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Design and Implementation a Smart System for Monitoring the Electrical Energy based on the Internet of Things

Nabaa Ali Jasim [1,a], Haider Th. Salim AL Rikabi [1, b]

Affiliations
[1]Electrical Engineering Department, Wasit University, Wasit, Iraq

Correspondence
[a]nabaaj301@uowasit.edu.iq
[b]hdhiyab@uowasit.edu.iq

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Abstract

In this article, an open source monitoring system based on Internet of Thing (IoT) is designed to monitor electrical energy consumption. This system provides real-time information about energy consumption over time. To implement this system, sensors were used to measure data, a Raspberry as an application server to display and store data, and microcontrollers to collect information. The process of data transfer via the Internet using the Message Queuing Telemetry Transport (MQTT) protocol between the microcontroller and the server. Through the experimental results obtained from the proposed system, the voltage, current, active power and power consumption were successfully recorded.

Keywords: Internet of Things, ESP32 microcontroller, Raspberry pi 3, power consumption sensors, Things board platform.

الخلاصة: في هذه المقالة، تم تصميم نظام مراقبة ذكي مفتوح المصدر قائم على إنترنت الأشياء لمراقبة استهلاك الطاقة الكهربائية. هذا النظام يوفر معلومات في الوقت الفعلي حول استهلاك الطاقة بمرور الوقت. لتنفيذ هذا النظام تم استخدام اجهزة استشعار لقياس البيانات و جهاز الراز بيري باي كخادم تطبيق لعرض البيانات وخزنها و مايكروكنترولر لتجميع المعلومات. تتم عملية نقل البيانات عن طريق الانترنت باستخدام بروتوكول MQTT (نقل رسائل القياس عن بعد في قائمة الانتظار) بين المايكروكنترولر و السيرفر. من خلال النتائج التجريبية التي تم الحصول عليها من النظام المقترح تم تسجيل الجهد و التيار و الطاقة النشطة و استهلاك الطاقة بنجاح.

1. INTRODUCTION

The Internet of Things (IoT) is one of the modern technologies that present a large number of applications in the electric power sector in terms of transmission, distribution and consumption. Implementing an intelligent monitoring system for the amount of energy consumed in accordance with the IoT, can help improve the energy efficiency of buildings, residences, etc. [1-3]. It also provides real-time information about energy consumption. Therefore, designing and implementing smart energy monitoring in accordance with IoT applications is a theme of increasing significance in many researches and projects, among which are: Simonov et al. [4], explained the role of the Future Internet (FI) in the smart grids. In addition, enlightening how the anticipatory knowledge of the future occurrences of the energy consumption dynamics may be effectively promptly exchanged between competing actors [5, 6]. They focused on how to model, measure, monitor, optimize and control complex interdependent event flows happening in power grids, representing a significant infrastructure characterizing smart cities. they projected and discussed the use of Future Internet (FI). It provides the multiplicity of services, enabling the management of many different aspects of urban life [6, 7].

According to HoHuh et al. [8], the Programmable Logic Controller (PLC) technology was used to create a foundation for the micro the smart metering system, which monitors, controls, and manages household power flows, is a critical component of the micro grid system and relies heavily on projected technology. To transmit data, it relies on existing 220V power lines, so they expect it to complement both wireless and cable-based technologies [9,10].

Khan and his colleagues [11] described a power monitoring system based on the IoT in their project. The system is capable of measuring and analysing electrical parameters such as voltage, current, active power, and the energy "Thing Speak" is an IoT based software application used to get real-time electrical data from consumers and electric power corporations in the SG (smart grid) paradigm can better accomplish their usage to reduce billing costs by employing this data [12-15].

This paper describes designing and development an intelligent monitoring system for consumed electrical energy using the IoT applications. Were three sensing nodes used to measure and collect the electrical parameters of voltage, current, frequency and energy consumed. This data is sent to the server to manage and monitor it with supplied power, thus the server knows the trespassers on the electrical line. Where smart management and monitoring of electrical energy in building or homes is a key aspect of building efficient smart cities [16-18].

