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# DESIGN AND DEVELOPMENT OF CYBER PHYSICAL SYSTEMS (CPS) BASED INTELLIGENT SMART ENERGY MANAGEMENT SYSTEM WITH PREDICTIVE ANALYTICS

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**Abstract:** The rising demand for electrical energy and the need for efficient resource management have encouraged organizations and institutions to adopt intelligent technologies for monitoring and controlling energy consumption. The application of this technology has transformed and improved the organization's daily operations. In this study, the researcher designed and developed a Cyber-Physical Systems (CPS) Based Intelligent Smart Energy Management System with Predictive Analytics for Carlos Hilado Memorial State University, Philippines, integrating effective and efficient computational intelligence, communication networks, and physical sensing devices that enable automated electrical consumption control, real-time monitoring, and predictive analysis. To evaluate current energy consumption patterns and develop a functional CPS-based system, the study employed a descriptive developmental research approach. Energy sensors, PIR sensors, and a NodeMCU ESP8266 microcontroller were used in the system architecture to acquire real-time data, which is then transmitted to a web-based platform for monitoring and analysis. With the goal of forecasting energy demand and supporting energy optimization, predictive analytics applications

**assess both historical and current data. To ensure efficient and secure power management, the system also incorporates automated power management techniques with relay modules, magnetic contactors, and overload relays. To ensure systematic design, development, and validation, this study adopted a Hybrid Agile-V Model software development life cycle. Experts used McCall's Software Quality Factors to evaluate the system, while end users used the System Usability Scale (SUS). The evaluation results showed that the system's functionality, dependability, usability, and efficiency were all at acceptable levels. The proposed CPS-based intelligent energy management system offers an effective solution for improved operational intelligence, promotes sustainable energy practices in educational institutions, and enhances energy efficiency.**

**Keywords: Assistance, Emergency, GPS, System, Technology**

## I. INTRODUCTION

Industries have enhanced and modernized their facilities and current systems through constant innovations, inventions, and the emergence of new advanced technologies. Technological advances in computing and communications have led to the development of emerging technology called Cyber Physical Systems (CPS). CPS is the integration of the physical world with communication and computation capabilities. These systems are designed to achieve performance, robustness, reliability, and efficiency in interacting with the physical environment [1]. The term Cyber Physical System or CPS is defined as the integration of computational and physical processes within the framework of the Internet of Things [2]. With ongoing advancements in technology, a potential innovation [3], future industrial systems can be realized using cyber-physical systems (CPSs), which promote the coexistence of cyber and physical components in a network structure to collaboratively perform system functions [4].

In this digital age, the use of technology has marked a significant turning point for organizations and industries to enhance their existing systems. The rising costs and demand for energy have prompted many organizations to seek smart ways to monitor, control, and conserve energy [5]. However, it is widely understood that achieving energy savings in buildings is a challenging and complex task [6]. Traditional energy management systems used by electrical cooperatives often face issues such as high operating costs, inefficient power distribution, and inaccurate meter readings. To address these challenges, CPS (Cyber Physical Systems) Based Intelligent Smart Energy Management Systems (ISEMS) with Predictive Analytics have emerged as a state-of-the-art solution, integrating automation, real-time monitoring, and predictive analytics to optimize energy consumption.

Most industries rely on electrical consumption to ensure efficiency in their services and production. Electricity serves an important function, not only as a source of lighting but also as supporting energy for daily activities [7]. In the Philippines, as in many other countries, electricity plays a vital role in everyday life, powering everything from household appliances to industrial machinery. However, the increasing reliance on electrical energy presents the challenge of managing and optimizing its use, especially in environments where large-scale consumption is unavoidable, such as universities and other educational institutions [8]. Smart offices are gaining popularity due to their numerous benefits. These offices allow remote control of appliances, with office automation enhancing efficiency and profitability for employees [9]. Rapid technological advancements influence lifestyle habits, leading to greater electrical energy consumption. Monitoring the electricity meter in real time encourages users to use electricity more responsibly, thereby improving energy management efficiency [10]. Cyber Physical Systems (CPS) provide an outstanding foundation for developing advanced industrial systems and applications by integrating innovative functionalities through the Internet of Things (IoT) and the Web of Things (WoT), enabling the connection of physical operations with computing and communication infrastructures [11].

This paper explores the design and development of a CPS-Based Intelligent Smart Energy Management System integrated with predictive analytics. The proposed system aimed to improve energy efficiency, enhance operational intelligence, and contribute to the development of next-generation smart grids that are resilient, adaptive, and environmentally responsible.

