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Smart Energy Monitoring System for Power Utilisation

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Abstract: Growing concerns over increasing energy consumption and the necessity of waste reduction have underscored the significance of efficient energy management in residential, commercial and industrial facilities. Conventional approaches of energy metering primarily rely on manual readings. There are no real-time reads of these scans and measurement errors together with incorrect power usage and slow fault detection tend to occur. In this work, a Smart Energy Monitor System based on an Arduino UNO R4, ESP8266 Wi-Fi module, RS-485 communication interface and EMS-09 multifunction meter was designed to tackle these challenges. The device measures voltage, current, power factor, and power and energy on all three phases continuously. It automatically records data using Google Sheets through a cloud platform. Real-time monitoring allows users to discover abnormal load patterns, pinpoint inefficient loads, and monitor energy consumption trends. Energy trends will allow users to do better load calculations and see spiked load patterns. The solution is well suited for schools and small industry environments with its accuracy, low cost, and reliable performance. The convergence of embedded systems and IOT is an enabling technology having practical implication for smart, automated, sustainable energy management.

Keywords: Energy Monitoring, IoT, Arduino UNO R4, EMS-09 Meter, Modbus RTU, ESP8266, Google Sheets Logging.

I. INTRODUCTION

If we are going to keep universities and businesses running smoothly, then places like these will need power the whole time. Many legacy analog meters are guilty of unreliable updates, allowing power waste and higher electricity expenses to creep up unnoticed. New studies demonstrate how the Internet of Things might help solve these problems. For example, in [1] there is an IoT-based monitoring system that emphasizes the need for real-time measuring data to enhance energy visibility. Also Reference [2] shows the beneficial aspects of online dashboards for energy analysis and demonstrates how a web platform developed on Raspberry Pi can facilitate monitoring from distance.

Providing monitoring and alerting will enable people to do something about their power usage when they realize that it is too high. There are many ways to convey this information. The smart-meters are based on Android operating systems, giving users real time feedback, which is accessible by residents while they're out and about. Users can get notifications on their phones when they are away from home. Wireless technologies involving low-power communication, such as ZigBee, implemented with Arduino make possible the monitoring of energy without the requirement for wires between devices.

This dissertation expands on existing work, and presents a model of the Smart Energy Monitoring System as it would exist at MITT. The Arduino UNO R4 that we used, combined with a multifunction meter EMS-09, RS-485 ModBus RTU communication and calculations for three-phase electric systems made it possible to obtain high-quality real-time electrical parameters. Similar to the cloud computing models in [1] and [2], the ESP8266 module is installed on each mosquito trap, collecting data and transmitting it to a Google sheet. The data is now retrievable by users at any time and in the context of their location. We will therefore develop an efficient, scalable and comprehensible energy monitoring system for institutional use, with focus on cloud based services.

II. METHODOLOGY

The Smart Energy Monitoring System developed in the work used a sensing-to-cloud system that had been developed by several researchers. An example is the work that demonstrates how to monitor in real time electrical apparatus using an Arduino-based solution in [6]. This also emphasizes the need for accurate voltage and current readback on a consumer side. Moreover the article in [7] provides a broader view on the issues that need to be taken into account for implementing it and their scalability,

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particularly compared with systems based only on manual interaction and intervention.

Automated metering solutions enabled by IoT are discussed in [8]. These are examples of how advanced monitoring systems can more effectively and reliably respond with load control and communication technologies. In [9], the sensor and IoT-based communication model for reading smart energy meters where a number of Measurement Units are employed to measure and record their time-stamped data using different Processing Modules before being transferred to Cloud Connectivity, which embodies three functionalities i.e., Measurement Units (e.g. concentrators), Processing Modules, and Cloud Connectivity is presented. This duo makes it possible for you to always stay in the loop. The EMS-09 is similar to the systems described in [6] and [9]. It guarantees precision with internal signal conditioning and high-speed sampling, especially for load imbalances. Fifth, "The meter has standard RS-485 Communication Interface and Modbus RTU protocol that the long-distance communication between meters and master has been realized according to [8].

