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Smart Energy Meter with Load Control Using IOT

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ABSTRACT:

As India moves closer to a new golden age of prosperity, one of the biggest issues facing the power industry is electricity theft, which causes an annual revenue loss of $17 billion and almost 80% of power outages. Transmission, distribution, and general technical and commercial losses are made worse by the current inadequate infrastructure, since the country's energy production is predicted to exceed 250 GW by August 2023. This paper presents a smart energy monitoring and analysis system based on the Internet of Things (IoT) to address these issues. In addition to precisely tracking the energy use of different devices, the suggested system seeks to detect and measure electricity theft. Real-time power usage data is sent straight to the electrical board via Internet of Things sensors, allowing for the quick identification of irregularities that might point to theft. The system also makes automatic invoicing possible by giving customers consumption data, which ensures accountability and openness in energy use. In addition to reducing power theft, the implementation of this advanced monitoring system encourages effective energy management and improves the sustainability of the power industry overall.

KEYWORDS: electricity theft, energy management, Smart Energy Meter, power industry, Internet of Things sensors.

INTRODUCTION:

The rapid increase in energy consumption driven by population growth, urban expansion, and widespread use of electrical devices has created a strong need for efficient energy management solutions. In many existing systems, conventional energy meters are still widely used, which are limited to recording cumulative energy usage without offering any real-time visibility or control. This lack of detailed monitoring often results in inefficient energy utilization, unnoticed power wastage, and increased operational costs for consumers. Moreover, the absence of immediate feedback prevents users from making informed decisions regarding their energy consumption behaviour. With the advancement of embedded systems and communication technologies, the integration of the Internet of Things (IoT) into energy management has opened new possibilities for intelligent monitoring and control. IoT-based systems enable continuous data acquisition, remote accessibility, and automated decision-making, thereby improving overall system efficiency. Recent developments in smart energy solutions emphasize real-time monitoring, data analytics, and user interaction. However, many of these systems are primarily focused on data visualization and lack effective mechanisms for direct load control and alert generation. The proposed system, as illustrated in the block diagram, presents a structured approach to address these limitations by combining sensing, processing, communication, and user interaction within a unified framework. Electrical appliances connected to the system act as variable loads, and their energy consumption is continuously tracked using a current sensor. This sensor plays a crucial role in capturing real-time current variations corresponding to different appliance operations. The collected analogy signals are then forwarded to the Arduino Uno, which performs data acquisition and converts the sensed values into meaningful digital information suitable for further processing. To enable seamless connectivity and remote monitoring, the system incorporates a NodeMCU module with integrated Wi-Fi capability. The NodeMCU acts as a communication bridge between the hardware unit and cloud-based platforms, ensuring that the processed data is transmitted securely and efficiently. Cloud integration allows users to access energy consumption details from any location, making the system highly flexible and user-friendly. In addition, the cloud platform can store historical data, which can be useful for analysing consumption trends and identifying patterns over time. An important feature of the proposed system is its ability to provide real-time alerts and notifications. By setting predefined threshold values, the system can detect abnormal energy usage conditions and immediately notify the user through SMS alerts or monitoring interfaces. This functionality is particularly useful in preventing energy wastage, detecting faulty appliances, and ensuring safe operation of electrical systems. Furthermore, the system can be extended to include load control mechanisms, enabling users to switch appliances on or off remotely based on energy requirements. Another advantage of this approach is its scalability and adaptability to different environments such as homes, offices, and small industrial setups. The use of cost-effective components like Arduino Uno and NodeMCU makes the system economically feasible while maintaining reliable performance. Compared to traditional systems, the proposed design offers improved transparency, better user engagement, and enhanced control over energy usage. In summary, the “Smart Energy Meter with Load Control Using IoT” provides an integrated solution that not only monitors energy consumption in real time but also supports intelligent decision-making and control actions. By bridging the gap between conventional metering and modern smart systems, the proposed approach contributes to efficient energy utilization, reduced operational costs, and the development of sustainable energy management practices.

