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IoT-Based Energy Meter for Remote Monitoring and Managements of Power Consumption

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ABSTRACT- Real-time monitoring of several parameters such as the current and the rated power is provided by this design. Users become more conscious of their consumption with specifications based on recorded data using this design. Additionally, it enables users to quickly identify abnormal issues such as spikes that result in device failure. Also, this design offers remote access to received data by cloud platforms with mobile applications. This study evaluates the performance of an Energy Monitoring distributed among 17 electrical devices in three houses over a period of 30 days. The design demonstrated high accuracy and minimal error in its readings for the related devices with effectively capturing detailed energy consumption values. Based on results, the analysis of power and current efficiency at different power levels reveals notable performance variations. House 1 runs efficiently at low power levels; yet, efficiency levels indicate higher power levels with (96% ,97%) power and current reading efficiency respectively. House 2's efficiency at medium power displays more pronounced inefficiencies than House 1's, although it still keeps its current efficiency constant with (90% ,97%) power and current reading efficiency respectively. House 3 demonstrates that it is ideally adapted to handle high power levels, exhibiting the highest overall efficiency in high power conditions with (97% ,98%) power and current reading efficiency respectively. The extra power in every case shows how well help users to use this design with the extra reading power for other devices or reducing house power to reduce in electrical bill cost.

Keywords: Energy Meter, Internet of Things, Arduino, Real Time Monitoring.

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1. INTRODUCTION

Wide range of IoT application issues arisen these days and growing with the need of providing practical answers. Monitoring system based IoT has been proposed in several studies by using different types of applications to omit human interference like android applications as in [1]. This article presented an alert system when excessive consumption in energy occurred in Electrical units. Arduino Uno with specific type of sensors is utilized for this purpose to deal with electrical pulses in order to minimize traditional human mistakes. While obtaining meter readings in addition to illegal power Source detection appears to be extremely challenging with time-lost process. An easy obtainable technique to deliver power consumption data by different users wirelessly to measure parameters in addition to detect illegal users. In [2], authors suggested a smart meter to create the bill automatically and electricity amount measurement which utilized by different IoT appliances. Authors also suggested system to have the ability of quickly energy fraud identification. When fraud detection have been discovered, user will be disconnected from IoT services with indication to both sides the customer and supplier as well. Remote monitoring of IoT data can be done with web or mobile applications as well, that of these applications has their functionality privileges. As in [3], comparing results was done through 7 days tasted on recording data about active power and energy using IoT features. This study provided higher accuracy y with about 2% and 1% in power and energy respectively. In the Same Contest, for such an objective system Should be designed with several topologies which deal with different sources as in [4]. Monitoring Costumer's loading energy is essential to the rule of energy saving because it leads to provide a comfortable controlling methods, they can assess suppliers. IoT provided monitoring in addition to controlling and saving energy when data is correctly gathered from users and shown in some webpage applications as in [5]. Controlling process is also needed in real time data to gain a full management process that can provide a balancing in efficiency level. Authors in [6], presented an optimization technique for this purpose using LoRa modulation. In this paper, measuring parameters *via* Sensors have been feed to IoT cloud server. Overall system performances were increased and controlled in the final system node. In IoT system, devices are connected without human hand especially for working devices through remote control. Smart meters assess to recode data for companies, factories and homes as well with either current or voltage recording ability as in [7]. In this paper, authors display their work through phone applications and website with indication message when overloading current occurrences. Real time easily and readable bill enable users to manage energy usage as a suggested study for domestic applications in Mexico as in [8]. Authors provided low cost-design based on sensors and photon electronic board, which can be used by anyone. Output power is received after analyzing process with a specific algorithm to provide alert with amount of power usage. Energy Monitoring benefits are wide, reduce cost of electrical bill is considering an essential privilege through managing of wasting power. Authors presented their work to solve obstacles relates to extensive use of IoT especially in Smart Grid fields as in [9]. In this study author presented several parameters monitoring using "Things Speak" software to fill electrical bill. While in [10], Authors presented a controlling system it to increase Smart Grid performance to 99.74% through ANFIS controller. *Figure (1)* shows the IoT Design Concept for Energy Meter (EM) general system. Sensitive information transmitted to the cloud through IoT Sensors, could be leakage or being extracted. In [11], authors addressed the issue of extracting private customer's data while meter is sending for monitoring energy by using RepEl design. They used implemented algorithm on embedded node to for monitoring the leakage information of 4 houses to hide the privacy data from required data. This work provided about 10% or less of leakage information from selected houses with only 3% of working shift in IoT devices. New devices that day by day introduced especially with IoT applications with population growth has created significant hard less for users to try managing related energy. Smart meters are also shown widely not for energy monitoring, but also for management process. In [12], different communications approaches with different protocol strategies smart meter design for 4 companies based on IoT devices.

In order to enable remote monitoring and management of energy use, smart meters with internet connectivity are integrated into the design and execution of energy meter monitoring over the Internet of Things. Compared to standard analog meters, this method has many benefits, such as automatic invoicing, real-time data collecting and better energy management as explained in [13] and [14]. Sensors, connectivity modules and microcontrollers are commonly found in Internet of Things smart meters, while sensors monitor voltage and current. The communication module sends data to cloud servers for monitoring and analysis, frequently using technologies like WiFi or LoRaWAN as presented in [15-17]. An ATMEGA 328p and node MCU Micro Controller, for instance was used to create automated billing and detect power theft as introduced in [14]. Despite the many advantages of smart meters, some applications still favor classic analog meters because of the high deployment and operational costs of smart meters. However, these problems were resolved, particularly in rural regions by implementing Low Power Wide Area (LPWA) platforms like LoRa as suggested in [13] and [16]. Furthermore, blockchain technology was being investigated to improve smart metering systems' data security and privacy as mentioned in [18]. IoT-based energy meter monitoring systems offer effective, affordable options for automatic invoicing, remote control, and real-time tracking of energy consumption. Depending on the particular needs and limitations of the application region, these systems have been implemented utilizing a variety of technologies, ranging from basic WiFi modules to more sophisticated LoRaWAN networks as introduced in [17], [19] and [20]. Smarter and more sustainable energy systems were made possible by the combination of IoT and energy metering, which not only increases performances but also makes advanced features like demand-side management and power theft detection possible which is explained more in [21].

