlling and wireless communication, power supply variable (220V AC), load to supply the system circuit with current, temperature sensor ("MAX6675"), sensor ("PZEM-004T") to measure the value of current, voltage, power, frequency as well as power factor. Using (Node MCU) in this prototype because it has a processor (2 * Xtensa 32-bit LX6), massive memory (RAM 512KB) and (Flash 16MB), and (Wi-Fi) feature cheap and built-in.

2.2 The System's Overall Structure

The system is divided into two parts, the first part is the hardware components as indicated in paragraph (2.1), and the second part is the programs. The sensors are programmed using the (Arduino IDE) program and the programming language (C ++). The package for ESP32, and all the necessary libraries to work which are (PZEM004Tmaster), (PZEM004Tv03master), (CayenneMQTTESP32), (max6675) is loaded from web [10], then upload the code to (Arduino IDE) and get the data in real time on platform called (My Device Cayenne) through which we obtain data in the form of graphs, digital readings or tables, a structure of the system is shown in Figure 1.

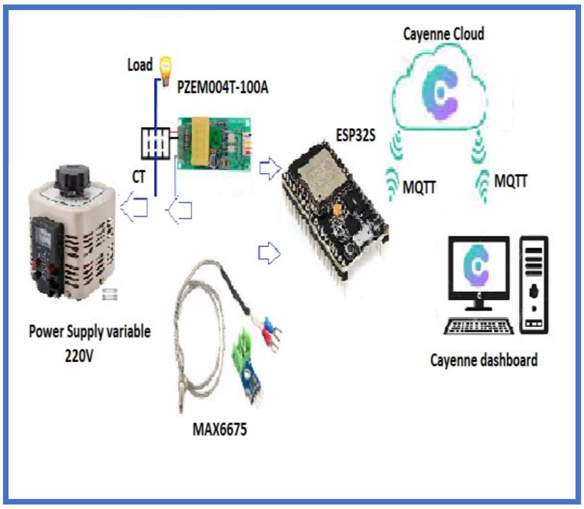

Figure 1 Structure of the system

3. DESIGN & WORKING PRINCIPLE

3.1 "ESP32" Microcontroller Module

"The ESP32 is a dual-core board with two Xtensa LX6 processors. It was launched as a replacement for the μC ESP8266 by Espressif Systems in September

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2016." The ESP32 appliance is a versatile Wi-Fi and Bluetooth embedded microcontroller. The memory is huge (RAM 512KB) (Flash 16MB). In addition, 448KB of ROM, 520KB of SRAM and two (8KB) of RTC memory are plant memories [11]. There are 36 GPIOs in ESP32, 14 of which are Analog to Digital Converter (ADC) that could be wired to the sensors; in addition, ESP32 has ISP pins used to link the ESP32 to the SD card reader. VCC supplied for the ESP32 is ranged 2.2V to 3.6V. A micro-USB is used by ESP32 to upload the software and supply it with power, or a (3.7V) battery is used to supply it with power [12]. ESP32S Board shown in Figure 2.

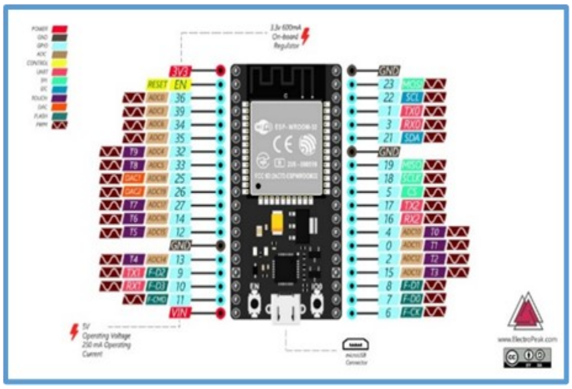

Figure 2 ESP32S Board [13]

3.2 Temperature Sensing Unit (TSU)

Many reasons can lead to malfunctions and damage for the equipment in power substations, so monitoring the temperature in substations is necessary, because it is one of the important matters that negatively affect the equipment [2].

The MAX6675 Thermocouple Temperature Module is a digital converter K-Type thermocouple with a maximum measurement range (0 °C to + 1024 °C). Via a 3-wire SPI interface, the MAX6675 sensor interferes with a microcontroller (ESP32). The technical specifications of the sensor are: VCC Range (3.0 to 5.5V), Imax (1.5mA), Thermocouple Dimensions (45cm) [14]. Details of this sensor are shown in Figure 3.

