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Development of intelligent smart energy monitoring systems for renewable energy source using Proteus-8 environment and validated with experimentation

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Abstract

Customers of energy, both in residential and commercial structures, are now more interested in lowering their energy usage as an effect of the feed-in tariffs for renewable resources and the recent rise in electricity rates. The central control system and smart power Plug proposed in this study use the XBee communication protocol to manage energy use. Smart energy management systems are used to measure and optimize power use at the consumer premises level. The design and development of wireless smart Plugs that can assess several power characteristics and gather data on the real-time power use of individual consumer appliances is the main goal of this paper. An XBee transmitter and receiver node aids in the formation of the Consumer Area Network, which is created by the SEMS setup. The central node's real-time data collection allows for the scheduling and prioritization of the appliances. Consumer appliance datasets may be created using the SEMS setup, and additional datasets can be utilized for load disaggregation. The configuration of the system allows for wireless data transfer from smart outlets to a central controller. The connected devices to the smart Plug are then turned on or off by the system using control instructions generated by the data analysis. According to test findings, the suggested smart Plug can assess the power consumption of wirelessly connected devices up to 18 meters away with accuracy and without compromising data. Based on a planned user program code, the central controller is capable of successfully controlling several Plugs. The proposed Smart Energy Management algorithm demonstrates that using smart Plugs as load controllers results in a decrease in energy consumption of 0.811 kW min (0.0134 kWh) with the right scheduling algorithm, the suggested smart Plug technology may, therefore, be used to its full potential in a smart energy management system. The data's findings show how much better the proposed approach is than the standard ones in use now.

Keywords: Intelligent Smart Energy Management System, Smart meter, Smart Plug, ZigBee, Monitoring system, Internet of Things, Renewable energy

Introduction

Deregulation in the power industry brought about a substantial change in the industry's growth, enabling industrial and commercial users to create energy at a lower cost and even sell it to customers. Numerous elements, including privatization, being dependable and affordable, customer attention, and innovations, are linked to deregulation in the electricity industry [1]. In a smart grid context, a distribution automation system is essential because it may speed up time-consuming operations by repeating them more quickly. The management of outages and system failure recovery are both important aspects of distribution system automation [2]. The Distribution Automation System provides several benefits in terms of money, customers, and maintenance. Customers and utilities alike depend on the electric distribution system to function reliably [3]. The majority of power outages are brought on by dangerous environmental conditions and power line obstructions. These gadgets gather a great deal of data and provide nearly instantaneous system operating monitoring [4].

In recent decades, there has been a tremendous lot of progress in the field of renewable energy sources (RES). The key driving force behind RES's substantial integration with smart grid systems is a lack of conventional fuel-based energy [5]. SEMS plays a crucial role in lowering power usage at the customer premises level. A crucial component of SEMS setup is effective energy management with household appliances. Information about user activity and context may also be utilized to better optimize SEMS's use of energy [6]. The primary objective of SEMS is to minimize energy usage while taking user comfort into account; to do this, energy consumption monitoring and appliance control mechanisms are required. In this study, the prominent feature is the recommended smart energy management system with smart Plug capabilities [7]. The sections below provide more information on this work's contribution:

A study of pertinent literature is initially offered to understand the current level of the art in this discipline at this time. The specifics of the proposed work are described in the part that follows, taking into account the consumer environment system's energy optimization approach [9]. The next section goes into additional detail about simulating an energy meter in a Proteus environment with different power quality characteristics. The experiment makes use of an Arduino Uno ATMega328 microprocessor, and an LEM LA-55P Hall Effect current sensor and XBee series-2 modules are used to demonstrate the serial connection shown in Fig. 1. Finally, the work's future scope and conclusion are discussed [10].

Recent increases in both the global population and the economy have led to a sharp increase in the trend of electrical energy consumption. However, due to constraints in electrical energy supply networks, utility regulators employ a variety of tactics to lower end-user consumption, including high tariff rates, tariff time usage, and demand response programs [11]. Because of the depletion of oil supplies, the volatility of oil prices, and the detrimental effects of fossil fuels on the environment, including CO_2 emissions, energy authorities also work to minimize reliance on fossil fuels [12]. End users must curtail their energy use by implementing behavioral modifications and utilizing energy-efficient appliances and equipment. Globally, governments encourage energy consumers to reduce their energy use through the promotion of renewable energy sources, raising consumer awareness, and providing incentives to those who do

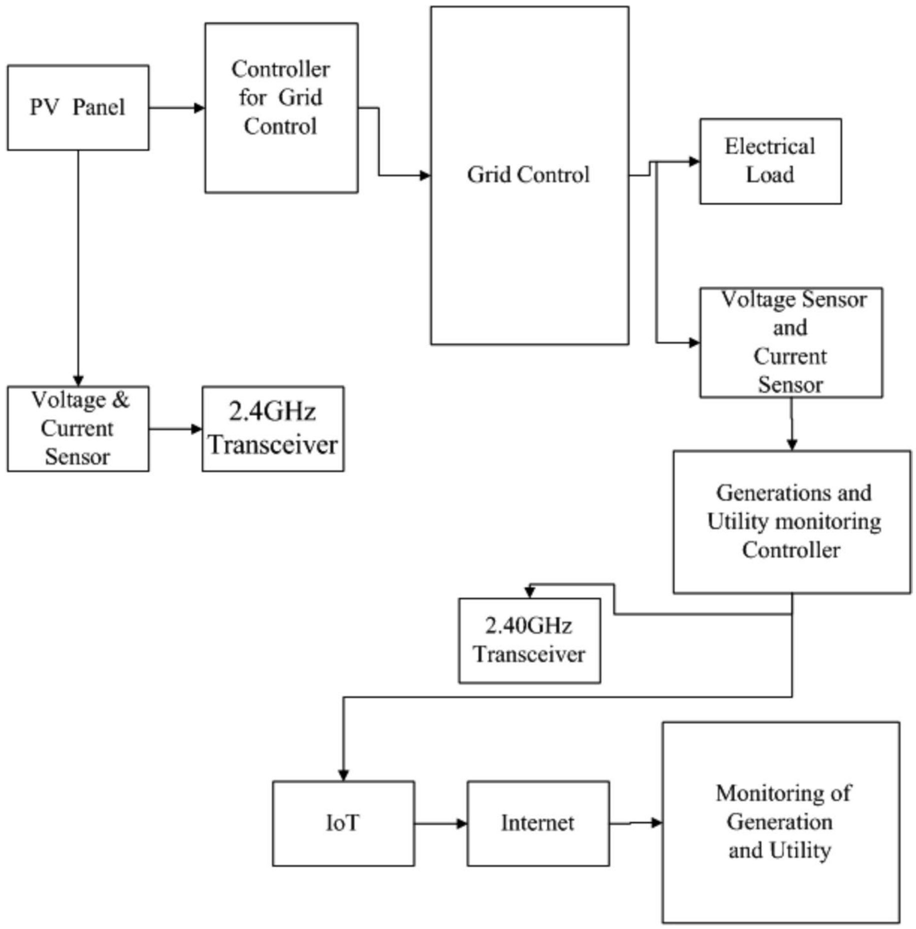

Fig. 1 Proposed system architecture [8]

so [13]. Using energy-efficient appliances (like LED lights), switching out conventional equipment for smart ones (like remotely controllable outlets), employing integrated photovoltaic systems, warning customers about their energy use, and putting in place intelligent energy management systems that supervise smart devices are additional viable solutions [14].