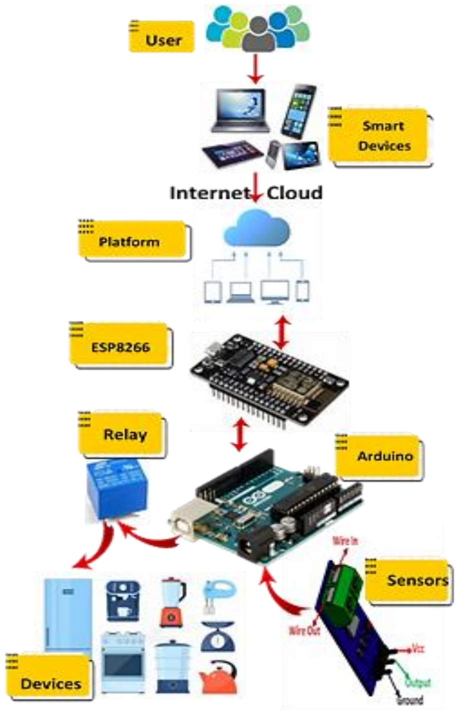

Figure 1. IoT Design Concept for Energy Meter general system

With numerous concepts and implementations being put out to address energy saving and effective management, smart energy monitoring systems have been grown in significance in recent years. Open-source hardware and software platforms have been used to create Arduino-based energy meters, that use touch screen interfaces to capture and show historical energy usage statistics as in [22]. In order to conserve energy and money, these technologies let consumers observed usage trends and adjust their energy consumption habits. With features like data storage, remote monitoring and the ability to measure various variables simultaneously, IoT-based smart meters have also grown in popularity as introduced for the same purpose in [16] and [23]. Energy monitoring systems now incorporate cutting edge wireless technologies like Zigbee, IoT, Android mobile apps and cloud computing, which allow for real time power consumption tracking, the detection of unusual usage patterns, and the estimate of energy bills as in [24]. It is noteworthy that LoRaWAN connectivity has proven to be very successful in rural areas for IoT-based smart meters, offering low-power,

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long-range and economical solutions as mentioned in [16]. There was a lot of space for improvement in management and energy savings through the use of smart energy monitoring systems. These systems include characteristics like wireless communication, real-time monitoring and even artificial intelligence approaches. They range from straightforward Arduino-based designs to more intricate IoT-enabled solutions as suggested in [25]. To improve user identification and billing procedures, the combination of RFID technology and prepaid systems has also been investigated in [26]. In order to further optimize energy use and progress green technology, future smart meters may integrate sophisticated capabilities like power quality monitoring, PV integration and appliance usage scheduling as in [25].

2. MONITORING SYSTEM USING ARDUINO

Current technologies make network system or basically IoT more popular and led Industries to enter new worlds. Serves every day are need to be enhanced in every aspect to move with the idea of transforming human interference to machine monitoring and controlling. IoT related gadget make this Controlling need essential issue to manage devices using low-cost boards like Arduino as in [27]. In this paper, authors Controlling the two-wheel robot balancing with static or unstable objectives. This objective was achieved in a second demonstrating the intended control's ability to keep device in a steady state. Controlling medium for crops as in greenhouses was also designed using Arduino based on IoT principles idea as in [28]. Arduino was used due to its simplicity for constructing comparable climate conditions and can be operated such with little experiences. The system delivers their judgments gathered data from greenhouses through different type of sensors and data will be transferred through IoT. The rightest decision should be made to improve micro grid working with the ability of stabilization using principles of Arduino and IoT as in [29]. Environment parameters are determined through sensors that subsequently delivered to the management system to regulate the energy. Temperature monitoring and controlling is also required for several fields as in goat pen management in [30]. Marinating healthy animals should produce food properly which reduce the slow manual observation based on outcomes with SSR relay assistance allows to adjust the heat for goat pens through utilized relay. Irrigation systems also designed through the idea of IoT, sensors and Arduino boards like smart irrigation doors which controlling the opening and closing gate for this System as in [31]. In this study, door will be controlled to assist fields like rice from drying through Connected adequate types of sensors for water levels and a city. A specific amount of water level is the basic parameter to turn on or tum off water pump and shown through Android application. Information based on IoT technology with Arduino should be sent in a short of time to deliver these data to Arduino application. Achieving the desired objectives for such fields and application should be done through fast devices with low power operation. Advanced technologies in sensors makes authors to investigate the differences between Arduino and other devices as in [32]. Based on these advanced approaches in IoT, Solar Power tracking could significantly increase solar system efficiency through Keeping it directly facing the sun through days. This can also have done by controlling motors which calibrate the two solar impact angles with Arduino assistance as suggested in [33]. Panel weights, moving rotation, borders and sensors are some of adjusting points that may limit this work and need to be in consideration. Weather monitoring and building energy management using IoT and Arduino involve using sensors and controlees to gather data from different environmental conditions. These data will be analyzed often through online applications for decision or automate responses as explained in [34], [35]. These fields and systems need to setting alerts for extreme conditions or unusual energy recorded pattern. In addition, IoT provides accession to real time information from any device and anywhere with the privilege of energy saving and improving system as in this work. The contribution of this paper is the implementation of Energy Meter over IoT using Arduino can significantly improve the management of energy consumption through different smart devices. This design provides real time monitoring including current, voltage and rated power. these data make users more aware of their consumption with specification as well. It is also allowing users for the prompt detection of unusual cases like spikes that lead to equipment failing or in efficiencies or in their working [36], [37] and [38]. Also, analyzing of historical data related to houses and facilities can be store for unusual patterns identifications. This system also provides a remote access through mobile application of received data via cloud platforms with the ability of controlling energy consuming devices remotely [39]. This work reduces the need of manual management by improving access ability from anywhere. [40], [41]. This study provides information about non-efficient devices with recommendations for reducing energy consumption with faults alert continuously as in [42]– [44]. These type of studies helps to eliminate unnecessary used energy which lead to saving cost and reduced electrical bills. In addition, the study provides the advanced implementation of control straightens regarding real-time data with the ability of integration with other smart homes. It is also offering practical platform for experimenting with IoT, energy monitoring and data analysis that helps researchers to gain knowledge about IoT applications as mentioned in [45]. The design of energy meter monitoring over IoT using Arduino contributes to modem energy management through Smart houses or even smart cities. It provides real-time data collection, wireless monitoring process and increasing controlling capabilities. This design led to substantial cost saving with better understanding of energy patterns.

3. METHOD AND MATERIALS

3.1. Hardware Components

3.1.1. Arduino Nano

Some of IoT applications prefer Arduino Nano among other Arduino types due to critical factors. Space Size limitation makes Nano version easy to be embedded into small devices or projects. Uno and Mega version are even larger which make them inconvenient and considering as a disadvantage for size constrained projects. Working with projects related to power

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consumption, monitoring devices is also should have low power to sustain the long battery life compared to high power of Uno and Mega Version. In addition, Nano board is easier to integrate into circuit and typically cheaper than other versions. IoT applications need to deal with analog inputs in addition to features like PWM which Nano provide it as in Uno and Mega but with compact size and similar functions. Arduino Nano is perfect in general for IoT small projects due to its compact size, low power and cost effectiveness as mentions above.

3.1.2. ESP8266 Wi-Fi

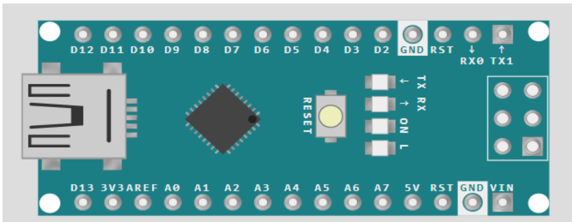
Several reasons that make ESP8266 Wi-Fi preferred over their similar function family in IoT applications and for a wide range when Wi-Fi feature is crucial. Design simplicity, low cost in addition to working ability up to 160 MHz due to 32bit RISC processor make ESP8266 has adequate power for many IoT applications. While other devices that have Wi-Fi such as Arduino-Uno has less processing Power with 8-bit processor speed and running at 16MHz only. Also, ESP8266 is accessible with Arduino programming due to its rich libraries and forums. It supports different power modes like sleep mode, which consumes little power and useful for battery dependent IoT devices. Furthermore, ESP8266 easy to program due to its compatibility with Arduino IDE and other developed equipment like platform IO and Node MCU firmware. Other devices and micro controller require additional modules unlike ESP8266 Which includes built in Components such as PWM, ADC and GPIO with more function achievement.