3.3 "PZEM-004T"Sensor

Modulus PZEM-004T developed by Peacefair Electronic (Ningbo Zhejiang, China). It accepts 80 to 260 V AC input voltage, 100A maximum current, and 45-65Hz frequency. It has an SD3004 SoC (produced by SDIC) embedded processing capability specified for electrical power measurement [15]."PZEM-004T"is used to measure voltage, current, frequency, power and power factor. The circuit of this sensor depends on the communication protocol (UART) to easily connect with the microcontroller ("ESP32") [16].

Specifications of "PZEM-004T":

- Voltage Supply: 5VDC
- Voltage Input: 80 – 260VAC
- Current measurement: 0 – 100A
- Operating frequency: 45 - 65Hz
- Power Range: 26000W
- Interface: UART TTL 5V.
- Measurement accuracy: 1.0 grade [16].

Details of this sensor are shown in Figure 4.

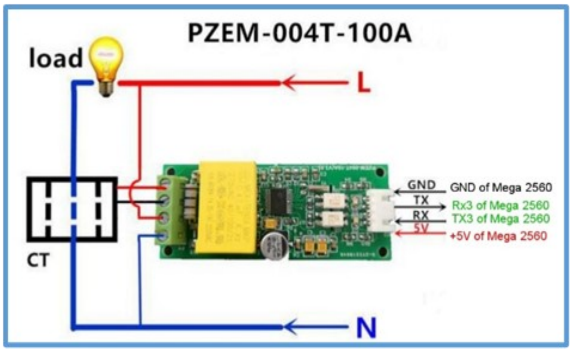

Figure 4 PZEM-004T module [17]

3.3 My Device "Cayenne Platform"

"My Device Cayenne Platform" is an Internet of Things platform that allows uploading data for IoT projects and creating monitoring by creating an account with your website (Figure 5) on the server of this platform for free from the web [18]. Data for projects are displayed on the dashboard, and this platform allows adding more than one project, and each project has a code especially, depending on the communication protocol (MQTT) [19].

Figure 5 Cayenne account

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"MQTT" is an abbreviated for "Message Queuing Telemetry Transport", which is the communication protocol used to communicate information over the Internet, it is based on the (TCP"/ IP) protocol developed by "IBM" in 1999, characterized by ease of use, uncomplicated, lightweight, low energy consumption Very fast in transferring information, it does not require a large use of memory, which makes it an ideal candidate for use in physical computing, it is also characterized by high reliability, depends in its work on Broker (MQTT Broker) [20], includes four parts:

Publish/"Subscribe", Message, Topic, and" Broker", shown in Figure 6.

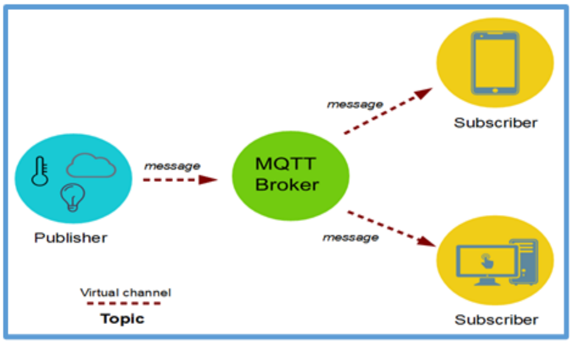


Figure 6 MQTT protocol [20]

4. IMPLIMENTATION OF THE SYSTEM

Connecting of the electrical circuit is shown in the Figure 7 and Figure 8. Arduino IDE" platform was used to generate the main code of the system and download the necessary libraries mentioned in paragraph 2.2, the "IDE" platform will create a Hex file and then upload the code to the board. "IDE environment", it contains two parts: an editor and a translator. This environment backing C and C ++ languages.

