Indonesian Journal of Electrical Engineering and Computer Science
Vol. 29, No. 2, February 2023, pp. 825~837
ISSN: 2502-4752, DOI: 10.11591/ijeecs.v29.i2.pp825-837

Adaptation of powerline communications-based smart metering deployments with IoT cloud platform

Shaimaa Mudhafar Hashim, Israa Badr Al-Mashhadani
Department of Computer, College of Engineering, Al-Nahrain University, Baghdad, Iraq

Article Info

Article history:

Received Apr 25, 2022
Revised Sep 24, 2022
Accepted Oct 14, 2022

Keywords:

Arduino
Power line communication
Sensor
Smart Meter
ThingSpeak

ABSTRACT

The necessity of energy management and optimization through smart devices has an essential role in sustainable energy. Smart grid features and cutting-edge technologies are progressively integrated into traditional electricity networks. One of these features is the interference between power line communications and internet of things (IoT). The introduction and deployment of these grids are mainly focused on the development of the field of smart metering. A new proposed module for smart meter design within the existing infrastructure grid system using power line communication (PLC) is presented. The system will include a transmitter with a microcontroller (MCU) and numerous sensors, as well as communication channels that include PLC and an in-house powerline network, and a receiver with an MCU. The suggested system interacts with the IoT system, characterized by a free web interface showing the data directly in real-time. Based on real-world experience, this paper develops guidelines for various aspects of PLC Smart Metering network deployment via the cloud environment. The practical result of packet losses is about 0, 1, or 2 characters of received data, and the time difference between transmitter and receiver is about 5000 milliseconds for a fixed transmission line.

Corresponding Author:

Shaimaa Mudhafar Hashim
Department of Computer Engineering, College of Engineering, Al-Nahrain University
Baghdad, Iraq
Email: shaimaa.mudhafar@gmail.com

1. INTRODUCTION

Integration of intermittent renewable energy sources into the power supply chain, ensuring dependable electricity delivery, and more effective use of existing electrical infrastructure is one of the smart grid (SG) goals [1]. To ensure energy economy and dependability, smart grids are gradually replacing the old power system. Internet of things (IoT) technology is impressive in SGs because it allows efficient data flow between various components of the SG. Power conservation is the key use of IoT technologies [2], [3]. Power line communication (PLC) is first described as IoT technology that allows data to be sent via power lines [4]. PLC makes advantage of existing infrastructures (such as power lines) whose primary function is to transmit AC or DC electric power for data transmission purposes. Power line carrier communication (PLCC) is a natural communications solution for smart grids since it uses existing power lines. The underlying infrastructure that supports the various types of PLC is the current electric grid [5]. Some components, such as sensors, smart energy meters, and grid monitoring controls, are essential for the smart grid to establish real-time communication between consumers and appliances [6].

The standard grid is evolving into a new generation of networks known as smart grid, providing new features to energy suppliers and customers [7]. The goal of this evolution is to meet the needs that are increasing today, such as the increasing need for sustainable energy.

One of the main differences between a traditional grid and a smart grid is how different features of the networks are treated, as shown in Figure 1. The conventional electric grid illustrate in Figure 1(a) has a hierarchical architecture where the energy flows from the generation plant to the final user crossing different substations; however, in the smart grid illustrate in Figure 1(b), all features of each element can produce or extract power from the network, and information of each element can be transmitted. This new perspective is required to connect the new devices that will be installed and the forthcoming distributed generation plant into the network [7].

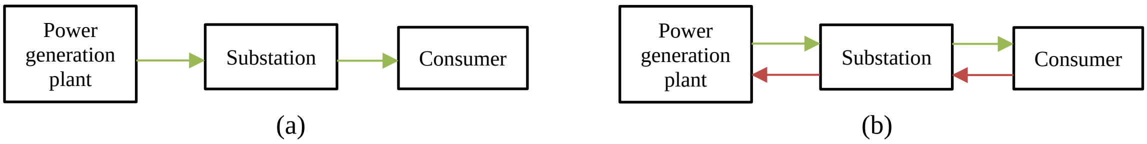


Figure 1. Comparision between traditional grid and a smart grid: (a) conventional grid scheme and (b) smart grid scheme [7]

In comparison with traditional electric power grids, smart grids [8], [9] has several advantages to several factor such as (data flow, electricity generation, grid topology, sensors, monitoring, outage recovery, testing, and type of control). As will be shown in Table 1 few points of compression between SGs and traditional grid are titled.

Table 1. Smart grid compared with traditional grid [8], [9]

	Traditional grid	Smart grid
Data flow	One-Way Communication	Two-Way Communication
Electricity generation	Centralized Generation	Distributed Generation
Grid topology	Hierarchical	Network
Sensors	Few Sensors	Lots Sensors
Monitoring	Blind	Self-Monitoring
Outage recovery	Manual Restoration	Self-Healing
Testing	Manual Check/Test	Remote Check/Test
Type of Control	Limited Control	Pervasive Control

In most cases, SGs [10] contain various networking technologies. power line communication is one of the networking methods suggested for SG's power line communication, which coexisted with SG and enabled high-speed connection to various SG applications. PLC works by transmitting data across a conductor and existing power lines. Since of its unique qualities, such as high-speed communication and low-voltage power lines, PLC technology has various benefits for SG. These benefits are the large area of coverage and mobility, but the drawbacks are Sources of high noise on electricity lines, and the signal is attenuated and distorted [10].

Regarding the previous study, the researcher Zhilenkov *et al*. [11] provided some information on constructing IoT systems utilizing power line communication (PLC) technology, as well as some issues, such as the usage of aluminium wire, which produces a lot of noise, as opposed to copper, which produces less noise. Celestino and Vargas-Cuentas [12], created a smart energy meter using the ESP8266 Wi-Fi module. The proposed system assists with energy efficiency difficulties by providing real-time access to information. Kumar [13], this project required the creation of a complete Power Line Communication - based smart house architecture. This eliminates wireless interference and packet loss while enhancing range and scalability and lowering battery consumption. Using Power Line Communication-based systems lowers costs and improves efficiency. Basha *et al*. [14], a design and implementation of a data transmission-based remote Control utilizing the KQ330 module and an MCU are described in this article. From the provided result, the load may be adjusted to meet the user's needs. The FSK-KQ330 modem, located between the electrical cable and the MCU, is responsible for data transmission and reception. In this paper [15], the PLC system is based on an FSK-KQ330 controller. The system's core CPU is an STC MCU, while the modem module is an FSK-KQ330. Data signals can be sent via power lines using a master-slave arrangement. It may be utilized not just for controlling intelligent home systems and also for controlling intelligent switches and equipment from a distance. Ali *et al*. [16] works on home automation with the ThingSpeak platform. ThingSpeak offers enhanced data protection, data management, and visualization. The data is analyzed on the cloud, and real-time statistics are delivered via a mobile application. Varpe *et al*. [17] proposes an IoT energy meter with a current, voltage, and monitoring system that uses a node MCU and an energy meter with a microcontroller system to monitor energy meter readings via the internet. Gaggeo *et al*. [18] focuses on mentioning the basic elements of smart meters, techniques, and protocols that can be used to exchange data and the pros and cons of each. A proposal has been made for the development of smart meters. This proposal is based on the low-power wide area network, a group of communication technologies for the Internet of Things.