3.1.3. ACS712 Sensor

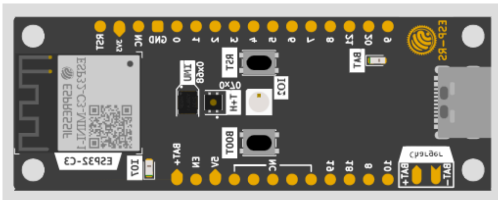
In current measurements devices, ACS712 is preferred than plenty of similar function devices due to Hall Effect characteristics. Therefore; ACS712 measure the flowing current through a conductor without effecting or even without directly touching it, that avoid any electrical interferences. Some current sensors used shunt resistors or other techniques that require good calibration, in addition to heat increments with voltage drops effect. At the same time, ACS712 consists of sensing element for current and conditioning circuits with a single board that assess design to be easier and low-cost. ACS712 is available in multiple current ranges such as ±30A, which allows for flexibility in sensor selecting that match specific IoT applications. In case of zero current flowing, ACS712 has low voltage at offset case which provides more accurate measurements with less drifting over time. Other sensors provide more complexity in design to show an analog voltage unlike ACS712, which has this privilege that simplifies the integration with ADCs to read measurement data. Utilization of ACS712 provides well isolation between low voltage connected devices which used in this project and high currants ±30 A devices that need to be measured. This property enhances safety in addition to risk reduction of damage to connected sensitive boards like Nano or ESP8266 Wi-Fi.

3.1.4. SRD-05V Relay

SRD-050V has an easy way to interface with a variety of low voltage system and compatible with utilized components like Arduino Nano, ESP8266 and ACS712. Other relays require additional circuit for voltage conversion due to it high voltage operation like 12V or even 24V. SRD-O5V Relay has the ability for controlling multiple devices at the same time due to its ability of switching between two different circuits. This project needs component that can handle high current and voltages because of reliable switching with physical contacts ability. This project also needs an isolation between load and controlling circuit which should protect electronic components from sever load condition. *Figure (2)* explain the usage of these components in this work. The Arduino Nano acts as the central controller in this work for processing data and executing commands. It was connected to an ACS712 sensor, which measures the electrical current flowing through a circuit. The ESP8266 Wi-Fi module enables the Arduino Nano to communicate wirelessly to send data to the internet. The SRD-05V Relay operates as a switch that the Arduino Nano use to control high power devices like turning devices on/off based on the data from the current sensor. These components create a system for monitoring and controlling electrical devices with wireless communication capabilities by the help of Arduino.



(a)



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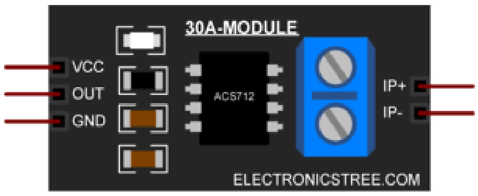

(c)

(d)

Figure 2. The proposed system components (a) Arduino Nano, (b) ESP8266 Wi-Fi, (c) ACS712 sensor, (d) SRD-05V Relay

3.2. Software Architecture

3.2.1. Arduino IDE and Libraries

The Arduino IDE was used to program the system and standard libraries were also used to integrate the Arduino Nano and ESP8266. To connect to the internet, the ESP8266 makes use of libraries ESP8266WiFi.h and WiFiClient.h which were compatible with the Arduino IDE.

3.2.2. Communications

Standard serial communication was used as the communication protocol between the Arduino Nano and the ESP8266 Wi-Fi module. ESP8266 receives data from the Arduino and uses Wi-Fi to communicate it to an IoT server. A smartphone software like RemoteXY, which offers a graphical user interface for monitoring sensors like temperature, current consumption and illumination, was utilized to keep an eye on this data.

3.3. Communication Protocols

3.3.1. Wi-Fi (ESP8266)

Facilitate communication between an IoT server and the smart meter system, the ESP8266 module joined a Wi-Fi network. Receive data to and from the server, the ESP8266 makes use of TCP/IP protocols. Current readings and the condition of electrical devices managed by the relay were among the real-time data that the system sends to the server.

3.3.2. Wireless Data Transfer

The ESP8266 wirelessly sent the current measurement data from the ACS712 sensor to the IoT server for analysis. This stage guarantees that consumers used the smartphone application to remotely monitor and control gadgets in their houses.

3.4 System Integration and Functionality

3.4.1. Monitoring and Control

The ACS712 sensor sent input to the Arduino Nano which serves as the main processor and measures current consumption. The SRD-05V relay utilized this information to regulate the linked appliances' power condition by turning them on and off. Through a smartphone application, users remotely monitoring with controlling the system due to the ESP8266's ability to establish wireless contact with the IoT server.

3.4.2. System Design and Reproducibility

The system described was based on the modularity of its components (ESP8266, Arduino Nano, ACS712 and SRD-05V relay) that making it simple for readers to recreate the system for comparable IoT applications. To increase the design's reproducibility, the article added wiring diagrams, precise software code in addition to step-by-step instructions.

3.5 Wiring Diagrams and Component Connections

The following wiring diagram outlines the different components of the system with connection way.

3.5.1. Component Connections

1- Arduino Nano

- A0 was connected the output of the ACS712 current sensor to read the analog voltage corresponding to the current measurement.
- D2 was connected to the SRD-05V relay to control switching of the connected devices.
- GND was connected to the ground (GND) pins of all other components.
- VCC was Powered from the 5V supply.

2- ESP8266 Wi-Fi Module

- TX/RX was connected to the RX/TX pins of the Arduino Nano for serial communication.
- VCC was connected to the 3.3V power supply.
- GND was connected to the ground of the system.

3- ACS712 Current Sensor

- VCC was connected to the 5V supply.
- GND was connected to the common ground of the system.
- The analog output pin of the ACS712 was connected to the A0 pin of the Arduino Nano for current measurement.

4- SRD-05V Relay

- VCC was connected to the 5V supply.
- GND was connected to the ground.
- The input control pin of the relay was connected to a digital pin on the Arduino Nano D2.
- COM was connected to the power line of the appliance or device being controlled.
- NO was connected to the device's power line (for switching on/off).

3.5.2. Wiring Diagram

- Arduino Nano (A0) → ACS712 (OUT)
- Arduino Nano (D2 or D3) → SRD-05V Relay (Control Pin)
- Arduino Nano (GND) → All GND pins
- Arduino Nano (5V) → ACS712 (VCC), SRD-05V Relay (VCC), ESP8266 (VCC)
- ESP8266 (TX/RX) → Arduino Nano (RX/TX)

3.5.3. Software Code and Libraries

The software code was written using the Arduino IDE and utilized several libraries for communication and sensor interfacing. Below are the utilization libraries for this design:

1- ESP8266WiFi.h
2- ACS712.h
3- WiFiClient.h
4- ArduinoJson.h

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In addition, functions were utilized for establishing connections to the local Wi-Fi network and another function for sending the current measurement data to an IoT server by HTTP. Also, another function was used and called to the system to read the AC current value from the ACS712 sensor.

