A Comprehensive Analysis of IOT Based Electricity Monitoring System

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Abstract—Organizations with high energy consumption rates, including distribution centres, manufacturing enterprises, and huge office buildings, should prioritize energy monitoring and control. Significant cost savings and enhanced sustainability may be achieved by these organizations via the use of electricity monitoring and management systems. Energy metres and sensors gather data on energy use in real-time as part of energy monitoring. Energy management software is used to examine this data and find trends and patterns in energy consumption. Smart choices about energy optimization and waste reduction may be made using this data. In order to address the current problem, this study presents an Arduino-based smart energy monitoring and conservation system that is based on the internet of things (IoT). Reducing energy consumption and expenditures while increasing electrical equipment efficiency is the main objective of the suggested solution and this paper utilizes the power of an efficient communication technologies called Internet of Things (IoT) and the conventional General-Packet-Radio-Service (GPRS) to manage the data maintenance and communication services. As well as the resulting shows the efficiency of both the technologies in clear manner. These systems are able to optimize the operation of electrical equipment according to specific usage patterns and environmental circumstances by using real-time data acquired by sensors. This research presents an innovative energy monitoring system, the Intelligent Electricity Monitoring Scheme (IEMS), and assesses its performance by cross-validating it with the traditional technique, GPRS based Energy Monitoring (GPRSEM).

***Index Terms*—Intelligent Electricity Monitoring, Smart Controller, Voltage Sensor, Current Sensor, IEMS, Energy Monitoring, GPRSEM, Power Tracking**

I. INTRODUCTION

Energy management is only one area that has benefited from the new age of connectedness and intelligence brought about by the fast development of the Internet of Things [1]. In light of the importance of cutting-edge technology in meeting the rising demands of sustainable energy and energy consumption, this article dives into a thorough evaluation of an internet of things (IoT)-based power monitoring system. Novel approaches that reveal patterns of energy consumption in real time are urgently required in light of the rising worldwide demand for electricity as well as the critical need to reduce environmental impacts. More precise data collecting, improved analytics, and educated decision-making for commercial and residential energy users are all possibilities with the incorporation of IoT into electricity tracking devices [2][3]. The analysis begins with a brief background on the research, highlighting how the Internet of Things (IoT) is changing the game when it comes to conventional methods of power monitoring [4][5]. The increasing demands on energy supplies and the negative effects on the environment from unregulated consumption are brought to light, and the necessity for smart systems that can optimize energy usage is emphasized. Incorporating Internet of Things (IoT) technology with power monitoring, this study seeks to investigate the strengths and weaknesses of such systems in delivering useful data for sustainable, cost-effective energy management. Presenting the power monitoring system that is based on the internet of things (IoT) as a groundbreaking breakthrough within the larger framework of smart energy solutions, the introduction lays the groundwork for a thorough analysis of the system. Whether in a home, commercial, or industrial situation, electricity monitoring is an essential part of modern infrastructure management. Traditional approaches frequently can't keep up with the ever-changing patterns of energy consumption and don't give useful information in real time. The Internet of Things (IoT) paradigm brings a comprehensive view by including smart sensors that record exact data points pertaining to power, voltage, current, and environmental factors [6].

To produce, distribute, and control electrical power, a generator essentially consists of a system of linked parts [7]. Power plants, transformers, transmission lines, and distribution systems are all part of it. The generator guarantees a consistent flow of power for a variety of uses, from household appliances to manufacturing machinery. To fulfill the needs of consumers, its efficiency and steadiness are vital. The generator can be equipped with state-of-the-art technology that allows it to monitor and control voltage and current levels. This allows it to operate at its best and avoid problems like overloads or under loads [8]. It is the job of the power supply unit to regulate the flow of electricity from the generator so that it meets the specifications of all the devices that are attached to it. Because it allows for the collection of power system data in real-time, the IoT module is crucial in this setting. The power system's performance can be optimized, monitored, and controlled remotely through this integration, leading to more efficiency, less downtime, and better overall reliability. When it comes to electrical systems, voltage and current sensors are crucial for keeping everything running smoothly. By measuring the difference in electrical potential, voltage sensors aid in avoiding overvoltage and under voltage, two possible hazards that could harm machinery or halt production. Alternatively, current sensors monitor the passage of electric charge to guarantee that electrical equipment receives the correct current. By giving real-time feedback, these sensors help keep the power system stable and safe by enabling immediate modifications and interventions when needed [9] [10].