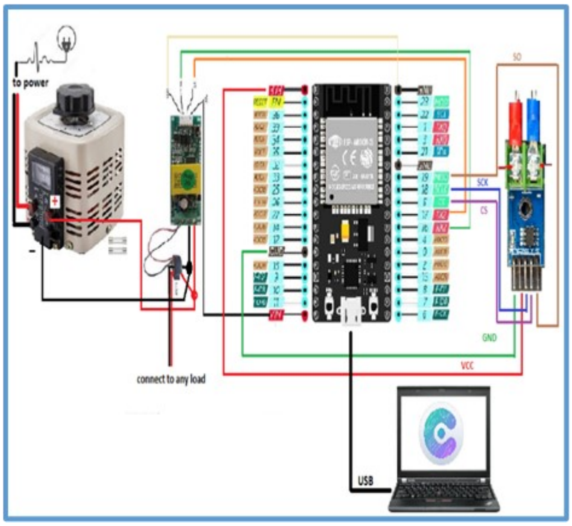


Figure 7 The electrical circuit of the system

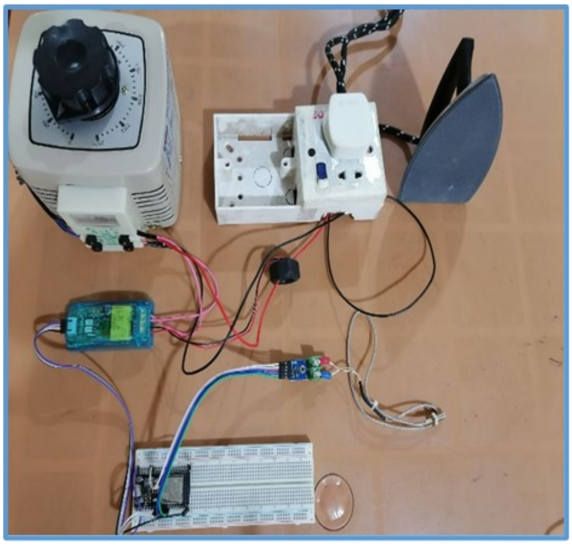


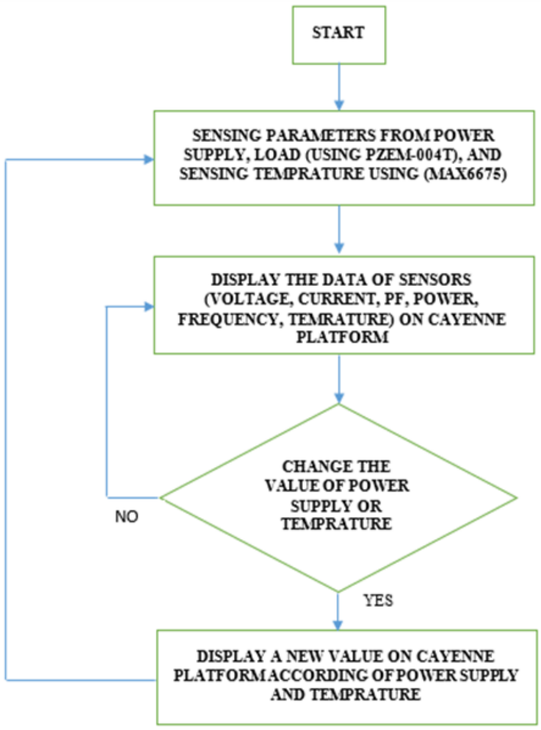
Figure 8 The Real circuit of the system

Steps of implementation the system:

Step 1: Initially the sensors (PZEM-004T)& (MAX6675) will sense the parameters from (Power Supply 220V & Load).

Step 2: The sensed data is sent to ESP32S microcontroller.

Step 3: The sensed data are save and display on the (My Device Cayenne) platform using Wi-Fi network.



Flow Chart. Steps for implementing the system.

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The Flow Chart, explains the steps for implementing the system.

5. RESULTS AND INTERPRETATION

Monitoring results of sensor readings on the cayenne platform are shown in Table 1, there are total of 6 channels used on the dashboard to show the sensors' data, temperature value (23°C), Frequency (50HZ), PF (1), we noted the voltage value (11,390V), and the current value (29.160A) according to the power supply variable, which we changed to obtain variable values. When writing the initial code, the voltage value was multiplied by (100), and the current value by (60). These are default values to express the true value of each transducer in the power substations.