3.6 Power Consumption and Efficiency

The Arduino Nano normally took just about 19 mA of power with 0.01 mA when in sleep mode with fewer operations. During Wi-Fi connectivity in particular, the ESP8266 consumes the highest power usually read between 70 and 200 mA. This value is appropriate for battery-powered applications because its power consumption lowered to 20 µA when in deep sleep mode. The ACS712 sensor uses 10 mA of power, which is effective when considering the whole power. Turning on the relay normally uses around 70 mA, although this is just temporary which also may have occurred when the relay is turned on. The total power consumption of the system in two available modes are:

• The Active Mode when Wi-Fi was connected: Depending on the Wi-Fi module and sensors working mechanism, the system need between 100 and 300 mA.

• The Sleep Mode when ESP8266 was sleep: If the Arduino was inactive and the ESP8266 was placed into deep sleep then the power consumption lowered to 20–50 mA.

Figure (3) represented the proposed system for three houses with different numbers of electrical devices. Its first check the energy meters in each of the three houses to see how much electricity they are using at a given time. Each house may have different amounts of electrical devices, so their energy usage will different practically. Every day for a month, write down the energy readings from the meters in each house, which asses to keep track of the accuracy of meter readings. Analyze data from all three houses to understand how their energy meter usage patterns differ or still has the stability readings.

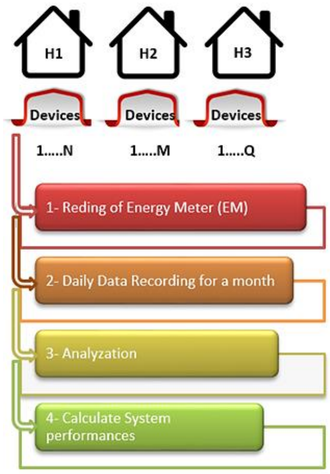

Figure 3. The design procedure and related measuring methodology for Energy Monitoring (EM) proposed system

For example, compare the energy reading of devices in House number 1 for several days and compare it together to evaluate system performances based on differences between readings. These steps will be repeated for all three houses for the same purpose. After all of three above steps, evaluate how well each house's energy system meter is performing. When energy readings are consistent over selected period, it means that the meter reading is stable. Compare the performance of each house to see if they are using this meter efficiently based on selected devices.

Figure (4) shows all system components (Arduino Nano, ESP8266 Wi-Fi, ACS712 sensor and SRD-05V Relay) inside a box to create a compact device which monitor the related readings for selected electrical devices. The Arduino Nano get information from the ACS712 sensor, which measures the current, while the ESP8266 Wi-Fi enables wireless communication. The SRD-05V controls high power devices by turning them on/off based on the Energy Meter readings. The box keeps all these components organized and making the system functional and easy to manage.

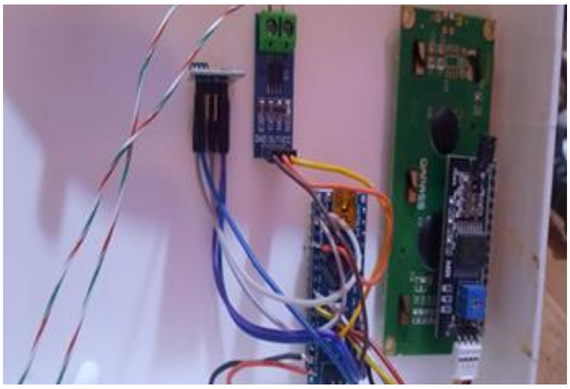

Figure 4. Proposed system implemented inside a plastic box

In another side, relays connected directly between Arduino and appliances as shown in *figure (5)* below. The relay with power source 5V DC work on process the output signals from microcontroller to control the appliances (turn on or turn off). It operates as electronically circuit to closing and opening electronic contact circuits. After connection, components install electric point on the box.

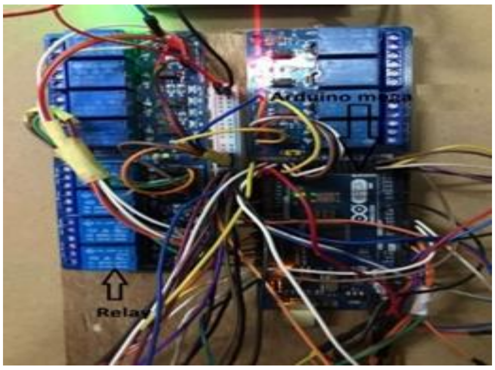

Figure 5. Relay connection with microcontroller

The system comprises several sensors and actuators, which connected to the Arduino controller. The main objective of the controller in turn is to send and continuously update the user data to the Internet of Things server *via* the ESP2866 Wi-Fi chip. Homeowner, in turn can monitor the collected data from the sensors such as (temperature, intensity, lighting, the consumed, and the amount of water in the water tank) by the smartphone application (RemoteXY) to control the amount of the electricity consumed in the house.

4. DESIGN RESULTS

After completing the process of connecting all of the electronic parts of proposed system and installing them in a suitable plastic box. The code was uploaded with application (RemoteXY) connections. In this project different devices were connected to measure their energy and current for 30 days from the 1st of July/2024 to the 31st of July/2024 and monitored the consumption of the amount of energy for a single day on 15/7/2024 as shown in *table 1, 2* and *table 3*.

Table 4 shows a comparison between the proposed design and other related design. In [46], the system with a 2-kW power rating and 92.5% efficiency was designed for low-capacity applications while the remaining 7.5% was lost. In [47], there was a significant reduction in both watering usage and energy consumption for low power applications. The design in [48] was adaptable to a wide range of power levels (50 to 634 W) while maintaining high efficiency (80% to 100%), which indicates system's reliability in different operational cases. While in [49], authors focused on longer testing issue which would be necessary to fully validate the system's performance and reliability over extended periods. Another researcher worked with a design that would handle up to 1.5 kW and is priced at a low cost of $4.61, which indicates affordability and efficiency in control applications as in [50]. The energy consumption varies across different cases as studied and designed in [51], with a savings of 25 kWh indicates that the design has successfully reduced energy consumption across these scenarios. The proposed model performs very well in terms of both power and current reading efficiency. Each house from three selected houses in the model maintains high levels of efficiency, which suggests effective energy management and optimal performance. The proposed 10 kW design demonstrates the best efficiency compared to the higher kW design and the low-power application as well. It maintains high efficiency in both power and current measurements, suggesting that it is a well-optimized solution for its intended scale. This design is also presenting a cost-effective and efficient solution which is valuable for residential or lower-power facilities. The proposed model's high efficiency in power and current readings across three houses underscores its effectiveness in energy monitoring based on *table (1-4)*. The proposed design can be considering as strong suggestions for applications where efficiency and performance are crucial.