Soni and Subhashini [19], the smart grid relies heavily on communication infrastructure. End-users may lower their electricity consumption by employing smart home appliances to avoid peak hours and to use renewable energy instead of utility energy, which is a fantastic example of internet of things (IoT) deployment in grid communication. Luka *et al*. [20] overviews SG technologies, focusing on PLC technology. The function of PLC in the deployment of smart grids across various voltage networks also was discussed. Alubodi *et al*. [21], a meter was designed and tested in real-time in a few Karbala homes, with measured voltage, current, and power factors. Three communication techniques were used to convey the data obtained from the testing location to a data concentrator unit (DCU) (Bluetooth, XBee, and GSM). The data was then sent through GSM from the DCU to the server. Ibrahim *et al*. [22] describes creating a web-based surveillance system with a specialized Android-based mobile application utilizing a Raspberry Pi and its auxiliary parts, including a Pi-Camera, PIR motion sensor, Ultrasonic sensor, and web-based and mobile application. The suggested method has been successful in notifying home users of any intrusions via SMS and email.

Ali *et al*. [23] explains how to use an IoT platform to monitor water quality continually. The proposed system has five sensors: a pH sensor, a temperature sensor, a light intensity sensor, and a GPS tracker (IMU). IMU is a new component in the system that uses flow analysis to determine the direction of x and y for planning and locating water quality issues. Real-time data monitoring is done using the IoT platform provided by the ThingSpeak application. Data on acidity, temperature, light intensity, position, and acceleration have been effectively gathered constantly by creating an IoT-based water quality catchment monitoring system. Mahamad *et al*. [24], use a Raspberry Pi embedded system to create a cloud-based people counter and submit the collected data to the IoT platform ThingSpeak. The project's initial phase involves simulation and Python and OpenCV code development. A Pi camera is utilized for hardware development to record video and track human movement. The Raspberry Pi is the system's microcontroller and processes the footage to carry out people counting. People used stored camera footage and the ThingSpeak platform to display the data as part of an experiment to evaluate how well the system performed in the real world. Ali *et al*. [25], uses MATLAB® programming platforms to create a remote monitoring system for a pressure regulator utilizing the internet of things (IoT) communication tool.

The NodeMCU is a microcontroller with an ESP8266 for Wi-Fi connectivity, and it is used in the construction of monitoring systems for acquisition and communication. This system enables the monitoring of both the pressure regulator's reference and the transducers' machine information. One benefit of this kind of development is that the server is free and the system is inexpensive. This kind of project may also enhance the infrastructure of engineering lab equipment so that it can be controlled remotely. Miry and Aramice [26], the purpose is to enhance an intelligent water quality monitoring system for various locations. With a smart alert from the ThingSpeak action application and IFTTT, the system may be monitored on a PC and smartphone. To consistently maintain clean water, it offers rapid and simple turbidity and TDS level monitoring. An appropriate platform for examining and contrasting the sensor data has been supplied by ThingSpeak and the react application notifies the user through email based on the supplied data. Gunawan *et al*. [27], described the creation of an internet of things-based power factor meter. Data could be transferred to a remote server for data recording and additional analysis using the Wi-Fi or ethernet module on the Arduino. Utilizing several relays coupled to capacitor banks with varied capacities, power factor enhancement was devised. For simplicity of installation, a non-invasive current sensor was employed to measure the current. Using a manual ammeter, the accuracy of the chosen sensor was calibrated; the difference is approximately 1.79%. Venugopal and Govender [28], discusses a load analysis and power management system that satisfies the demands of intelligent energy metering and automated load control. Proteus visual design was used to simulate and evaluate different load values that are equivalent to residential and industrial load characteristics for the single-phase and three-phase load analysis and power management system. Therefore, the user can simply understand the information presented about the system. Utilizing this data will allow users to monitor their energy use more accurately and make a contribution to lowering their individual energy consumptions.

This research aims to investigate the applicability of sending and receiving data using existing infrastructure (power line cable) with power line communication module (KQ-330 PLC module) for smart meter grid system-based IoT via a cloud environment (ThingSpeak website) and determine the packet losses rate and the amount of time delay between data of transmitter part (smart meter) and receiver part.

2. METHOD OF PROPOSED SYSTEM

2.1. System design and architecture

The proposed system for investigating the applicability of sending and receiving data using PLC for smart meter grid systems via a cloud environment is described in this section. This system will include the design of each device in terms of electrical and software components. Figure 2 shows the generic block diagram of the proposed system design. This suggested system is divided into two parts: the transmitter part (smart meter part) and the receiver part (server part). The smart meter is composed of current and voltage sensors coupled to a microcontroller to calculate the power consumption of the connected appliances. The PLC model adopted in this project is KQ-330 to transmit the data to the server, and the obtained data will be monitored via a computer screen. The acquisition of cloud applications is to administrate data remotely. As well as a web-based interface for reading counter parameters such as current in amps (A), the voltage in volts (V), apparent power in watts (W), power factor, the real power in watts (W), and frequency (Hz) for energy management was devised.