The statistical data indicate that electrical energy loss may be effectively addressed by sending out information on end-user energy usage patterns regularly [15]. Demonstrate how exchanging information about energy consumption may impact appliance usage and result in a 20% reduction in energy use. To track and control the amount of electrical energy used in homes and businesses, a plethora of tools and software applications have been developed [16]. Certain methods just aid in estimating energy usage [17], while others provide greater details regarding the financial gains from shutting off unused equipment or rearranging usage times, among other advantages of energy conservation. To inform users of the significance of lowering energy use, other strategies include displaying precise load qualities or illustrating them with visually striking imagery, such as a picture of a melting glacier with a polar bear. Recent technical developments have made it possible to automate the control of certain equipment [18]. The development of intelligent power plugs and Plugs, which can manage individual loads at any time of day, marked the beginning of this advancement. Through the monitoring and management of household appliances without compromising user experience, smart Plugs help consumers save money on power. In the end, this entire experience served as the foundation for contemporary ideas about the astute customer. Building energy consumption is linked to control-related issues according to research from the National Building Controls Information Programme [19].

This study indicates that issues related to software development, interference from operators, and input device controls are the primary sources of inefficiencies in building energy utilization systems. There are a few design issues with smart outlets that relate to the energy efficiency and management needs that were previously addressed [20]. For example, the programming code used in power and energy calculations is reduced, and a fixed voltage signal is utilized instead of voltage sensors, which might result in erroneous information being provided. These drawbacks motivate efforts to create a precise and regulated smart Plug that makes use of XBee wireless technology and the low-cost Arduino microcontroller [21]. Uncertain power source is a frequent issue that occurs in various circumstances. These days, any problem with the distribution of electricity caused by a total loss of electrical power paralyzes the entire system. When there is a distribution line fault, the smart grid has the extra benefit of automatic rerouting. Smart grids are user-friendly, assisting users in controlling their power use and serving as a link between consumers and their utilities [22]. Utilizing a smart grid is necessary to increase transmission line efficiency, lower power consumption, and lower costs.

Smart grid-enabled wireless sensor networks are an advantage for intelligent devices. WSNs are used in lifestyle applications nowadays. For commercial and residential clients alike, the smart grid has shown to be effective [23]. Automated rerouting on flexible loads allows commercial and residential clients to receive an ideal energy bill. Only a network connected with the energy source control can do this among the most advanced technologies for keeping an eye on a variety of applications in the majority of situations is a wireless sensor network [24]. When there are power outages because of natural catastrophes, the smart grid can simply implement balancing measures. Rising distribution generation can boost grid sovereignty. Other defects, such as voltage increase and reverse power flow, do not exhibit these benefits [25]. The first portion of this essay addresses the requirement for resolving identified issues. The conventional approaches are described in the next section. The suggested technique is the subject of the third part. The results and comments are covered in the fourth part. The conclusion and the area of future research are presented in the last part [26].

The following is how the literature is arranged in this paper: Sect. "Methodology" provides a summary of the recommended architecture and a breakdown of the recommended system after this introduction. The recommended control approach and the application of various optimization techniques are enclosed in Sects. "Advanced smart energy management system model" and "Internet of things." The experimental setup and general system organization are fully explained in Sect. :"Procedure for working of the proposed system." The findings and observations concerning the created control systems are presented in Sect. "Results and discussions" and "Proteus environments for simulating energy meter." The final Sect. "Conclusion & future work" of the paper is presented.

Methodology

A Central Gateway node is utilized by a smart Plug to establish communication with a specific home device. A microcontroller unit, sensors, an XBee communication module, and a relay unit are the essential components of a smart Plug. The relay device controls the power supply to the appliances [27]. A smart Plug-equipped display gadget indicates how much energy each appliance uses. Individual appliance power usage data is transmitted to the central Gateway, where it is evaluated to help determine the best course of action given the limitations of the available power. Using an XBee connection module, a smart Plug system may get data and monitor and operate appliances [28]. Hybrid architecture with three distinct layers, a network layer, a server layer, and a client layer, was presented by Song et al. The mobile node, developed by the system's creators, is capable of sensing and interpreting internal environmental data before positioning itself appropriately. To build a consumer monitoring system with an appropriate network route construction and event tracking capacity, a hybrid sensor network was used [29].

A recommended intelligent consumer automation system has a feature for a widespread consumer network. Through the integration of sensed data from the active sensor network, sensors and actuators are efficiently employed to monitor and regulate the state of consumer appliances [31]. The framework that was created contains sensing components for gathering data from the environment of consumer sensors that have been placed and decision components for processing and activating service components such as consumer automation or consumer security shown in Fig. 2. Lastly, the appliance's state is controlled via the use of control components. The washbasin and the central network node connect via communication components [32]. A decision control strategy was proposed for the user profile and light illumination-based model. The system considers the two illumination sources for the study of light intensity and background light, respectively. To decrease power consumption and satisfy user requirements, the model takes into account the lighting of light by the various user profile actions [33].

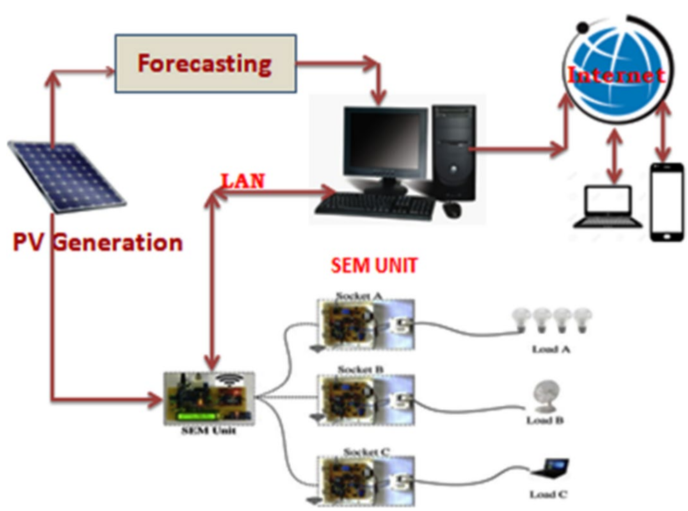

Fig. 2 IoT-based Energy Monitoring System [30]

XBee and Wi-Fi network compatibility is facilitated via a central consumer gateway in a proposed consumer automation system. The performance of the coexistence of the XBee and Wi-Fi networks is tested using an experimental configuration. A writer also makes an effort to pinpoint the issue behind the sluggish adoption of consumer automation systems [34].

