# INTEGRATING A RE-PROGRAMMABLE MICROCONTROLLER FOR EFFICIENT ROOM ENERGY MANAGEMENT

*** Arlene a. Baldelovar, Paul Joseph M. Estrera, Ulrich Lee F. Uy**
University of Science and Technology of Southern Philippines
* For correspondence; Tel. + (63)912-837-7007, *arlene.baldelovar@ustp.edu.ph
*For correspondence; Tel. + (63) 9158120273, *E-mail: paul.estrera@ustp.edu.ph

***ABSTRACT:*** *This research study focuses on the development and evaluation of a Room Energy Management System integrated using a Re-programmable Microcontroller. The system incorporates a control monitoring system with a loading circuit for effective monitoring and switching of electrical loads. The study employed a Prototyping Based Methodology anchored in the Software Development Life Cycle (SDLC) method, encompassing the phases of planning, analysis, design, and implementation. The system was evaluated to assess its software quality, including functionality, reliability, maintainability, efficiency, usability, and portability. The evaluation involved personnel from the Deans, Plant, Facility office, and Security Guard assigned in the college. The results of the evaluation demonstrated excellent performance in terms of functionality, reliability, usability, efficiency, maintainability, and portability for both the software and hardware aspects of the Room Energy Management System integrated with a Re-programmable Microcontroller.*

**Keywords** : Re-programmable Microcontroller, Real-time data, Temperature control, Energy consumption

## I. INTRODUCTION

In today's era of automation, advanced programmable controllers have revolutionized various aspects of daily life, including homes, offices, schools, and industries. One area that benefits from this technological advancement is the implementation of a Room Energy Management System integrated using a re-programmable microcontroller. This system plays a crucial role in efficiently managing electronic equipment, specifically lights and fans, in every classroom, laboratory, and office within the entire building of St. Therese-MTC Colleges. The study primarily focuses on three key offices: the Physical Plant and Facilities office, the Deans Office, and the security guards.

The Physical Plant and Facilities office monitors and controls electronic equipment, such as lights, fans, and other electronics, based on predefined schedules set by the Deans and Department Heads. This automated system utilizes a centralized database, allowing for easy control and switching of electronic equipment without the need for excessive manual intervention.

The Dean's Office is tasked with establishing real-time schedules for classrooms and offices. They can update the status and address any concerns related to the electronic equipment, which can be accessed from the main server assigned to the Physical Plant and Facilities office.

The security guards utilize cellphones to monitor classrooms, laboratories, and offices during their patrols. St. Therese MTC-Colleges, a prestigious maritime institution in Iloilo City, offers a wide range of programs and fields of study, from basic education to college degrees. The college houses numerous classrooms, laboratories, and offices with excellent facilities, necessitating secure monitoring and control of electronic equipment.

Currently, manual control methods are employed, leading to inefficiencies and unnecessary time consumption. Staff members are required to physically check each room throughout the college campus, resulting in extra effort. Moreover, factors such as rising electricity costs and the need for onsite maintenance operations further underscore the need for an advanced monitoring and control system.

The implementation of a Room Energy Management System at St. Therese MTC-Colleges' Magdalo Site aims to address these challenges by providing an automated and centralized solution.

The system will not only optimize energy consumption but also reduce operational costs associated with manpower and maintenance.

**Statement of the Objectives**

***General Objective***

This study aimed to develop Room Energy Management System integrated using a Re-programmable Microcontroller.

***Specific Objectives***

Furthermore, this study aims to:

1. manage room schedule
2. develop a system that can manipulate the power load of a certain classroom using software and web application
3. controlled and Monitor power classroom operation
4. Evaluate the developed software in terms of: Functionality, Reliability, Usability, Efficiency, Maintainability, and Portability

**Conceptual Framework**

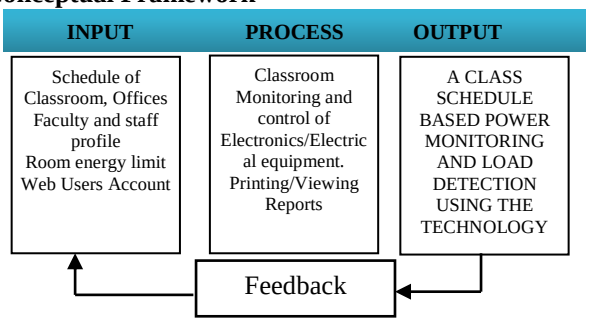


**Figure 1. The Input-Process-Output of Room Energy Management System integrated using Re-programmable Microcontroller**.