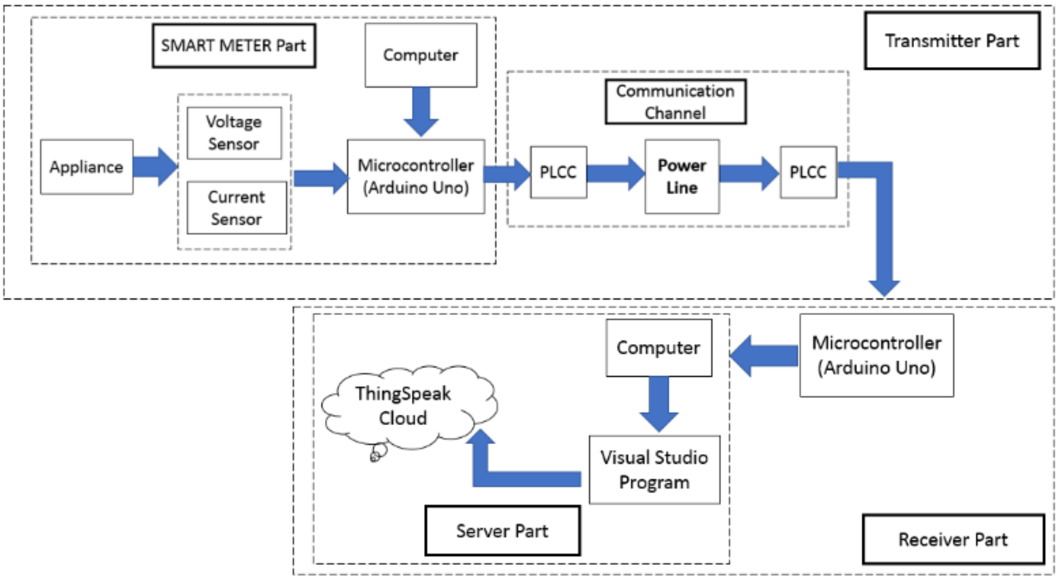
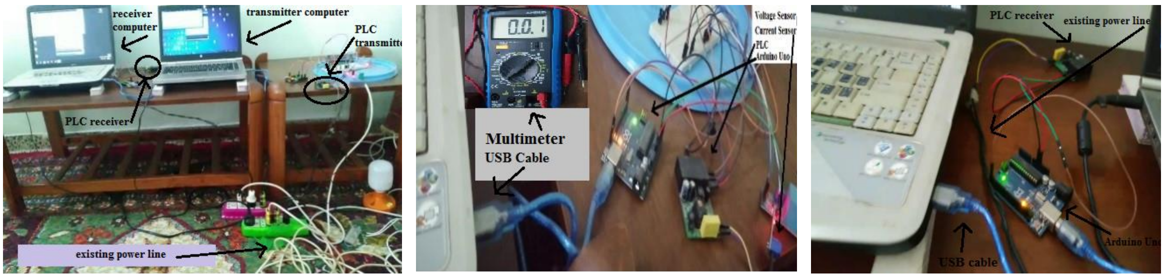


Figure 2. Block diagram of the proposed system architecture

2.2. Hardware design

One of the goals of the suggested system is to construct a low-cost smart meter grid system as shown in Figure 3 based on an Arduino Uno board that will track power usage. The following electrical components were used for design and execution: two Arduino Uno, one ZMPT101b voltage sensor, one ACS712 current sensor, and two KQ-330 Power line carrier communication for transmitter and receiver, as illustrated in Figure 2 previously. The complete hardware system implementation illustrate in Figure 3(a), which contains a transmitter part as shown in Figure 3(b) and the receiver parts is shown in Figure 3(c).



(a) (b) (c)

Figure 3. Smart meter grid system: (a) full hardware system, (b) transmitter part, and (c) receiver part

2.2.1. Transmitter part

The transmission part consists of two parts: smart meter and communication channel. The first part is a smart meter based on microcontroller (Arduino Uno) and many sensors (voltage and current). The purpose of smart meter is to calculate many parameters such as (voltage, current, apparent power, power factor, real power, and frequency). The second part is a communication channel based on KQ-330 PLC module with existing infrastructure (220 V AC power line cable) to transfer data from smart meter to receiver part, these parts will be discussed below.

2.2.2. Smart meter part

The component or devices that are used in the smart meter are the following:

- Microcontroller (Arduino Uno): The first Arduino Uno board was selected as the foundation for the design of a smart meter gadget. This device's functions are driven by a microcontroller unit[29].
- Voltage sensor (ZMPT101B): This is an AC single-phase voltage sensor with a voltage transformer ZMPT101B for computing voltage and power. It has high precision and sufficient accuracy and withstands 250V AC. As well as the reasonable cost and size [30].
- Current sensor (AC712): The ACS712 sensor will operate while an existing sensor uses the hall effect standard [24]. A conductor in a magnetic field generates a voltage across its edges, which is orthogonal to current and magnetic field directions. Furthermore, regardless of the higher voltage, it is a method that decreases the risk of destroying the existing conduction-side observation circuit [31].

The smart meter is formed from the design of the transmission section, which includes as its primary part the Arduino Uno board coupled with an ATmega328 microprocessor and an external 16 MHz oscillator. The Arduino Uno's primary function is to determine current (Amp), voltage (V), apparent power (W), power factor, real power (W), and frequency (Hz). The prototype diagram of the transmitted side is shown in Figure 4. The equation that uses in calculating the mentioned parameters will be demonstrated as the following: The Apparent power will be calculated in Watt by using (1):

$$S = V * I \qquad (1)$$

where V is the voltage in (Volt), and I is the current in (A). The power factor will be determined using (2):

$$P.F = cos\theta \qquad (2)$$

where θ is an angle, and P.F is the power factor (unitless). Real power will be calculated in watts as (3):

$$RP = V * I * P.F \qquad (3)$$

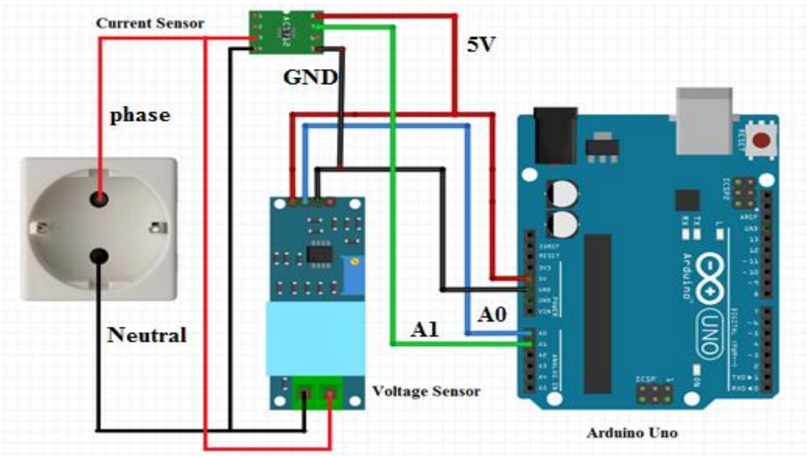


Figure 4. Prototype diagram of transmitter side (smart meter)

The program contains an Arduino IDE setting program, such as defining the library and parameter of the voltage and current sensor and then processing the readings from the serial monitor of the computer. The data flow process of the transmitter part implementation is shown in Figure 5.