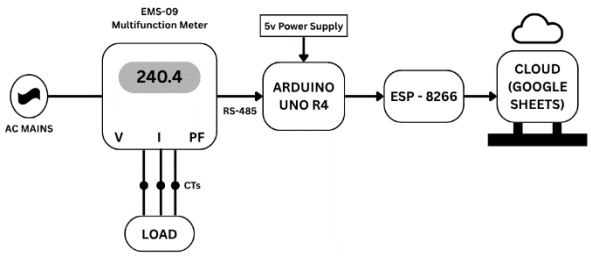

Fig 1. Block Diagram of Energy MonitoringSystem for Power Utilization

The block diagram below shows a system level perspective. It shows how everything connects and how data is passed back and forth. 5 [-] On the lefthand side, the EMS-09 Multifunction Meter is connected to a 3-phase network. The EMS-09 Multifunction meter derives all necessary measurements directly from detected electrical parameters (current via current transformers and voltage using voltage inputs). Once the electrical parameters have been acquired by the EMS-09 Multifunction Meter, they are then transmitted to a RS-485 Communication interface. The EMS-09 Multifunction Meter is interfaced with the Arduino UNO R4 through an RS-485 to TTL level adapter. This is an adapter for level-shifting between the EMS-09 Multifunction Meter's differential signaling to 0V~3.3V range of Arduino UNO R4 This allows safe connection between instrument and TTL logic system! The system is controlled by the processor Arduino UNO-R4, which generates a request for reading of data packets and read the necessary information. This includes integrity checks and time-stamping for logging data using the real-time embedded monitoring techniques presented in [6] and [8].

Once the data has been processed, the Arduino will transmit it to an ESP8266 Wi-Fi module interfaced with our network. The ESP8266 resorts to cloud solutions like [8],[9] to make HTTP GET requests, with all the readings its has received. It will then send these requests to Google Sheets via its native Google Apps Script API. This configuration enables remote users to retrieve, save and display energy trends from any PC with Internet access. They also are able to measure their energy demand over time and compare the performance of different stages, so that they can make educated decisions regarding how to use energy and preventive maintenance.

III.IMPLEMENTATIONANDSIMULATION

The hardware and software parts of the system have been integrated by following the techniques that were used in previous IoT-based smart meter systems. Monitoring systems on the ESP8266 platform from [10] and an energy system controlled by microcontroller from [13] had the greatest influence on the design of this system.

The hardware installation began at the installation of the EMS-09 meter to 3-phase power. The above installation process is consistent with the sensing schemes of [11] and [14]. Safe, accurate current measurements can be taken with the EMS-09 using current transformers. It communicate over RS-485 protocol, which also has been reported as a reliable communication method [12]. Since the EMS-09 meter uses RS-485 for communication, an RS-485 to TTL converter is used to connect it with the Arduino UNO R4 in the control system. The EMS off the ES-09 meter is read using Modbus with an Arduino UNO R4 and this data is sent to the ESP8266.

Wi-Fi communication is controlled by the ESP8266 module. It applies wireless data upload methods in [10], [14] and utilizes a smart plug monitoring system from [15]. The ESP8266 translates the meter readings into HTTP GET requests, and then sends these to Google Sheets via Google Apps Script.

In software side, we developing the program in Arduino IDE using Modbusmaster, SoftwareSerial and ESP8266_WIFI libraries. This data was grabbed by Google Apps Script and written to Sheets. The system can readily produce graphs of energy trend or performance by phase automatically. The result is that real-time energy consumption can be monitored with minimal human intervention.

IV. RESULTANDANALYSIS

The Smart Energy Monitoring System was tested in a real-world setting using methods to evaluate systems based on IoT monitoring and AI-supported smart meters. The EMS-09 multiple-function meter gave users live readings of voltage, current, power factor, and total energy consumed. It also tracked the load across all three phases. This setup

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allowed observers to see load variations in real-time. The displayed values were then used as a baseline to check the data collected by the Arduino. During the testing period, we compared the EMS-09's display screen with the data sent to the cloud. This was done to confirm that the data being collected was correct and responsive. An example of how the EMS-09 meter presented data visually can be seen in Fig. 2, where each parameter is available for immediate reference during testing.