Figure 1. Shows the flow of the research process. The areas are composed of inputs which are the data elements needed as a basis for the proposed *of* Room Energy Management System integrated using a Re-programmable Microcontroller of St. Therese MTC-Colleges Magdalo Site and the problems encountered and feedback from the users of the present system. Conduct Interviews and observations, were the instruments used in data gathering.

**REVIEW OF RELATED LITERATURE**

This related literature and related systems in which the study is based. These are concepts, theories and techniques in the selected studies that are beneficial to the insight of the present study.

The paper presents a practical method for modeling and solving a dynamic resource allocation of automatic scheduling problem using a forward chaining heuristic approach, in the case of an undergraduate Student's Thesis and Project presentations timetable. Poor scheduling practices would cause double-assignations of lecturers, prolonged postponement and cancellations of presentations as well as inefficient use of time and resources. This method will follow pre-assigned logic rules and algorithms to fit the optimization criteria's [1].

Primarily in large commercial buildings, the use of Building Automation System (BAS) is to monitor and control various building systems, including, heating, ventilation and air condition (HVAC) and lighting. The energy management systems (EMS) or energy management and control systems (EMCS) or direct digital control (DDC) systems are sometimes referred to as BASs. BAS contained of a set of hardware and software integrated into a single architecture to monitor and control buildings' HVAC systems. BAS may also help to control or monitoring of lighting, security, and fire systems in the building. To provide thermal conditioning and ventilation services, while diminishing maintenance and operating costs are the objectives of HVAC controls [2].

The utilization of environmentally responsive workstations (ERWs) fosters an enhanced sense of comfort and autonomy among employees regarding their workspaces. Through desktop control units, employees have the ability to personalize their environment by adjusting temperature, lighting, air flow, and acoustic settings to suit their preferences. Additionally, the automation of the building management system ensures comprehensive integration of security and fire systems. Operations personnel can leverage available cost reports and trend analysis to optimize the overall efficiency of the facility.

A Building Management System (BMS) is a computer-based control system that manages and controls the mechanical and electrical services of a single building, up to an entire area of buildings. If the implementation and operation of a BMS is successful then it allows the building performance to be developed and energy savings to be achieved. In order for the facilities to maintain a comfortable environment in all buildings so it requires some form of mechanical and electrical services such as boilers, heating and ventilation plant. This is being controlled in order to ensure that, for example, for you to maintain comfortable conditions in the occupied space then you have to provide sufficient heating. In some buildings, services are controlled by manual switches, time clocks and thermostats which provide "on" and "off" signals in order to operate the building services as required. However, in many buildings, BMS is used to make sure that the variable signal responses are in an efficient and flexible manner to match a gradually changing environment.

The vital role of BMS is to facilitate the operation and evaluation of a "green building." It helps in the control of various building design, as well as by recording building operating data and considering other important information. When mixed with various building systems such as heating, ventilating and air conditioning (HVAC) equipment, security access control systems and lighting are being obtained. A BMS is composed of sensing devices, software and microprocessor-based controllers which are used for monitoring and controlling equipment. The controllers communicate with each other and provide a centralized PC-based operator interface.

Energy Management and Control System (EMCS) is a centralized system that receives and monitors information from various sensors. It allows the building owner to control actions based on the sensors' outputs. EMCSs may be very simple and limited only in performing the system for monitoring and data visualization or they may merge all building systems and include automated control. An EMCS also enables automation of different physical tasks that would be performed manually at a specific piece of equipment such as operating dampers daily to keep them from sticking[3].

A computerized intelligent network of electronic devices will monitor and control a large number of individual systems by the help of Building Automation system. By using intelligent automated systems, it lessens the energy and maintenance costs in the building that can be made more secured. [4]

A control system with loading circuit to control the monitoring and switching of electrical loads on and off. A current transformer was used for monitoring the real status of the electrical loads.[5]

The researcher employed the Software Development Life Cycle (SDLC) method in designing the system. The researcher had undergone the different phases of SDLC such as planning, analysis, design, and implementation.

