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DEVELOPMENT AND ACCEPTABILITY OF AN OFFICIAL SCHEDULE-BASED CONTROL OF ELECTRICAL CIRCUITS

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ABSTRACT

The main thrust of the study is to develop a device/system that is designed to control and manage the use of electrical devices and sources in classrooms based on prescribed class schedules. The device/system was used to control the convenience outlets, lighting, and electric fans situated in the classroom. The system may be programmed within any duration as the administrator sees appropriate which may be within a week to as long as a whole semester. The system will automatically manage the electrical circuit based on the programmed schedule. During unscheduled use of the classroom, the occupants shall not be able to operate any of the electrical facilities inside the room.

After assembly, the system was implemented using the high current control, programmable control, override, and electronic noise filter sections. The system was subjected to periodic observation by the researcher to ensure functionality and reliability. Based on the cost-benefit analysis conducted by the researcher, the system can significantly reduce the electric consumption of the University if fully implemented. The system was deemed to be very acceptable by its potential end-users.

To further enhance the study it is recommended that to ensure the optimum operation of the system, a technician may be assigned for its regular maintenance. Future researchers may modify the system by adding more features like a remote control to easily program the schedules. The device may be installed inconspicuously to avoid unauthorized handling.

Keywords: schedule-based, control, electrical, programmable

INTRODUCTION

In Southeast Asia, the Philippines is one of the countries with the highest power rate. The major reason for this sky-high electricity rate, according to PDP-DOE, is the absence of government subsidies. Thailand, Indonesia, Vietnam, and Malaysia provide subsidies to their citizens. They also imposed the taxes, fees and other charges in the power industry. These countries monopolized the three important factors in the electricity market. Unlike in the Philippines, the government of Thailand, Indonesia, Vietnam, and Malaysia controlled or owned the generation, transmission, and distribution of electricity.

The existing energy management systems used and employed today are focused on monitoring the peak-hour usage of electricity. The system determines the use of electricity patterns and gives recommendations on the favorable time to use electricity. Some of the existing systems can also adapt to the recommendations and execute them via smart home devices installed in the house. Most of the systems target industries and homes' electricity usage but none or limited to academic institutions. The researcher exploits this gap to install a system that helps the academic institution to decrease electricity consumption and costs.

The Bulacan State University, College of Industrial Technology (BuISU-CIT) is has 2,848 officially enrolled students for the Academic Year 2018-2019. These students spend more time in the school than in their own home, based on the class schedules.

As observed, the students, during free time, would rather stay in other vacant rooms to wait for the next classes. In turn, the students use the electrical equipment and carelessly leave theseturned on. They also charge their electronic gadgets such as cellular phones and laptop computers. The unauthorized use of electricity by the students contributes to the electricity expenses of CIT and of the university in general.

In view of the problems and issues cited, the researcher prompted to develop a schedule-based control of electrical circuits for academic classrooms.

Related Studies

Martirano (2011) stated in his paper entitled "Lighting Systems to Save Energy in Educational Classrooms" in order to decrease the electricity consumption of interior lighting of building, the following could be employed: new more efficient equipment (lamps, control gear, etc.), utilization of improved lighting design practices (localized task lighting systems), and

improvements in lighting control systems. By efficiently controlling the luminance of the light to a level suitable to the need of the building user will allow the conservation of energy.

The focus of Martirano's research study is the interior lighting system of an educational classroom at the University where he is affiliated. He emphasized the control of the luminance level of the lights installed in the classroom based on the user's needs. The control will be done manually. The prototyped device controls all the electrical circuits of the academic classroom. It shut-off all the circuits automatically.

According to Villanueva (2017) with her research paper entitled "Automated Classroom Management System" the classroom installed with this system had significantly decreased in electric consumption. The main thrust of this investigation is to decrease the wasted electrical energy inside the academic institution. The main function of the system is to automatically control the ON/OFF mode of electrical facilities connected to it. The device has a sensor installed in the entrance door that serves as counter plus (+) and another sensor connected to the exit door that serves as counter minus (-). The signal from these sensors is processed with the use of a microcontroller unit (MCU). If the data recorded in the MCU becomes zero (0), the device assumes that there are no more people inside the classroom. That is the time when the electrical facilities connected to it automatically shut down or turn off. With the use of this system, the worries about unattended electrical facilities will be lessened.