### *Objectives of the Study*

The study Design and Development of a Cyber-Physical Systems (CPS)- Based Intelligent Smart Energy Management Systems with Predictive Analytics for the four (4) Campuses of Carlos Hilado Memorial State University specifically aimed to (1) design a CPS architecture that integrates real-time edge intelligence with cloud-

based analytics for flexible and scalable energy management. (2) Design and develop a web-based system to monitor and control electrical energy consumption. (3) Integrate predictive analytics algorithms to forecast both short-term and long-term energy demand using real-time and historical consumption data. (4) Assessed the system features and functions based on the Expert's evaluation using McCall's Software Quality Factors. (5) Determined and evaluated the effectiveness of the proposed features using the System Usability Scale (SUS) for end-users.

## II. MATERIALS AND METHODS

### A. Research Design

This study used the Descriptive Development Research (DDR) Approach. A descriptive research design, which involves collecting quantitative data, will be carried out through surveys. Descriptive research is defined as a research method used to describe the existing phenomena as accurately as possible [12]. Using descriptive research helps evaluate current energy usage patterns, predictive accuracy, system performance metrics, and surveys users to understand their awareness of and experience with CPS-based ISEMS. Conversely, development research design is a study approach that systematically develops, tests, and evaluates CPS-based ISEMS. This approach allows researchers to assess a web-based application and a CPS prototype. The process is often iterative and incorporates feedback from actual implementation.

### B. Respondents of the Study

The respondents of the study include the Administrators, such as the Executive Directors and College Deans, Staff, and selected Faculty from the four (4) Campuses of Carlos Hilado Memorial State University. These respondents are the direct and indirect users or end-users of the CPS (Cyber Physical Systems Based Intelligent Smart Energy Management Systems). Additionally, an expert group was included to test the system's functionality and reliability. The sample size of the respondents was determined using Slovin's formula for proper distribution, as shown in Table 1.

Table I. Summary of Evaluators of the CPS device and System

Evaluators Classification	Number of Evaluators
Expert's Group	5
Sample Population Group	
B.1. Administrator	5
B.2. Faculty & Staff	40
<b>Total</b>	<b>50</b>

### C. Research Instrument

The research instrument used in this study is a standardized questionnaire, McCall's Software Quality Factors, to evaluate software quality for experts. McCall's Software Quality Model was developed to assess the relationships between external factors and product quality criteria. The quality characteristics are classified into three main groups: 11 factors describing the external view of the software, 23 quality criteria representing the internal view, and metrics that define and provide a scale and measurement method. The number of factors was reduced to 11 for simplicity: Correctness, Reliability, Efficiency, Integrity, Usability, Maintainability, Testability, Flexibility, Portability, Reusability, and Interoperability.

Another instrument used is the System Usability Scale (SUS) for end users, as it is a standardized questionnaire applicable to CPS-based ISEMS. The SUS was specifically designed to provide designers and evaluators with a quick and accurate way to assess a system or product's perceived usability. The SUS data and scores can be analyzed to offer numerous metrics of perceived usability. The System Usability Scale (SUS) is undoubtedly the most widely used usability questionnaire. The standard version of the SUS consists of 10 items, each with five response options anchored by "Strongly Disagree" and "Strongly Agree." It is a mixed-tone questionnaire, with the odd-numbered items having a positive tone and the even-numbered items a negative tone [14].

### D. Sampling Technique

The researcher used purposive sampling in this dissertation. Purposive sampling involves selecting specific individuals within a population for a particular study or research project. It is defined as the intentional selection of

specific units, such as individuals, cases, or events, based on their relevance to the research question. This method allows researchers to gain deep insight into complex phenomena (Tajik *et al.*, 2025).

In this study, the researcher conducted an actual evaluation of the respondents by inviting them to test the CPS device and its system functionality, performance efficiency, and accessibility. Using purposive sampling, the researcher gathered five (5) IT experts, five (5) administrators, and forty (40) faculty and staff members of Carlos Hilado Memorial State University.

#### E. System Architecture

The system architecture diagram of a Cyber Physical Systems (CPS)-Based Intelligent Smart Energy Management System with Predictive Analytics shows the process where only one user, the admin, monitors energy consumption using the CHMSU-ISEMS web application.

