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IoT Based Hybrid Smart Water Meter for Domestic Utilities

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Abstract

In the evolving world, automation plays an important role to make the life easier. Enhancing the properties to reduce the time and efforts of human or an organization. The automation is leading to betterment of the world but there are some fields where automation is not yet opted. The project "IOT Based Smart water and EB meter for Domestic Utilities" is to leverage automation in local monitoring of domestic utilities especially for government using Embedded System and Cloud Technology. A master-slave configured project using ESP32 as main controller to gather data in local and building a server to store the data in cloud. The project utilizes a hybrid working model to enhance the capability in future. The slave unit containing two ESP32 measuring water and electrical supply in home with the help of sensors. Once the values are taken. The slave communicates to Master ESP32. The Master ESP32 enabled with Wi-Fi interacts with the server to save values in the databases. As the project is enabled with Master-Slave Hybrid configuration it improves the upgradability. The main purpose of the project is to reduce the need of man power for measuring the Water and Electrical usage values in homes, more visibility on usage using statistical charts and tables through online, reducing the cost and more upgradability.

Keywords— Embedded System, Water Monitoring, EB Monitoring, ESP32, Sensor, Arduino IDE, Cloud, Database, Statistics

I. Introduction

The rapid growth in the urban population has made difficult for the government to measure various parameters such as water and electricity consumption. The traditional consumption metering includes using of AMR infrastructure which often lacks real-time monitoring capabilities resulting in manual reading of values, need of more human power, less details over usage, misreading of values, manual billing and so on. This will lead to serious issues. However, it's time to change traditional way of metering to modern metering way that's AMI (Advanced Metering Infrastructure). By using the modern technologies, the cons can be removed. The project includes the using of sensors, AMI infrastructure, Hybrid communicating model, Cloud database and Web technologies to build solution. By introducing these technologies, the "IOT Based Smart water and EB meter for Domestic Utilities" project enables wireless communication using ESP32 microcontroller, real-time data sharing, protective data, automated billing and avoids human error. The project consists of three ESP32 microcontrollers where two ESP32 act as slave and other ESP32 is the master. One of the Slave ESP32 is connected to the water flow sensor to measure the

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household water consumption. The other Slave ESP32 which is connected to the module PZEM-004T to measure the electrical parameters such as voltage, current, active power and energy consumption. The measured values from both the Slave ESP32 are sent to the Master ESP32 through Wi-Fi. Once data are collected by the Master ESP32. The Master ESP32 connected to the Cloud server will send the values to the cloud database. The database will store the values. By using the stored values Stats, data observation and automated billing can be made.

- **Real-Time Monitoring and Data Analysis:** In real time, users and organization can be able to see the values in offline and online. In offline they can see the digital values and by using the website and application the stats and data analysis can be seen through internet [10], [11].
- **Wireless Communication for Flexibility and Scalability:** As the system implies wireless communication the need of wire configuration is totally avoid this could allow more space. And also, won't lead to wire failure or any other troubles [12], [13].
- **Smart Alerts and Notifications:** As the data are available on cloud in case of any malfunction and also by setting up some limit. When limit exceeds the Alerts and Notifications can be triggered using Cloud functions [11][13].
- **Automated Billing:** The main motive of the system is to avoid the man power to measure the parameters and to manually upload the data. When data are upload automatically in the server. The Billing will become easy and leads for less errors [14], [15].
- **Cost-Effective Solution:** The proposed IoT system is built with comparatively less amount of money than traditional AMR water meters. As the project reduce the human power the amount spend for human salary can be used for building the system and having internet connection [16].

This research shows that a sustainable and effective method of taking the parameters measuring in household may be achieved by combining IoT technology with water meters and Eb meters. The ESP32 microcontrollers power the system's master-slave setup, which allows for smooth Wi-Fi data flow and communication with the cloud. In addition to improving the precision of water consumption and EB meter values monitoring, this method paves the way for smart water networks, which may aid in the conservation of resources and the improvement of urban infrastructure design. The rest of this article will discuss the system's design, how the smart water meter and EB meter is built, the components used, the protocols for communication, and the possible advantages of incorporating it into contemporary cityscapes. This study's overarching goal is to provide evidence that smart water meters and EB meter enabled by the internet of things may improve ways for management practices, leading to greater operational efficiency and environmental friendliness in a variety of industries.