LITERATURE SURVEY:

Recent developments in smart energy and IoT-based monitoring systems have shown significant progress in improving efficiency, reliability, and user interaction. In 2024, Bawankar et al. presented a method to upgrade conventional water meters by integrating IoT modules powered through solar energy. The system performs local data processing using edge computation, thereby reducing dependency on centralized servers and improving real-time monitoring accuracy, which was reported to be approximately 97.69% under test conditions [1]. In a related study, Khan et al. (2024) analysed large-scale energy distribution challenges and proposed a statistical framework to support smart grid implementation, particularly within developing infrastructure environments. Their work highlights the importance of structured planning and data-driven strategies for optimizing energy utilization [2]. Security and privacy in smart grid systems have also been widely addressed. Akgün et al. (2023) introduced a privacy-preserving mechanism combining Trusted Execution Environments with aggregation techniques to protect consumer data during transmission and processing [3]. Similarly, Tari et al. (2023) contributed by developing a comprehensive real-time dataset consisting of multiple electrical parameters collected from household appliances, addressing the lack of reliable datasets required for validating energy management algorithms [4]. Energy forecasting and intelligent control strategies have been explored using advanced computational models. Nabavi et al. (2023) proposed a hybrid approach integrating Discrete Wavelet Transform with Long Short-Term Memory networks to handle fluctuations in renewable energy systems. Their model demonstrated improved prediction capability with relatively low error margins ranging between 3.63% and 8.57% [5]. In another work, Saleem et al. (2023) developed an IoT and 5G-enabled Smart Energy Management System incorporating demand-side management techniques to enhance real-time control and optimize energy consumption at the user level [6]. Hardware-level optimization and system efficiency have also been investigated. Li et al. (2023) proposed a decoupled optimization algorithm to improve stress distribution in power electronic components such as IGBTs, resulting in enhanced performance and computational efficiency [7]. From a consumer perspective, Fakhar et al. (2022) introduced a smart scheduling mechanism that recommends appliance operation during off-peak hours, achieving significant cost savings of up to 84% [8]. Scalable communication technologies for smart cities were addressed by Sushma et al. (2022), who utilized Low Power Wide Area Networks to enable efficient long-range monitoring of water and energy usage with minimal power consumption [9]. Earlier, Al-Ghaili et al. (2021) provided a comprehensive review of Energy Management Systems in buildings, categorizing their functionalities and demonstrating measurable improvements in efficiency through optimized control strategies [10]. Machine learning techniques have also played a crucial role in energy monitoring. Franco et al. (2021) evaluated multiple models, including FFNN, LSTM, and SVM, for appliance-level load identification, with neural network approaches achieving higher accuracy levels [11]. In addition, Jamil et al. (2021) proposed a block chain-based framework for secure and transparent energy trading, addressing trust issues in conventional systems [12]. Sustainable energy solutions were explored by Kalkal and Ravi Teja (2021), who developed a hybrid renewable system for rural electrification, ensuring continuous power supply while achieving economic and environmental benefits [13]. Earlier studies also focused on grid stability and monitoring challenges. Meegahapola et al. (2020) analysed oscillatory stability in renewable-integrated power systems using synchrophasor-based techniques, emphasizing the need for advanced monitoring solutions [14]. In the same year, Saleem et al. (2020) proposed a Non-Intrusive Load Monitoring-based IoT system to track energy consumption patterns without requiring complex hardware installations, improving user awareness and energy efficiency [15].