The system gathers real-time energy data through the physical layer using an energy sensor and a PIR (Passive Infrared) sensor. The energy sensor measures electrical parameters such as voltage, current, and power consumption, while the PIR sensor detects occupancy to decide whether appliances should stay on or be turned off if not in use. These sensors connect to a NodeMCU ESP8266 microcontroller, which processes the sensor data locally. The microcontroller sends the collected data to a central server via an internet connection. The server receives and stores the sensor data, allowing for further analysis. At this point, the predictive analytics module analyses historical and real-time data to forecast future energy use and identify the university's consumption patterns. Based on these predictions, the system can anticipate peak demand periods and suggest or automatically activate energy-saving strategies.

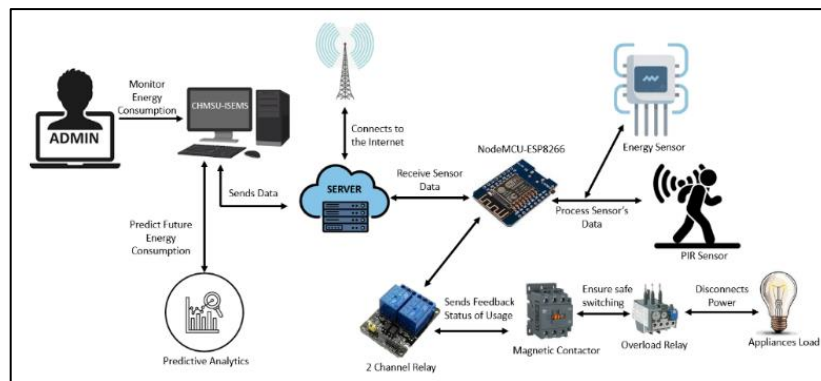


Fig. 1. Assembly Diagram of CPS-Based ISEMS with Predictive Analytics

The control system operates using actuators such as a 2-channel relay, a magnetic contactor, and an overload relay. The server sends feedback signals to the relay module, which then controls the magnetic contactor that safely connects or disconnects power to the appliance's load. The overload relay protects by automatically disconnecting power or shutting off the room's appliances, ensuring safety and protecting equipment. The CPS-based system continuously monitors, predicts, and optimizes energy use while maintaining operational safety and efficiency through a closed-loop interaction of sensing, data processing, predictive analysis, and automated control.

#### F. Software Life Cycle Model

Software organizations can greatly improve their output quality if they have a clearly defined and documented software process, along with the right techniques and tools to evaluate its effectiveness. Without a well-defined process, it is impossible to measure success or understand how to improve development capabilities.

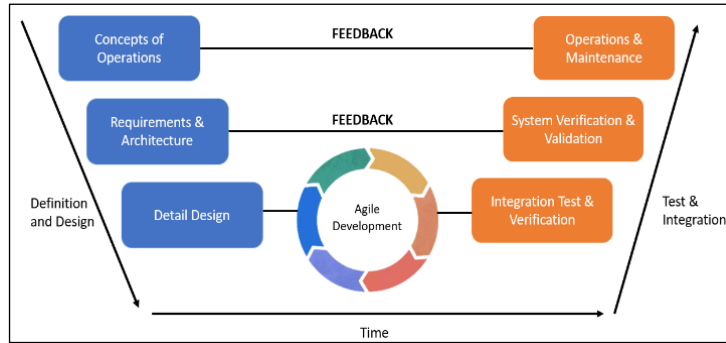


Fig. 2. Hybrid Agile V-Model Methodology

The diagram illustrates how Agile development approaches and the V-Model were combined to create the recommended cyber-physical system. The left side depicts the definition and design phases, including concepts of operations, requirements analysis, system architecture, and detailed design. To systematically and continuously incorporate predictive analytics and control functionalities, the central development phase employs Agile iterations. Each development stage is carefully reviewed against its corresponding design phase, shown on the right side, which includes testing, integration, verification, validation, and operations. To maintain system safety and reliability, ongoing feedback enables adaptability and optimization.

1.) *Concepts of Operations*

This is the first phase of the Hybrid Agile V-Model, in which the system's concepts, goals, and objectives—such as its functionality, usability, and reliability—are established for CHMSU stakeholders. The Concept of Operations provides a crucial foundation for managing the design, development, and assessment of systems. It helps create a shared understanding of system requirements and operational expectations among users, developers, and stakeholders. The Concept of Operations details how sensors, controllers, software platforms, and users work together to monitor energy consumption, analyze data, and automatically optimize energy use in real time for complex systems like Cyber-Physical Systems (CPS)-based Intelligent Smart Energy Management Systems with Predictive Analytics. This systematic description ensures the achievement of the system's objectives, efficient implementation, and effective operations.