2. Design and Implementation of the System

2.1. System Overview

In this paper, the design of an open source monitoring system in the electrical sector is presented, which was built on the latest architecture, the IoT. The suggested system consists of data collecting sensors, a microcontroller for getting and handling sensor data, and a things board IoT server for data storing and human-machine interfaces. The MQTT protocol is utilizing a MQTT client on the ESP32 to transfer sensor data from the microcontroller to the things board IoT server through a local Wi-Fi connection, with the Things Board IoT server serving as a MQTT Broker. Such system provides appropriate and timely intervention. The methods for system design and analysis, along with dashboards made on the Things Board IoT server, have been displayed. Figure (1) show the diagram of the proposed system.

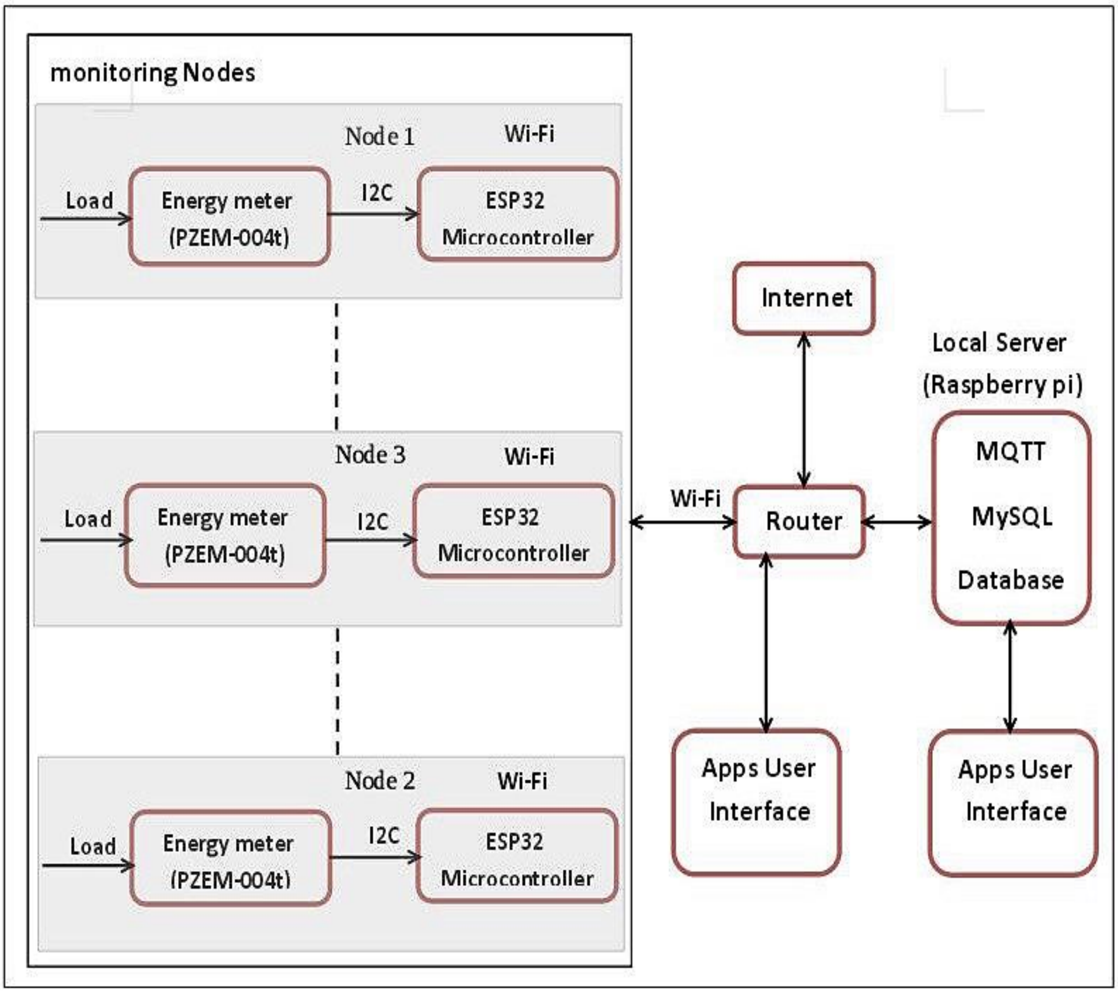

Figure 1 The block diagram of the proposed system.