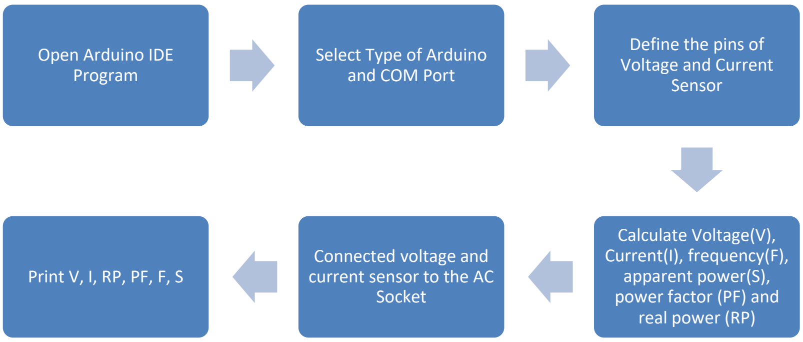


Figure 5. Data flow process of the transmitter part

2.2.3. Communication channel

A diagram of the communication channel (power line communication module (KQ-330 modem) with existing infrastructure (power line cable)). PLC modem is connected with the transmitter part (smart meter part based on Arduino Uno connected with voltage and current sensors to calculate several parameters (voltage, current, apparent power, power factor, real power, and frequency)) and then sending experimental data to receiver part. Figure 6 illustrate transmitter Arduino Uno connected with receiver KQ-330 modem, the voltage sensor pins (GND, VCC, and OUT) connected with Arduino Uno pins (GND, 5V, and A0) respectively, current sensor pins (GND, VCC, and OUT) connected to microcontroller pins (GND, 5V, and A1) respectively, and two pin AC voltage is connected to 220 V AC socket.

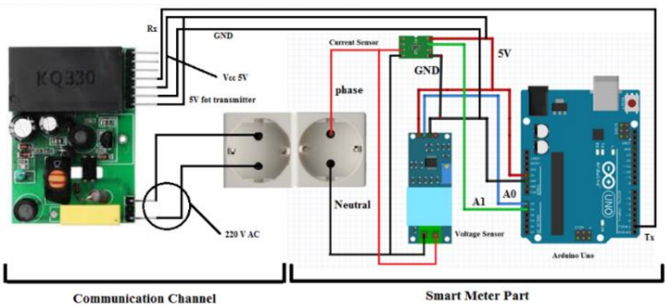


Figure 6. Prototype of smart meter part with the communication channel

This channel consists of the In-house powerline network and power line carrier communication KQ-330 shown as:

- In-house powerline network: Ordinary duty PVC cable for use in domestic appliances and offices. Generally unsuitable for outdoor use or industrial applications. The properties of the cable used in this work are shown in Table 2.

Table 2. properties of the cable

Properties	Number
No. of cores	2
cross-sectional area mm²	0.75
Nominal thickness of insulation mm	0.6
overall diameter mm	6.3

- Power line communication KQ-330: The KQ-130F or KQ-330 contains nine pins, as shown in Figure 7. It is built for 220V AC based on high interference, high attenuation, environmental distance requirements, data transmission reliability, and the design and development of high-cost carrier modules. It is utilized to communicate data to the power line for metering, street, intelligent home, fire, and other building control applications [32].

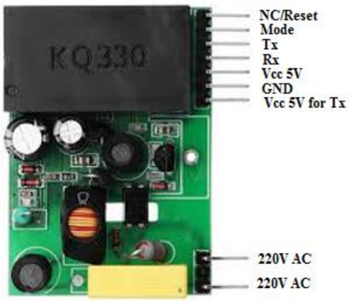


Figure 7. KQ-330 power line communication

2.2.4. Receiver part (server Part)

The server side is the data receiving device responsible for the communications between the smart meter and the cloud website (ThingSpeak cloud). The component or devices used in the receiver are the PLC, Arduino Uno (as mentioned in section 0), and a computer to monitor the received data. The hardware design is shown in Figure 8.

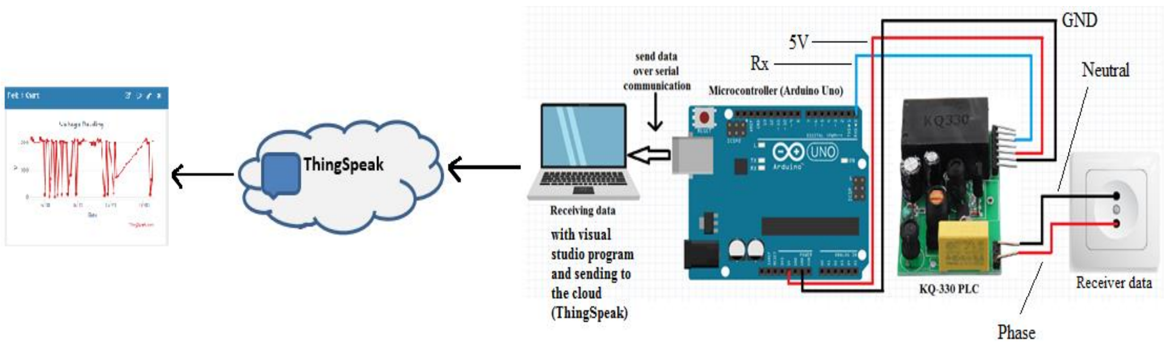


Figure 8. Design prototype of server-part

The software written in the Arduino IDE (integrated development environment) program will firstly select the COM port used and choose the type of Arduino (is Arduino Uno), then writing the code (consisting of define the pins of all devices used then writing the equations for calculate the voltage, current and power and finally printing the results). The data flow process of receiver part implementation is shown in
Figure *9* in detail.

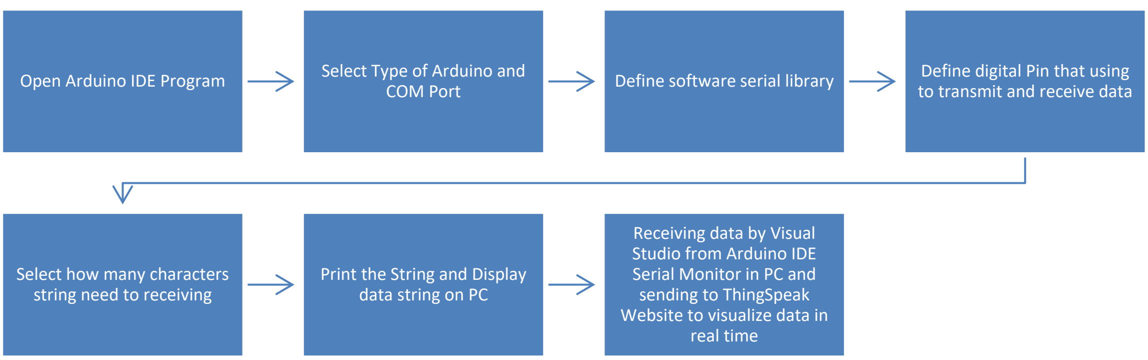


Figure 9. Data flow process of receiving part

3. RESULTS AND DISCUSSION

This section presents samples of real-time numerical data and an evaluation to propose a system in terms of packet losses (error rate) and time. In the transmitter part, the experimental results appear in Table 3 and Table 4. These readings are for the current (A), voltage (V), apparent power (VA), power factor, real power (W), and frequency (Hz) of many appliances in the house. The smart meter has been tested on four electrical appliances: a lamp, a hair dryer, and an electric oven. Error rate between smart meter reading and multimeter is calculated as in (4):

$$Error\% = \frac{Smart\ meter - Multimeter}{Smart\ meter} * 100\% \tag{4}$$

Table 3. Experimental readings for different appliances

Appliances	Speed	Smart meter reading (Current (Amp))	A- Meter Reading (Current (Amp))	Error%	Smart meter reading (Voltage(Volt))	V- Meter Reading (Voltage Volt))	Error%
Lamp	-	0.19	0.189	0.53	215.97	215	0.45
Hair dryer	1	2.37	2.363	0.296	217.18	218	0.38
	2	3.69	3.679	0.299	213.20	215	0.84
	3	5.05	5.058	0.162	211.99	213	0.47
Electric oven	1	6.98	6.96	0.287	194.81	196	0.61
	2	8.85	8.78	0.797	197.18	198	0.41
	3	9.74	9.65	0.93	209.76	210	0.11