2.) *Requirements and Architecture*

During this phase, functional and non-functional requirements are analyzed and translated into a system architecture. It involves defining the modules to be designed for the system, including data flows and processes, hardware-software interactions, communication protocols, and system constraints.

2.a) *Context Flow Diagram*

A context flow diagram is a type of data flow diagram that simply shows the data flow at the top level, or Level 0. The functions of an entire system in terms of its interactions with external entities are defined at this stage by a single observable process node. In this study, the background flow diagram illustrates and explains the mechanism of the CPS-based ISEMS with Predictive Analytics, enabling a full understanding of the device implementation

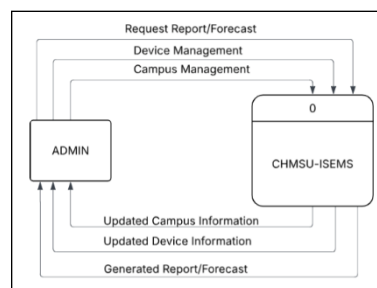


Fig. 3. Context Flow Diagram

### 2.a) Data Flow Diagram

When creating applications, a DFD (Data Flow Diagram) describes where the data comes from, where it goes within the system, and how it is stored. Therefore, data flows interact with the final storage. The Data Flow Diagram illustrates the overall operation and functionality of the CPS-Based ISEMS with predictive analytics, helping users understand its processes.

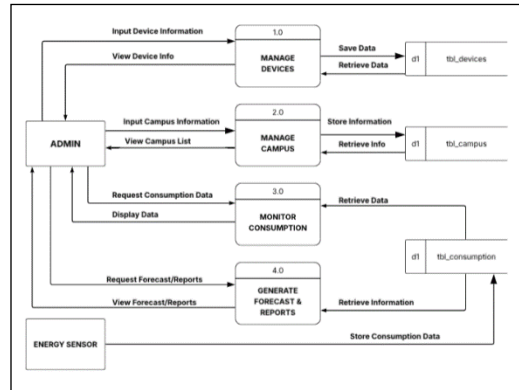


Fig. 4. Data Flow Diagram

### 3.) Detail Design

In this phase, each module is refined into more detailed specifications, including the user interface, database design, control logic, and algorithms.

#### 3.a) Assembly Diagram

The design and development of a Cyber-Physical Systems (CPS)-based intelligent smart energy management system, intended for automated control and real-time monitoring of electrical consumption, is illustrated in the diagram. The system's main controller and processing unit is the NodeMCU ESP8266 microcontroller. It is powered by a regulated power adapter connected via a USB cable. Data acquisition and load control are facilitated by the NodeMCU's connections to various components, including the PZEM004T energy sensor, a PIR motion sensor, and a relay module.

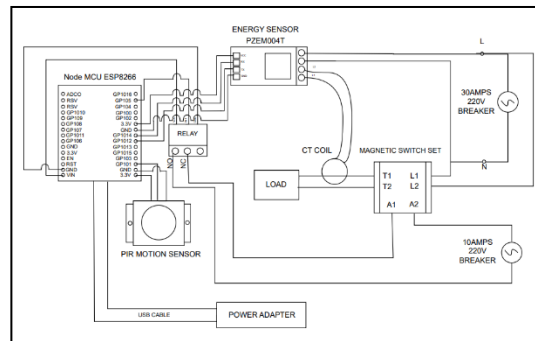


Fig. 5. Assembly Diagram of CPS-Based ISEMS

The main power line is protected by a 30A circuit breaker, which initially receives 220V AC power. To measure voltage directly, the PZEM004T energy sensor is connected to the supply line; to measure current, a current transformer (CT) coil is clamped around the live conductor leading to the load. These observations enable real-time calculations of power and energy consumption. For monitoring and analysis, the energy data is transmitted via serial communication to the NodeMCU.

A magnetic switch set (contactor) controls the load and ensures safe switching of high-current devices. The contactor's coil terminals are A1 and A2, its input terminals are T1 and T2, and its output terminals are L1 and L2. The contactor coil is energized by the relay module after receiving a signal from the NodeMCU. When energized, the contactor allows electrical power to flow by closing the circuit between the supply and the load. When the signal is turned off, it disconnects the load and opens the circuit. The control circuit includes a 10A circuit breaker to protect low-power components from overloads or short circuits.

The NodeMCU also features a PIR motion sensor for occupancy detection. To save energy, the system can automatically turn on the load when motion is detected and turn it off after a set period without motion. Overall, the diagram shows a system that combines sensing, processing, protection, and actuation to enable automated switching, smart monitoring, and efficient energy management.