2.1.1. Energy monitoring sensors

The PZEM-004t unit is responsible for measuring all electrical parameters which are voltage, current, active power and power measurement [19-21]. Due to its ability to store data when power failure as well as store energy data accumulated before power failure, so it is very easy to use. The maximum current that the sensor can measure is 100 amperes, while the range of detectable AC voltage is 80 to 260 volts. Figure (2) shows a simple diagram of an IoT power monitoring node.

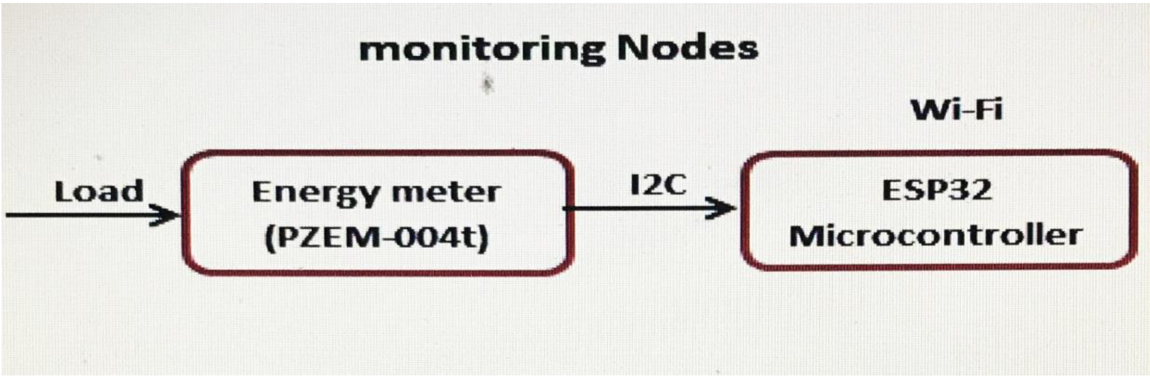

Figure 2 A simple diagram of an IoT power monitoring node.

In order to send measured data from PZEM-004T to network or internet, ESP32 is used to communicate with PZEM-004T via Inter-Integrated circuit (I2C) protocol. Figure (3) shows the prototype of a power monitoring node in which the PZEM-004T is connected with the ESP32 via the I2C protocol port. The ESP32 software was developed using the Arduino software environments. The main function of the ESP32 is used to collect power data from the PZEM-004T and send the received data to the server wirelessly, via Wi-Fi. The data will be sent to the server approximately every 10 seconds. Data is transferred over the internet using the MQTT protocol.