Table 1 The results at power supply 113V

Timestamp	Device...Y	ChannelY	Sensor Name	Sensor ID	Data T...Y	Unit	Values
2020-11-28 1:55:09	aseel	3	CURRENT A	618f6340-2fc2-11eb-883...			29.160
2020-11-28 1:55:09	aseel	4	POWER W	6121d460-2fc2-11eb-b7...			55.300
2020-11-28 1:55:09	aseel	5	PF	60ed7df0-2fc2-11eb-a2e...			1.000
2020-11-28 1:55:09	aseel	6	TEMPRATURE	78b65bf0-2fc2-11eb-877...		c	23
2020-11-28 1:55:09	aseel	2	FREQUENCY HZ	620640f0-2fc2-11eb-a2e...			50.800
2020-11-28 1:55:08	aseel	1	VOLTAGE V	1d13d080-2fc6-11eb-a2e...			11390.000

End of list

Figure 9 shown the results in dashboard when power supply 113V.

Figure 9 The results on dashboard at power supply 113V

Monitoring results of sensor readings on the cayenne platform are shown in Table 2, temperature value (23°C), Frequency (50.800HZ), PF (1), we note the voltage value (7040V), and the current value (21.100A), when the power supply variable approximately equal to (70V).

Table 2 The results at power supply 70V

Timestamp	Device...Y	ChannelY	Sensor Name	Sensor ID	Data T...Y	Unit	Values
2020-11-28 1:42:39	aseel	4	POWER W	6121d460-2fc2-11eb-b7...			20.900
2020-11-28 1:42:39	aseel	5	PF	60ed7df0-2fc2-11eb-a2e...			1.000
2020-11-28 1:42:39	aseel	6	TEMPRATURE	78b65bf0-2fc2-11eb-877...		c	22.75
2020-11-28 1:42:39	aseel	2	FREQUENCY HZ	620640f0-2fc2-11eb-a2e...			50.800
2020-11-28 1:42:39	aseel	3	CURRENT A	618f6340-2fc2-11eb-883...			17.880
2020-11-28 1:42:38	aseel	1	VOLTAGE V	1d13d080-2fc6-11eb-a2e...			7010.000
2020-11-28 1:42:24	aseel	4	POWER W	6121d460-2fc2-11eb-b7...			21.100
2020-11-28 1:42:24	aseel	5	PF	60ed7df0-2fc2-11eb-a2e...			1.000
2020-11-28 1:42:24	aseel	6	TEMPRATURE	78b65bf0-2fc2-11eb-877...		c	23
2020-11-28 1:42:24	aseel	2	FREQUENCY HZ	620640f0-2fc2-11eb-a2e...			50.800
2020-11-28 1:42:24	aseel	3	CURRENT A	618f6340-2fc2-11eb-883...			18.000
2020-11-28 1:42:23	aseel	1	VOLTAGE V	1d13d080-2fc6-11eb-a2e...			7040.000
2020-11-28 1:42:08	aseel	6	TEMPRATURE	78b65bf0-2fc2-11eb-877...		c	23
2020-11-28 1:42:08	aseel	2	FREQUENCY HZ	620640f0-2fc2-11eb-a2e...			50.800
2020-11-28 1:42:08	aseel	3	CURRENT A	618f6340-2fc2-11eb-883...			17.820
2020-11-28 1:42:08	aseel	4	POWER W	6121d460-2fc2-11eb-b7...			20.800

Figure 10 shown the results in dashboard at power supply 70V.

Figure 10 The results on dashboard at power supply 70V

Figure (11) and (12) show other results when changing the power supply to (110V) & (131V).

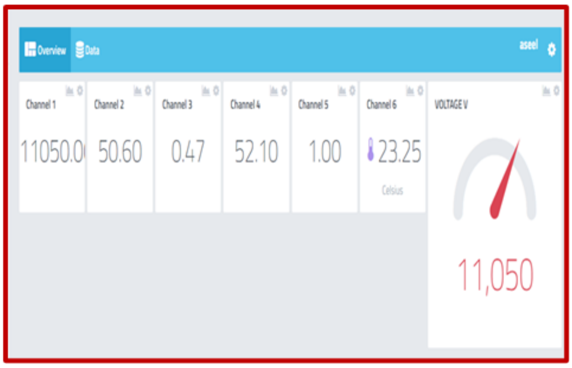

Figure 11 The results on dashboard at power supply 110V

The Cayenne dashboard provides us with historical reports and we can view them anytime we need it, and it can be downloaded, as seen in Table 3, as an excel table.