The study of Villanueva had a similar purpose of what the researcher would like to investigate. The Development and Acceptability of Schedule-Based Control of Electrical Circuits is also aiming to minimize the electricity consumption of an academic institution. The developed system by Villanueva depends on the accuracy of the MCU to interpret the presence of the people inside the classroom in controlling the mode of the load connected to it. While the system developed by the researcher automatically changes the mode of the electrical circuit connected to the device based on the programmed schedule. It has no ability to determine the presence of humans inside the classroom. The system shut off the electrical circuit of the classroom if the programmed device commands it even if the room is empty or not.

In the study of Pangilinan and Maroma (2014) entitled "Energy Management System for High Current Load," the two investigated the integration of motion sensors to trigger the main control circuit to change the mode of the high current load to ON or OFF mode. The system limits or reduces the electricity consumed by the loads when there is no human activity inside the facility. The researchers also added that with the use of this system, the waste of energy and potential fire hazard will reduce. In addition, the two proponents employed a sensing section to trigger the high current control circuit. These sensors are a network of motion sensors that are strategically positioned to an angle to maximize their function. These sensors provide the

necessary data or pulses to trigger the main control circuit to change the mode of the high current load. According to the study, as long as there are human activities or movement within the vicinity of the system the high current load still operates but if the opposite happens with the specified delay schedule it will turn the loads OFF.

The studies of Villanueva and Pangilinan are both sensor-based aimed to shut-off the electrical circuit connected to the device if there are no human activities inside the rooms. The device developed by Villanueva strictly implements the proper use of the entrance and exit doors of the classrooms in order to achieve the accurate response of the control system. If the users of the room did not comply with the strictly designated entrance and exit, the system will give wrong interpretation to the total numbers of the people inside the classroom. In that case, the system may turn the lightings of the rooms OFF even if there are still people inside or the vice versa.

On the other hand, the system developed by Pangilinan and Maroma, utilized the use of motion sensors to determine the presence of human activities inside the rooms. If there is no motion detected inside the rooms, it triggers the electrical load OFF with little delay. The purpose of the delay is to protect whatever electrical appliances are connected to the system. Now, the prototype system is somewhat similar to the two discussed systems in terms of cutting the unnecessary use of electricity inside the classrooms but this system has no sensors connected to it.

The only input to be processed by the system is purely the programmed official schedule of the classroom where the device is installed. As mentioned, the device does not care about the presence of human inside the classroom. The system automatically turns the electrical circuits OFF if it is time. The only human intervention can be done to the device is during the process of programming the official schedule of the classroom and the use of the override system.

Statement of the Problem

The general problem of the study is: “How to develop and design a schedule-based academic room’s electrical management system for the College of Industrial Technology?”

Specifically, the study sought answers to the following questions:

1. What are the appropriate components to be used in the system in terms of the following sections:
 - 1.1. high current control section;
 - 1.2. programmable control section;
 - 1.3. override section; and
 - 1.4. electronic noise filter section?
2. What tests and modifications are necessary to optimally operate the system?
3. How may a cost-benefit analysis be conducted to determine the viability of the system?
4. How may the system acceptability be measured in terms of the following construct:
 - 4.1. Functionality;
 - 4.2. Reliability;
 - 4.3. Usability;
 - 4.4. Efficiency;
 - 4.5. Maintainability; and
 - 4.6. Safety?

Assumption of the Study

The Official Schedule-Based Control of Electrical Circuits is a system designed to significantly reduce the electrical energy consumption of the College of Industrial Technology and its end users.

METHODS

Research Design

This study utilized the developmental research method in fabricating the Schedule-Based Control of Electrical Circuit. The researcher adapted the type 2 developmental research to construct the project. Type 2 studies may have a model construction phase, a model implementation phase, and a model validation phase (Richey and Klein, 2005, p. 27). The first step is to conduct a deep analysis of existing research findings that apply to the project being developed. These findings may lead to the development and construction of the project. The developed prototype must undergo field testing to determine the functionality and possible improvement of the project. After the final testing and revision of the prototype, this must undergo validation to determine the acceptability of the system (Robles, 2018).

Planning is fundamental to the development stages of this study. This stage will dictate the outcome of the study. The researcher analyzes the device's requirements diligently, from designing the diagram to finding the right components to fabricating the circuit. Preparing the right tools to be used in the project's fabrication is also carefully plotted. The researcher's strategy was to identify the project's inputs, process these by placing the relevance to the project, and finally analyze if these will obtain the desired output.

Population

The respondents of this study in gathering the relevant data are the Faculty, Utility Personnel, and Administrators of the Bulacan State University, and Electrical and Electronic Experts.