Table 4. The experimental value of power and frequency for different appliances

Appliances	Speed	Apparent power (VA)	Power factor	Real power (W)	Frequency (Hz)
Lamp	-	41.20	0.63	25.9	50.44
Hair dryer	1	513.81	0.74	378.6	50.44
	2	787.62	0.91	714.2	50.44
	3	1070.48	0.90	963.9	50.44
Electric oven	1	1358.89	0.89	1205.1	50.21
	2	1744.21	0.90	1575.0	50.22
	3	2043.51	0.91	1853.0	50.56

The data transmission mode in this work is the serial data transmission mode, in which the data that is approximately 50 characters (as the data transmitted for the proposed system is characterized as 50 characters) is sent serially one after the other at a time over the transmission channel. In serial data transmission, the system takes several clock cycles to transmit the data stream, which causes a delay. It is also the responsibility of the receiver to receive the transmitted data correctly. Therefore, the receiver continuously receives the information at the same rate the transmitter sends it. These comprise data are either a complete character's data (If no error is detected in the received data) or if an error is detected with one character to two characters loss. This raises the need to find the packet losses between transmitter and receiver (number of transmitter and receiver packets contains parameters such as V=, F=, I=, RP=, PF=, S= with space between each parameter, and value of parameters) as shown in Table 5.

When the pulse (such as 1, 2, 3) first sends data containing many characters, the receiver receives a packet with error. This situation will calculate the packet losses and time difference between transmission and receiver data, as shown in Table 5. As for the time difference between the sender and the recipient, it is 5,000 milliseconds, as shown in Table 5, and the reason for this delay in the transmitter program is one of the serial data transmission mode requirements to be able to obtain ideal data set in receiver part as long as possible.

Within the obtained data, as shown in Table 5, there are undefine characters data and a lot of uncompleted data before reaching original data of transmitter part, as shown in Figure 10. To reduce error detected data (uncompleted data and unknown characters) as shown in Figure 10, the site between completed data will be sent in 250 characters instead of 50 characters, with a delay value of 4500 milliseconds as one of the solutions to this issue. As shown in Table 6, when sending the transmitter part single line data continuously, the receiver part will receive a data set simultaneously and not a single line as in the transmitter part. The other benefit is also when there is a data set received, and this allows to choose the most accurate reading of the device from the set of received readings.

The reading values in the receiver part are uploaded into ThingSpeak and these data can be accessed from any device or a browser. The Microsoft visual studio connected with the Arduino Uno receiver part as shown in Figure 11, to receive the data and sending to the ThingSpeak cloud which shows the visualization from the web browser as shown in Figure 12.

Table 5. data transmission and receiving with packet losses and time difference

	Time	Values
Data Transmission 1	19:38:35	V=226.52 F=49.77 I=1.78 RP=286.7 PF=0.71 S=402.34302
Number of transmitter packet		52
Data Receiving 1	19:38:40	V=226.52 F=49.77 I=1.78 RP=286.7 PF=0.71 S=402.3430
Number of receiver packet		51
Difference time between transmission and receiving		5000 millisecond
Packet losses		Number of transmitter packets - Number of receiver packets = 1
Data Transmission 2	19:39:42	V=219.15 F=50.16 I=1.82 RP=299.3 PF=0.75 S=399.59302
Number of transmitter packet		52
Data Receiving 2	19:39:47	V=219.15 F=50.16 I=1.82 RP=299.3 PF=0.75 S=399.59302
Number of receiver packet		52
Difference time between transmission and receiving		5000 millisecond
Packet losses		Number of transmitter packets - Number of receiver packets = 0
Data Transmission 3	19:40:44	V=223.45 F=49.93 I=1.69 RP=275.5 PF=0.73 S=377.38302
Number of transmitter packet		52
Data Receiving 3	19:40:49	V=223.45 F=49.93 I=1.69 RP=275.5 PF=0.73 S=377.383
Number of receiver packet		50
Difference time between transmission and receiving		5000 millisecond
Packet losses		Number of transmitter packets - Number of receiver packets = 2

Figure 10. Uncompleted and undefine data between correct data

Data was aggregate the hair dryer appliance and some appliances such as (lamp and electric oven) from the website ThingSpeak online to gathered, visualize, and analyze in real time data streams in the cloud using time graphs for the voltage, current as shown in Figure 13, apparent power, power factor as shown in Figure 14, real power, and frequency shown in Figure 15.

Table 6. Transmitter and receiver data with time and packet losses

	Time	Values
Data Transmission 1	13:41:57.183	V=199.81 F=49.77 I=1.78 RP=276.7 PF=0.78 S=356.37302
	13:42:01.804	V=202.19 F=49.77 I=1.70 RP=281.4 PF=0.82 S=343.35302
	13:42:06.458	V=219.01 F=50.21 I=1.73 RP=295.5 PF=0.78 S=378.33302
	13:42:11.114	V=215.02 F=49.93 I=2.29 RP=363.6 PF=0.74 S=492.32302
	13:42:15.740	V=227.39 F=49.88 I=1.69 RP=288.9 PF=0.75 S=385.12302
Number of transmitter packet		260
Data Receiving 1	13:42:31.474	V=199.81 F=49.77 I=1.78 RP=276.7 PF=0.78 S=356.37302
	13:42:31.520	V=202.19 F=49.77 I=1.70 RP=281.4 PF=0.82 S=343.35302
	13:42:31.567	V=219.01 F=50.21 I=1.73 RP=295.5 PF=0.78 S=378.33302
	13:42:31.614	V=215.02 F=49.93 I=2.29 RP=363.6 PF=0.74 S=492.32302
	13:42:31.661	V=227.39 F=49.88 I=1.69 RP=288.9 PF=0.75
Number of receiver packet		249
Packet losses		Number of transmitter packets - Number of receiver packets = 11
Data Transmission 2	13:42:20.398	V=219.06 F=49.99 I=1.77 RP=294.0 PF=0.76 S=387.67302
	13:42:25.049	V=214.61 F=50.15 I=1.73 RP=281.1 PF=0.76 S=370.58302
	13:42:29.669	V=211.46 F=49.99 I=1.74 RP=280.7 PF=0.76 S=367.15302
Number of transmitter packet		156
Data Receiving 2	13:42:53.844	V=219.06 F=49.99 I=1.77 RP=294.0 PF=0.76 S=387.67302
	13:42:53.891	V=214.61 F=50.15 I=1.73 RP=281.1 PF=0.76 S=370.58302
	13:42:53.938	V=211.46 F=49.99 I=1.74 RP=280.7 PF=0.76 S=367.15302
Number of receiver packet		156
Packet losses		Number of transmitter packets - Number of receiver packets = 0
Data Transmission 3	13:42:34.319	V=205.21 F=49.77 I=1.84 RP=284.4 PF=0.75 S=377.62302
	13:42:38.978	V=204.04 F=49.82 I=1.72 RP=279.8 PF=0.80 S=351.36302
Number of transmitter packet		104
Data Receiving 3	13:42:54.031	V=205.21 F=49.77 I=1.84 RP=284.4 PF=0.75 S=377.62302
	13:42:54.078	V=204.04 F=49.82 I=1.72 RP=279.8 PF=0.80 S=3
Number of receiver packet		96
Packet losses		Number of transmitter packets - Number of receiver packets = 8