The accuracy of serial communication was verified by monitoring the output of the Arduino UNO R4 on the Arduino IDE serial terminal. The process for validating the RS-485 Modbus RTU communication method was similar to the methods used for checking smart energy communication systems [18] and simulating smart monitoring systems [19]. All readings from the RS-485 Modbus RTU interface were compared to the values shown on the EMS-09 meter. They were found to be within a very small range of error, confirming that the data was collected correctly.

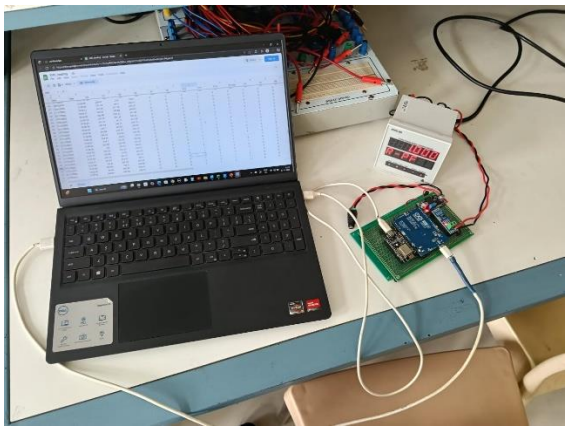

Fig 2. Display Readings from the EMS-09 Meter

As shown in Figure 3, communication between the EMS-09 and Arduino was successfully maintained. The noise immunity ensured that the data stream did not obviously change during continuous sampling. This is evident in the smooth transmission of data, which makes it a stable and reliable method for transferring data to the ESP8266 module.

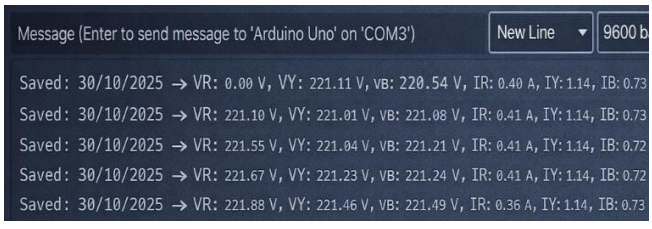

Fig 3.Arduino Serial Output

The ESP8266 connected to Google Sheets and uploaded data at regular intervals using an HTTP GET method as part of the Cloud Integration Test. Monitoring with cloud-based technology and the systems available through the Cloud helped verify the testing. Each uploaded entry included an automatic timestamp, which allowed for time series analysis of energy consumption. As shown in Fig. 4, Google Sheets offered a clear and organized table that documented all electrical parameters. It also included auto-generated plots to visualize power trends and phase stability across the phases. The system has remained operational without packet loss, which boosts confidence in the wireless link's sustainability and the reliability of Cloud Data Logging.

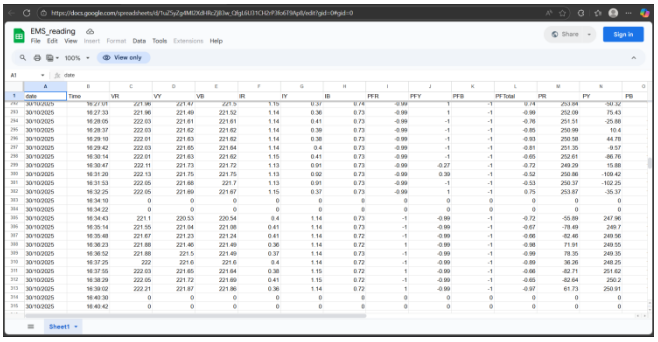

Fig 4. Data uploaded to Google Sheet

The system demonstrated high performance overall, with strong accuracy and reliability. Testing and results from other IoT-based energy monitoring systems, as shown in [22], and smart energy metering solutions in [23], confirmed this. The EMS-09 Meter, Arduino serial monitor, and cloud interface using Google Sheets showed significant agreement across all trials. There were minimal deviations in how each device measured electrical parameters. This suggests that the methods for obtaining data, establishing a serial connection, and transferring data to the cloud from the meter are correct.