A dynamic network is formed by the interconnection of various sensors, made possible by strong Internet of Things (IoT) communication protocols and wireless technologies. This network feeds real-time data to centralized cloud servers. These servers not only store the data, but they also do complex studies to find trends and patterns thanks to their robust data processing capabilities. An IoT-based system like this has numerous benefits. The capacity to optimize energy consumption results in substantial cost reductions, while real-time monitoring enables fast responses to abnormalities or inefficiencies. Remote control features allow users to actively manage their electricity usage, while predictive maintenance skills ensure that equipment lasts a long time. In line with worldwide initiatives to decrease energy waste and carbon footprints, the ultimate aim is not only efficiency but also a concrete contribution to environmental sustainability.

II. RELATED STUDY

Plenty of people and places in the community have access to electricity right now [11]. Electricity requirements vary from one individual to another based on the specific electrical devices in use. An enormous amount of electrical power is generated when electrical devices are used excessively. The topic of power usage has been debated for quite some time. The overarching goal of this study is to provide an IoT-based, custom electronic sensor for tracking power usage. In addition, the article clarified the relationship between the custom electronic sensor's input and output locations. System requirements, design, implementation, and testing and analysis are the four stages that make up this research approach. The designed system can retrieve data on power, voltage, and current. Following data processing by Arduino UNO, the ESP8266 directly communicates with the Blynk Application for Android smartphones through the Internet. The program's main loop's constant values are obtained by voltage testing in the voltage and current sensors. To further verify the system's accuracy, we measure both the input value and the Blynk Application value [11].

Rapid economic growth in Vietnam over the past two decades has resulted in skyrocketing levels of both energy consumption and carbon emissions [12]. The country's approach to socioeconomic development has resulted in heavy industry and building using the majority of the electricity. Without accurate data on energy use, it will be impossible to implement an energy conservation strategy in industrial facilities. Installing energy monitoring systems that provide statistics on energy consumption on a daily, monthly, and annual basis can greatly contribute to improving energy efficiency. In addition, the Law on Energy Efficient Use mandates that large energy-consuming firms in Vietnam use energy-efficient solutions. Consequently, the purpose of this research was to assess the effectiveness of an energy monitoring system in a representative Vietnamese large energy consumer. Six months after the power monitoring system was installed, the investigation found that a total of 191,923 kWh of electricity was saved. The business was able to save around $19.584 and cut carbon dioxide emissions by 139-tones. Furthermore, power monitoring systems have a return on investment period of approximately 14 months, and the plant can lower its yearly energy expenses by approximately 9.62%. Consequently, in order to manage energy waste in the sector of home industry, power monitoring systems should be pushed in factories of varying sizes [12].

Air pollution has been on the rise in Latin America and the Caribbean due to the region's heavy reliance on energy produced primarily from fossil fuels [13]. The household sector's generation and consumption of electricity is a major contributor to this issue. Contrarily, new studies show that smart energy metres in industrialized nations cut power usage since they constantly provide feedback to the user. This study details the design and execution of an electrical energy consumption monitoring system that makes use of Internet of Things (IoT) smart sensors. Instantaneous power, electrical efficiency, energy spent, and cost are all computed by the system. A WIFI ESP8266 module processes and transfers the information of these variables to a ThingSpeak server, which functions as a cloud database. In addition, a database-integrated Android app was created to let users see how the variables behave. We checked the smart sensor's readings with those of an oscilloscope and a multi-meter to ensure its accuracy. There were relative errors ranging from -2.34 to 1.92% [13].

Building a web-based system to track a home's electrical energy usage in real-time is the goal of this project [14]. A micro-CPV system installed on the top of this house is responsible for producing this electrical energy. A micro-CPV's optical components include a multi-junction solar cell, a spherical lens for secondary optical purposes, and a Fresnel lens for primary use. In the first section of this study, a small photovoltaic concentrator system with a geometric concentration ratio of 100× is examined. The second section is intended to track the power output of the micro-CPV system. The sensing peripheral node is constructed using an ESP8266 controller chipset. It operates a relay and a PZEM-004T current sensor. Consequently, the optical element has an acceptance angle of 1.5° and an optical efficiency of about 83%. The design of the monitoring system showcases its capacity to track energy usage and current in real-time through a web server tailored to update the power consumption profile in a particular smart home environment, as well as through a computer or smartphone. We were pleased with how effectively the electric power usage monitoring system performed overall. With its current settings, the monitoring system is able to deliver a 0.6% hit with remarkable precision [14].