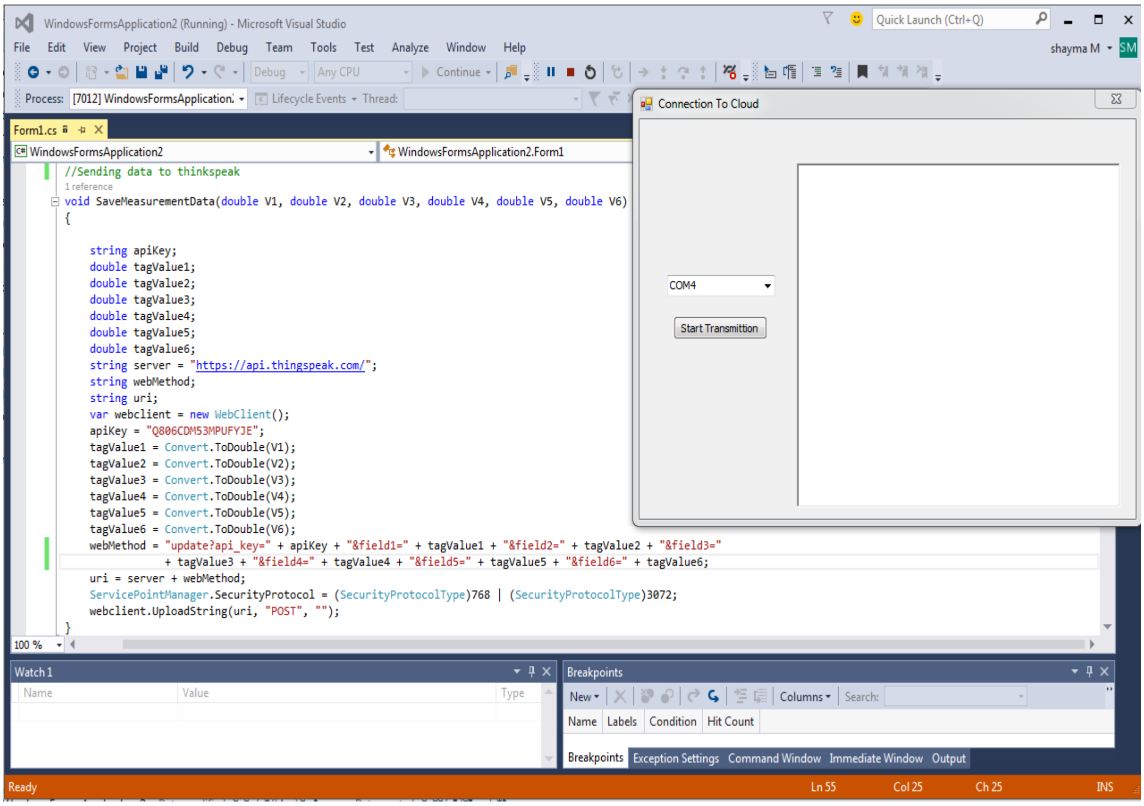


Figure 11. Microsoft visual studio connected with Arduino Uno receiver

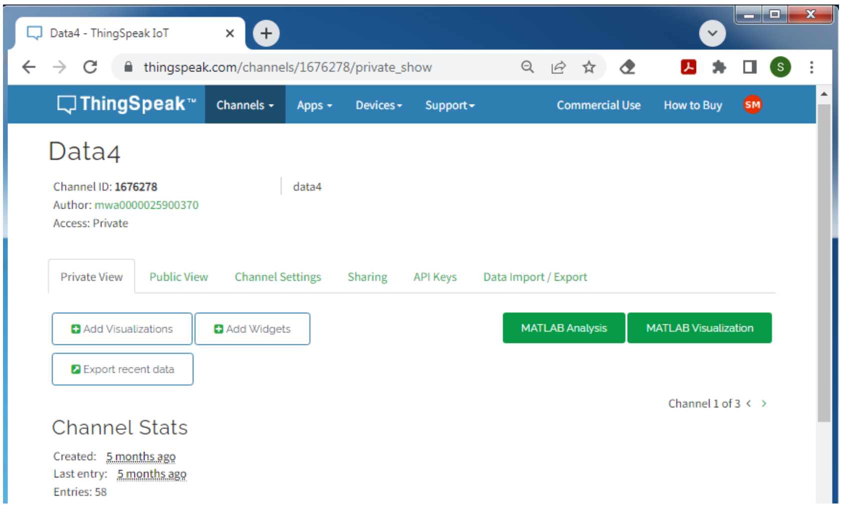


Figure 12. Receive data sent to ThingSpeak cloud

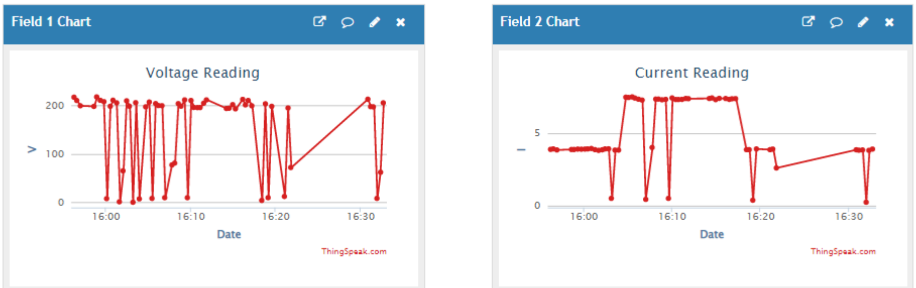


Figure 13. Time graph analysis for voltage and current

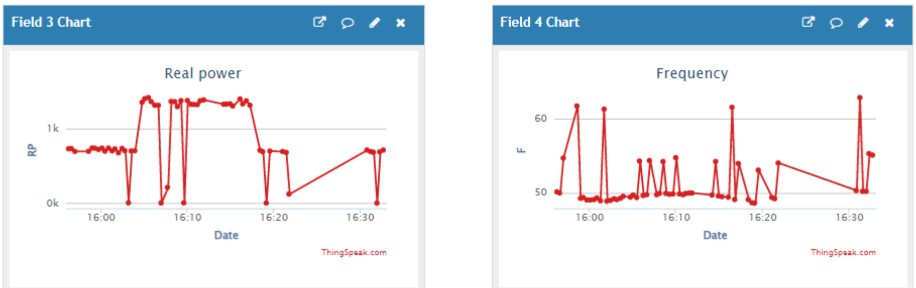


Figure 14. Time graph analysis for voltage, current, real power, and frequency

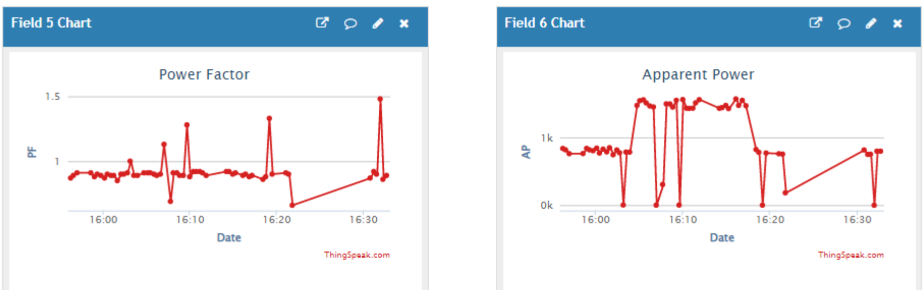


Figure 15. Time graph analysis for power factor and apparent power

4. CONCLUSION

This research proposes a smart grid method based on power line communication (PLC). To investigate the performance of PLC in the smart grid industry through a cloud environment has been experimented with different appliances using a fixed length of power line transmission. Power parameters such as voltage, current, apparent power, power factor, real power, and frequency are tested in the smart meter part. The KQ330 was chosen as a module for the power line carrier data communication used in the system as this type is considered compatible with Arduino and uses existing cables and infrastructure. The smart meter proposed to establish an infrastructure for the smart grid. According to the obtained experimental results, the packet losses in practical design from the transmitting data of smart meter to the receiving part by KQ330 PLC module in (20 m) length cable was between zero to two with several data uncompleted between required data (completed data). The delay in the program of the transmitter part time is 5,000 milliseconds. A procedure has been suggested to reduce the uncompleted data to obtain the original data (required data) at most as possible. Regarding the implementation of the server part, which is connected with the visual studio program for sending data to the cloud environment, the results have indicated the effectiveness of power line communication channel performance in data transfer. This approach also sustains consumer conduction with the real-time power consumption by the ThingSpeak website. Moreover, future studies will be conducted by designing a grid system with other power line communication technologies (G3-PLC and PRIME) using different lengths and cores of transmission lines and then compared with the KQ-330 power line communication module used in this research.

REFERENCES

[1] L. T. Berger, A. Schwager, and J. J. Escudero-Garzás, “Power line communications for smart grid applications,” *Journal of Electrical and Computer Engineering*, no. March 2013, 2013, doi: 10.1155/2013/712376.