A Smart Energy Management System (SEMS) energy optimization system uses XBee technology and remote tracking to reduce standby power usage. The suggested system consists of a consumer server, an XBee hub, power outlets coupled to XBee communication and control buttons, and decreasing light intensity. A power outlet can measure the amount of power used by the connected consumer appliance [35]. According to the suggested system, if a certain appliance's power consumption falls below a predetermined level, AC power is automatically shut off after a predetermined period. By altering the appliance's identity in the user interface, the proposed approach further offers the mobility of a portable appliance to a number of power outlets spread around the XBee service area. This method might not be suitable for a device like a PC, though, as some crucial data may be lost if it is promptly turned off [36].

The availability of renewable energy sources makes consumer appliance scheduling based on dynamic load priority, and it is possible to monitor household load appliances in real-time. The energy consumption of consumer appliances, both real-time and non-real-time, is separated into two categories. The categories of periodic and non-periodic appliances are further separated according to the amount of energy they consume in non-real-time. Appliances that display their current energy use are not planned; they are fixed as soon as they become problematic. Appliances that use energy outside of real-time are dynamically scheduled and given a higher priority [37]. The authors developed a real-time home load scheduling technique to schedule the appliances depending on the production of real-time renewable energy sources. This work [38] does not investigate the integration of renewable energy sources with battery state of charge. The present status of the device is taken into consideration by the appliance dynamic priority system provided by an intelligent cloud energy management system. The availability of renewable energy is considered while scheduling appliances. A resident's activity patterns, the surrounding environment, and the embedded battery conditions are used to classify home appliances into groupings of Type-A, Type-B, and Type-C. Type-A appliances cannot be switched off since proper operation depends on the user's engagement [39]. When scheduling Type-B appliances, the user's threshold values for things such as temperature, lighting, and humidity are compared to the ambient circumstances. Due to their dependence on batteries, Type-C appliances can be scheduled by the state of the batteries. The authors successfully implemented and tested the experimental setup [40]. A more advanced approach proposes utilizing renewable energy sources and hybrid electrical storage to lower domestic energy usage. The proposed approach can use load shedding to assign priorities and select from a range of alternative energy sources. Additionally, it offers several scheduling options for the demand side as well as the generation side [41].

The suggested combination of conventional power systems and renewable power systems aids in determining the most economical ways to use energy and household equipment. In this study, the authors take into account both conventional and renewable power systems during the charging process. The authors presented a multi-dimensional threshold technique, wherein many thresholds are employed to assess if the CPS or RPS should fulfill the power requirements of certain appliances [42]. The appliance state is monitored by the system, and the appliance status is controlled by a personal computer [43]. In contrast with earlier research, the current study focuses on developing an SEMS system to measure various power metrics for load appliances both in steady state and during transient states. Further SEMS arrangement is utilized to control alternative energy generation for low grid demand and effective use of renewable energy sources. It is possible to schedule loads and assign them a priority on the consumer's premises. To properly regulate and manage the appliances, aggregated data from smart and submeters may also be utilized for load disaggregation methods like Non-Intrusive Load Monitoring [44].

Advanced smart energy management system model

XBee is used as the communication interface in the power negotiator's design, as shown in Fig. 3. Instead of connecting to a power outlet directly, each appliance is connected to a different interface known as a smart Plug. The user must press the pushbutton on the smart Plug to turn on the appliance [45]. The master receives a request from a smart Plug, processes it through use a power negotiation algorithm to ascertain a power budget before taking appropriate action. Choose whether to accept the request or reject it. The appliance is turned on when a request is granted, and the smart Plug starts tracking how much energy it uses until the master turns it off or preempts it. The appliance's overall energy consumption is then updated in the master [46].

A smart Plug replaces a standard power outlet and contains a switching circuit, an MCU, a current sensor, and a communication interface shown in Fig. 4. A smart Plug can do the following tasks:

- Calculate instantaneous electricity used by a connected appliance.
- Calculate the appliance's energy use.
- Executes the power negotiation requisition process and decides whether to switch on or off the appliance.

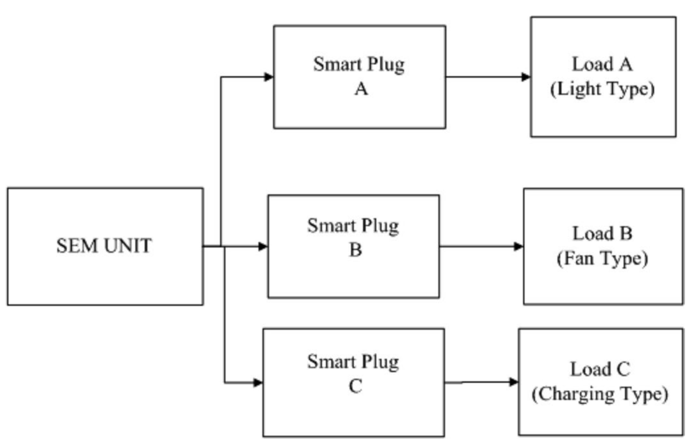

Fig. 3 Proposed Smart Energy Management System Model [15]

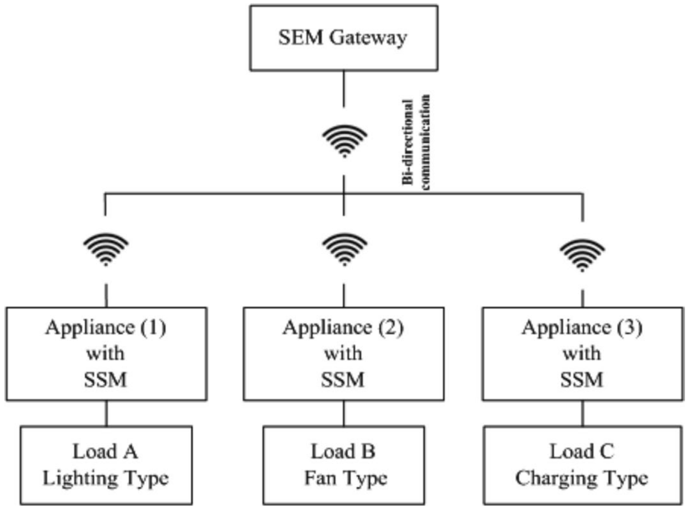

Fig. 4 Block diagram of Smart Energy Management System [48]

To test the functionality of the energy meter design, the initial simulation component of this effort is completed. The energy meter's hardware experimental design is also put to use [47].