Table 1. Energy Meter Reading for one selected day (15/7/2024) among three houses with different electrical devices for HOUSE_1

House Number	Device Name	Input Parameters		Output Parameters		Power Reading Efficiency	Current Reading Efficiency
		Actual Power in Watt	Actual Current in mA	Power Value in Watt	Current Value in mA		
HOUSE_1	Hair Dryer (1st Speed)	400	1750	368.76	1676.18	92%	96%
HOUSE_1	Hair Dryer (2nd Speed)	700	3200	688.1	3127.72	98%	98%
HOUSE_1	Beard Shaver	3	13	2.62	11.93	87%	92%
HOUSE_1	Fridge	350	1600	340.53	1547.88	97%	97%
HOUSE_1	Laptop	110	500	105	477.29	95%	95%
HOUSE_1	Plasma TV	130	600	120.36	547.08	93%	91%
HOUSE_1	Fan	60	250	54.91	248.32	92%	99%
Total Sum		1753	7913	1680.28	7636.4	96%	97%

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Table 2. Energy Meter Reading for one selected day (15/7/2024) among three houses with different electrical devices for HOUSE_2

House Number	Device Name	Input Parameters		Output Parameters			
		Actual Power in Watt	Actual Current in mA	Power Value in Watt	Current Value in mA	Power Reading Efficiency	Current Reading Efficiency
HOUSE_2	Fridge	290	1350	287.09	1304.97	99%	97%
HOUSE_2	Water Filter System	8	38	7.71	35.07	96%	92%
HOUSE_2	Water Dispensers Cooling Water case only	190	900	184.7	839.55	97%	93%
HOUSE_2	Water Dispensers Cooling and Heating Water case	650	3000	597.62	2716.47	92%	91%
HOUSE_2	Lamp	24	100	23.68	98.527	99%	99%
HOUSE_2	Electric Oven	2500	7500	2482.7	7492	99%	100%
Total Sum		3650	12888	3583.5	12486.58	98%	97%

Table 3. Energy Meter Reading for one selected day (15/7/2024) among three houses with different electrical devices for HOUSE_3

House Number	Device Name	Input Parameters		Output Parameters			
		Actual Power in Watt	Actual Current in mA	Power Value in Watt	Current Value in mA	Power Reading Efficiency	Current Reading Efficiency
HOUSE_3	Blender	85	400	80.8	367.29	95%	92%
HOUSE_3	Electric Kettle	1850	8500	1839.54	8495.03	99%	100%
HOUSE_3	Vacuum Cleaner (1st Speed)	650	3000	621.06	2822.98	96%	94%
HOUSE_3	Vacuum Cleaner (2nd Speed)	1500	6600	1414.21	6428.24	94%	97%
HOUSE_3	Washing Machine	500	2200	453.01	2059.15	91%	94%
HOUSE_3	Iron	2200	10200	2185.94	9987.42	99%	98%
HOUSE_3	Steam Iron	1900	8200	1794.51	7976.08	94%	97%
Total Sum		8685	39100	8389.07	38136.19	97%	98%

Table 4. Comparison result based on electrical devices used and monitoring places

Reference Number	Parameters		Accuracy (or other related metrics)
	Device Name	Maximum rating power	
[46]	5 Homes (4 devices)	2 kW	1.85/2= 92.5%
[47]	Irrigation Scheduling System(pump)	Low Power Application	59.61% watering usage decreasing 67.35% energy consumption, +22.58% crop yield increasing
[48]	Fan plus two lamp types	[50 – 634] W	[80% - 100%]
[49]	Greenhouse Environment	Low Power Application	The design has been tested during a time of about 30s.
[50]	PV energy Monitoring	1.5kW	Controller price ($) = 4.61
[51]	Electrical devices	- 0.5 kWh case1, - 0.35kWh case 2 and -18 kWh case 3	Increase for all cases (with 25-kWh savings value
The proposed Methodology	Three Houses with 6,5 and 6 respectively	10kW	Power and Current Reading Efficiency for Three Houses are (96%,97%), (98%,97%) and (97%,98%) Respectively

User satisfaction was depended in practical on the accuracy of the data, the ability of the system to provide real-time feedback in addition to the ease of interaction through the user interface through the mobile phone. The user key satisfying metrics were data accuracy as shown in the efficiency data above, the system's ability to provide accurate readings for power and current directly influences user satisfaction.

Also, higher efficiency which was near to 100% for all utilized devices in three houses demonstrated that users trusted the data and take actions based on accurate information. While, the Wi-Fi-based system allowed real-time monitoring by RemoteXY, meaning users continuously monitoring their devices, leading to higher satisfaction due to instant control over their appliances. The ability to control devices remotely based on real-time data demonstrated high level of satisfaction, as users took immediate action to reduce energy consumption or troubleshoot issues. Based on results, Table 5 shows user satisfaction over different house readings and their ability of controlling measurement process.

Table 5. User satisfaction over different house readings based on measurement data

Requirement	HOUSE_1	HOUSE_2	HOUSE_3
Response Time	156 ms	147 ms	145 ms
User Satisfaction	96%	98%	97%
Control and Feedback	Remote control by app. and high accuracy	High accuracy with real-time feedback	Real-time energy consumption data with quick device switching

Another factor of user satisfaction was response and switching time for data transmission from sensor to cloud via ESP8266 and SRD-05V Relay respectively. These two factors for three utilization houses, based on design various factors as Wi-Fi stability and sensor processing time are shown in *table 6*. The range of response times varies slightly, with some devices like the Fridge which in House 1 and Iron in House 3 had faster transmission times due to simpler data requirements. While devices like the Electric Oven in House 2 had higher response time due to the larger amount of data being transferred. In the other hand, the fridge and water dispensers had longer switching times which is considering as high power needed devices with higher inrush currents. Also, devices like the Lamp and Beard Shaver had faster switching times because they are relatively low power devices compared to others, meaning less mechanical work for the relay to switch on and off.

Table 6. Response and switching time over different house readings based on measurement data

House Number	Device Name	Relay Switching Time (ms)	Sensor to Cloud Response Time (ms)
House 1	Hair Dryer (1st Speed)	25 ms	150 ms
House 1	Beard Shaver	20 ms	180 ms
House 1	Fridge	30 ms	120 ms
House 1	Plasma TV	20 ms	160 ms
House 1	Laptop	15 ms	145 ms

House 1	Fan	18 ms	170 ms
House 2	Fridge	28 ms	130 ms
House 2	Water Filter System	22 ms	160 ms
House 2	Water Dispensers (Cooling)	30 ms	140 ms
House 2	Water Dispensers (Heating)	26 ms	155 ms
House 2	Lamp	12 ms	120 ms
House 2	Electric Oven	25 ms	150 ms
House 3	Blender	20 ms	160 ms
House 3	Electric Kettle	30 ms	130 ms
House 3	Vacuum Cleaner (1st Speed)	18 ms	140 ms
House 3	Washing Machine	27 ms	145 ms
House 3	Iron	22 ms	125 ms
House 3	Steam Iron	19 ms	150 ms

Table 7 shows that all devices in the three houses are operating within the acceptable range for IoT data transmission which is less than 200 ms, ensuring real-time data communication to the cloud for monitoring. While, the SRD-05V relay performs high efficiently with switching times less than 25ms which it was suitable for controlling high-power devices with minimal delay.

Table 7. Response and switching average time over different house readings based on measurement data

House Number	Average Response Time/ms	Average Relay Switching Time/ms
House 1	156ms	22ms
House 2	147ms	23ms
House 3	145ms	23ms

Figure (6) and *figure (7)* show the total average efficiency for house_3 and the three houses according to related devices with the efficiency reading of one house based on power and current reading. The design displays a 96% power reading efficiency and a 97% current reading efficiency in House 1's low power case. This indicates that 96% of the input power is effectively used, with the remaining 4% denoting the quantity of power that is accessible for other uses instead of being lost. Furthermore, a 97% current efficiency means that 97% of the input current is utilized efficiently, leaving 3% extra. The design operates very well at low power levels, as indicated in *table 5* with leaving a low value for other possible devices. The power reading efficiency for House 2 at medium power is 90%, while the current reading efficiency stays at 97%. In this case, 90% of the input power is effectively utilized, leaving 10% extra value. The design is less efficient at medium power levels, as evidenced by this from 96% in House 1's low power case. The design retains good current management at medium power levels, which stands at 97%, does not alter in spite of this decline in power efficiency. The remaining 10% of power might be used for another application after good controlling and management. The power reading efficiency in House 3's high power case jumps to 97%, while the current reading efficiency rises to 98%. Just 3% of the input power is left over after 97% of it is properly used at high power. The design is more suited for high power levels, based on *table 6* by the efficiency gain over the medium power case. With only 2% of the input current remaining after effective utilization, the current efficiency of 98% indicates that almost all of it is utilized. This increased efficiency at high power suggests that the design is better suited to manage high power processes, which reduces the amount of excess power that is left over. The efficiency of House_3 measurements for the power and current is shown in *figure (6).* While the total reading efficiency is shown in *figure (7)* for the whole devices.