### 3.b) Orthographic Diagram

The front view and structured layout of the CPS-Based Intelligent Smart Energy Management System are shown in the orthographic diagram, which also makes clear how all the main parts are connected and arranged within the control enclosure. The system is divided into three primary sections, as shown in the diagram: load switching, sensing and control, and power supply and protection.

The main protection device for the incoming AC supply is the 30A, 220V circuit breaker located in the upper right section. This breaker allows the live (L) and neutral (N) wires to enter, safeguarding the entire system from overload and short circuit conditions. The power line then disconnects from the magnetic switch set and the energy monitoring devices. The control and auxiliary circuits are protected from excessive current by the 10A, 220V breaker below it.

The PZEM004T energy sensor, which is directly connected to the AC supply for voltage measurement, is in the center of the diagram. Current sensing is achieved without direct electrical contact by clamping a CT (Current Transformer) coil around the live conductor leading to the load. The NodeMCU ESP8266 receives real-time data on voltage, current, power, and energy from the PZEM004T via a serial communication cable. This setup maintains electrical isolation and safety while enabling accurate monitoring.

The NodeMCU ESP8266 serves as the main controller in the left sections. It is powered by a regulated power adapter connected through USB. The energy sensor module and PIR motion sensor send input signals to the microcontroller. It then provides control signals to the relay modules according to the programmed logic. The relay modules separate the high-voltage power circuit from the low-voltage control circuit, acting as intermediate switching devices.

The contactor, or magnetic switch set, is shown as the primary load-switching device in the lower-right section. Through the relay module, its coil terminals (A1 and A2) are energized. The contactor's main terminals (T1–L1 and T2–L2) close when it is activated, enabling power to flow from the supply to the load. The circuit opens and disconnects the load when deactivated. This setup guarantees that low-voltage signals from the microcontroller are used to securely regulate high-current loads.

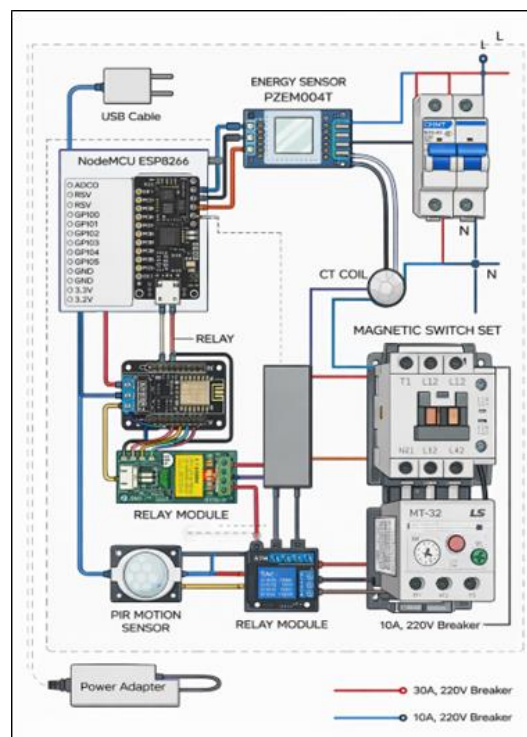


Fig. 6. Orthographic Diagram for CPS-Based ISEMS with Predictive Analytics

Overall, the orthographic diagram provides a clear and well-organized view of the system's physical layout and wiring. It illustrates how energy parameters are measured, how the microcontroller processes control decisions, how power flows from the source through safety devices, and how a contactor switches the load. The diagram highlights that the sensing, processing, protection, and actuation components are integrated into a single Cyber-Physical Energy Management System.

### 3.c) User Interface

Figure 7 displays the login page. On the login page, the user will enter the username and password to access the system.

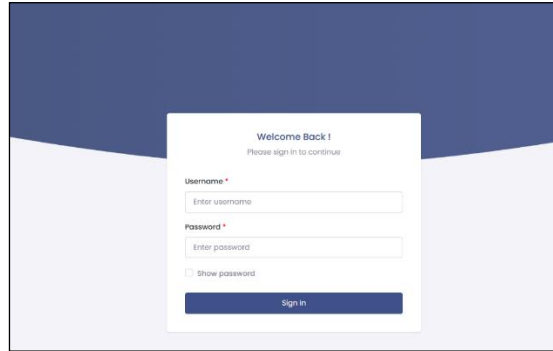


Fig. 7. Log-in Page

Figure 8 displays the energy consumption dashboard. This is where the administrator can monitor the daily energy use of each room. They can select campuses, and it will show their energy usage.