Moreover, the monitoring system operated steadily over long periods, making it suitable for long-term monitoring applications. It also offered real-time cloud visualization of consumption data, allowing users to easily see their usage patterns, changes in electrical load across all three service phases, and overall consumption trends. This feature improves usability and makes the data easier to understand. Ultimately, the results of this project validate the effectiveness of the designed system and its application in institutional, industrial, and large-scale energy management settings, where continuous monitoring is essential.

V. CONCLUSIONANDFUTURE ENHANCEMENT

“Smart Energy Monitoring System is an affordable technical solution to convert this traditional energy system into a smart energy monitoring system where the users can monitor every appliance’s power consumption with synchronization and real time access. This project helps to track live electrical appliances on a smartphone by making

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use of the latest technology in IoT and "Embedded systems". Users can view their power measurement data over the Internet by using the ACS-09 multi-function meter working with Arduino R4 and ESP8266 Wi-Fi module. This automated operation minimises the requirement for manual measuring and enhances precision. It further assists users to take better decisions regarding their energy consumption and load management for saving energy. "This approach and results prove that the system can be portable for different type of institutions, laboratories and small enterprises aiming at adopting an IoT-based smart metering system, which corresponds to requirements resulting from the progress referred to for smart grids.

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AUTHORS PROFILE

Ravikumar R, M. Tech in VLSI Design and Embedded Systems, pursuing PhD in the area of Power Optimization in Wireless Sensor Networks for IOT applications from VTU Belgaum under the guidance of Dr.Rajalakshmi M C, Professor, Department of ECE, VVIET, Mysore. Currently working as an Assistant Professor in Department of Electronics and Communication Engineering, Maharaja Institute of Technology, Thandavapura. Have 15 Years teaching experience. Interest area VLSI, Embedded Systems, IoT, Computer Networks and Electrical. Participated in Professional body activities of IETE such as workshops and seminars.

Monikka P,is a BE. student, Department of Electronics and Communication Engineering, Maharaja Institute Of Technology Thandavapura. Interest Areas: VLSI Design, Embedded Systems, Internet of Things (IoT), Antenna Design and Electromagnetic Wave Propagation. Strong technical background in C, Python, Embedded C, and

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Verilog along with hands-on experience in microcontroller-based systems and hardware–software integration; help Preferred: web design and user interface experience. Design and simulation tools using Cadence Virtuoso, CST Studio Suite, ANSYS HFSS have been supported for comprehensivly understanding of electronic circuits and RF system analysis. Smart energy monitoring, embedded IoT applications-based academic projects have enriched me with the real-time data acquisition, system building at gate level development and feasible problem solving.

Nandana Prakash, a BE (final year) student. student of Maharaja Institute of Technology, Thandavapura in Electronics and Communication Engineering and areas of Interest are Embedded Systems, Automation, IOT and Applied Electronics. She is skilled in C, C++, Python and Verilog language evident from getting hands on experience of system using Arduino based systems" and Hardware Software Integration. This has enhanced her Electronics System Design and Analysis knowledge using different tools such as MATLAB, Cadence, Keil uVision, Proteus, LabVIEW, Arduino and Xilinx. While working with academic projects including Smart Energy Monitoring Systems and IoT based applications, she has gained Real-Time Data Acquisition, Systems Implementation and Problem Solving skills. My ambition is to grow with the field of Electronics in the area like embedded and Smart Energy Systems by continual Learning and Innovation.

Rithin S K, a final-year B.E. student in Electronics & Communication Engineering, Maharaja Institute of Technology, Thandavapura with special interests in VLSI Designing, Embedded System, Antenna and Wave Propagation, Networking, IoT.

Saniya S, a final year Bachelor of Engineering (B.E.) Electronics and CommunicationEngineering student from Maharaja Institute of Technology, Thandavapura. Specifically intrigued by VLSI design, embedded systems, software as well as the Internet of Things (IoT). has the technical base contact you covered (experience in semiconductors and embedded design and proficiency in C, basic Java, Python, Verilog or Cadence Virtuoso). acquired practical knowledge on system design, hardware-software integration and real-time monitoring applications through a project called Energy Monitoring System. aspires to work in core electronics companies and learn new technologies which are the need of the hour with hardwork in embedded and VLSI domains, respectively.