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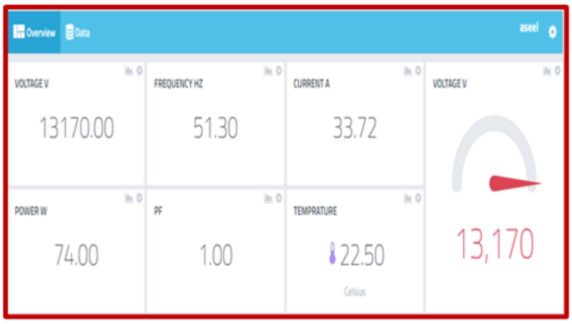

Figure 12 The results on dashboard at power supply 131V

These reports indicate the following:

•Timestamp, for example: Sun Des 06 2020 2:30:28.
•Device ID: 60578730-2e5c-11eb-a2e4-b32ea624e442.
•Device Type: digital or analog sensor or actuator.
•Sensor ID: all sensors have an ID of their own.
•Sensor name: all sensors have their own name.
•Data type.
•Unit: unit of measurement.
•Value: sensor reading.

We can use these reports, to verify the overall device performance and sensitivity of the sensors used. This is achieved by analyzing the channel data that interacts with the sensor, so these reports are very useful because they provide us with very important details that can be used to analyze the system and measure a stability of it.

Table 3 Data report

	A	B	C	D	E	F	G	H
1	Timestam	Device ID	Channel	Sensor Name	Sensor ID	Data Type	Unit	Value
2	2020-11-2	60578730-	2	FREQUENCY HZ	620640f0-2fc2-11eb-a2e4-b32ea624e442			50.70000076
3	2020-11-2	60578730-	1	VOLTAGE V	1d13d080-2fc6-11eb-a2e4-b32ea624e442			11430
4	2020-11-2	60578730-	4	POWER W	6121d460-2fc2-11eb-b767-3f1a8f1211ba			52.20000076
5	2020-11-2	60578730-	6	TEMPRATURE	78b65bf0-2fc2-11eb-8779-7d56e82df461	temp	c	22
6	2020-11-2	60578730-	2	FREQUENCY HZ	620640f0-2fc2-11eb-a2e4-b32ea624e442			50.59999847
7	2020-11-2	60578730-	3	CURRENT A	618f6340-2fc2-11eb-883c-638d8ce4c23d			0.470999986
8	2020-11-2	60578730-	5	PF	60ed7df0-2fc2-11eb-a2e4-b32ea624e442			1
9	2020-11-2	60578730-	1	VOLTAGE V	1d13d080-2fc6-11eb-a2e4-b32ea624e442			11080
10	2020-11-2	60578730-	5	PF	60ed7df0-2fc2-11eb-a2e4-b32ea624e442			1
11	2020-11-2	60578730-	6	TEMPRATURE	78b65bf0-2fc2-11eb-8779-7d56e82df461	temp	c	22
12	2020-11-2	60578730-	3	CURRENT A	618f6340-2fc2-11eb-883c-638d8ce4c23d			0.472000003
13	2020-11-2	60578730-	4	POWER W	6121d460-2fc2-11eb-b767-3f1a8f1211ba			52.29999924
14	2020-11-2	60578730-	2	FREQUENCY HZ	620640f0-2fc2-11eb-a2e4-b32ea624e442			50.59999847
15	2020-11-2	60578730-	1	VOLTAGE V	1d13d080-2fc6-11eb-a2e4-b32ea624e442			11090
16	2020-11-2	60578730-	5	PF	60ed7df0-2fc2-11eb-a2e4-b32ea624e442			1
17	2020-11-2	60578730-	6	TEMPRATURE	78b65bf0-2fc2-11eb-8779-7d56e82df461	temp	c	22
18	2020-11-2	60578730-	4	POWER W	6121d460-2fc2-11eb-b767-3f1a8f1211ba			53.20000076
19	2020-11-2	60578730-	2	FREQUENCY HZ	620640f0-2fc2-11eb-a2e4-b32ea624e442			50.59999847
20	2020-11-2	60578730-	3	CURRENT A	618f6340-2fc2-11eb-883c-638d8ce4c23d			0.476000011
21	2020-11-2	60578730-	1	VOLTAGE V	1d13d080-2fc6-11eb-a2e4-b32ea624e442			11170
22	2020-11-2	60578730-	3	CURRENT A	618f6340-2fc2-11eb-883c-638d8ce4c23d			0.47299999
23	2020-11-2	60578730-	4	POWER W	6121d460-2fc2-11eb-b767-3f1a8f1211ba			52.70000076