Internet of things

The main platform for IoT learning is the Raspberry Pi. The controller and the Raspberry Pi are connected. After setting up the Ethernet connection, log into the Raspberry Pi to begin creating an IoT platform [49]. Python is the programming language used. To track energy use statistics for specific devices, Raspberry Pi sends energy data to a server connected to the internet shown in Fig. 5. Real-time energy data is stored in the cloud and made accessible to other programs for monitoring and analysis [50]. To switch on or off the device, the Raspberry Pi receives a control signal from the same server. According to the flowchart below, these are the many processes for building an IoT platform [51].

Procedure for working of the proposed system

Step 1: Arduino is interfaced with current sensors.

Step 2: We estimate each load's power usage based on data from current sensors.

Step 3: The Raspberry Pi serves as a gateway that allows the linked load to be turned on and off remotely and to communicate the power level to the internet.

Step 4: The Raspberry Pi and Arduino interact with each other over a serial interface.

Step 5: Arduino measures the load's current consumption and determines its power.

Step 6: To get such data, the Raspberry Pi sends the "p" character to Arduino.

Step 7: Subsequently, Arduino provides the power level in the format that is displayed below.

Step 8: The Raspberry Pi accepts it and decodes it to provide two power levels.

Step 9: Then, according to ThingSpeak, it uploads these values to an IoT platform.

Step 10: A program to remotely turn on and off the load is operating concurrently.

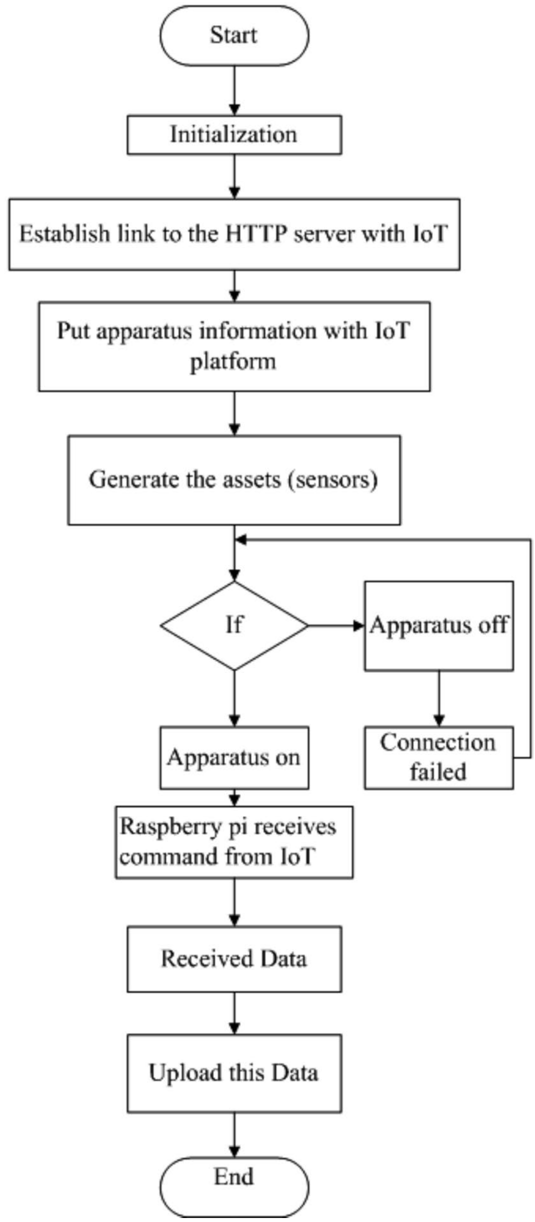

Fig. 5 IoT-based device control [52]

Step 11: On ThingSpeak, we will receive a graph showing the power usage of each load.

Results and discussion

The initial simulation phase of this project is carried out to verify the energy meter design's functionality. Moreover, the energy meter's hardware experimental design is completed.

Figure 6 depicts the system's experimental setup. For both AC and DC transmissions, the ACS 712 current sensor provides accurate current measurement. These sensors work well for monitoring and gauging systems' overall power usage. Up

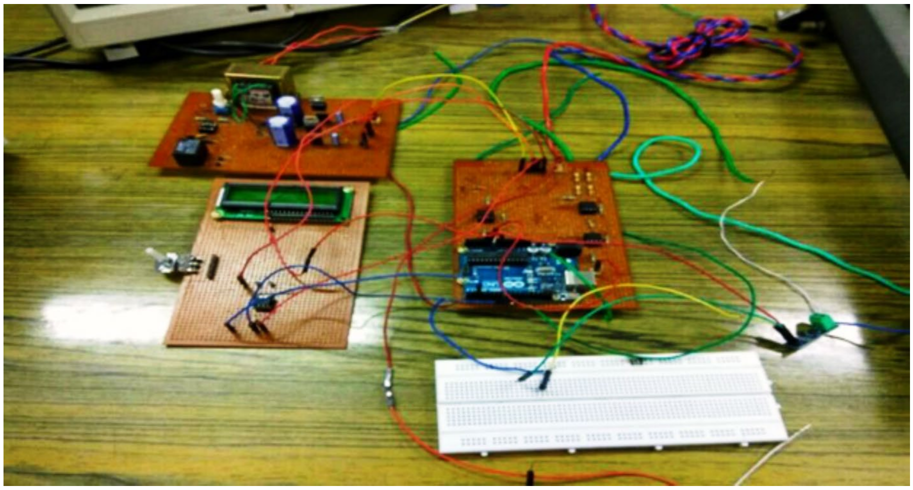

Fig. 6 Experimental setup

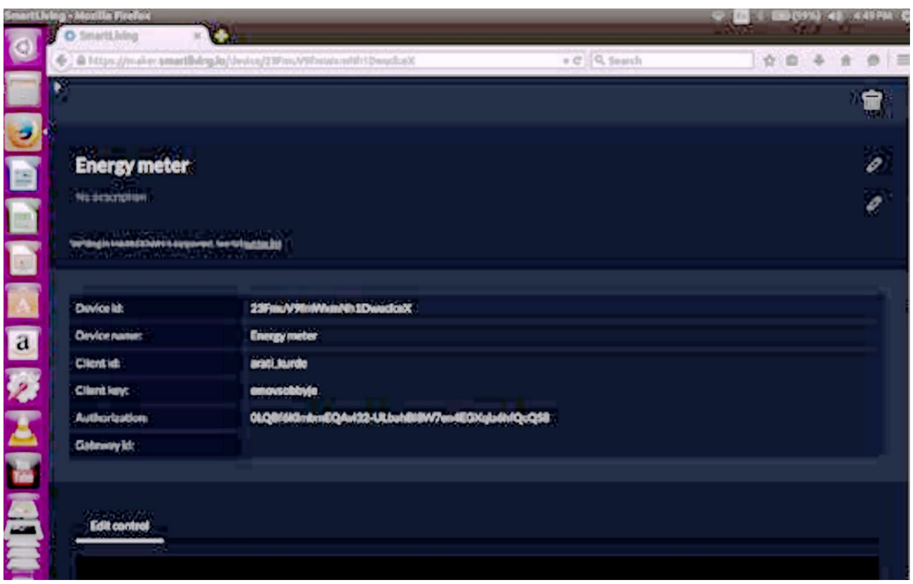

Fig. 7 Application for a web page on the user interface system

to 20A of AC may be measured using the ACS712 current sensor. The relay circuit is used to remotely control a single device via the Internet of Things.