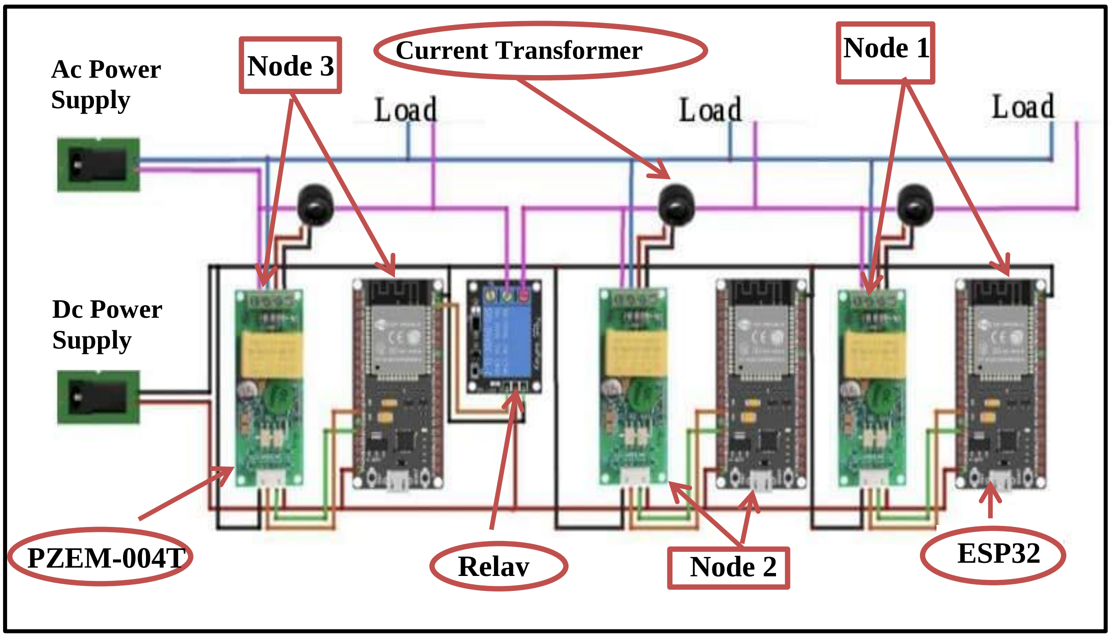

Figure 3 The prototype of a power monitoring node in which the PZEM-004T is connected with the ESP32.

As shown in Figure (3), the proposed smart meter system consists of three smart meter nodes in order to build a wireless sensor network, each smart meter node consists of ESP32 and PEZM-004T. The PEZ-004T module is solely responsible for all measurements of electrical parameters (voltage, current, power consumption and frequency) in the first and second smart meter node. The third node is responsible for monitoring the energy consumed by all nodes connected to it and sending the measured values continuously to the data center. The power readings of the third node are compared with the readings of the power consumed by the first and second node in the server to see if the electrical power has been exceeded. The Relay was also connected to the first node in order to provide protection against under-voltage and over-voltage. The smart meter continuously measures the voltage in order to protect the system and the devices connected to it. The low voltage is set to be less than 200v and the overvoltage is higher than 230v. If the voltage reading is outside these limits, the main relay will be turned off until the acceptable voltage level is restored.

2.1.2. Local Server

The Raspberry is a small, low-cost single-board computer that is the main peripheral unit. It is used in this paper as a server to provide human machine interactions, data storage, and dashboards and data dissemination. Raspberry has a CPU, 1GB RAM, 4 USB ports, and Ethernet for connectivity [22].

2.1.3. MQTT protocol

The Message Queuing Remote Transfer (MQTT) protocol was used to send data over Wi-Fi. MQTT is a lightweight message distribution/contribute based message transfer protocol that runs on TCP/IP communication. It was used in the proposed system because it is a good solution to design because it provides easy connection between the server and many IoT nodes [23, 24]. The central server is called the broker, the sensor nodes can subscribe to the topic and the topics are created automatically. It can also spread data to subjects of any type of data. The things board Server serves as a MQTT broker in this scenario. The things board IoT server is installed on a Raspberry with a Postgres-SQL database, and the MQTT client library (Arduino PubSubClient) is developed on an ESP32 microcontroller employing the Arduino IDE to gather sensor data and disseminate it to the server (MQTT Broker).

2.1.4. Software

Data measurements and collection are made possible by using developed Arduino IDE software written and loaded into the ESP32 microcontroller. Next, the ESP32 microcontroller, which is programmed and configured as an MQTT client with the help of the PubSubClient MQTT library, receives and processes this data from the sensors. Finally, the acquired system data is then propagated or transmitted over the MQTT protocol over a locally created TCP/IP Wi-Fi connection to the self-hosted things board IoT server platform, configured as an MQTT broker. The data received in the things board server node is displayed as telemetry messages. The server node is configured so that this data is automatically supplied to dashboards that are created and monitored remotely. Figure (4) depicts a process of flowing data in the projected system.