The purpose of this project is to acquire the remote electrical parameters like Voltage, Current and Frequency and send these real time values over GSM network using GSM Modem/phone along with temperature at power station. This project is also designed to protect the electrical circuitry by operating an Electromagnetic Relay. This Relay gets activated whenever the electrical parameters exceed the predefined values. The Relay can be used to operate a Circuit Breaker to switch off the main electrical supply. User can send commands in the form of SMS messages to read the remote electrical parameters. This system also can automatically send the real time electrical parameters periodically (based on time settings) in the form of SMS. This system can be designed to send SMS alerts whenever the Circuit Breaker trips or whenever the Voltage or Current exceeds the predefined limits. This project makes use of an onboard computer which is commonly termed as microcontroller. This onboard computer can efficiently communicate with the different sensors being used. The controller is provided with some internal memory to hold the code. This memory is used to dump some set of assembly instructions into the controller. And the functioning of the controller is dependent on these assembly instructions. The controller is programmed using Embedded C language.[6]

The paper presents a microcontroller-based power management system (PMS), designed for the online operation of an experimental low voltage microgrid equipped with a battery storage system and two power supplies: a kilowatt

(kW)-class proton exchange membrane (PEM) fuel cell (FC) and a photo-voltaic (PV) module emulator, both connected to a low voltage ac node. The connections of the energy sources to the common ac bus make use of power inverters with specific functionalities. The ac node feeds electric active and reactive load emulators able to reproduce programmable profiles. The automatic PMS provides the microgrid monitoring and the FC power scheduling in both grid-connected and islanded operating conditions. The paper describes the structure and functionalities of the PMS as well as a specific experimental investigation aimed at assessing the dynamic performance of the microgrid in islanded conditions.[7]

The paper proposes a smart system for controlling the air-conditioners and lighting system in a lecture hall. The idea is to read the information of person who is entering the lecture hall by using a Radio Frequency Identification (RFID) reader and activate the Air-Conditioning and Mechanical Ventilating System (ACMV) and lighting system. The system consists of a Radio Frequency Identification (RFID) reader, microcontroller and a Graphical User Interface (GUI) that will be used as a secondary control panel substituting the RFID reader. By applying this system, the energy consumption is reduced compared to the conventional method. As a preliminary result, a 35% reduction in the energy consumption of the air-conditioning and lighting system in UMP lecture room has been achieved. [8]

**Methodology of the Study**

After in-depth analysis of the current system, a new system design was realized. Analysis includes thorough study and observation concentrated on the monitoring of lights and other appliances in every classroom and offices.

***Project Description***

This proposed Room Energy Management System integrated using a re-programmable microcontroller will be incorporated in the main server and the web application to monitor every room and can control to switch on/off. Main Server will be located at the Physical and Plant Facilities office.

***Activity Diagram***

Activity Diagram for the main screen for the dean's office as shown in Figure 1. was used to detail conditions where parallel processing may occur in the implementation of some activities.

The Deans office is responsible to encode the Faculty List that duly assigned in every classroom, room schedule, set the energy limit in the office and classroom and the web user (Security Guard) for patrolling in every classroom and offices.

**New Room Schedule**

Activity Diagram for New Room Schedule show the Dean personnel is only authorize to add schedule every room. By selecting room Nos, Selecting date & time Action and selection action on/off status.

Add New Schedule

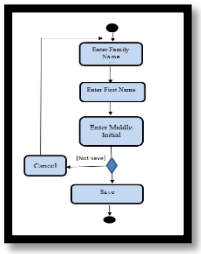


**Figure 2. Activity Diagram Add New Schedule**

Activity Diagram for Faculty List shown in figure 2. This enter the family name, first name, and middle initial also select cancel and save option.

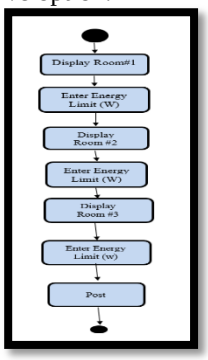


**Figure 3. Activity Diagram Add Faculty List**

Room Energy Limit

Activity Diagram for Faculty List shown in figure 4. This update every room assigned like Room #1, Room #2 and Room #3 with their energy limit in terms of watts.