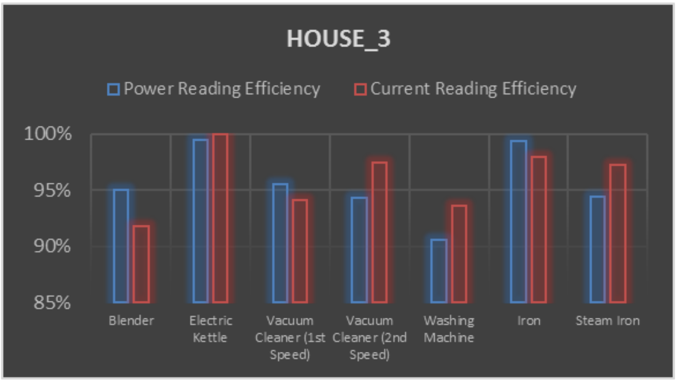

Figure 6. The efficiency reading of HOUSE_3 based on power and current reading

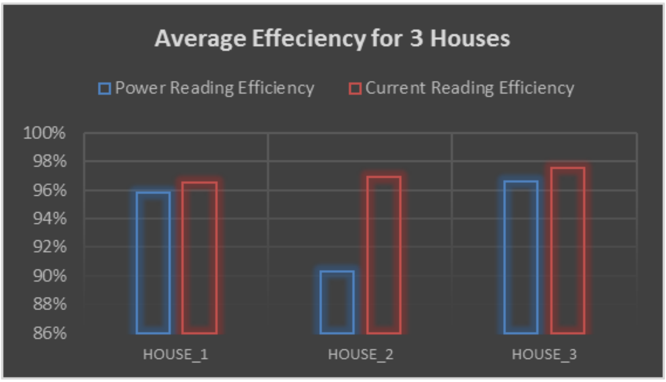

Figure 7. The total average efficiency for the three houses according to related devices for both power and current

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A review of three selected devices, the hair dryer's (with 2 speed) and beard shaver's power readings throughout the period of the designated month indicates that all devices' operations were highly stable which is shown in *figure (8).* This implies consistent performance with little variation in power consumption or in power reading.

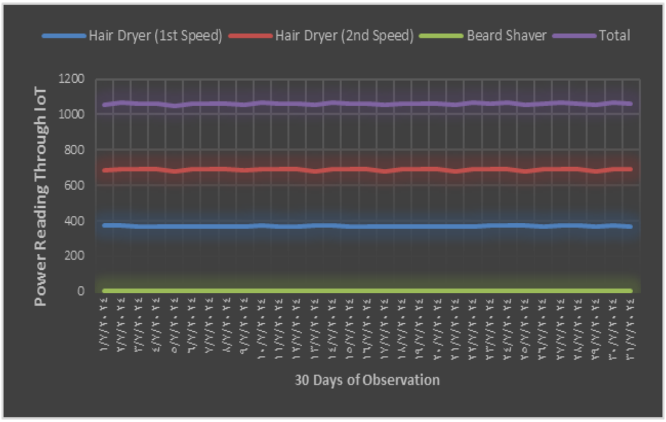

Figure 8. Power reading stability among 30 days and for three different devices

5. CONCLUSION

The examination of power and current efficiency at varying power levels reveals significant differences in performance based on Table (4-7). When power levels are low, House 1 operates efficiently; however, when power levels rise, efficiency levels indication. In comparison to House 1, House 2's efficiency at medium power shows more notable inefficiencies, but it still maintains a steady current efficiency. With the best overall efficiency in high power settings, House 3 shows that it is well-suited to manage high power levels. The additional power (remaining efficiency numbers) in each scenario reveals how successfully each system transforms input power and controls current at different power levels. Energy meter monitoring over IoT is a very important way to monitor energy usage and make informed decisions about energy consumption. By using IoT-enabled Energy Meters (EM), it possible to track energy consumption in real-time and identify areas where energy can be saved by using control system. In this paper, researchers provide a conclusion for EM monitoring over IoT. IoT enabled EM provide a significant advantage over traditional energy meters by allowing remote monitoring and control of energy consumption. With IoT, the energy usage data can have transmitted in real-time to a cloud-based platform, where it can have analysed and processed and sending to users. This work investigates the efficiency of EM system applied to 15 distinct electrical devices across three houses over a single month. The system exhibited low error rates and high accuracy in recording energy consumption data. This evaluation proves the system's reliability in delivering precise with stable readings by offering a clear view of energy usage patterns across 15 devices. The results highlight the system's potential to enhance energy management by providing detailed, which improve energy efficiency and reduce consumption in electrical bills. It is also enables homeowners to track their energy consumption and identify areas where they can be decreasing energy consumption. Researchers advantage of IoT-enabled energy meters is their ability to provide alerts and notifications when a building's energy consumption exceeds a certain threshold. An alert was sent to the building or any related responsible indicating that energy usage needs to reduced. This helps to prevent wastage of energy and decreasing energy bills.

The results of *tables 5,6* showed that the complexity of the devices and their power needs significantly influenced the response and switching times for data transfer and device management. Response times were slower for devices that required more extensive data, such the Electric Oven in House 2 and faster for devices with simpler data transmission needs like the Fridge in House 1 and Iron in House 3. Conversely, low-power devices like the lamp and beard shaver benefited from faster switching, whereas high-power equipment like the refrigerator and water dispensers displayed longer switching times because of their larger inrush currents. However, as Table 7 demonstrates, every device in the research kept response times below the 200 ms barrier, guaranteeing successful real-time communication with the cloud. With switching durations of less than 25 ms, the SRD-05V relay also showed remarkable efficiency, which makes it ideal for handling high-power devices with little delay. All measurement results demonstrated that the system can fulfil the performance standards needed for dependable and effective IoT device management.

REFERENCES

[1] R. Islam, S. Sarker, S. Mazumder and M. R. Ranim, "An IoT based Smart Energy Meter Monitoring System using Android Application," Int. J. Adv. Res. Sci. Commun. Technol., vol. 4, pp. 459–463, 2022, doi: 10.48175/ijarsct-5053.

[2] R. Amudhevalli and T. Sivakumar, "IoT Based Smart Energy Metering System for Monitoring the Domestic Load Using PLC and SCADA," IOP Conf. Ser. Mater. Sci. Eng., vol. 1055, no. 1, p. 012154, 2021, doi: 10.1088/1757-899x/1055/1/012154.

[3] J. Varela-Aldás, S. Silva, and G. Palacios-Navarro, "IoT-Based Alternating Current Electrical Parameters Monitoring System," 2022.