As shown in Figure 13, the Cayenne platform provides us with a data graph that shows the relationship between the sensor's time and value. The graph shown in Figure 13 shows the readings of the value of voltage from (1:05) to (2:25). Depending on the value of the variable voltage given for the power supply (220V), we find an increase and decrease in the readings.

The graph shown in Figure 14 shows the readings of the current value from (2:00) to (2:30). We observe an increase and decrease in the readings depending on the value of the variable voltage supplied to the designed system.

Figure 13 graph of the voltage values

Figure 14 graph of the current values

The graph shown in Figure 15, shows the readings of temperature values over a period of time (10 minutes). The temperature rises to around (37°C), because the sensor senses the temperature of the hand due to pressure on the end of the thermocouple by the hand.

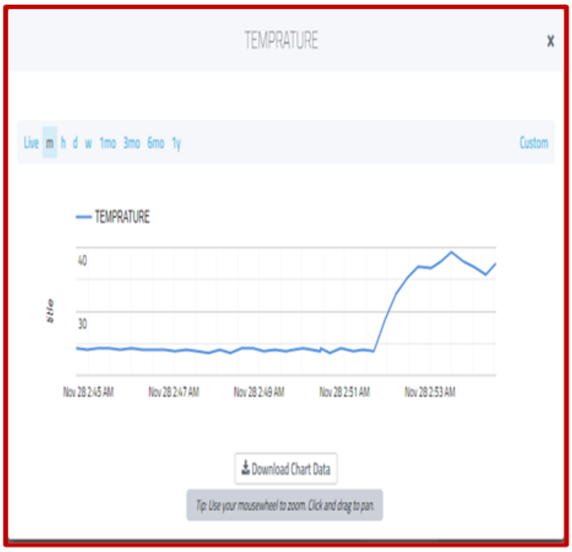

Figure 15 graph of the temperature values

6. CONCLUSION AND FUTUREWORKS

Designing a prototype of a monitoring system for important parameters in power substations based on Internet of Things technology, to reduce disasters and economic losses in important equipment in sub-stations. Monitoring parameters included voltage, current, frequency, power, power factor and tempera-ture. PZEM-004T and MAX6675 sensor were used to obtain these parameters. Data is continuously trans-mitted and displayed in real time on the Cayenne plat-form via the ESP32S module. We evaluate the sys-tem's performance through analysis the data of sen-sors by engineers and technicians.

The user can retrieve daily, weekly and monthly data due to the use of the MQTT Cloud supported by the Cayenne platform. The proposed system is ready for testing in the actual substations and to obtain real-time readings by using the values of the transducer that is used in each substation. The management of-fice in the substations can access this data, analyze it by a specialized engineering technical team, and make early warning in case of any emergency, which reduc-es the severity of disasters in the power stations. The proposed system can be enhanced in the future by using additional sensors to monitor the humidity in the substations and regulate the disconnection of the line when the parameters threshold limit is reached. This is done by using relay devices to control of dis-connecting of the line and return it. It becomes a sys-tem of controlling and monitoring together.

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Authors Biography

Aseel Yousif Mohammed received the B.Sc. degree, in 2010, in Computer Engineering from University of Mosul, Iraq. Currently, she is working for M.Sc. Degree in Computer Engineering at Mosul University's College of Engineering. She has been employed at the Ministry of Electricity in Iraq since 2013 until now; she is interested in doing research in Internet of Things and Smart solutions for monitoring electrical power stations.

Dr. Rabee Moafaq Hagem is currently assistance professor in University of Mosul; he received the B.Sc. and Msc. degree, in 1998 and 2001 meanwhile, in Electronic and Communication Engineering from it. His Ph.D. degree in underwater optical wireless communication for real time swimmers was from Griffith University / Brisbane / Queens-land / Australia back in 2014. His current research interests include IoT for smart cities, optical wireless communication, smart sensors designing and implementation, embedded devices for the tracking of athletes and review of sports results.

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