The web page application for the system's user interface is depicted in Fig. 7. Here, a connection to the IOT platform's HTTP server is established.

The IoT module cannot create new devices by itself. On the manufacturer's website for the IoT platform, manually add more devices. Here, there have two different kinds of web page utilized.

- *Smart Living Maker* The AllThingTalk developer platform with AllThingTalk development platform, Smart Living, you can easily establish a connection and initiate communication with your devices. Set up a connection and loads. Based on asset profiles, create device setup controls.

- *ThingSpeak* This is an Internet-of-Things platform for open data. Move current data to the cloud so you can access it later. Examine and display the information. Our device gets instructions and data from the cloud through MQTT after running the program in simulation. Device data is collected and sent to servers via a protocol called MQTT. As shown in Figs. 8 and 9, the gadget is managed using the Smart Living Maker platform.

Real-time data is stored in the cloud using ThingSpeak. Plot Fig. 10 energy vs. load time graph. To analyze and visualize the data, the user instructs the controller to operate the device by pressing a push button that is available on the mobile application or online dashboard.

Proteus environments for simulating energy meter

Proteus software is used to simulate a single-phase energy meter, and Fig. 11 illustrates the simulation environment. The simulation's design uses a differential amplifier circuit to lower the supply voltage and a DC offset circuit to turn on the positive signal. The Proteus-8 simulation library and the Arduino IDE are combined to simulate this model. A HEX file is created when the code has been developed in the Arduino IDE. The Proteus simulation environment uploads the resulting HEX file to the Arduino prototype. A 10-bit internal ADC is incorporated into the Analog pin of the analog signal will be digitalized by the controller. The voltage signals are then modified to satisfy the necessary power quality requirements.

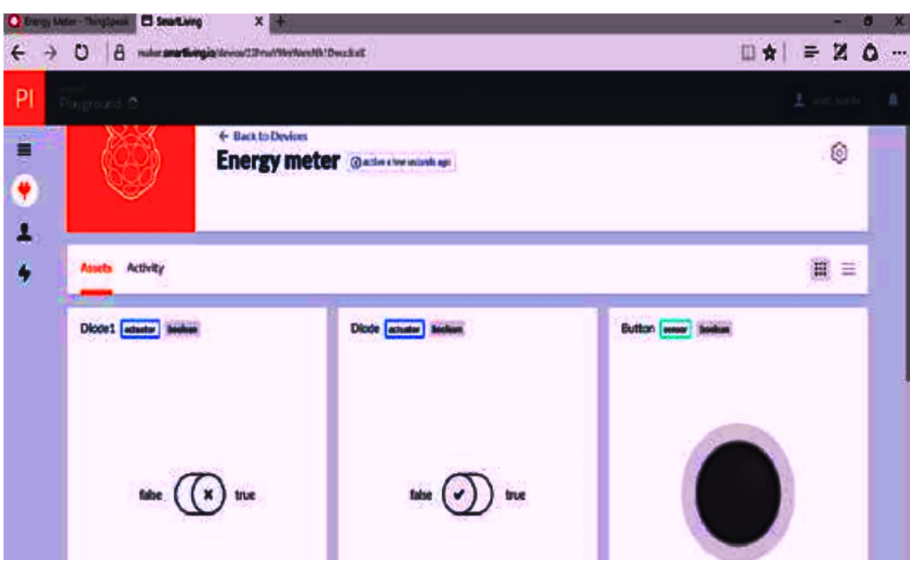

Fig. 8 Push a button to use IoT to control an appliance

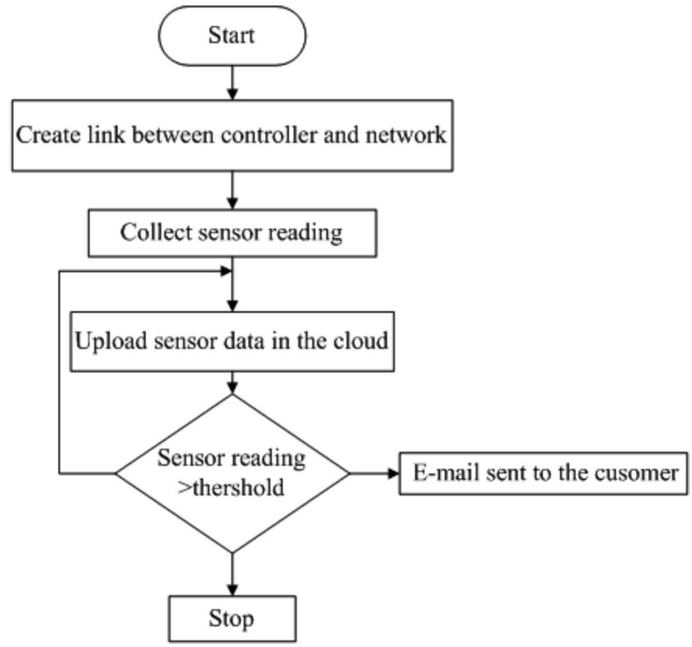

Fig. 9 Data upload to the cloud [25]

Fig. 10 Energy vs. time analysis of load

Voltage measurement

Since the microcontroller unit cannot be directly supplied with 230 V input, 230 V RMS must be monitored in this study because only voltages between 0 and 5 V can be read by microcontrollers. The internal circuitry of the microcontroller may be harmed if the input voltage exceeds 5 V. Voltage scaling then enters the picture. The measured grid voltage, 360 Vp-p, is depicted in Fig. 12. By choosing the proper input and feedback resistance values, a differential amplifier circuit may be utilized to