II. Related Work

IoT sensor alerts people across the world to the growing problem of water shortage by providing a simple and effective means of analyzing, controlling, and monitoring water consumption in both commercial and residential settings. A user-friendly smartphone app allows users to set a daily quota and receive notifications when they start to exceed their use. By providing detailed information on weekly, monthly, and yearly consumption of all three types of water, this app helps users create good water habits. This sensor isn't only for the own use; it also claims to encourage community involvement through the sharing of information and the promotion of sustainable water management. In light of the fact that IoT devices have the ability to revolutionize water-saving methods, development, implementation, and major impacts. Smart metering systems have been the subject of much study and development in response to the increasing need for precise consumption monitoring and effective water management. Among these innovations, RFID technology has become an important tool for updating water meters. With an eye on their technical foundations,

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uses, and prospective implications, the following literature review offers a synopsis of current research on RFID-based water smart meters. An IoT smart irrigation system with monitoring and control features, built using Blynk IoT software, is presented in this article. A moisture sensor, a water flow sensor, a 12V water pump motor, a relay module, and a NodeMCU ESP8266 microcontroller are all components that are integrated into the system. The Blynk mobile app allows users to automate watering schedules, manage the flow of water to plants, and remotely check soil moisture levels using this combination. Experimental findings showing the efficacy and dependability of the suggested solution are presented in this study, which also covers the system design, hardware setup, and software implementation.

A. RFID Technology in Utility Systems

RFID technology has been extensively studied and used in a number of utility systems, such as those that measure water, gas, and electricity. Kumar et al. (2014) states that RFID offers a practical method for identifying users and collecting data wirelessly. With an eye toward automating billing processes and decreasing reliance on human workers, this project investigated RFID for utility meters. Among RFID's many benefits, the authors emphasized its ability to boost consumption monitoring accuracy while cutting operating expenses. This study lays the groundwork for the integration of radio frequency identification into water metering systems [17], [18].

B. Digital Water Meters with IoT And RFID Integration

There is a lot of paper showing how can a digital water meters have developed and how they connect to the IoT. Exploring the integration of RFID and water meters based on the Internet of Things was done in Meena et al. (2017). This innovation allowed for the real-time monitoring of water use via the wireless transmission of data from digital flow monitors that were equipped with RFID tags. In addition to automating billing processes and improving water consumption accuracy, the study also showed that this strategy might pave the way for the development of RFID-and other wireless technology-based smart water meters [19], [20].

C. Smart Water Metering for Resource Management

Gupta et al. (2018) carried out research on smart water meter installation for better management of urban water resources. In order to better remotely monitor water consumption and identify abnormalities like leaks or unlawful usage, the research examined the function of RFID. Researchers showed that by using RFID technology, a more responsive and user-friendly system could be created, benefiting both utility companies and consumers. The results indicated that RFID-enabled smart metres had the potential to improve resource planning and water conservation [21], [22].

D. Energy Efficiency and Smart Meter Communication

Improving smart meters' energy efficiency has been a major focus of current research. Smart meters, including those that use RFID, have their power usage investigated by Zhang et al. (2019). While RFID allows for smooth data collecting transmission, their study showed that it also adds to power consumption if not configured correctly. Their proposal to improve smart metering systems by combining RFID with low-power communication protocols brought attention to the need of environmentally friendly energy use in RFID-based solutions [23], [24].

E. RFID-Based Automated Billing Systems

Patel and Sharma (2020) zeroed attention on the use of RFID in water meters to automate pricing processes. Their study detailed the process by which user accounts connected to RFID tags enable

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the meter to automatically transmit data to central billing software. They discovered that this strategy significantly reduced operating expenses for utility companies, improved accuracy, and decreased billing anomalies compared to typical manual methods. Research has shown that customers are happier with RFID-based systems since their invoices are more accurate and sent out more quickly, and the billing process is also more transparent. Here is the breakdown of the remaining sections of the paper: The study's rationale and key findings are detailed in Section II. Section III presents the relevant literature. Our suggested approach's system architecture is detailed in Section IV. Section V explains the suggested method, together with the experimental findings and simulation. The last section of the document is Section VI, which contains the conclusion [25], [26].

III. Proposed Work

A. Existing Solution vs Proposed Solution

The technologies used to monitor various domestic utilities are outdated. In domestic, the most commonly used technology is Automatic meter reading (AMR) technology [21][22] involving visiting the water meter and EB meter to collect the data. The proposed solution involves utilizing of Advanced Metering Infrastructure (AMR) and cloud technology to automate the process. To make advancement in the existing solution this system equips master-slave configuration to meet the future needs, reliability and upgradability.