Table 1 shows the number OF respondents per category who evaluated the system. The researcher selected 62 respondents: 57% faculty members, 6% electrical experts, 11 % electronics experts, 15% Administration, and 11% utility personnel.

The administrators who served as respondents were the College Deans, Directors, College Secretaries, Department Heads, Vice Presidents, and other heads offices. The researcher chose the administrators as the respondents having the authority to implement and provide the budget for the system.

Table 1. Frequency and Percentage Distribution of Respondents

Respondents	Frequency	Percentage
Administrators	9	15 %
Electrical Faculty	4	6 %
Electronics Faculty	7	11 %
Faculty Members	35	57 %
Utility Personnel	7	11 %
Total	62	100%

Aside from being the implementor, the administrators are exposed to the operational expenditures of the University, especially on the electricity expenses. Faculty members and utility personnel are the end-user of the system. Moreover, faculty members and utility personnel observe the unauthorized use of electricity, loitering, and littering by the students. They are capable to evaluate the acceptability of the system. The electrical and electronics department faculty members served as validators for the safety and functionality of the prototype. These faculty members are experts in the field with full understanding on how the system works. Lastly, they know the functions of each component and determine the weakness and strengths of the system.

Instrument

To determine the acceptability of the prototype system, the main instrument used for this purpose is the questionnaire. ISO 9126 (Zeiss et al., 2008) is a standardized evaluation instrument intended for software product assessment. The researcher slightly modified this instrument to adapt to the needs of assessing the system. This standard serves as the major evaluation instrument to gather the needed data. The following are the criteria composition of the instrument: functionality, reliability, usability, maintainability, workability, and safety.

Data Gathering Procedure

The major data-gathering method employed in this study is the survey questionnaire method. The researcher distributed and retrieved the questionnaires personally. The researcher secured permission from the respondent's administrators to distribute questionnaires, conduct an experiment, cost-benefit analysis, and install the device and data mining.

The researcher sought the aid and help of the university community to properly evaluate and assess the system through survey questionnaires.

In order to undertake the cost-benefit analysis of the system, the researcher tabulated the construction cost of the project (materials cost) and subtract the estimated conserved electricity converted to pesos. The researcher enumerated the electrical loads of the target academic room as the basis for the computation of the conserve electricity. In terms of the Return of Investment (ROI), the amount of electricity conserved during down-times of the room and its equivalent in pesos was computed.

Process and Analysis

The data gathered in the study is presented, tabulated, and analyzed quantitatively with the use of descriptive statistical measures. These measures are the mean, percentage, and frequency counts. To ensure the validity and accuracy of the processed data, the researcher sought the assistance of a reputable statistician in the preparation of the data. This study will utilize the 5-point Likert scale as shown in the Table 2. To measure the acceptability level of the system, the respondents were asked to indicate the level of their agreement with every point or parameter to be presented through the survey questionnaires. To determine the conserved energy with the system installed, the researcher identified the estimated energy losses each day and subtracted the energy consumed by the device (energy losses – device’s energy consumption). The difference was multiplied by the number of school days in a month (energy conserved per day X 24 days).

Table 2. The Likert Scale

Numerical Rating	Verbal Interpretation
4.51 – 5.00	Highly Acceptable
3.51 – 4.50	Very Acceptable
2.51 – 3.50	Acceptable
1.51 – 2.50	Moderately Unacceptable
1.00 – 1.50	Unacceptable

The product was multiplied by the current electricity rate to find the monthly savings in terms of the Philippine peso. To identify the annual savings, the monthly savings were multiplied by 10 months (based on the school calendar).

RESULTS

The main problem of the study is “How to develop and design a schedule-based academic room’s electrical management system for the College of Industrial Technology? The findings of this problem are summarized.

To clearly understand and interpret the data collected, the researcher presented the design and fabrication of the prototype and the several parts that correspond to the specific problem stated in Chapter I. The first part presented the appropriate components used in the system. The second part pertains to the tests and modifications to optimally operate the system. The fourth part presented a cost-benefit analysis of the project. The last part shows the evaluation of the system's acceptability in terms of the following parameters: (1) functionality, (2) reliability, (3) usability, (4) maintainability, (5) portability, (6) workability, and (7) safety.

The researcher developed a working diagram of the circuit. It includes a flowchart, sketches of the circuit, a mock-up wall design, and the specifications and enclosure of the project. A flowchart was a great tool for the researcher that served as the guide for the fabrication process of the project. With this, it is easy for the researcher to analyze and identify the circuit flaws and apply the iterative process.