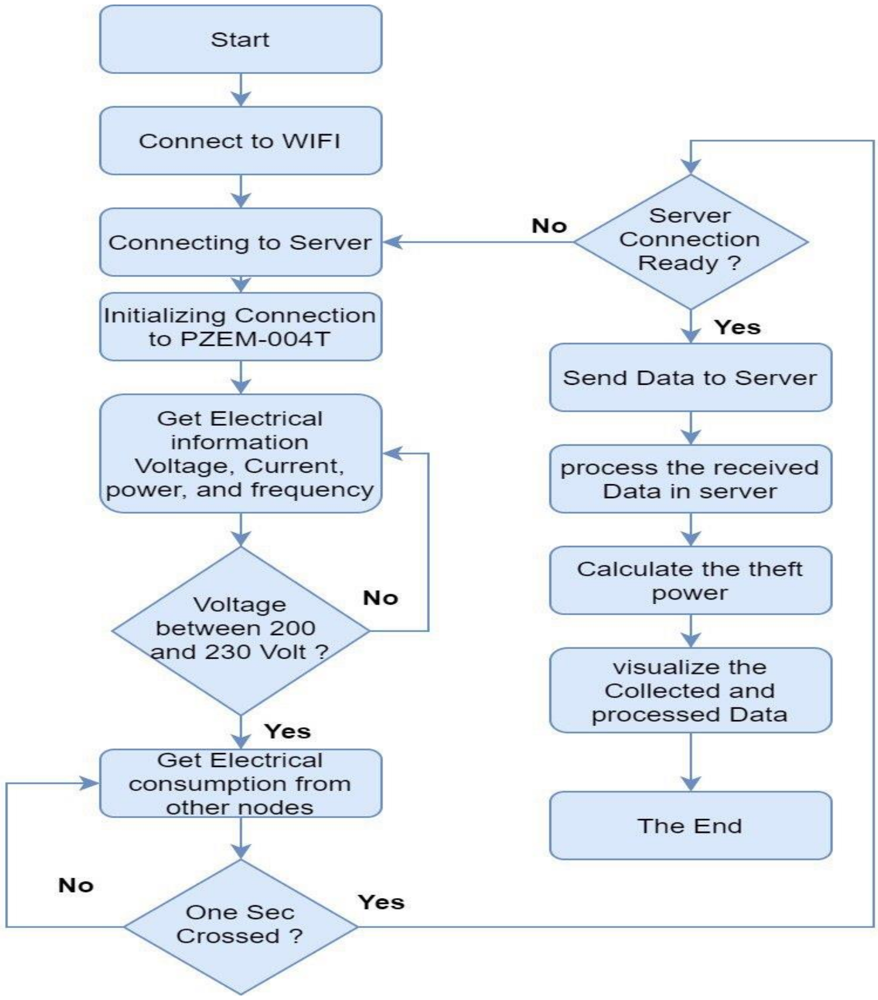

Figure 4 It represents a process of flowing data in the projected system.

3. Experimental Result

It is possible to create consumption patterns through the data received from the smart monitoring systems. Different consumption patterns are obtained from different users, companies, even geographic regions, etc. Through this data, studies can be conducted for electricity management and the maximum power generation can be adjusted according to energy consumption. The electrical parameters of current, frequency, and power are measured and shown as in Figure (5).