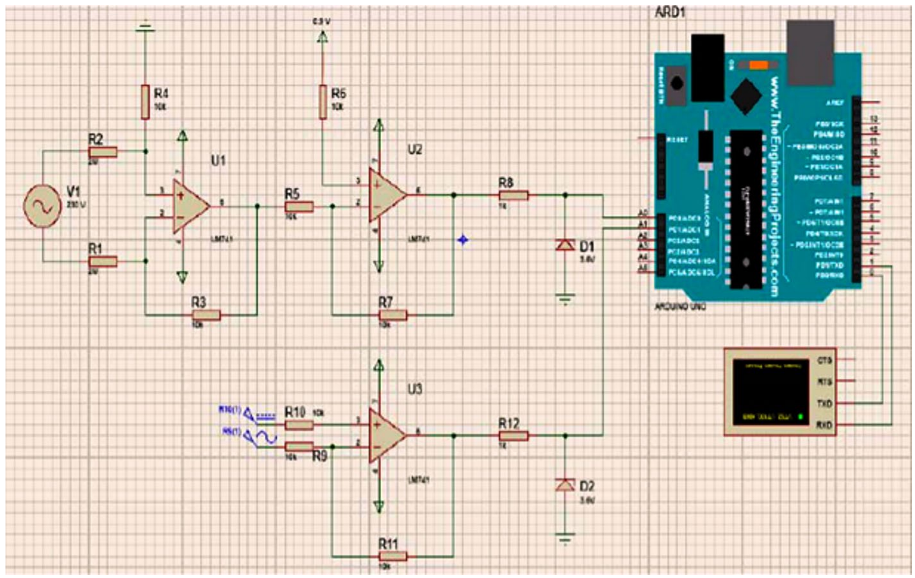

Fig. 11 Energy meter simulation in the Proteus-8 environment

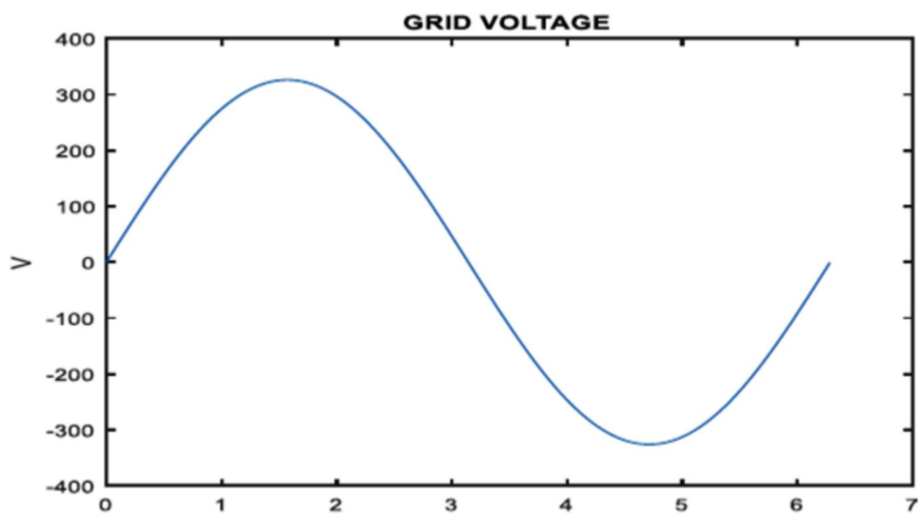

Fig. 12 Grid shown on the waveform measuring the voltage

reduce the voltage. As shown in Fig. 13, a sizable DC offset voltage can be applied to further read the voltage in the microcontroller unit.

Current measurement using ACS712T

Using an ACS712T 30A current sensor module, line current is first reduced. Since there will be a 2.5 V DC offset in the sensor output, there is no need to employ a separate circuit for offset. The sensor's sensitivity is 66 mV/A. For example, a sine wave with a 2.5 V DC offset will have an output of 132 millivolts from peak to peak when a 2 A line current is used. The load is linked in series with the current sensor module; this produces a signal that is proportionate to the load current.

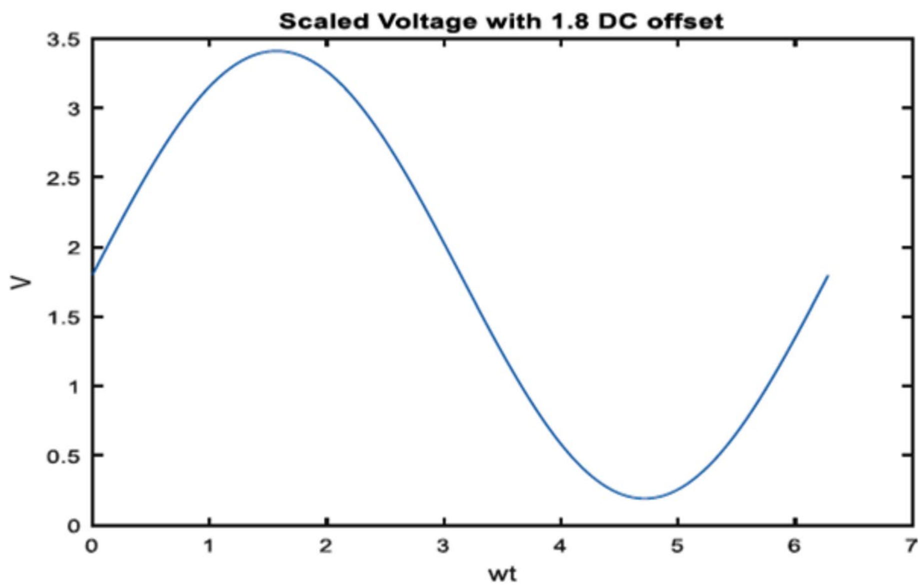

Fig. 13 Waveform displaying reduced voltage with a DC offset

Table 1 Arduino Uno specifications

Arduino Uno	ATmega328
Working voltage	5.0
Supply voltage	7.0–12.0
Input voltage	6–20 V
Digital I/O pins	14
Analog pin	6
PWM output	6
Current	40 E-3
Current for 3.3 V	50 E-3
Flash memory (KB)	32
SRAM (KB)	2
EEPROM (KB)	1
Clock speed (MHz)	16

$$\mathrm{Vout} = \mathrm{K} * \mathrm{Iin}$$

where the ACS712 data sheet indicates that "K" is equal to 66 mV/A.

Creation of an experimental energy meter configuration

The energy metes hardware circuit is shown in Fig. 6. A $\pm$12 V DC power supply unit constructed using the integrated circuits LM7812 and LM7912 powers the DC power op-amps in the signal conditioning circuit. A rheostat load is defined as one that is rated at 15 A and 4.3 ohms. Instantaneous RMS Voltage and Instantaneous RMS Current, Table 1, which were produced by varying the voltage and instantaneous current signals, show several metrics, including energy usage, frequency, voltage fluctuation, apparent power, average power, power factor, and overall harmonic distortion. Table 1 shows a list of the specifications for the Arduino Uno Microcontroller device.