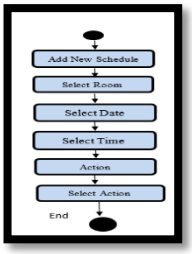


**Figure 4. Activity Diagram Add room Energy limit**

***Use Case Diagram***

The Use Case Diagram in Figure 2 demonstrates as the end user (Dean Office, Physical plant and the Security Guard). The Deans office manages the user account of the web users, add new schedule of the classroom for monitoring, register list of faculty, assign energy limit per classroom and different offices. In managing the web user account, the admin extends its function to add, edit and update user account.

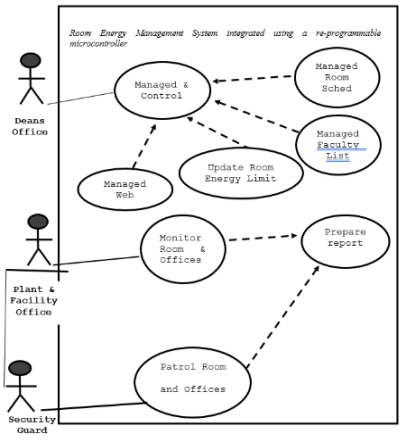


**Figure 5. The Room Energy Management Use Case Diagram**

### *Class Diagram*

A diagram is mainly designed for developers to provide the conceptual model and architecture of the system being developed. Typically, a class diagram consists of more than one class or all the created classes for a system.

It is a type of structure diagram and looks similar to a flow chart having three main parts illustrated in rectangular boxes. The first or top part specifies the class name, the second or middle specifies attributes of that class and the third or bottom section lists the methods or operations that specific class can perform.

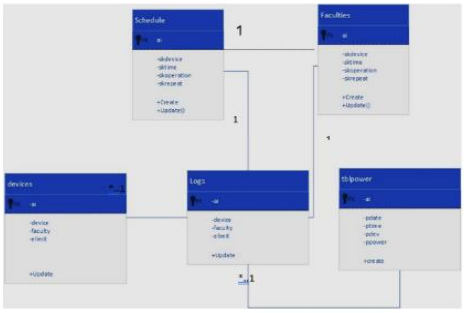

**Figure 6. A Class Diagram of Room Energy Management System integrated using a Re-programmable Microcontroller.**

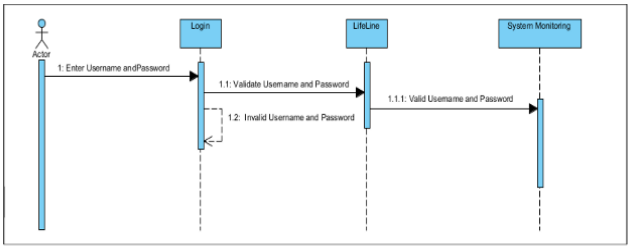


**Figure 7. The sequence Diagram for Log in Room control monitoring**

### *Sequence Diagram*

Sequence Diagram emphasizes the monitoring of room based on scheduled (room#, date, and time) whether it is on/off status. The system also monitor the energy consumed with used of personal computer.

There are two (2) ways to display the room monitoring (on/off)

1. Loading with the used of cellphone
   In Figure 7, the user must enter his or her username and user password. The system will validate the user account if it is valid or invalid. If it is invalid, the user will enter his/her username and password again until it is correct. Once it is valid, the user can already access the room control monitoring.

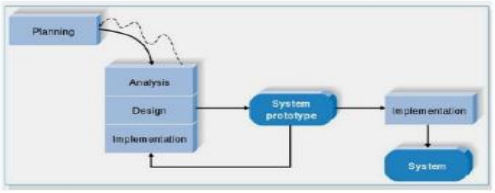


**Figure 8. Prototyping Methodology**

The researcher used the Prototyping Based Methodology in developing the system. The System emphasizes modest, iterative application development in which every recapitulation is a complete software project, together with planning, analysis, design, system prototype implementation, and system.

***Planning phase***.

The study was performed by recognizing problems, setting the objectives, the probable solution, the scope and limitations of the system. Additional data needed were gathered through strategies regarding the manual operation.