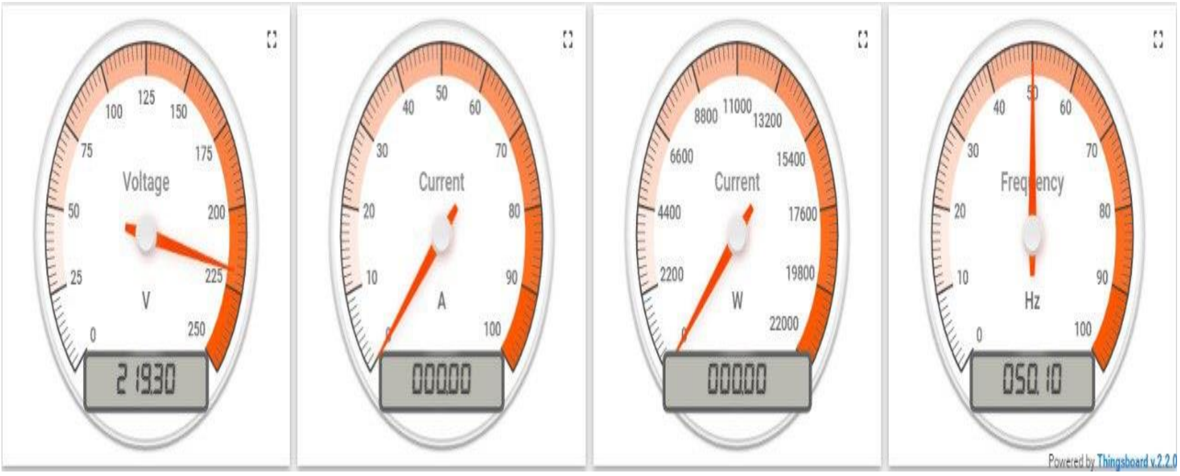

Figure 5 It shows that the measurements of the electrical parameters.

In Figure (6) and Figure (7), measurements are shown in the form of a curve with time to find the amount of energy consumed with different periods.

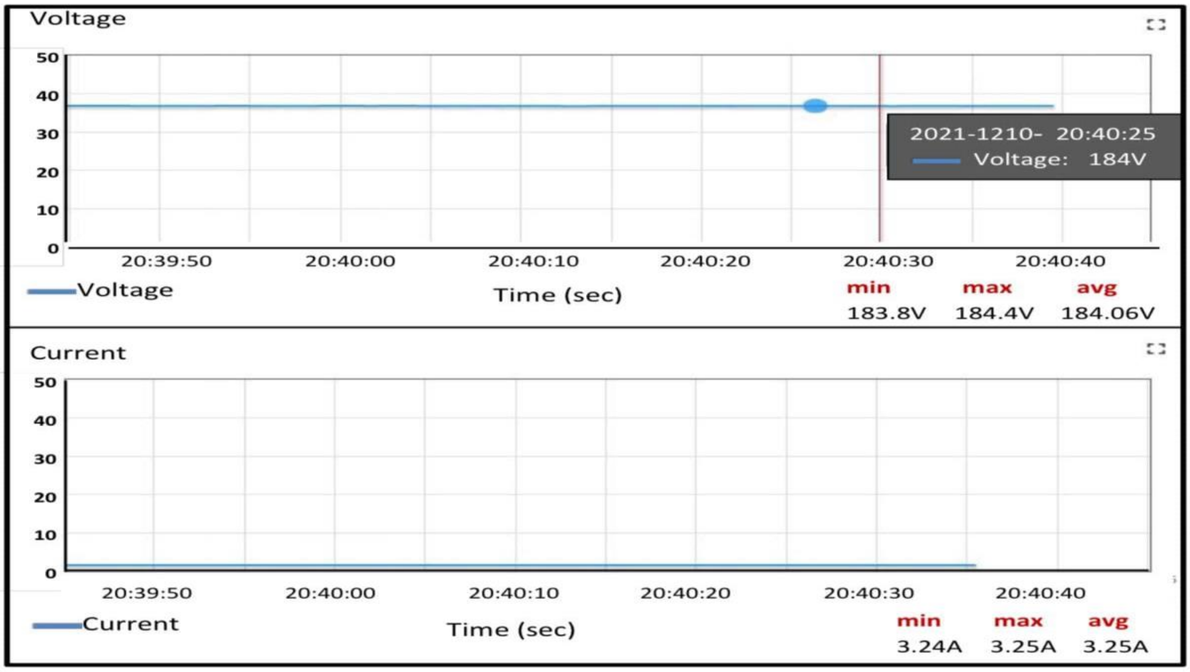

Figure 6 Read electrical parameters (voltage and current) over time.