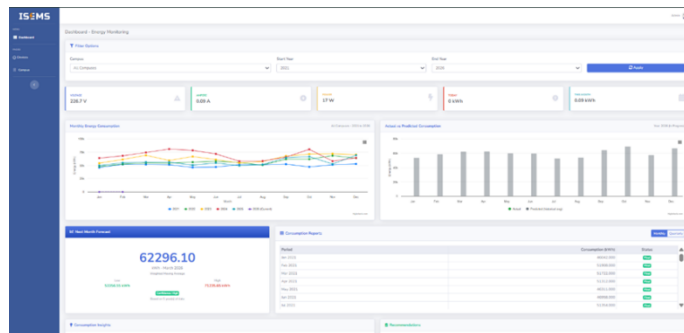


Fig. 8. Dashboard -Energy Monitoring Page

Figure 13 displays the Manage Devices Page, where the administrator can track the locations of devices used by the University.

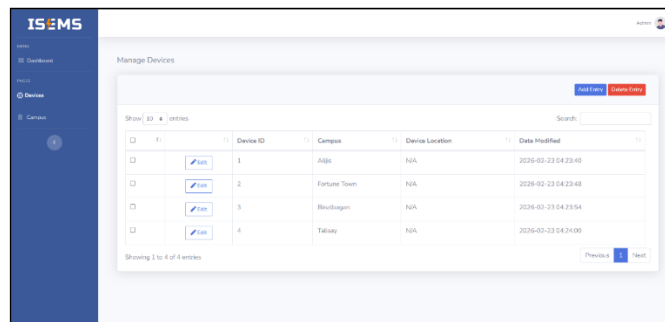


Fig. 9. Manage Devices Page

Figure 10 displays the Energy Consumption Dashboard. Here, the admin can monitor consumption reports, the upcoming forecast, and consumption-related insights and recommendations.

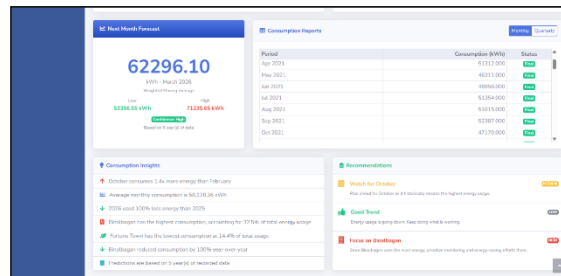


Fig. 10. Dashboard for Energy Consumption

#### 4.) Agile Development

The Agile Development process is an iterative cycle in which each sprint includes coding, unit testing, continuous integration, and feedback-driven refinement. Throughout the development process, developers may adapt to changes and improve the system, given agile development's focus on flexibility, continuous improvement, and incremental progress. Agile enables incremental development through short periods of work called sprints, in contrast to traditional development methodologies that follow a strict sequential framework. Developing specific system features, testing them, and refining them according to reviews are among the primary goals of each sprint.

The web-based monitoring application, sensor integration, predictive analytics module, and automated control mechanisms are just some of the features that the researchers carefully developed and refined during the creation of the CPS-Based ISEMS using the Agile process. To ensure that newly developed components work seamlessly with existing modules, developers implemented algorithms, conducted unit testing, and performed continuous integration at each iteration. The system was continuously updated throughout this iterative process, ensuring that the CPS's software and hardware components function properly together. Using the iterative approach allows for quick adaptation to system changes and ongoing improvement. This gives the developer an opportunity to update the software in line with the study's system objectives. During Agile development, thorough testing has been carried out to ensure that the software and CPS device achieve full functionality and performance.

#### 5.) Integration Test and Verification

In this phase, Agile sprints involve integrating and testing individual modules to ensure they align with the software's objectives, functionality, and processes. This phase ensures that the system's components and features function properly during integration and that it conforms to the specified design standards and requirements. Integration testing and verification are essential for maintaining seamless interaction and integration among sensors, microcontrollers, servers, and the web-based monitoring system, given that CPS comprises both hardware and software components. Through testing, the developer could receive feedback and improve the system. Errors were identified and updated. Identifying interface errors, communication interruptions, and data discrepancies that may occur when modules interact is the fundamental objective of integration testing. Connecting the energy sensors, PIR motion sensors, NodeMCU ESP8266 microcontroller, relay modules, and a web-based application was part of the integration testing for the CPS-Based ISEMS. In the process, the developers validated that the sensors' real-time data was correctly transmitted to the microcontroller, processed appropriately, and then forwarded to the central server for storage and analysis. The predictive analytics module's ability to accurately evaluate the acquired information and produce energy consumption predictions was also verified through integration testing.