***Analysis Phase.***

In the analysis phase, end user of the system requirements are analyzed and the system goals converted into the defined system functions that the organization intends to develop.

### *Class Diagram*

A diagram is mainly designed for developers to provide the conceptual model and architecture of the system being developed. Typically, a class diagram consists of more than one class or all the created classes for a system.

***Design Phase***. focuses on high level design like, what programs are needed and how they going to interact. This involved in designing database consist of creating tables, graphical user interfacing of the system

***In the implementation phase***. the different modules of the system were integrated to build the entire system. The software was put into a test operation with the programmers and end users to gather feedback on the features and operations of the system.

### *Project Evaluation*

The system was evaluated by thirty (15) respondents to validate its conformance to software quality model. This model was accepted for the evaluation of the potential user to manipulate the system.

**Table 1. Likert Scale Rating**

| Rating | Description |
|---|---|
| 4.21 - 5.00 | Excellent |
| 3.41 - 4.20 | Very Good |
| 2.61 - 3.40 | Good |
| 1.81 - 2.60 | Poor |
| 1.0 1.80 | Very Poor |

**Data Gathering Instrument**

The evaluation criteria of the software for the proposed system will be rated based on product quality model, considering the criteria such as performance efficiency, compatibility, usability, reliability, security, maintainability, efficiency,

## RESULTS AND DISCUSSIONS

The result collected the findings of the research on the performance of the Room Energy Management System. The presentation includes the description of the developed system as well as the analysis of the data gathered on the evaluation of the developed system in terms of its product quality and quality in use.

**Table 2. Software's overall result of evaluation**

| Variables | Mean | Description |
|---|---|---|
| Functional Suitability | 4.4 | Excellent |
| Performance Efficiency | 4.5 | Excellent |
| Compatibility | 4.5 | Excellent |
| Usability | 4.6 | Excellent |
| Reliability | 4.5 | Excellent |
| Security | 4.5 | Excellent |
| Maintainability | 4.6 | Excellent |
| Portability | 4.6 | Excellent |
| Effectiveness | 4.7 | Excellent |
| Efficiency | 4.6 | Excellent |
| Satisfaction | 4.5 | Excellent |
| Freedom from Risk | 4.7 | Excellent |
| Context Coverage | 4.3 | Excellent |
| Mean | 4.5 | Excellent |

The overall results of the evaluation based on product quality and quality in use of the developed system for the Room Energy Management System integrated using a re-programmable microcontroller show in the above table has a grand mean of 4.5 which is interpreted as excellent.

## SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

*Summary*

The system aimed to developed the Room Energy Management System. There are fifteen (15) respondents of the study who were purposely identified and carefully chosen. These were composed of seven (6) from the Deans office, six (6) from the office of Plant and Facilities, three (3) from the security, randomly selected for this purpose

***Product Quality***

The result of the evaluation show that the system's functional suitability was excellent. This means that the system's set of function covers all the specified tasks and user objective. It can provide the correct results, and the functions facilitate of specified tasks and objects.

***Quality in Use***

As to the system's effectiveness, the result show that the descriptive meaning is excellent. The developed system is effective to the users as to accuracy and completeness of the specified goals.

The overall mean obtained as to the performance of the prototype of the Room Energy Management System is excellent.

***Conclusions***

On the bases of the preceding results, the following conclusions were drawn:

1. The system met its objectives in terms of managed, monitor and controlled the lights and other appliance in real time;
2. The system can monitor, managed and control the room schedule;
3. The system can turn on/off the lights at a real time basis;
4. The developed system/software had complied with the in terms of product quality and quality in use; and
5. Experts agreed that the system met its objectives because they understood the features of the system and its process.

**Recommendations/Suggestions:**

The researchers would like to recommend the system to be used in the office and classroom to be used to managed, monitor and controlled in real time especially light and other appliances including the monitoring of work load in the office.

## REFERENCES

[1] Fiarni, C., Gunawan, A. S., Ricky, & Maharani, H. (2015). Automated Scheduling System for Thesis and Project Presentation Using Forward Chaining Method with Dynamic Allocation Resources. Procedia Computer Science, 72, 209-216.