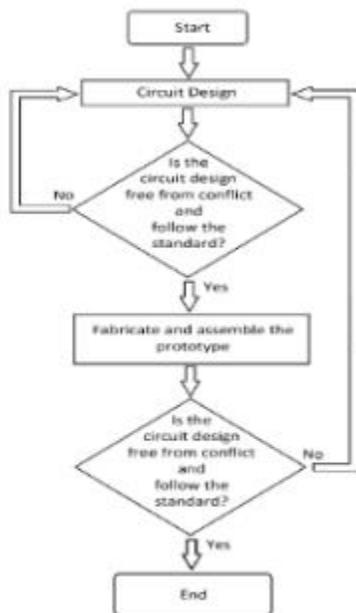


Figure 1. The Flowchart of the Project

Figure 1 shows the flow chart of the project. It starts with the circuit design based on the objectives. The next part analyzes whether the design has no defects and conforms to the safety standard. If passed, it will proceed to the fabrication and assembling of the project, otherwise, the researcher will go back to the circuit design part and rethink, analyze, and troubleshoot the

circuit design. If the prototype functions as expected, the final output would be the Official Schedule-Based Control of Electrical Circuits. If the prototype does not achieve the expected result, the researcher will go back to the design and analyze the errors.

The researcher carefully laid out the sketches of the circuit. Two types of illustrations or diagrams were used in this project: the block diagram and the pictorial wiring diagram. The block diagram will show the circuit's different stages and functions. It would be easy for the researcher to analyze and troubleshoot the project if errors and problems arose. The schematic diagram of the project would serve as the project's blueprint. It will show the exact components' placement, signal flow, and voltage flow. The pictorial diagram or the components layout would serve as a tool for the researcher to correctly place each component in its proper place. Figure 10 shows the block diagram of the project. It is divided into 12 different functional blocks. The input block serves as the mechanism to record the official schedule of the academic room. The official schedule of the utilization of the academic room was recorded on the timer circuit block. It also controls the On/Off mechanism of the high current control circuit. The backup battery block is a button battery (CR2032) with a 3-volts rating internally connected to the programmable timer to preserve and maintain the recorded official schedule in the memory chip of the timer. It also controls the On/Off mechanism of the high current control circuit.

AC Source block is the supply voltage from the electricity distribution companies (electric utility companies). The project is designed to operate in a 220-240 volts range. Main Protection Circuit provides the overall protection for the control and load circuits. It consists of Mini-Circuit Breaker (MCB) as the current capacity is based on the standard set by Philippine Electrical Code (PEC). It also serves as the main control switch of the entire circuit. High Current Control Circuit is the section that controls the load.

This section's component is a contactor with a 220-volt energizing coil and a rating of 220/230 volts 60 Hz. The timer circuit directly controls this component. The override circuit section serves the prototype's feature to use the classroom's electrical facility by overriding or neglecting the official schedule programmed to the timer circuit. This section is represented by an MCB which has the current rating based on PEC. Load is the device, components, or appliances that will consume electricity to function. In this study, the load was the electrical circuit of the academic room such as the convenience outlet, electric fan, and lighting.

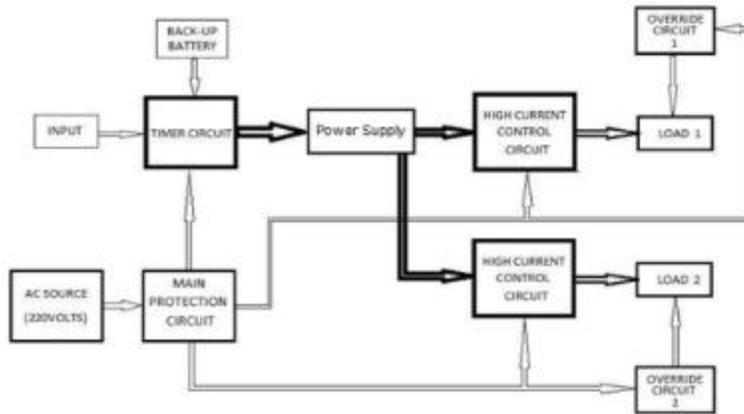


Figure 2. The Block Diagram of the Project

Fabrication Phase.