#### 6.) System Verification and Validation

In this phase, to confirm accuracy, performance, security, dependability, and usability, the entire system is evaluated against the original specifications and architecture. In system development, system verification and validation are essential processes to ensure that a system is created accurately and meets the users' intended requirements. To ensure that the developed system functions in accordance with the specified design and fulfills the project's objectives, these processes are executed throughout the system development life cycle. System verification is the process of determining whether the system has been developed in accordance with the technical specifications, system architecture, and design requirements. During development, verification focuses on ensuring that every

module, subsystem, and component is correct. To ensure the system operates as intended and all components are correctly connected, this process typically includes code reviews, unit testing, integration testing, and system testing. Verification indicates that the sensors, microcontrollers, communication modules, predictive analytics algorithms, and control mechanisms in a Cyber-Physical Systems (CPS)-Based Intelligent Smart Energy Management System are functioning as expected and interact with other components. System validation, on the other hand, is the process of assessing the system to verify whether it achieves the requirements and expectations of stakeholders and end users. The primary objective of validation is to determine whether the system successfully resolves the issue for which it was developed. This involves evaluating the system's overall efficiency, performance, usability, and effectiveness in simulated or real-world settings. Validation in this project involves evaluating the CPS-based Intelligent Smart Energy Management System to assess its ability to accurately monitor energy use, forecast energy demand, and optimize energy usage on university campuses. Based on the system's objectives and features, the system has been validated and recognized. These processes validate that the system not only meets technical requirements but also accomplishes its stated objective of enhancing energy monitoring, control, and optimization in the university.

### 7.) *Operations and Maintenance*

The final phase of the system development life cycle is operations and maintenance, during which the developed system is implemented, used by end users, and continuously monitored to ensure accurate operation and long-term viability. The system enters operational use after deployment. Performance improvements, issue fixes, upgrades, and ongoing monitoring are carried out. Iterative improvements are made possible by feedback loops that connect back to earlier stages. This phase focuses on the system's utilization in the real-world environment as well as its regular maintenance, updates, and troubleshooting after deployment.

Operations refer to the day-to-day functioning and utilization of the system by authorized users or administrators. During this phase, the system is fully operational and executing its intended functions, including process monitoring, control, and management. The web-based application for the Cyber-Physical Systems (CPS)-Based Intelligent Smart Energy Management System (ISEMS) continuously monitors electricity use across the campuses. Energy usage data is displayed on the monitoring dashboard after the system processes real-time sensor data, including motion detectors and energy meters, via the microcontroller and server. To make accurate decisions about energy usage and optimization procedures, administrators may review consumption patterns and analyze system alerts.

On the other hand, maintenance defines the continuous process of updating, maintaining, and improving the system after its initial deployment. Through time, maintenance ensures the system's dependability, security, and effectiveness. Troubleshooting software defects, modifying predictive analytics algorithms, enhancing system features, and ensuring compatibility with new hardware or software technologies are among the activities included in this phase.

## III. RESULTS AND DISCUSSION

Regarding the design and development of the Cyber-Physical Systems (CPS) Based Intelligent Smart Energy Management System for Experts' Evaluation, the system received an overall average score of 4.79, categorizing it as "Good." This suggests that, overall, the system performs reliably and meets most quality standards.

Most of the evaluated criteria—such as auditability, accuracy, completeness, communication commonality, conciseness, consistency, observability, operability, security, data commonality, decomposability, and execution efficiency—received an average score of 4.8, all rated as “Good.” These consistent scores indicate that the system is well-balanced across various technical and usability aspects.

Several criteria received the highest rating of 5 (Very Good), including simplicity, traceability, expandability, generality, and modularity. This shows that the system is easy to understand, adaptable, scalable, and well-structured, which are crucial for long-term maintenance and growth.

On the other hand, a few areas received slightly lower scores, though they still fall within the “Good” range. These include self-documentation (4.4), training (4.6), controllability (4.6), error tolerance (4.6), and hardware independence (4.6). These results suggest minor opportunities for improvement, especially in making the system more user-friendly in terms of documentation, ease of learning, error handling, and versatility across different hardware setups.

For the end-users' evaluation, using the System Usability Scale (SUS) to assess respondents' perceptions of the devices and system, the final score was 83.72 (Grade A), which is considered Excellent in effectiveness based on the Verbal Interpretation.