[2] N. A. Qarabsh, S. S. Sabry, and H. A. Qarabash, “Smart grid in the context of industry 4.0: An overview of communications technologies and challenges,” *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 18, no. 2, pp. 656–665, 2020, doi: 10.11591/ijeecs.v18.i2.pp656-665.

[3] Q. Ou, Y. Zhen, X. Li, Y. Zhang, and L. Zeng, “Application of internet of things in smart grid power transmission,” in *Proceedings - 2012 3rd FTRA International Conference on Mobile, Ubiquitous, and Intelligent Computing, MUSIC 2012*, Jun. 2012, pp. 96–100, doi: 10.1109/MUSIC.2012.24.

[4] M. K. N. Jadhav and P. P. M. Soni, “A review on application of narrowband power line communication in medium voltage smart distribution grid,” *International Research Journal of Engineering and Technology (IRJET)*, vol. 4, no. 11, pp. 259–262, 2017.

[5] F. Li, X. Luo, X. Cheng, and S. Liu, “Impact of the winding area of enameled wire on packaging performance of a closed loop Hall effect current sensor,” in *Proceedings - Electronic Components and Technology Conference*, no. August 2015, pp. 1631–1635, 2012, doi: 10.1109/ECTC.2012.6249055.

[6] S. S. Reka and T. Dragicevic, “Future effectual role of energy delivery: A comprehensive review of Internet of Things and smart grid,” *Renewable and Sustainable Energy Reviews*, vol. 91, no. June 2017, pp. 90–108, 2018, doi: 10.1016/j.rser.2018.03.089.

[7] A. Acquaviva, “Desing and development of a novel smart-meter for improved Smart Grid management,” Thesis, Universitat Politecnica de Catalunya (SPAGNA), 2018, [Online]. Available: https://webthesis.biblio.polito.it/8217/1/tesi.pdf.

[8] H. Farhangi, “The path of the smart grid,” *IEEE Power and Energy Magazine*, vol. 8, no. 1, pp. 18–28, 2010, doi: 10.1109/MPE.2009.934876.

[9] R. Ma, H. H. Chen, Y. R. Huang, and W. Meng, “Smart grid communication: Its challenges and opportunities,” *IEEE Transactions on Smart Grid*, vol. 4, no. 1, pp. 36–46, 2013, doi: 10.1109/TSG.2012.2225851.

[10] V. C. Gungor et al., “A Survey on smart grid potential applications and communication requirements,” *IEEE Transactions on Industrial Informatics*, vol. 9, no. 1, pp. 28–42, 2013, doi: 10.1109/TII.2012.2218253.

[11] A. A. Zhilenkov, D. D. Gilyazov, I. I. Matveev, and Y. V. Krishtal, “Power line communication in IoT-systems,” in *Proceedings of the 2017 IEEE Russia Section Young Researchers in Electrical and Electronic Engineering Conference, ElConRus 2017*, 2017, pp. 242–245, doi: 10.1109/EIConRus.2017.7910538.

[12] D. Narciso-Celestino and N. I. Vargas-Cuentas, “Smart energy meter prototype for single-phase power lines in Peru,” *International Journal of Engineering Trends and Technology*, vol. 69, no. 4, pp. 209–214, 2021, doi: 10.14445/22315381/IJETT-V69I4P229.