B. System Components and it uses

i. Power Supply: The components in the system are powered using power supply board consisting of Step-down transformer, Full wave rectifier, Filter and Regulator. The project uses two fixed voltage IC 7812 which is +12V and IC 7805 is of +5V. This power supply is mainly used for water flow sensor setup as EB meter has no restrictions.

ii. LCD Display: The LCD Display is utilized in both water meter and EB meter to display the values in local. Once the values are gained using the Slave ESP32 from sensor. It will display the value using this LCD Display. The LCD Display used with Hitachi's HD44780 controller has at most 80 characters and 14 pins.

iii. ESP32: The ESP32 microcontroller is the brain of the project. At the selling price of Rs. 611.18 The ESP32 offer Wi-Fi access for internet access and local networking, Bluetooth (Classic & BLE) for wireless communication and ESP-NOW for low power wireless communication. The project consists of three ESP32. Two Slave ESP32 and One Master ESP32 and configured using Arduino IDE. The Slave ESP32's are connected to the Master ESP32 via Wi-Fi. The master ESP32 is the one which uses internet to share the data received from Slave to Cloud database. To ensure the safety of Slave ESP32 it is enclosed inside a safety box with their sensors/modules. The Slave ESP32 is connected to the sensors that collects the value and displays the value in local LCD display. Then sends the value to the Master ESP32 that directly sends the value to Cloud database using API calls.

iv. Energy meter module: The module used to measure the critical parameters such as voltage energy and current is PZEM-004T. The Test range for following parameters are Energy - 0 to 9999kWh, Voltage - 80 to 260V AC and Current - 0 to 100A.

- **Slave ESP32**: Responsible for measuring the crucial parameters of Energy.
- **Master ESP32**: Receives data from the slave ESP32, processes it, and then uploads it to a server in the cloud so that it may be remotely monitored by the user or the organization.

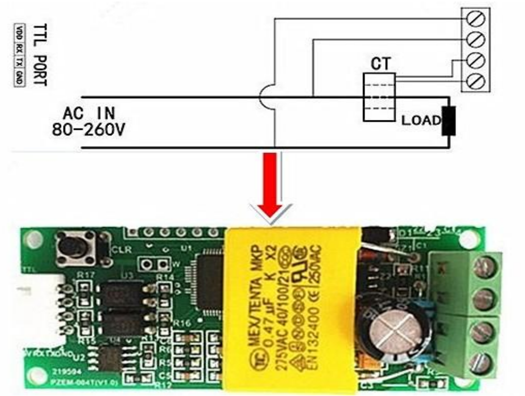

Fig.1 Wiring diagram of Pzem-004t

v. Water Flow Sensor

Water Flow sensor is connected to the water supply, has a pinwheel sensor that monitors the volume of liquid that has gone through it. Inbuilt magnetic Hall Effect sensors generate electrical pulses with each turn. The sensor is walled off from the water pipe, the hall impact sensor is safe from water damage. The sensor is equipped with three wires: one for ground (black), one for 5-24VDC power, and one for Hall's effect pulse output (yellow). By counting the pulses that the sensor produces, this can easily ascertain the water flow rate. The volume of one pulse is around 2.25 milliliters. Because the sensor isn't an extremely accurate instrument, this should bear in mind that the pulse rate is somewhat affected by the fluid pressure, the flow rate, and the orientation of the sensor. Careful calibration is required for accuracy levels over 10%. Regardless, it's great for basic measurement tasks! For instance, an example Arduino script that estimates the water flow in liters per hour and does the arithmetic for this can test the sensor quickly. This algorithm makes quick work of capturing the pulse signal and translating it to liters per minute since the signal is just a square wave.

Pulse frequency (Hz) / 7.5 = flow rate in L/min. (1)

Fig.2 Water Flow Sensor

- **Slave ESP32**: Responsible for measuring the Flow and speed.

- **Master ESP32**: Receives data from the slave ESP32, processes it, and then uploads it to a serverthe cloud so that it may be remotely monitored by the user or the organization.

vi. Cloud database and webpage

For cloud, Amazon Web Services (AWS) is used. In AWS the following services are used for data storage, data analysis, webpage namely AWS API Gateway, AWS Lambda and AWS Cloud MySQL. For communication between the Master ESP32 and AWS, AWS API Gateway for creating the API endpoint to build the bridge. Using this API URL the Master ESP32 sends the acquired data. Once the data is received in the AWS API Gateway. Then, the data is sent to the AWS Lambda. AWS Lambda is a service used to run codes and functions online. AWS Lambda receives the data and communicates with AWS Cloud MySQL. The AWS Lambda only can be able to access or directly operate the database. The AWS Lambda runs the predefined codes to store the data in database.