[2] Katipamula, S., Underhill, R. M., Fernandez, N., Kim, W., Lutes, R. G., & Taasevigen, D. (2021). Prevalence of typical operational problems and energy savings opportunities in U.S. commercial buildings. Energy and Buildings, 253, 111544.

[3] Eusoff, M. F., Ismail, M. R., & Ismail, M. R. (2015). Potential of building automation system towards efficient energy management of healthcare buildings. International Journal of Energy Technology and Policy, 11(2), 142. https://doi.org/10.1504/IJETP.2015.069815

[4] Ahmad, M. W., Mourshed, M., Mundow, D., Sisinni, M., & Rezgui, Y. (2016). Building energy metering and environmental monitoring – A state-of-the-art review and directions for future research. Energy and Buildings, 120, 85-102.

[5] Rashid, F., Rashid, F., Ahmad, R., Talha, H. M., Khalid, A., & Khalid, A. (2020). Dynamic Load Sharing at Domestic Level Using the Internet of Things. International Journal of Integrated Engineering, 12(4), 57-65. https://doi.org/10.30880/ijie.2020.12.04.006

[6] Sachan, A. (2012). Microcontroller Based Substation Monitoring and Control System with GSM Modem. IOSR Journal of Electrical and Electronics Engineering, 1(6). https://doi.org/10.9790/1676-0161321

[7] Belvedere, B., Bianchi, M., Borghetti, A., & Paolone, M. (2009). A microcontroller-based automatic scheduling system for residential microgrids. In PowerTech, 2009

IEEE Bucharest. DOI: 10.1109/PTC.2009.5281929. Retrieved from IEEE Xplore.

[8] Pebrianti, D., Othman, N. L., Bayuaji, L., Saad, N. Md., & Abas, M. F. (2016). SMART LECTURE HALL CONTROL SYSTEM USING MICROCONTROLLER. ARPN Journal of Engineering and Applied Sciences, 11(14). ISSN 1819-6608. Retrieved from Asian Research Publishing Network (ARPN)

[9]. Amin, Roshna M. Mohammed and Miran Hikmat Mohammed Baban. "Implementation of Controlling Home Appliances Via Secure Short Message Service Technology." *Tikrit Journal of Engineering Science* 28 (2021): 21-30.

[10]. Chalagulla, D., Jayateertha, J., Kudimi, C.R., Manitha, P.V., & Sujith, M. (2018). Efficient Energy Utilization Control with Remote Network Access. *2018 International Conference on Communication, Computing and Internet of Things (IC3IoT)*, 262-266.

[11]. Heslop L, Howard A, Fernando J, Rothfield A, Wallace L. Wireless communications in acute health-care. *J Telemed Telecare.* 2003;9:187–193. [PubMed] [Google Scholar]

12. Bird SB, Zarum RS, Renzi FP. Emergency medicine resident patient care documentation using a hand-held computerized device. *Acad Emerg Med*. 2001;8:1200–1203. [PubMed] [Google Scholar]

[13]. Hasan, Md. Mehedi et al. "Low-cost Appliance Switching Circuit for Discarding Technical Issues of Microcontroller Controlled Smart Home." *International Journal of Sensors and Sensor Networks* (2019): n. pag.

[14]. Firdaus, Ramli Mohammed and Edi Mulyana. "Smart Building Lighting System." *IOP Conference Series: Materials Science and Engineering* (2018): n. pag.

[15]. Kumar, J.. "Survey of Intelligent Lighting System." (2021).

[16]. Eastes L. Use of the personal digital assistant for point-of-care trauma documentation. *J Emerg Nurs.* 2001;27:516–518. [PubMed] [Google Scholar]

[17]. Traherne R, Diston A. Wireless technologies in health care. *Med Device Technol.* 2005;16:35–37. [PubMed] [Google Scholar]

[18]. Yoshihiro A, Nakata N, Harada J, Tada S. Wireless local area networking for linking a PC reporting system and PACS: clinical feasibility in emergency reporting. *Radiographics.* 2002;22:721–728. [PubMed] [Google Scholar]

[19]. Breslin S, Greskovich W, Turisco F. Wireless technology improves nursing workflow and communications. *Comput Inform Nurs.* 2004;22:275–281. [PubMed] [Google Scholar]