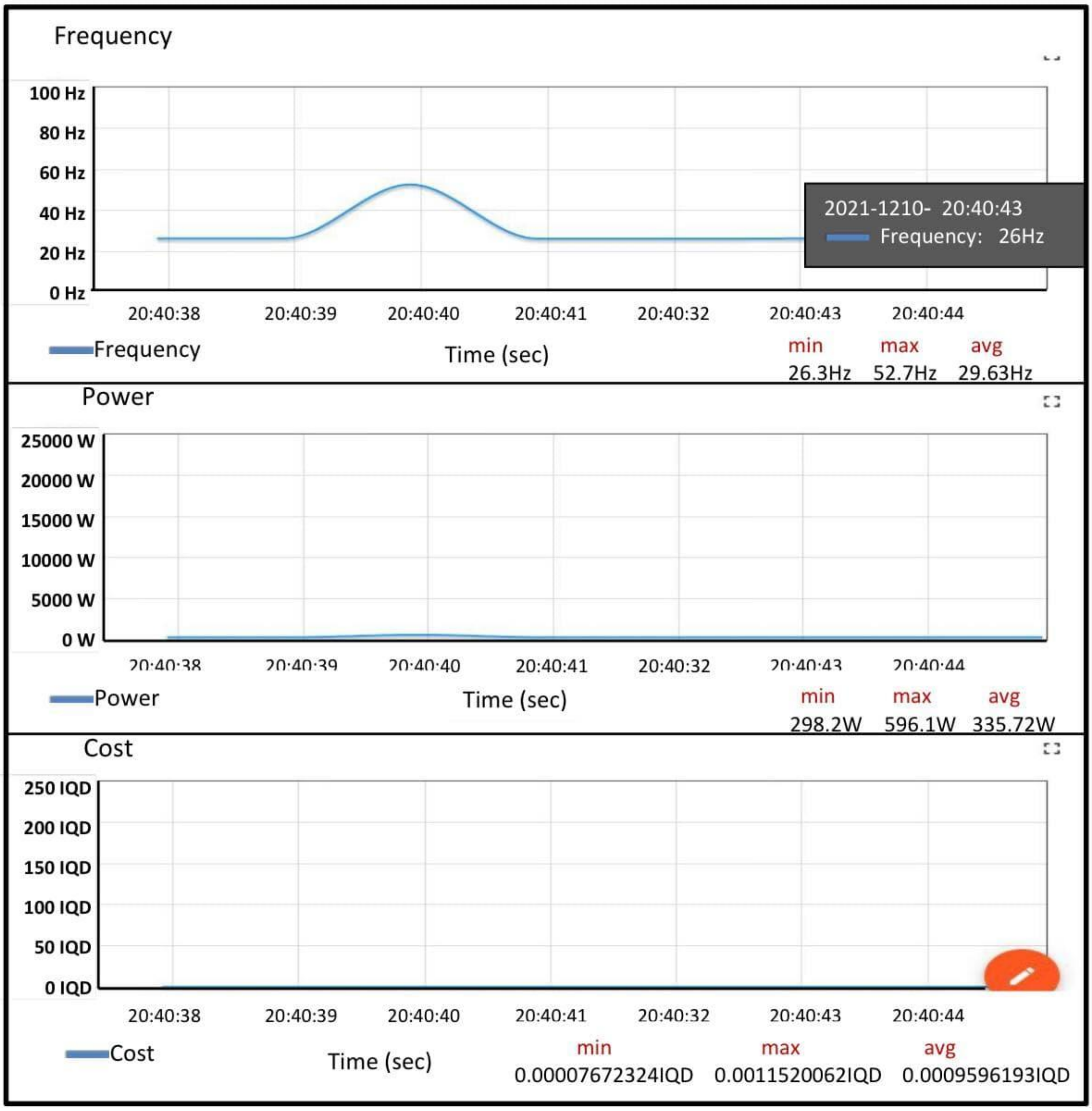

Figure 7 Read electrical parameters (frequency, power and cost) over time.

4. CONCLUSION

In this article, the design of an intelligent system for monitoring and measuring the consumed electrical energy and measuring electrical parameters based on the internet was presented and implemented. Because the data is collected by the wireless sensors of the network and transferred to the server via the Wi-Fi network in real time, this fact will lead to a reduction in the response time in front of leaks, fraud and so on. In addition, the implementation of this system will enable consumers to monitor their energy consumption and economy through the use of the internet of things or a smart phone application. In this way, citizens will be able to reduce their energy consumption and thus save energy and money.

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