PROPOSED METHODOLOGY:

The proposed system presents an IoT-based smart energy metering solution capable of monitoring electrical consumption in real time while also supporting load control and user notification features. The system is designed around a layered approach that includes sensing, processing, communication, and user interaction. At the input stage, multiple electrical appliances are connected as loads. The current drawn by these appliances is continuously measured using a current sensor. This sensor captures variations in current corresponding to different operating conditions of the loads. The analogy signal obtained from the sensor is forwarded to the Arduino Uno, which functions as the primary data acquisition and control unit. The Arduino converts the analogy signal into digital values and performs necessary computations to estimate energy consumption. The processed data is then transmitted to the NodeMCU module. Acting as a communication interface, the NodeMCU utilizes its built-in Wi-Fi capability to send the data to a cloud platform. This enables real-time monitoring of energy usage through remote devices such as smartphones or computers. The cloud platform also maintains a record of historical data, allowing users to observe usage trends over time. In addition to monitoring, the system incorporates an alert mechanism. When the measured energy exceeds a predefined threshold, the system generates notifications through SMS alerts or cloud-based applications. This feature helps users take immediate action to prevent excessive energy consumption. The design can be further extended to include relay-based load control, enabling remote switching of appliances based on user commands or system conditions. Overall, the proposed system offers a compact and efficient solution for smart energy management by integrating measurement, communication, and control within a single framework.

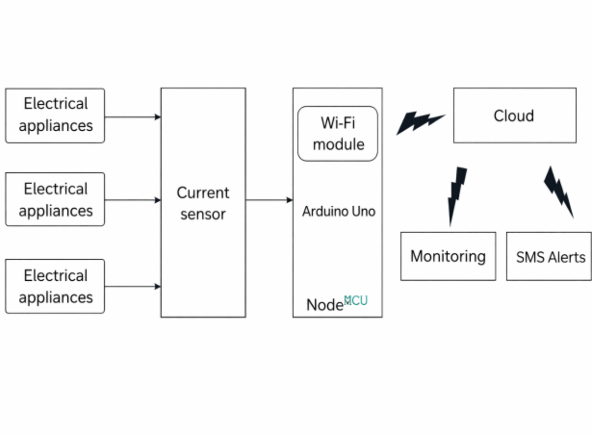

FIG: 1BLOCK DIAGRAM

HARDWARE WORKFLOW:

CURRENT SENSOR

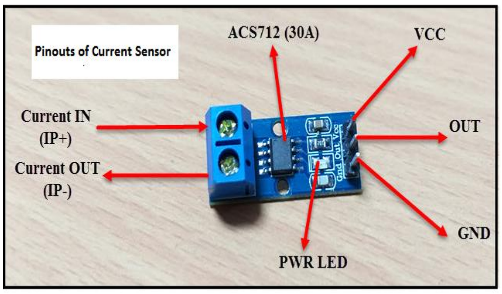

FIG: 2CURRENT SENSOR

The current sensor is responsible for measuring the flow of current drawn by connected electrical appliances. It operates on the principle of electromagnetic sensing, where the magnetic field generated by current flow is converted into a proportional voltage signal. This analogy output varies based on the load condition and is sent to the microcontroller for processing. The sensor ensures electrical isolation between the high-power circuit and control circuitry, improving safety. Its ability to provide real-time current measurements makes it suitable for monitoring dynamic load variations. Accurate sensing is essential for calculating energy consumption and detecting abnormal usage conditions in the system.

ARDUINO UNO

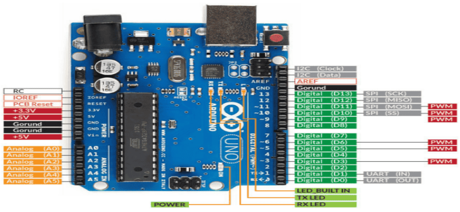

FIG: 3AURDINO UNO

Arduino Uno acts as the central processing unit of the system, handling data acquisition and initial computation. It receives analogy signals from the current sensor through its input pins and converts them into digital values using an internal analogy-to-digital converter. Based on the received data, the Arduino performs calculations to estimate current and energy consumption levels. It also manages communication with the NodeMCU module through serial interfacing. The simplicity, reliability, and wide support of Arduino make it suitable for embedded applications. Its role is crucial in ensuring accurate data processing and maintaining synchronization between sensing and communication stages.