#### IV. CONCLUSIONS

Therefore, concluded that the design of a CPS architecture integrating real-time edge intelligence with cloud-based analytics enables flexible and scalable energy management. The CPS device functions correctly during end-user testing. Communication between sensors and the network achieves its goals, giving users a clear understanding of the Intelligent Smart Energy Management Systems. Furthermore, the design and development of a web-based system for monitoring and controlling electrical energy consumption. Given the positive evaluation results, analyzing the deployment of a CPS-Based ISEMS with Predictive Analytics is highly appropriate following the Expert's review. Lastly, the Integrate predictive analytics algorithms to forecast both short-term and long-term energy demand using real-time and historical consumption data. Because of its Excellent results in evaluating the system's and equipment's effectiveness and performance, the study was considered highly appropriate by the university's administration, faculty, and staff.

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## REFERENCES

- [1]. Krishnan, N. ., & Karthikeyan, M. . (2017). 2017 IEEE International Conference on Computational Intelligence and Computing Research (ICIC): 2017 December 14-16 : venue: Tamilnadu College of Engineering, Coimbatore-641 659, Tamilnadu, India. IEEE.
- [2]. Al-Salman, H. I., & Salih, M. H. (2019). A review Cyber of Industry 4.0 (Cyber-Physical Systems (CPS), the Internet of Things (IoT) and the Internet of Services (IoS)): Components, and Security Challenges. *Journal of Physics: Conference Series*, 1424(1). <https://doi.org/10.1088/1742-6596/1424/1/012029>
- [3]. Farooq, M. U., Waseem, M., Mazhar, S., Khairi, A., & Kamal, T. (n.d.). A Review on Internet of Things (IoT). In *International Journal of Computer Applications* (Vol. 113, Issue 1).
- [4]. Leitão, P., Karnouskos, S., Ribeiro, L., Lee, J., Strasser, T., & Colombo, A. W. (2016). Smart Agents in Industrial Cyber-Physical Systems. *Proceedings of the IEEE*, 104(5), 1086–1101. <https://doi.org/10.1109/JPROC.2016.2521931>
- [5]. Al-Ali, A. R., Zualkernan, I. A., Rashid, M., Gupta, R., & Alikarar, M. (2017). A smart home energy management system using IoT and big data analytics approach. *IEEE Transactions on Consumer Electronics*, 63(4), 426–434. <https://doi.org/10.1109/TCE.2017.015014>
- [6]. Marinakis, V., & Doukas, H. (2018). An advanced IoT-based system for intelligent energy management in buildings. *Sensors (Switzerland)*, 18(2). <https://doi.org/10.3390/s18020610>
- [7]. Suherman, R., Nataraja, P. K., Pratama, A., & Kahfi, A. H. (2023). ELECTRICITY MANAGEMENT SYSTEM WITH TECHNOLOGY INTERNET OF THINGS. *Jurnal Techno Nusa Mandiri*, 20(2), 95–101. <https://doi.org/10.33480/techno.v20i2.4520>
- [8]. Muqheet, H. A. U., & Ahmad, A. (2020). Optimal scheduling for campus prosumer microgrid considering price based demand response. *IEEE Access*, 8, 71378–71394. <https://doi.org/10.1109/ACCESS.2020.2987915>
- [9]. Tayyeb, M., Hassan, S. Z., Kamal, T., Riaz, U., Zahoor, A., Khan, M. A., ... & Ahmad, D. (2019, July). Sensor Based Smart Office Control System. In 2019 International Conference on Electrical, Communication, and Computer Engineering (ICECCE) (pp. 1-5). IEEE.
- [10]. Jati, F. W., Bhaskara, K. J., Hasibuan, F. C., & Irawan, B. (2022). Prediction System on Electricity Consumption using Web-Based LSTM Algorithm. [CEPAT] *Journal of Computer Engineering: Progress, Application and Technology*, 1(02), 24. <https://doi.org/10.25124/cepat.v1i02.5227>

- [11].Lu, Y. (2017). Cyber physical system (CPS)-based industry 4.0: A survey. *Journal of Industrial Integration and Management*, 2(3). <https://doi.org/10.1142/S2424862217500142>
- [12].Atmowardoyo, H. (2018). Research methods in TEFL studies: Descriptive research, case study, error analysis, and R & D. *Journal of Language Teaching and Research*, 9(1), 197–204. <https://doi.org/10.17507/jltr.0901.25>
- [13].Ibrahim, A. (2016). Definition Purpose and Procedure of Developmental Research: An Analytical Review. *Asian Research Journal of Arts & Social Sciences*, 1(6), 1–6. <https://doi.org/10.9734/arjass/2016/30478>