Electricity has been more expensive due to rising demand and falling fossil fuel supplies in recent years [15]. Therefore, it is imperative that the community foster a habit of conserving electrical energy. In contrast, a system that can regulate energy consumption is essential for the widespread adoption of energy-saving practices. Because of these issues, we need to figure out how to promote a culture of reducing our electrical energy consumption. In order to promote an energy-efficient culture, this research suggests a framework that can help with active energy efficiency measures. The smart electrical panel is an integral part of this system, which keeps tabs on the power use, records it, gives detailed information, and analyses it. It also has the ability to automatically control electrical loads. Research and development is the process that is employed to do this research. An electrical power control and monitoring system prototype with a smart panel based on a Raspberry PI 3 and a PZEM-004t power energy meter has been developed in this research. Automatic control of electrical loads is performed and executed by the monitoring system. Data monitoring reports can be generated by the system on a daily, weekly, monthly, or yearly basis. It is clear that the system is capable of performing adequately based on the test findings. It is believed that this study would help develop a system that can bolster energy conservation initiatives by the government [15].

III. METHODOLOGY

Issues of security, interoperability, data privacy, and compliance with regulatory frameworks are crucial and require careful study. By successfully negotiating these obstacles, individuals and organizations may tap into this revolutionary technology's full potential and establish themselves as leaders in the power management revolution to come. In order to provide real-time insights into electricity use, an IoT-based power monitoring system comprises high-precision sensors, IoT communication protocols, and cloud analytics. Proactive decision-making as well as energy optimization are made possible by the system's use of smart metres and edge computing, which guarantee immediate data processing. A combination of automation capabilities, such as remote control and scheduling, and user-friendly dashboards makes monitoring a breeze. Sensitive information is protected by security measures, such as end-to-end encryption. Cost savings, predictive maintenance, and helping achieve sustainability targets through less energy waste are all benefits of the system.

Electricity is produced, transmitted, and distributed by a power system, which is an intricate network of electrical components. Most power grids consist of a number of components, including generators, transformers, transmission lines, distribution networks, and safety and control systems. A power system's principal objective is to supply users with electrical power in an efficient and dependable manner. Providing the electricity required to power homes, businesses, and industries, power systems are an essential part of modern life. To keep an eye on and manage the power flow, sophisticated control mechanisms and technology are used.

In comparison to the current method known as GPRS based Energy Monitoring (GPRSEM), the suggested system, Intelligent Electricity Monitoring Scheme (IEMS), helps to guarantee the efficiency and dependability of contemporary power systems and electronic devices by facilitating the generation, control, and visualization of electrical energy. The following figure Fig.1 shows the block diagram of the proposed system.

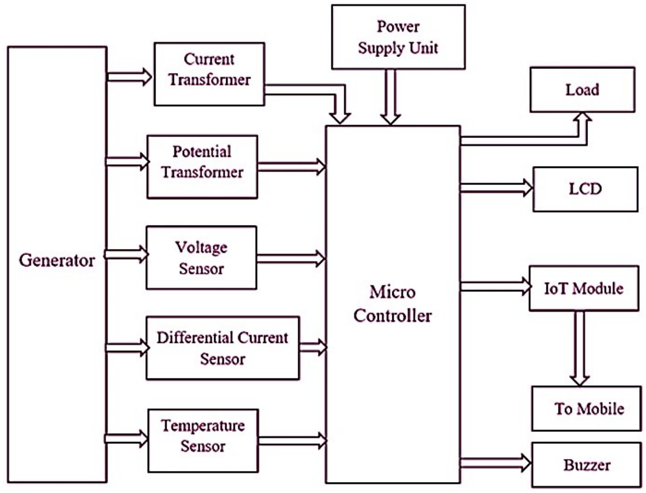

Fig.1 Block Diagram

In order to make the system accessible across a variety of platforms, the focus has shifted from monitoring to providing data analytics services. It includes renewable energy sources as well as has a global scalability strategy, making it easy to adopt in educational institutions. By establishing a mechanism for ongoing improvement and aligning with governmental efforts, the system meets the comprehensive monitoring demands, remains relevant in the ever-changing energy management landscape, and can adapt to new technologies.