[13] P. Kumar, “Design and implementation of Smart Home control using LabVIEW,” *Proceedings of the 3rd IEEE International Conference on Advances in Electrical and Electronics, Information, Communication and Bio-Informatics, AEEICB 2017*, vol. 115, no. 7, pp. 10–12, 2017, doi: 10.1109/AEEICB.2017.7972317.

[14] C. K. Basha, S. A. K. Jilani, and S. S. Sultana, “Power line data transmission based remote control with status feedback,” *International Journal of Advance Technology and Innovative Research*, vol. 08, no. 08, pp. 1582–1585, 2016.

[15] Y. Qun and Z. Jianbo, “Design of power line carrier communication system based on FSK-KQ330 module,” *EEA - Electrotehnica, Electronica, Automatica*, vol. 62, no. 3, pp. 135–142, 2014.

[16] M. Ali *et al*., “An IoT based approach for efficient home automation with ThingSpeak,” *International Journal of Advanced Computer Science and Applications*, vol. 11, no. 6, pp. 118–124, 2020, doi: 10.14569/IJACSA.2020.0110615.

[17] P. S. Varpe, P. A. Gorakshanath, and J. P. Shankar, “IoT based energy meter with measure current, voltage and cost monitoring,” *International Journal of Research in Engineering, Science and Management*, vol. IX, no. 2, pp. 4–8, 2020.

[18] G. B. Gaggero, M. Marchese, A. Moheddine, and F. Patrone, “A possible smart metering system evolution for rural and remote areas employing unmanned aerial vehicles and internet of things in smart grids,” *Sensors*, vol. 21, no. 5, pp. 1–23, 2021, doi: 10.3390/s21051627.

[19] P. Soni and J. Subhashini, “Future smart grid communication-deployment of IoT: Opportunities and challenges,” *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 23, no. 1, pp. 14–22, 2021, doi: 10.11591/ijeecs.v23.i1.pp14-22.

[20] M. K. Luka, S. W. Pallam, I. T. Thuku, and U. U. Etuk, “Narrowband-Power-line-communication-for-Smart-Grid.docx,” *International Journal of Scientific and Engineering Research*, no. September, 2015.

[21] A. O. A. Alubodi, I. B. N. Al-Mashhadani, and D. S. S. Mahdi, "Design and Implementation of a Zigbee, Bluetooth, and GSM-Based Smart Meter Smart Grid," *IOP Conference Series: Materials Science and Engineering*, vol. 1067, no. 1, p. 012130, 2021, doi: 10.1088/1757-899x/1067/1/012130.
[22] S. N. Ibrahim, A. H. H. Basri, and A. L. Asnawi, "Development of web-based surveillance system for internet of things (IoT) application," *Bulletin of Electrical Engineering and Informatics*, vol. 8, no. 3, pp. 1108–1116, 2019, doi: 10.11591/eei.v8i3.1520.
[23] M. Aznil Ab Aziz, M. F. Abas, M. K. Anwar Abu Bashri, N. M. Saad, and M. H. Ariff, "Evaluating IoT based passive water catchment monitoring system data acquisition and analysis," *Bulletin of Electrical Engineering and Informatics*, vol. 8, no. 4, pp. 1373–1382, Dec. 2019, doi: 10.11591/eei.v8i4.1583.
[24] A. K. Mahamad, S. Saon, H. Hashim, M. A. Ahmadon, and S. Yamaguchi, "Cloud-based people counter," *Bulletin of Electrical Engineering and Informatics*, vol. 9, no. 1, pp. 284–291, 2020, doi: 10.11591/eei.v9i1.1849.
[25] A. H. Ali, A. H. Duhis, N. A. Lafta Alzurfi, and M. J. Mnati, "Smart monitoring system for pressure regulator based on IOT," *International Journal of Electrical and Computer Engineering*, vol. 9, no. 5, pp. 3450–3456, 2019, doi: 10.11591/ijece.v9i5.pp3450-3456.
[26] A. H. Miry and G. A. Aramice, "Water monitoring and analytic based ThingSpeak," *International Journal of Electrical and Computer Engineering*, vol. 10, no. 4, pp. 3588–3595, 2020, doi: 10.11591/ijece.v10i4.pp3588-3595.
[27] T. S. Gunawan, M. H. Anuar, M. Kartiwi, and Z. Janin, "`Design of power factor meter using internet of things for power factor improvement, remote monitoring and data logging," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 17, no. 2, pp. 700–709, 2019, doi: 10.11591/ijeecs.v17.i2.pp700-709.
[28] C. Venugopal and T. Govender, "Load power and energy management system using proteus visual design software," *Indonesian Journal of Electrical Engineering and Computer Science*, vol. 20, no. 2, pp. 1044–1052, 2020, doi: 10.11591/IJEECS.V20.I2.PP1044-1052.
[29] Farnell, "Arduino Uno Datasheet," *Datasheets*, pp. 1–4, 2013. [Online]. Available: https://www.farnell.com/datasheets/1682209.pdf.
[30] G. L. S. Technologies, "AC Voltage Sensor (ZMPT101B)," *Global LogicaTM Software Technologies*, vol. VERSION 1., [Online]. Available: www.makemyproduct.com.
[31] Allegro®, "ACS712 [Datasheet]," *Allegro MicroSystems, Inc*, pp. 1–14, 2007 [Online]. Available: https://www.scribd.com/doc/284229122/ACS712-Datasheet.
[32] Series Performance, "KQ-130F power line carrier data transceiver module A," *KQ-130F Series Performance*, pp. 1–20, 2016. [Online]. Available: https://uamper.com/products/datasheet/KQ330.pdf.

BIOGRAPHIES OF AUTHORS

Shaimaa Mudhafar Hashim is an M.Sc. degree student in the research level at the Department of Computer Engineering, Al-Nahrain University, Baghdad, Iraq, and completed a B.Sc. degree in 2018 in the Department of Computer Engineering, Al-Nahrain University, Baghdad, Iraq. Miss. Shaimaa is interested in power management, Electrical and Electronic Systems, and Control of smart meter grid systems by using wireline technology. She can be contacted at email: shaimaa.mudhafar@gmail.com.

Israa Badr Al-Mashhadani was born in Baghdad, Iraq, in 1977. She received her B.Sc. degree in electronics and communication engineering from Al-Nahrain University, Iraq, in 1998. the M.Sc. degree in Electronic Circuits and Systems from Al-Nahrain University, Iraq, in 2001, and the PhD degree in electronic systems from the University of Reading, U.K, in 2017. Currently, she is a lecturer in computer engineering at the College of Engineering, Al-Nahrain University, Baghdad, Iraq. Her research interests include Non-Linear Circuits Analysis, Port-Hamiltonian Formulations, Memristive elements, and Smart Cities. She published several papers in different scientific journals and conference proceedings. She can be contacted at email: israa.b.al-mashhadani@nahrainuniv.edu.iq.