NODEMCU

FIG: 4 NODEMCU

The NodeMCU is a microcontroller-based module equipped with built-in Wi-Fi capability, used for enabling IoT connectivity in the system. It receives processed data from the Arduino and transmits it to a cloud server using wireless communication. The module supports various communication protocols, making it flexible for integration with IoT platforms. Its compact design and low power consumption make it suitable for continuous operation. The NodeMCU also handles remote access features, allowing users to monitor energy consumption from anywhere. It plays a key role in bridging the gap between hardware components and cloud-based monitoring systems.

CLOUD PLATFORM

FIG: 5CLOUD PLATFORM

The cloud platform serves as the central storage and monitoring interface for the system. Data received from the NodeMCU is stored and organized in the cloud, allowing users to access it through web or mobile applications. It provides visualization tools such as graphs and logs to analyse energy usage patterns over time. The cloud also enables remote interaction with the system, including alert notifications and control actions. By maintaining historical records, it supports better decision-making and energy optimization. The use of cloud technology ensures scalability, accessibility, and reliability in handling large amounts of data.

ELECTRICAL APPLIANCES (LOAD)

FIG: 6ELECTRICAL APPLIANCES

Electrical appliances represent the actual load connected to the system, such as lights, fans, or other household devices. These loads consume electrical energy, which is measured and monitored continuously. The variation in their operation directly affects the current sensed by the current sensor. By analysing this consumption, the system provides insights into usage behaviour. The appliances can also be integrated with control mechanisms such as relays for automated or remote switching. Studying load behaviour is essential for identifying inefficient usage patterns and improving overall energy management.

POWER SUPPLY UNIT

FIG: 7POWER SUPPLY

The power supply unit provides the required electrical energy for operating all system components. It converts the available input power into regulated voltage levels suitable for Arduino, NodeMCU, and sensors. Stable power supply is necessary to ensure consistent system performance and avoid fluctuations that may affect measurements. Proper isolation and regulation improve the safety and lifespan of electronic components. The design of the power supply also considers efficiency and reliability for continuous operation. Without a stable power source, accurate sensing and communication cannot be maintained effectively.

RESULTS AND DISCUSSION:

The developed system was tested under different load conditions to evaluate its performance in real-time energy monitoring and data transmission. Various electrical appliances with different power ratings were connected, and the current sensor readings were recorded through the Arduino. The measured values showed consistent variation corresponding to the switching of loads, indicating proper sensing and data acquisition. The processed data was successfully transmitted to the cloud using the NodeMCU module. Real-time monitoring was achieved, and the energy consumption values were displayed without noticeable delay. The system demonstrated stable communication performance under normal network conditions. Threshold-based alerts were also tested by increasing the load beyond predefined limits, and notifications were generated as expected, confirming the effectiveness of the alert mechanism. During continuous operation, the system maintained reliable performance with minimal data loss. Minor deviations in readings were observed, mainly due to sensor tolerance and environmental factors, but these did not significantly affect overall functionality. The integration of sensing, processing, and communication components worked efficiently as a unified system. The results indicate that the proposed system is capable of providing accurate monitoring and timely alerts, making it suitable for practical applications. The ability to observe energy consumption in real time helps users understand usage patterns and take corrective actions, contributing to improved energy efficiency.

CONCLUSION:

The developed system demonstrates an effective approach for real-time energy monitoring and basic load management using IoT technology. The integration of sensing, processing, and wireless communication enables continuous tracking of power consumption and timely user alerts, improving awareness and reducing unnecessary energy usage. The system performed reliably under different load conditions with acceptable accuracy. However, further improvements can enhance its capabilities. In future work, the system can be extended by incorporating automated load control, advanced data analytics, and machine learning techniques for predictive energy management. Integration with smart grid infrastructure and mobile applications can also improve scalability, user interaction, and overall system efficiency.