(i) Power Generator: Power systems, often called electrical power systems, are intricate networks that enable the production, conveyance, and consumption of electrical energy. Transformers, transmission lines, distribution networks, control devices, and power generation sources make it up. In order to meet the demands of consumers, power networks provide a steady supply of electricity. Power stations, wind farms, and other facilities can all be considered generation sources. Power is efficiently transmitted over long distances by use of transmission lines and transformers, which increase or decrease voltage as needed. The following figure Fig.2 shows the generator.

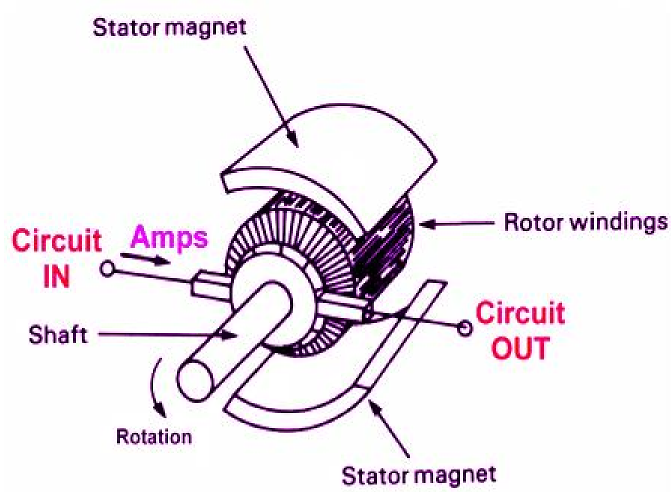

Fig.2 Generator

(ii) Current Sensor: A current sensor is a device that can detect current and convert it to a measurable output voltage. The current flowing via the measured route is directly proportional to this output voltage. Following that, an ammeter's display, a control system, or a data collecting system for further analysis can all make use of this output voltage signal. There are several varieties of sensors on the market, and each one is tailored to a certain set of environmental and climatic circumstances. Most people think of a current sensor as a current-to-voltage converter; by inserting a resistor into the current route, the current is transformed into voltage in a linear fashion. This makes current sensors the most common type of sensor used in this context. The following figure Fig.3 shows the current sensor.

Fig.3 Current Sensor

(iii) Temperature Sensor: Things that can detect the amount of heat in a specific area or on a specific object are called temperature sensors. When it comes to electrical systems, temperature sensors play a key role in keeping equipment from overheating by monitoring its thermal conditions. There are various varieties of these sensors, including infrared sensors, thermistor, and thermocouples. These sensors contribute to the overall safety and efficiency of electrical systems by continuously monitoring temperature levels, which helps maintain optimal operating conditions, avoid damage to components, and more. In order to measure temperature, thermocouples use a voltage that is directly proportional to the difference in temperature between two metal junctions. In addition to being widely employed in industrial settings, they are long-lasting and can withstand a broad range of temperatures. In contrast, the electrical resistance of a thermo switch changes substantially as its temperature rises and falls. The following figure Fig.4 shows the temperature sensor.

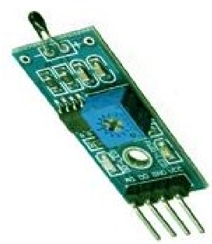

Fig.4 Temperature Sensor

(iv) Voltage Sensor: One way to measure voltage is with a voltage sensor. Depending on their design, voltage sensors can detect very low current levels or very high voltages. Many applications rely on these devices, such as power systems and industrial controllers. Measuring current (or amperage) and voltage are the two primary functions of voltage sensors. An operational amplifier (op-amp) and a voltage-sensitive resistor are the two main categories. Sensors that measure battery life or solar panel output are two examples of electronic circuits that use VSRs to detect minor changes in voltage. You can find operational amplifiers (op-amps) within micro-controllers like Arduino boards, and they are useful for driving motors and controlling LEDs. The following figure Fig.5 shows the current sensor.

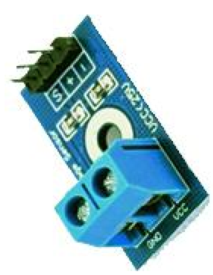

Fig.5 Voltage Sensor

(v) Arduino UNO: Composed of a central processing unit (CPU), random access memory (RAM), and programmable I/O peripherals, a micro-controller is a small integrated circuit. Embedded systems frequently employ micro-controllers for the purpose of controlling and managing the functioning of various electronic components. Because of their programmability, they can carry out predefined actions according to the instructions stored in their memory. Appliances, cars, industrial control systems, as well as consumer electronics are just a few of the many places you might find micro-controllers in use. The following figure Fig.6 shows the Arduino Uno.