Multiple electrical parameter calculations for a load

Instantaneous voltage and current

Before being processed by the microcontroller unit, the real voltage and current signals undergo signal conditioning. The kit's 10-bit ADC samples the circuit's analog values, which are then read using an ATMEGA328 Arduino UNO microcontroller shown in Fig. 14. The maximum sampling rate is determined by the ADC's resolution; every signal that is sampled yields instant voltage and current information.

Compute the real power

The real power of the circuit is ascertained by measuring the instantaneous voltage and current. Instantaneous power, or Pi, is computed as instantaneous voltage multiplied by instantaneous current. The total instantaneous power is computed after successive instantaneous values have been added up. To calculate the actual power use, divide the total instantaneous power by the number of samples. The actual power computation for "n" samples is shown in equation below.

$$P_i = V_i * I_i \tag{1}$$

$$\mathrm{P} = \frac{\sum P_i}{n} \tag{2}$$

where "P" is the real power.

Root-mean-square voltage and current

Below equation states that the mean and RMS values of the voltages are obtained by taking divided by the quantity of samples, the voltage's instantaneous product values, or "n" for the number "n" of samples

$$V_{rms} = \sqrt{\frac{\sum v^2}{n}} \tag{3}$$

$$I_{rm} = \sqrt{\frac{\sum i^2}{n}} \tag{4}$$

Apparent power

Below equation shows how the perceived power of the load is calculated as the sum of the RMS current and voltage measurements.

$$\mathrm{S} = \mathrm{V}_{rms} * \mathrm{I}_{rms} \tag{5}$$

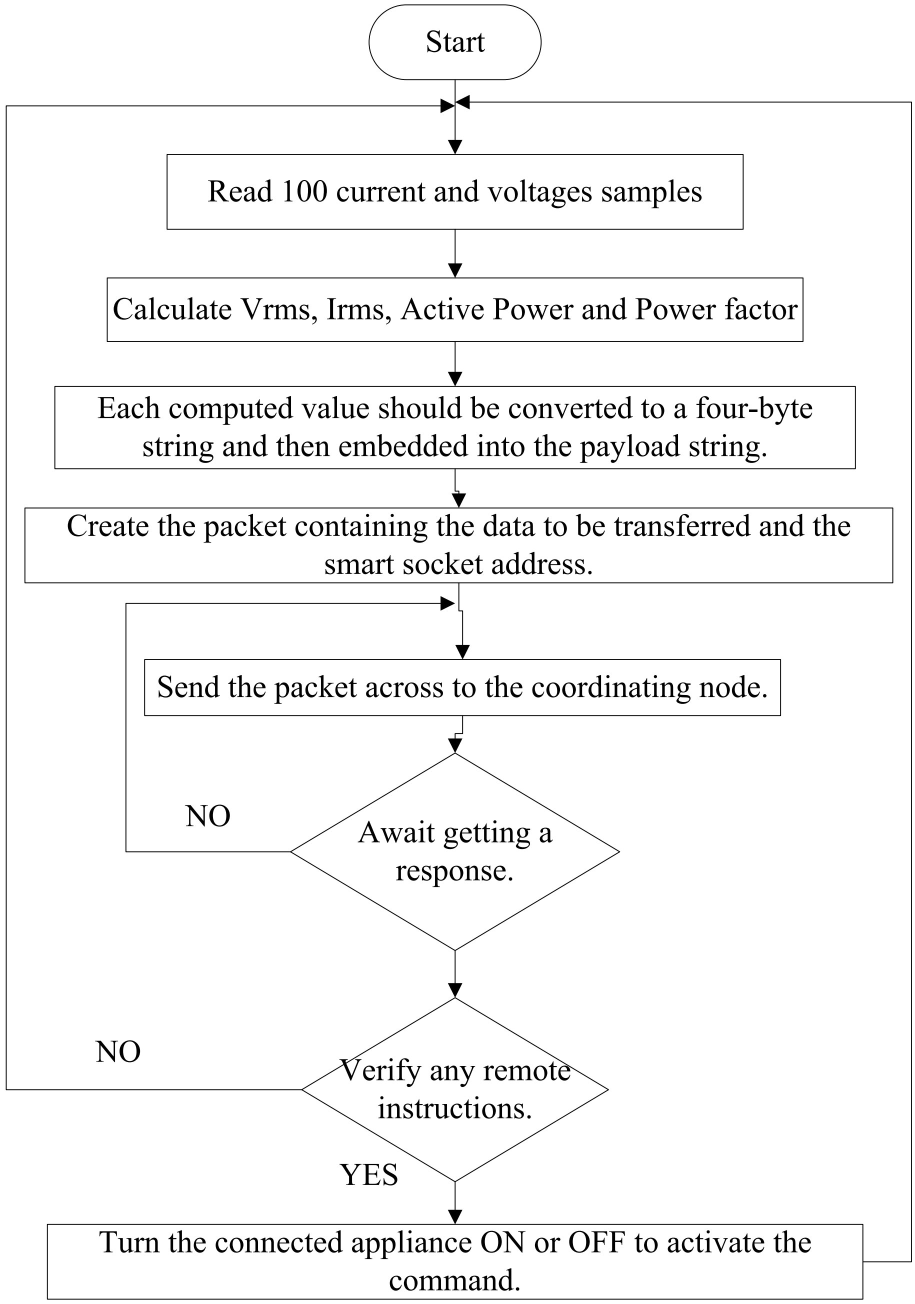

Fig. 14 Smart Plug data processing steps [36]

Power factor

Below equation provides the power factor parameter, which is determined by taking the apparent power and dividing it by the true power number.

$$\text{PF} = \frac{P}{S} \tag{6}$$

where "P" stands for perceived power and "S" for actual power.

Total harmonic distortion

Total harmonic distortion may be calculated as the product of all the harmonic components of the voltage or current waveform about its fundamental components. Below equation shows how the THD is calculated.

$$THD = \frac{\sqrt{V_2^2 + V_3^2 + \cdots + V_n^2}}{V_1} \tag{7}$$

where V1 represents the voltage waveform's fundamental frequency component's RMS value, and V2, V3… Vn represents its harmonic component's RMS value.

Energy

Below equation may be used to compute an appliance's energy by multiplying its power by the duration of its power consumption.

$$\mathrm{E} = \mathrm{P} * \mathrm{t} \tag{8}$$

where "t" indicates the amount of time the load used electricity, and "P" represents the power utilized.

The communication of XBee modules

Wireless end-point communication for devices is offered via XBee modules, which are embedded solutions. These modules quickly establish peer-to-peer or point-to-multipoint connections by using the IEEE 802.15.4 networking protocol [14]. Their purpose is to cater to high-volume applications that need consistent communication time and minimal latency. Utilizing the XBee standard, XBee enhances it and encapsulates it in a compact, well-designed container. This section describes how to use the XBee module to transmit data wirelessly from the Arduino, along with the setup that is needed. The XB24—ZWIT 007, the XBee module being using the XBee protocol, this case is also known as the XBee series-2 [15].