For Website development React JS is used. React JS is also connected to the AWS to fetch and analyze the data. The website include data to view and graphs. The developed website is formatted to build and hosted using Netlify.

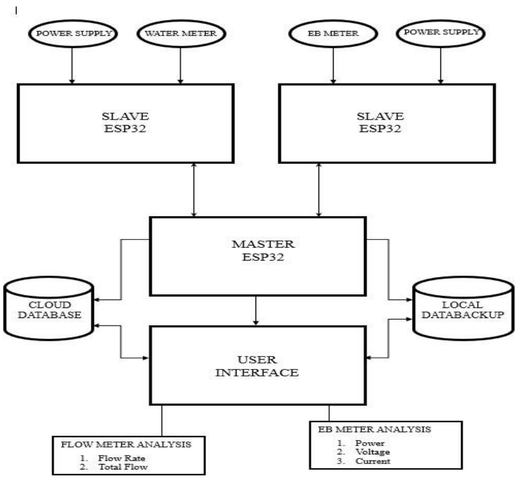

Fig.3. Block Diagram of Proposed System

The overall flow of the system is shown in the Figure 3.

IV. Results & Discussion

The outcomes from the water meter are shown in the Table 1 and EB meter is shown in Table 2. Based on the daily usage data the monthly usage is calculated. The database is created in a way to store the daily usage data and the monthly usage data for the water usage includes these parameters User id, Water Usage, Water speed, Entry Date and monthly data includes User ID, Total Water Usage, Average Water Speed, Total Bill, Payment Status and Entry month. For EB meter the Daily parameters are User ID, KWh, Current, Voltage and Entry Month and by using these values the monthly usage for EB meter is derived it includes User ID, Total KWh, Average Current Usage, Average Voltage Usage, Total Bill, Payment Status and Entry Month. Also using the values various charts are created to view the data easily. This chart will help the users to ensure the best ways to efficiently use the resources.

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To take the data from the sensors ESP32 uses inbuild library and formulas to calculate the value. When the master ESP32 sent the values AWS. The AWS Lambda performs various algorithms to manipulate and store the data. To view the data the user must upload User id and their password. Only when authenticated they will see the data. To ensure the data is private the password is introduced. The organization also can see the data to verify it.

User ID	Total Water Usage	Average Water Speed	Total Bill	Entry Month
6410452024120002	1230	54.405	5.535	FEB 2025
6410452024120002	1259	47.60636	5.6655	MAR 2025

Table 1: Overall monthly data from water meter

User ID	Total KWh	Average Current Usage	Average Voltage Usage	Total Bill	Entry Month Month
6410452024120002	160	13.5	229	10.37	FEB 2025
6410452024120002	410	15.2	231	26.91	MAR 2025

Table 1: Overall monthly data from EB meter

Fig.3. Offline output of Water meter

Fig 4. Offline output of EB meter

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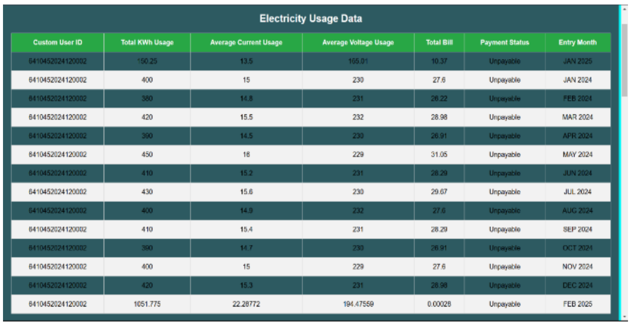
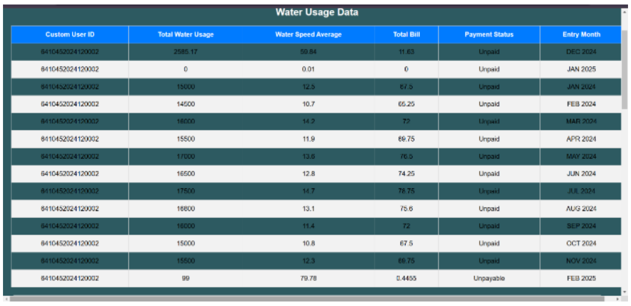