Fig.6 Arduino UNO

(vi) ESP32 Module: Devices that use the ESP32 modules frequently include devices for smart home security, such as video surveillance and electronic locks-automated heating, ventilation, and air conditioning systems, as well as intelligent thermostats-industrial smart gadgets, such as PLCs. Smart medical gadgets, like wearable health monitors. The following figure Fig.7 shows the ESP32 module.

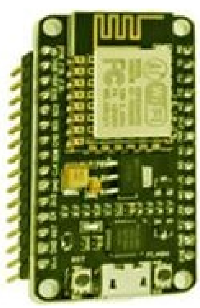

Fig.7 ESP32 Module

IV. RESULTS AND DISCUSSIONS

A crucial tool in many fields, simulation provides a digital setting in which to study and learn from real-world situations. Engineering and scientific professionals rely on it to investigate intricate occurrences, put ideas to the assessment, and enhance existing ones. Simulation speeds up invention by simulating complex procedures and systems, which allows for less expensive testing. Optimization of designs, prediction of results, and mitigation of risks are some of the many uses of simulation in fields as diverse as aerospace engineering, healthcare, and finance. Its strength is in its capacity to provide repeated testing and improvement by simulating situations that would be difficult or impossible to physically reproduce. The ability to test out new ideas, find solutions, and completely alter long-held assumptions is what makes simulation such a powerful tool for driving innovation. With the constant improvement of technology and processing capacity, simulation has managed to overcome obstacles such computational complexity and the need to validate models. To tackle these issues and make the most of them, multidisciplinary cooperation and spending on modelling structures are crucial. New developments in areas such as machine learning and high-speed computing bode well for the expansion and improvement of modelling in the years to come. Embracing simulation as an essential tool in R&D opens the door to revolutionary transformation as well as an infinitely innovative potential. The proposed model, Intelligent Electricity Monitoring Scheme (IEMS), is shown in Fig. 8 as an overview schematic diagram. It makes use of the Internet of Things (IoT) to facilitate efficient communication between the hardware unit and the server end.

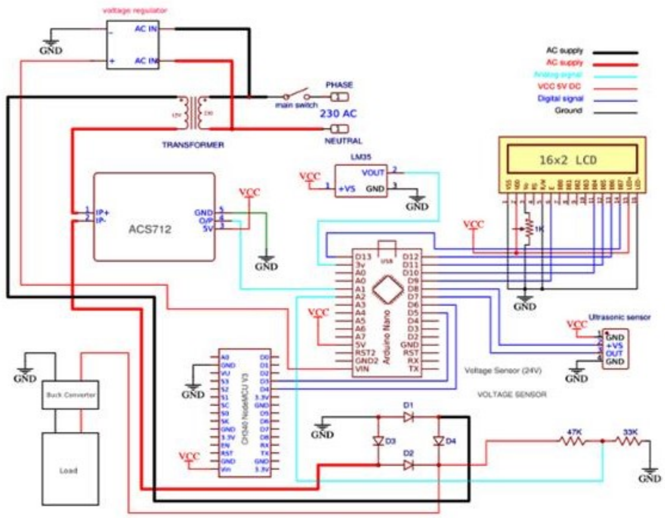

Fig.8 Schematic Diagram

In order to guarantee efficient data collecting, transmission, processing, and user engagement, there are a number of critical measures to take while setting up hardware for an electricity monitoring system that is based on the Internet of Things. First and foremost, it is critical to choose the right sensors. The voltage, current and power consumption readings taken by these sensors at different locations throughout the electrical infrastructure must be precise. Second, sensors must be able to communicate with a central processing unit (CPU) without any hitches by using suitable communication modules like Wi-Fi or Bluetooth.

Gathering and analyzing data from sensors is done by the central processing unit (CPU), which is usually a microcontroller such as Raspberry Pi or Arduino. Data storage decisions, such as whether to use local storage or cloud-based solutions, must be based on requirements. In addition, users cannot interact with the system, examine real-time data, or change preferences without a user interface, which may be developed as a web or mobile application. To keep sensitive information safe, security measures like encryption and access restrictions must be put in place. Figure 9 shows the hardware configuration of the proposed system, IEMS.