Two identical XBee modules are used in the experiment; one is linked to the Arduino and set up to send data, while the other is connected to the computer and set up to receive data as shown in Table 2. It should be noted that an XBee adaptor and an XBee USB Explorer are needed in order to connect the XBee modules to the Arduino and the computer, respectively. There are several companies selling XBee explorers and adapters, and any version will function well.

The XCTU configuration software was created by Digi International, the company that makes the XBee radiofrequency modules. Figure 6 displays how XBee modules are configured. XBee adapters are required, and PC software called XCTU is used to set up the module. Before changing the configuration from the coordinator to the router, or the other way around, it is advised to use reset mode.

When setting up a point-to-point connection between two XBee modules, one should be configured as a coordinator, or transmitter, and the other as a router, or receiver. The output of the XCTU software is exhibited in the serial terminal window shown in Fig. 15:

Table 2 Examining energy configurations using the Arduino console window

Parameters	Power parameters displayed		
	Example-x	**Example-y**	**Example-z**
Vrms (V)	221.79	222.84	220.78
Irms (A)	0.68	0.68	0.68
App. power (W)	131.75	131.48	130.87
Avg. power	131.52	131.48	130.87
Pf	1	1	1
Frequency (Hz)	49.49	49.50	49.49
Change in voltage	−3.12	−3.23	−3.84
THD	1.36	1.47	0.82
Energy	48.63	48.67	48.54

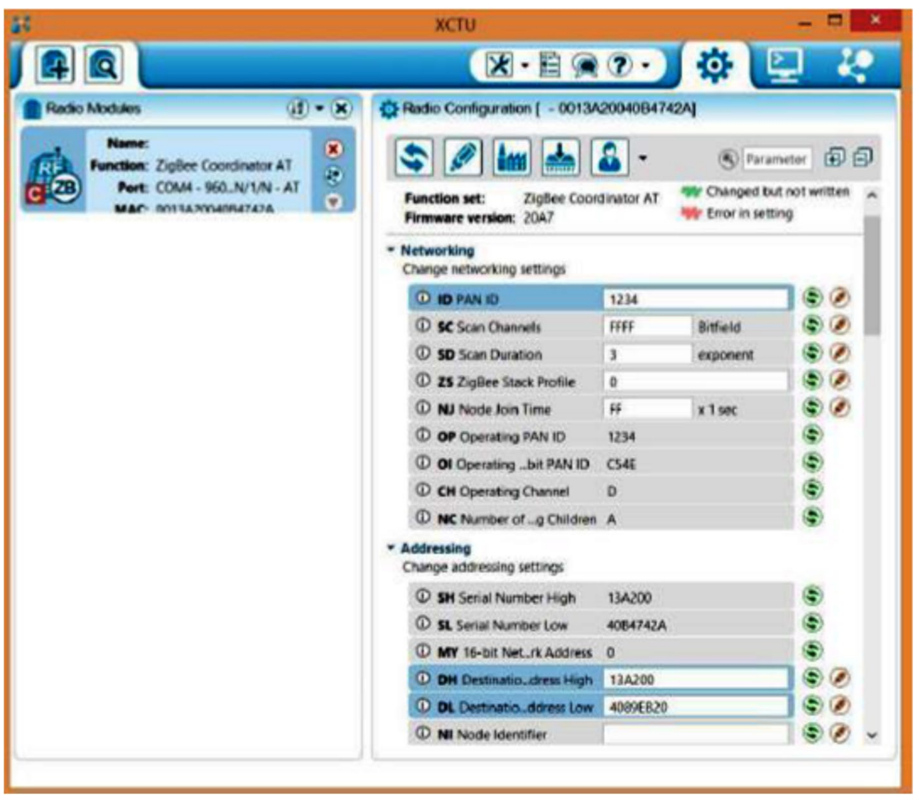

Fig. 15 Setting up XBee in router

Received data is shown in red characters, according to hexadecimal format, while sent data is represented by blue characters. Two XBee modules have successfully sent data as a consequence shown in Fig. 16.

Conclusion and future work

The primary objective of this project is to build a smart Plug for a consumer energy management system. Several electrical properties, an energy meter measures things such as power factor, average power, apparent power, total harmonic distortion (THD),

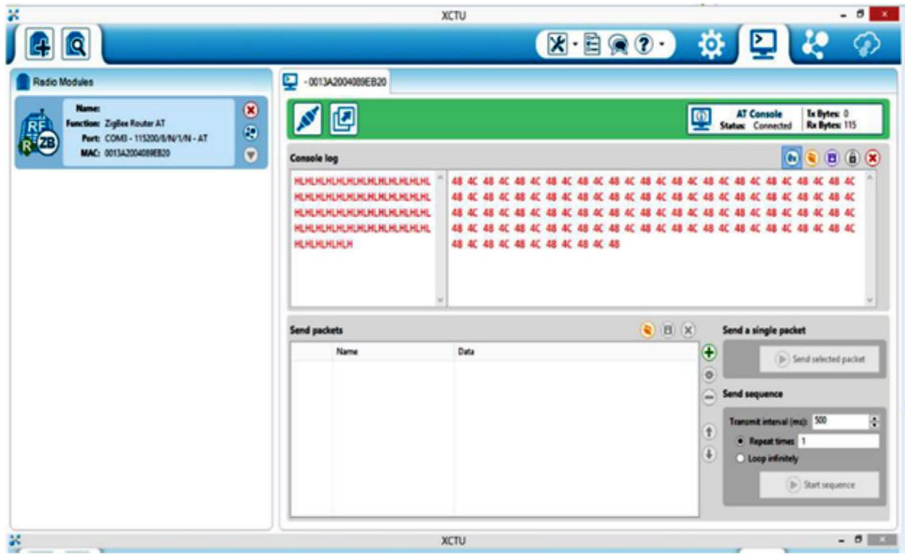

Fig. 16 Examining the serial link

and energy used. Following that, a serial monitor connection was made between the identical XBee units. To make a smart Plug device, XBee modules are combined with an additional Energy Meter. Subsequent efforts will concentrate on assigning a priority to every item and planning the appliance schedule to account for the power budget and peak demand.

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Author contributions
Challa Krishna Rao helped in conceptualization, formal analysis, investigation, methodology, supervision, validation, and writing—original draft. Prof. Sarat Kumar Sahoo helped in conceptualization, formal analysis, investigation, methodology, supervision, validation, and writing—original draft. Franco Fernando Yanine helped in conceptualization, data curtain, formal analysis, investigation, methodology, software, validation, and writing—original draft.

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Declarations

Competing interests
The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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