REFERENCES:

1. Kaur, G., Singh, N. & Kumar, M. Image forgery techniques: a review. Artif Intell Rev 56, 1577–1625 (2023). https://doi.org/10.1007/s10462-022-10211-7
2. Zanardelli, M., Guerrini, F., Leonardi, R., & Adami, N. (2022). Image forgery detection: a survey of recent deep-learning approaches. Multimedia Tools and Applications, 82(12), 17521- 17566. https://doi.org/10.1007/s11042-022-13797-w
3. Nabi, S. T., Kumar, M., Singh, P., & Aggarwal, N. (2022). A comprehensive survey of image and video forgery techniques: variants, challenges, and future directions. Multimedia Systems, 28(4). https://doi.org/10.1007/s00530-021-00873-8
4. Singh, G., & Singh, K. (2019). Digital image forensic approach based on the second-order statistical analysis of CFA artifacts. Forensic Science International: Digital Investigation, https://doi.org/10.1016/j.fsidi.2019.200899
5. Rani, A., Jain, A., & Kumar, M. (2021). Identification of copy-move and splicing based forgeries using advanced SURF and revised template matching. Multimedia Tools and Applications, 80 https://doi.org/10.1007/s11042-021-10810-6
6. Amrit, P., & Singh, A. K. (2022). Survey on watermarking methods in the artificial intelligence domain and beyond. Computer Communications. https://doi.org/10.1016/j.comcom.2022.02.023
7. Wan, W., Wang, J., Zhang, Y., Li, J., Yu, H., & Sun, J. (2022). A comprehensive survey on robust image watermarking. Neurocomputing. https://doi.org/10.1016/j.neucom.2
8. Evsutin, O., & Dzhanashia, K. (2021). Watermarking schemes for digital images: Robustness overview. Image Processing: Image Communication, https://doi.org/10.1016/j.image.2021.116523
9. Rani, A., Jain, A., & Kumar, M. (2021). Identification of copy-move and splicing based forgeries using advanced SURF and revised template matching. Multimedia Tools and Applications, 80, 23877–23898. https://doi.org/10.1007/s11042-021-10810-6

10. Reddy, V., Priyanka, P., Supriya, D. K., Vishnu, P., Kumar, A. D., & Gole, S. B. (2022). Fake Image Detection Using Machine Learning. International Journal of Advanced Research in Computer and Communication Engineering, 11 (1). DOI: 10.17148/IJARCCE.2022.11122
11. Nitthilan Kanappan Jayakodi, Janardhan Rao Doppa, and Partha Pratim Pande, "SETGAN: Scale and Energy Trade-off GANs for Image Applications on Mobile Platforms," 2020 IEEE/ACM International Conference On Computer-Aided Design (ICCAD), San Diego, CA, USA, 2020, pp. 1-8. doi: 10.1109/ICCAD45719.2020.9264078
12. Weitao Chen, Shubing Ouyang, Jiawei Yang, Xianju Li, Gaodian Zhou, and Lizhe Wang, "JAGAN: A Framework for Complex Land Cover Classification Using Gaofen-5 AHSI Images," IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, vol. 15, pp. 1591-1603, Jan. 2022, doi: 10.1109/JSTARS.2022.3144339.
13. Alexander Groshev, Anastasia Maltseva, Daniil Chesakov, Andrey Kuznetsov, and Denis Dimitrov, "GHOST—A New Face Swap Approach for Image and Video Domains," IEEE Access, vol. 10, pp. 83452-83462, Aug. 2022, doi: 10.1109/ACCESS.2022.3196668
14. Xiufang Li, Qigong Sun, Lingling Li, Xu Liu, Hongying Liu, and Licheng Jiao, "SSCV-GANs: Semi-Supervised Complex-Valued GANs for PolSAR Image Classification," IEEE Access, vol. 8, pp. 146560-146576, Jun. 2020, doi: 10.1109/ACCESS.2020.3004591
15. Jiafeng Xu, Dawei Jia, Zhizhe Lin, and Teng Zhou, "PSFNet: A Deep Learning Network for Fake Passport Detection," IEEE Access, vol. 10, pp. 123337-123348, Nov. 2022, doi: 10.1109/ACCESS.2022.3224235.