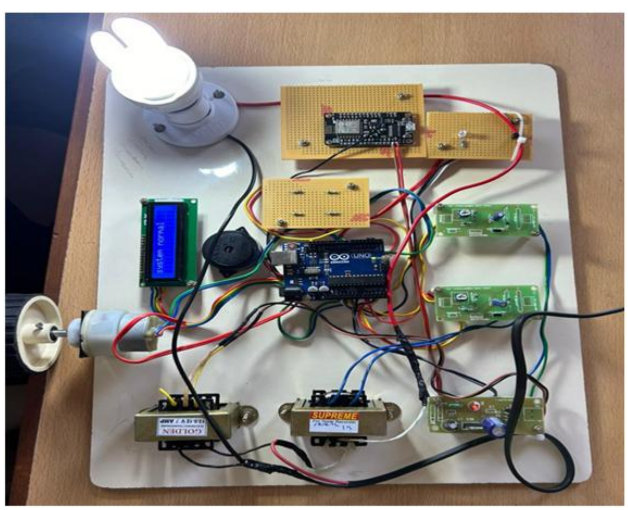

Fig.9 Proposed Hardware Unit

V.CONCUSSION

Finally, the systems indicate a critical milestone in promoting sustainable development and transforming energy management techniques. These systems provide proactive energy optimization and informed decision-making by providing users with real-time insights into energy usage trends by means of an effortless combination of gadgets, wireless networks, statistical analysis, and graphical user interfaces. Advances in effectiveness, economics, and sustainable development are driven by IoT-based systems for tracking, which help identify ineffectiveness, high-usage periods, and costly to operate products. In addition, these systems are driving a transition towards energy systems that are more sustainable, egalitarian, and robust, which in turn affects policymaking, infrastructure development, and social behaviour. Additional chances to improve grid resilience and sustainability can be found through the integration of smart grid technology and renewable energy sources into IoT-based monitoring systems. In addition, as connected devices continue to spread and integrate the prospect for cooperative energy administration efforts and demand-response programmes rises, encouraging an environment that is more flexible and adaptive.

REFERENCES

[1] Mohammad Kamrul Hasan, "Internet of Things-Based Smart Electricity Monitoring and Control System Using Usage Data", Wireless Communications and Mobile Computing, 2021, [online] Available: https://doi.org/10.1155/2021/6544649.

[2] S. Banik, "Prediction of electrical energy consumption based on machine learning technique", Electrical engineering, vol. 103, no. 2, pp. 19-28, 2021.

[3] Korakot Luechaphonthara and A Vijayalakshmi, "IOT based application for monitoring electricity power consumption in home appliances", International Journal of Electrical and Computer Engineering (IJECE), vol. 9, no. 6, pp. 4988-4992, December 2019.

[4] Yang Yunyi, "Research on network security protection technology of power monitoring system", Electronic components and information technology, vol. 4, pp. 124-125, 2020.

[5] John A. Adebisi, et al., "A survey of power-consumption monitoring systems", e-Prime - Advances in Electrical Engineering, Electronics and Energy, https://doi.org/10.1016/j.prime.2023.100386, 2024.

[6] N. A. Hussien, A. A. D. Al Magsoosi, A. A. D. Al Magsoosi, H. T. Salim AlRikabi and F. T. Abed, "Monitoring the Consumption of Electrical Energy Based on the Internet of Things Applications", Monit. Consum. Electr. Energy Based Internet Things Appl., vol. 15, no. 7, pp. 17-29, 2021.

[7] R. Govindarajan, et al., "Performance Analysis of Smart Energy Monitoring Systems in Real-time", Eng. Technol. Appl. Sci. Res, https://doi.org/10.48084/etasr.3566, 2020.

[8] C.Nagarajan and M.Madheswaran - ‘Experimental verification and stability state space analysis of CLL-T Series Parallel Resonant Converter’ - Journal of ELECTRICAL ENGINEERING, Vol.63 (6), pp.365-372, Dec.2012.

[9] C.Nagarajan and M.Madheswaran - ‘Performance Analysis of LCL-T Resonant Converter with Fuzzy/PID Using State Space Analysis’- Springer,Electrical Engineering, Vol.93 (3), pp.167-178, September 2011.