Electricity Usage Data

Custom User ID	Total KWh Usage	Average Current Usage	Average Voltage Usage	Total Bill	Payment Status	Entry Month
6410452024120002	150.25	13.5	165.01	10.37	Unpayable	JAN 2025
6410452024120002	400	15	230	27.6	Unpayable	JAN 2024
6410452024120002	380	14.8	231	26.22	Unpayable	FEB 2024
6410452024120002	420	15.5	232	28.98	Unpayable	MAR 2024
6410452024120002	390	14.5	230	26.91	Unpayable	APR 2024
6410452024120002	450	18	229	31.05	Unpayable	MAY 2024
6410452024120002	410	15.2	231	28.29	Unpayable	JUN 2024
6410452024120002	430	15.6	230	29.67	Unpayable	JUL 2024
6410452024120002	400	14.9	232	27.6	Unpayable	AUG 2024
6410452024120002	410	15.4	231	28.29	Unpayable	SEP 2024
6410452024120002	390	14.7	230	26.91	Unpayable	OCT 2024
6410452024120002	400	15	229	27.6	Unpayable	NOV 2024
6410452024120002	420	15.3	231	28.98	Unpayable	DEC 2024
6410452024120002	1051.775	22.28772	194.47559	0.00028	Unpayable	FEB 2025

Fig 5. Online output of EB meter



Water Usage Data

Custom User ID	Total Water Usage	Water Speed Average	Total Bill	Payment Status	Entry Month
6410452024120002	2585.17	59.84	11.63	Unpaid	DEC 2024
6410452024120002	0	0.01	0	Unpaid	JAN 2025
6410452024120002	15000	12.5	67.5	Unpaid	JAN 2024
6410452024120002	14500	10.7	65.25	Unpaid	FEB 2024
6410452024120002	16000	14.2	72	Unpaid	MAR 2024
6410452024120002	15500	11.9	69.75	Unpaid	APR 2024
6410452024120002	17000	13.6	76.5	Unpaid	MAY 2024
6410452024120002	16500	12.8	74.25	Unpaid	JUN 2024
6410452024120002	17500	14.7	78.75	Unpaid	JUL 2024
6410452024120002	16800	13.1	75.6	Unpaid	AUG 2024
6410452024120002	16000	11.4	72	Unpaid	SEP 2024
6410452024120002	15000	10.8	67.5	Unpaid	OCT 2024
6410452024120002	15500	12.3	69.75	Unpaid	NOV 2024
6410452024120002	99	79.78	0.4455	Unpayable	FEB 2025

Fig 6. Online output of Water meter

Fig 7. Bill Bar chart for Water meter in website

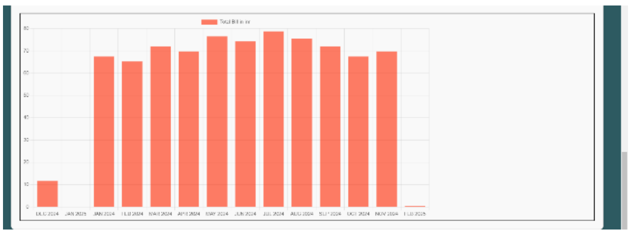


Fig 7. Bill Bar chart for EB meter in website

The Website include all the data and Bar chart to see the difference and status of users domestic utilities clearly. The Website includes more bar chart i.e. Each Month vs Average voltage value, Each Month vs Average Current usage, Each month vs power consumption for EB meter and Each Month vs Total Water Usage, Each Month vs Water speed Average for Water meter. The website can be easily customized by changing the React JS.
Website URL: amimeasurandstats.netlify.app

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V. Conclusion

The proposed IoT based smart monitoring system for domestic utilities can effectively overcome all the limitation faced on the traditional meters with the help of wireless communication, real time data collection and cloud technology. It also can be highly available when sharing the data and the process become much faster when using ESP32 microcontroller. With the help of AWS and React JS which allows user to access data remotely and analyze their consumption, promoting better cost and resource management. The system not only enhances the customer awareness on daily utility usage but also enables predictive analysis, easy billing and easily accessible. The wireless nature of the system eliminates the manual meter reading eliminating human errors and operational costs. Overall, this smart meter utility monitoring system contributes to sustainable resource utilization by encouraging responsible consumption habits. The future enhancement for the system is easily upgradable by adding some more functions it can perform functions including instant alert for excessive consumption or possible faults such as leaks or power overloads. Also, It can be enhanced for AI- driven consumption predictions, machine learning-based anomaly detection, and mobile app integration for more user friendly experience.

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