[4] N. Sulthana, P. N. Y, R. N, B. S, and K. B. S. Kumar, "Smart Energy Meter and Monitoring System using IoT," Int. J. Eng. Res. Technol., vol. 8, no. 14, pp. 50–53, 2020, [Online]. Available: www.ijert.org.

[5] K. Prakashraj, G. Vijayakumar, S. Saravanan, and S. Saranraj, "IoT based energy monitoring and management system for smart home using renewable energy resources," Int. Res. J. Eng. Technol., pp. 1790–1797, 2020.

[6] A. Ramelan, F. Adriyanto, B. A. . Hermanu, M. H. Ibrahim, J. S. Saputro, and O. Setiawan, "IoT Based Building Energy Monitoring and Controlling System Using LoRa Modulation and MQTT Protocol," IOP Conf. Ser. Mater. Sci. Eng., vol. 1096, no. 1, p. 012069, 2021, doi: 10.1088/1757-899x/1096/1/012069.

[7] M. Rupesh and N. Anbu Selvan, "Design of IoT Based Smart Energy Meter for Home Appliances," J. Phys. Conf. Ser., vol. 1964, no. 5, 2021, doi: 10.1088/1742-6596/1964/5/052001.

[8] R. O. J. Betancourt et al., "Iot-based electricity bill for domestic applications," Sensors (Switzerland), vol. 20, no. 21, pp. 1–16, 2020, doi: 10.3390/s20216178.

[9] F. Khan, M. A. B. Siddiqui, A. U. Rehman, J. Khan, M. T. S. A. Asad, and A. Asad, "IoT Based Power Monitoring System for Smart Grid Applications," 2020 Int. Conf. Eng. Emerg. Technol. ICEET 2020, no. April, pp. 1–5, 2020, doi: 10.1109/ICEET48479.2020.9048229.

[10] S. Ghosh, "Neuro-Fuzzy-Based IoT Assisted Power Monitoring System for Smart Grid," IEEE Access, vol. 9, no. December, pp. 168587–168599, 2021, doi: 10.1109/ACCESS.2021.3137812.

[11] P. Bovornkeeratiroj, S. Iyengar, S. Lee, D. Irwin, and P. Shenoy, "RepEL: A utility-preserving privacy system for IoT-based energy meters," Proc. - 5th ACM/IEEE Conf. Internet Things Des. Implementation, IoTDI 2020, no. April, pp. 79–91, 2020, doi: 10.1109/IoTDI49375.2020.00015.

[12] M. U. Saleem, M. R. Usman, and M. Shakir, "Design, Implementation, and Deployment of an IoT Based Smart Energy Management System," IEEE Access, vol. 9, pp. 59649–59664, 2021, doi: 10.1109/ACCESS.2021.3070960.

[13] A. Marahatta et al., "Evaluation of a LoRa Mesh Network for Smart Metering in Rural Locations," Electronics, vol. 10, no. 6, p. 751, Mar. 2021, doi: 10.3390/electronics10060751.

[14] M. Nilam, B. Sneha, K. K, D. B, and D. Ulfath, "Smart Energy Meter with Advanced Billing and Power Theft," International Journal of Advanced Research in Science, Communication and Technology, pp. 231–235, May 2024, doi: 10.48175/ijarsct-18530.

[15] A. Elkassar, A. A. Elfarag, W. A. M. Ghoneim, and E. Hamdan, "Design and Implementation of an Internet of Things Based Smart Energy Meter using Radio Frequency communication protocol," Oct. 2022. doi: 10.23919/eecsi56542.2022.9946585.

[16] I. K. Agung Enriko, A. S. Noor, and A. Zaenal Abidin, "Design and Implementation of LoRaWAN-Based Smart Meter System for Rural Electrification," Jul. 2021, pp. 1–5. doi: 10.1109/gecost52368.2021.9538704.

[17] K. E. Jack, L. Olatomiwa, M. O. Ameh, and U. A. Usman, "Development and Implementation of Energy Consumer Metering System with the Integration of Smart Users' Management Model," FUOYE Journal of Engineering and Technology, vol. 8, no. 3, Oct. 2023, doi: 10.46792/fuoyejet.v8i3.1013.

[18] V. Tayal, R. Bhakar, C. P. Barala, and H. K. Meena, "Blockchain Enabled Smart Metering Solutions: Challenges and Opportunities," Dec. 2022. doi: 10.1109/npsc57038.2022.10069901.

[19] P. Agrawal, D. V. Jain, Y. S. Solanki, H. Khatik, and A. Maheshwari, "Smart Industries in Industry4.0: An Iot and Cloud Based Real Time Energy Meter Monitoring System," International Journal of Engineering and Advanced Technology, vol. 9, no. 3s, pp. 4–7, Mar. 2020, doi: 10.35940/ijeat.c1002.0393s20.

[20] W. Hlaing, V. Nontaboot, N. Tangsunantham, S. Thepphaeng, T. Sangsuwan, and C. Pira, "Implementation of WiFi-based single phase smart meter for Internet of Things (IoT)," Mar. 2017, pp. 1–4. doi: 10.1109/ieecon.2017.8075793.

[21] S. P, S. K, L. P, S. R, D. R, and R. G, "Intrusive Energy Management with advanced smart metering and monitoring using IoT," Sep. 2022, pp. 359–364. doi: 10.1109/icirca54612.2022.9985661.

[22] M. Enam, H. A. Rahman, S. R. Hasan, and N. A. Khan, "Smart Energy Monitoring using Off-the-Shelf Hardware and Software Tools," Jan. 2013. doi: 10.2316/p.2013.800-111.

[23] T. D. L. Nguyen, N. D. Tran, and T. H. Tran, "Single-Phase Smart Energy Meter—IoT Based on Manage Household Electricity Consumption Service," springer singapore, 2020, pp. 1185–1193. doi: 10.1007/978-981-15-2780-7_122.

[24] R. Govindarajan, S. Meikandasivam, and D. Vijayakumar, "Performance Analysis of Smart Energy Monitoring Systems in Real-time," Engineering, Technology & Applied Science Research, vol. 10, no. 3, pp. 5808–5813, Jun. 2020, doi: 10.48084/etasr.3566.

[25] A. F. A. Aziz, S. N. Khalid, M. W. Mustafa, H. Shareef, and G. Aliyu, "Artificial Intelligent Meter development based on Advanced Metering Infrastructure technology," Renewable and Sustainable Energy Reviews, vol. 27, pp. 191–197, Jul. 2013, doi: 10.1016/j.rser.2013.06.051.

[26] R. Teymourzadeh, A. Abueida, K. Chan, M. S, and V. Mok, "Advanced Frequency Identification Power Metering System for Energy Usage." cornell university, Jun. 10, 2018. doi: 10.48550/arxiv.1808.02522.

[27] E. Q. Ahmed, I. A. Aljazaery, A. F. Al-zubidi, and H. T. S. ALRikabi, "Design and implementation control system for a self-balancing robot based on internet of things by using Arduino microcontroller," Period. Eng. Nat. Sci., vol. 9, no. 3, pp. 409–417, 2021, doi: 10.21533/pen.v9i3.2178.