[10] C.Nagarajan and M.Madheswaran - ‘Stability Analysis of Series Parallel Resonant Converter with Fuzzy Logic Controller Using State Space Techniques’- Taylor & Francis, Electric Power Components and Systems, Vol.39 (8), pp.780-793, May 2011.

[11] C.Nagarajan and M.Madheswaran - ‘Experimental Study and steady state stability analysis of CLL-T Series Parallel Resonant Converter with Fuzzy controller using State Space Analysis’- Iranian Journal of Electrical & Electronic Engineering, Vol.8 (3), pp.259-267, September 2012.

[12] Nagarajan C., Neelakrishnan G., Akila P., Fathima U., Sneha S. “Performance Analysis and Implementation of 89C51 Controller Based Solar Tracking System with Boost Converter” Journal of VLSI Design Tools & Technology. 2022; 12(2): 34–41p.

[13] C. Nagarajan, G.Neelakrishnan, R. Janani, S.Maithili, G. Ramya “Investigation on Fault Analysis for Power Transformers Using Adaptive Differential Relay” Asian Journal of Electrical Science, Vol.11 No.1, pp: 1-8, 2022.

[14] G.Neelakrishnan, K.Anandhakumar, A.Prathap, S.Prakash “Performance Estimation of cascaded h-bridge MLI for HEV using SVPWM” Suraj Punj Journal for Multidisciplinary Research, 2021, Volume 11, Issue 4, pp:750-756

[15] G.Neelakrishnan, S.N.Pruthika, P.T.Shalini, S.Soniya, “Perfromance Investigation of T-Source Inverter fed with Solar Cell” Suraj Punj Journal for Multidisciplinary Research, 2021, Volume 11, Issue 4, pp:744-749

[16] C.Nagarajan and M.Madheswaran, “Analysis and Simulation of LCL Series Resonant Full Bridge Converter Using PWM Technique with Load Independent Operation” has been presented in ICTES’08, a IEEE / IET International Conference organized by M.G.R.University, Chennai.Vol.no.1, pp.190-195, Dec.2007

[17] M Suganthi, N Ramesh, “Treatment of water using natural zeolite as membrane filter”, Journal of Environmental Protection and Ecology, Volume 23, Issue 2, pp: 520-530,2022

[18] M Suganthi, N Ramesh, CT Sivakumar, K Vidhya, “Physiochemical Analysis of Ground Water used for Domestic needs in the Area of Perundurai in Erode District”, International Research Journal of Multidisciplinary Technovation, pp: 630-635, 2019

[19] A. I. R. Fernando, et al., "Smart electricity monitoring and analysing an IoT system with a mobile application", International Research Conference on Smart Computing and Systems Engineering, DOI:10.1109/SCSE49731.2020.9312999, 2020.

[20] Aytun Onay, Gökhan Ertürk, et al., "A Smart Home Energy Monitoring System Based on Internet of Things and Inter Planetary File System for Secure Data Sharing", Journal of Computer and Communications. DOI:10.4236/jcc.2023.1110005, 2023.

[21] Ketaki S. Sudame, et al., "Design of an IOT Based Energy Monitoring System and Home Automation", Journal of Emerging Technologies and Innovative Research, 2020.

[22] D Eridani, et al., "Analysis of Custom IoT Based Electricity Monitoring System", IOP Conference Series: Materials Science and Engineering, DOI:10.1088/1757-899X/1071/1/012024, 2021.

[23] Minh Nguyen Dat, et al., "Assessment of Energy Efficiency Using an Energy Monitoring System: A Case Study of a Major Energy-Consuming Enterprise in Vietnam", Energies, https://doi.org/10.3390/en16135214, 2023.

[24] Víctor Sámano-Ortega, et al., "Electrical energy consumption monitoring system in the residential sector using IoT", IEEE Latin America Transactions, 2022.
[25] Sarah El Himer, et al., "Energy Consumption Monitoring System Based on IoT for Residential Rooftops", Computation, https://doi.org/10.3390/computation11040078, 2023.
[26] Fransiscus Yudi Limpraptono, et al., "Design of Power Monitoring and Electrical Control Systems to Support Energy Conservation", Innovation in Electrical Engineering, Information Technology and Renewable Energy for Welfare, DOI: https://doi.org/10.53560/PPASA, 2021.