[28] I. Ardiansah, N. Bafdal, E. Suryadi, and A. Bono, "Greenhouse monitoring and automation using arduino: A review on precision farming and Internet of Things (IoT)," Int. J. Adv. Sci. Eng. Inf. Technol., vol. 10, no. 2, pp. 703–709, 2020, doi: 10.18517/ijaseit.10.2.10249.

[29] M. M. Legha and E. Farjah, "IoT Based Load Management of a Micro-Grid Using Arduino and HMAS," vol. 16, no. 2, pp. 228–234, 2020.

[30] A. Hasibuan, A. Qodri, K. Kartika, and M. Isa, "Temperature Monitoring System using Arduino Uno and Smartphone Application," Bull. Comput. Sci. Electr. Eng., vol. 2, no. 2, pp. 46–55, 2021, doi: 10.25008/bcsee.v2i2.1139.

[31] L. M. Silalahi, S. Budiyanto, F. A. Silaban, and A. R. Hakim, "Design a Monitoring and Control in Irrigation Systems using Arduino Wemos with the Internet of Things," J. Integr. Adv. Eng., vol. 1, no. 1, pp. 53–64, 2021, doi: 10.51662/jiae.v1i1.13.

[32] K. Singh and D. Bura, "Internet-of-Things (IoT): Distinct Algorithms for Sensor Connectivity with Comparative Study between Node MCU and Arduino UNO," Nveo-Natural Volatiles Essent. Oils …, vol. 8, no. 4, pp. 4313–4324, 2021.

[33] M. N. A. Mohd Said, S. A. Jumaat, and C. R. A. Jawa, "Dual axis solar tracker with iot monitoring system using arduino," Int. J. Power Electron. Drive Syst., vol. 11, no. 1, pp. 451–458, 2020, doi: 10.11591/ijpeds.v11.i1.pp451-458.

[34] M. Uzair, S. Y. Al-Kafrawi, K. M. Al-Janadi, and I. A. Al-Bulushi, "A Low-Cost IoT Based Buildings Management System (BMS) Using Arduino Mega 2560 and Raspberry Pi 4 for Smart Monitoring and Automation," Int. J. Electr. Comput. Eng. Syst., vol. 13, no. 3, pp. 219–236, 2022, doi: 10.32985/IJECES.13.3.7.

[35] J. Mabrouki, M. Azrour, D. Dhiba, Y. Farhaoui, and S. El Hajjaji, "IoT-based data logger for weather monitoring using arduino-based wireless sensor networks with remote graphical application and alerts," Big Data Min. Anal., vol. 4, no. 1, pp. 25–32, 2021, doi: 10.26599/BDMA.2020.9020018.

[36] N. Al-Oudat, A. Aljaafreh, M. Saleh, and M. Alaqtash, "Iot-based home and community energy management system in Jordan," Procedia Comput. Sci., vol. 160, no. 2018, pp. 142–148, 2019, doi: 10.1016/j.procs.2019.09.454.

[37] Ida Bagus Gede Purwania, I Nyoman Satya Kumara, and Made Sudarma, "Application of IoT-Based System for Monitoring Energy Consumption," Int. J. Eng. Emerg. Technol., vol. 5, no. 2, pp. 81–93, 2020.

[38] S. J. Mohammed, M. S. Mohammed, and N. M. Nasir, "IoT-Traffic Networks Effective Features Based on NSGA-II Technique," J. Internet Serv. Inf. Secur., vol. 14, no. 2, pp. 247–267, 2024, doi: 10.58346/jisis.2024.i2.016.

[39] M. Alshamrani, "IoT and artificial intelligence implementations for remote healthcare monitoring systems: A survey," J. King Saud Univ. - Comput. Inf. Sci., vol. 34, no. 8, pp. 4687–4701, 2022, doi: 10.1016/j.jksuci.2021.06.005.

[40] Z. S. Ageed et al., "A State of Art Survey for Intelligent Energy Monitoring Systems," Asian J. Res. Comput. Sci., vol. 8, no. 1, pp. 46–61, 2021, doi: 10.9734/ajrcos/2021/v8i130192.

[41] F. Jamil, S. Ahmad, N. Iqbal, and D. H. Kim, "Towards a remote monitoring of patient vital signs based on iot-based blockchain integrity management platforms in smart hospitals," Sensors (Switzerland), vol. 20, no. 8, 2020, doi: 10.3390/s20082195.

International Journal of
Electrical and Electronics Research (IJEER)
Research Article | Volume 12, Issue 4 | Pages 1427-1439 | e-ISSN: 2347-470X

[42] M. G. M. Almihat, M. T. E. Kahn, K. Aboalez, and A. M. Almaktoof, "Energy and Sustainable Development in Smart Cities: An Overview," Smart Cities, vol. 5, no. 4, pp. 1389–1408, 2022, doi: 10.3390/smartcities5040071.

[43] M. A. Ramírez-Moreno et al., "Sensors for sustainable smart cities: A review," Appl. Sci., vol. 11, no. 17, pp. 1–29, 2021, doi: 10.3390/app11178198.

[44] P. Mishra and G. Singh, "Energy Management Systems in Sustainable Smart Cities Based on the Internet of Energy: A Technical Review," Energies, vol. 16, no. 19, 2023, doi: 10.3390/en16196903.

[45] J. Li, M. S. Herdem, J. Nathwani, and J. Z. Wen, "Methods and applications for Artificial Intelligence, Big Data, Internet of Things, and Blockchain in smart energy management," Energy AI, vol. 11, no. October 2022, p. 100208, 2023, doi: 10.1016/j.egyai.2022.100208.

[46] M. Afzal, Q. Huang, W. Amin, K. Umer, A. Raza, and M. Naeem, "Blockchain enabled distributed demand side management in community energy system with smart homes," IEEE Access, vol. 8, pp. 37428–37439, 2020, doi: 10.1109/ACCESS.2020.2975233.

[47] C. Jamroen, P. Komkum, C. Fongkerd, and W. Krongpha, "An intelligent irrigation scheduling system using low-cost wireless sensor network toward sustainable and precision agriculture," IEEE Access, vol. 8, pp. 172756–172769, 2020, doi: 10.1109/ACCESS.2020.3025590.

[48] S. G. Priyadharshini, C. Subramani, and J. Preetha Roselyn, "An IOT based smart metering development for energy management system," Int. J. Electr. Comput. Eng., vol. 9, no. 4, pp. 3041–3050, 2019, doi: 10.11591/ijece.v9i4.pp3041-3050.

[49] T. Pisanu, S. Garau, P. Ortu, L. Schirru, and C. Macciò, "Prototype of a low-cost electronic platform for real time greenhouse environment monitoring: An agriculture 4.0 perspective," Electron., vol. 9, no. 5, 2020, doi: 10.3390/electronics9050726.

[50] Y. Cheddadi, H. Cheddadi, F. Cheddadi, F. Errahimi, and N. Es-sbai, "Design and implementation of an intelligent low-cost IoT solution for energy monitoring of photovoltaic stations," SN Appl. Sci., vol. 2, no. 7, pp. 1–11, 2020, doi: 10.1007/s42452-020-2997-4.

[51] E. A. Affum, K. A. P. Agyekum, C. A. Gyampomah, K. Ntiamoah-Sarpong, and J. D. Gadze, "Smart Home Energy Management System based on the Internet of Things (IoT)," Int. J. Adv. Comput. Sci. Appl., vol. 12, no. 2, pp. 722–730, 2021, doi: 10.14569/IJACSA.2021.0120290.