The researcher built the prototype based on the parameters set in the design phase. The project used an MCB panel box as housing for both the circuit's protection, control, and timer circuits. The lower part of the MCB bay of the panel box was utilized as the enclosure of the timer circuit and the function keys.

The researcher built a mock-up board that mimics the classroom electrical setup. The mock-up board will hold the entire electrical circuits and loads. The loads used in the study are electric fan and LED bulb which are commonly found in an academic room. The electrical circuits in the prototype are convenience and light outlets.

Table 3. Materials used in High Current and Programmable Control

Description	Quantity	Picture	Function
Sino Timer TM-618	1 piece		Provide the 119 pair of timer schedule for device turn ON and OFF
Rocker Switch	1 piece		Control the supply of the Sino Timer
Momentary-push Switch	8 pieces (1 green and 7 red)		It is used to give input to the timer during schedule programming.
EMI Filter	1 piece		It filter out any unwanted electrical noise that enter the Sino Timer
60 Ampere MCB DIN-type	1 piece		Serve as the main electrical protection circuit
25 Ampere 220 Volts Contactor DIN-Rail Type	2 pieces		Each this contactor controls the supply voltage of the load circuit
20 Ampere MCB DIN-Rail Type	4 pieces		2 pieces used in the light and convenience outlet loads and another 2 pieces for the load overrides.
Snubber Circuit	1 piece		Use to remove the kickback voltage generated by the contactor to avoid unwanted resetting of the timer
4.0 mm ² THHN Copper wire	2 meters		Use for the interconnection of the protection, override, convenience outlet, and lighting circuits.
Hook-up wire	5 meters		Use for the interconnection of the timer circuit to the momentary switches.
PZ-40 DIN Rail 16-way enclosure	1 piece		It is the housing of the MCB and the timer circuit.
Acrylic sheet	5" by 8"		It is used to mount the LCD display, rocker switch and the push-button momentary switches

At the lower part of the enclosure, hold the timer circuit. This circuit consists of Sino 220-volts 7-day programmable relay-controlled timer. This timer was modified in a way that is easy to operate. The researcher used a normally-open push-button switch wired to the timer main board.

Assembly and Mounting Phase.

In this phase, the researcher installed, assembled, and mounted all the components based on the design, from the wiring of the MCB and timer circuit inside the circuit breaker panel up to the electrical circuit side.

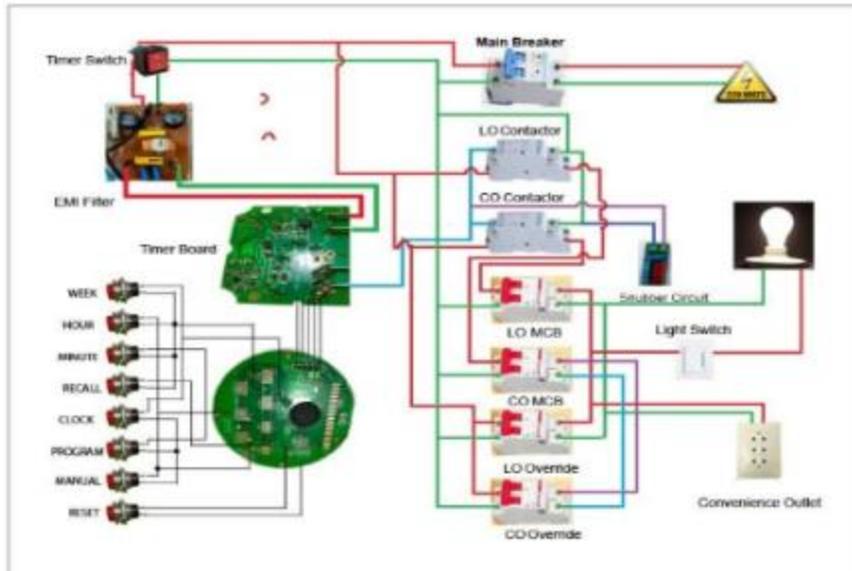


Figure 3. Wiring Diagram of the System

Appropriate Components

What are the appropriate components to be used in the system in terms of the following sections; high current control section, programmable control section, override section, and electronic noise filter section?

The parameters and specifications of the materials used in the system followed the minimum standards for constructing electronics and electrical circuits. Furthermore, the factors considered in the study include the planning, designing, fabrication, assembly, and mounting phase of the development of the system. All the necessary materials and electrical connections are identified during this phase.

The materials for each section of the system were established. For the "High current control section of the system, the researcher installed the main breaker with 60-ampere capacity, 220-volts contactor for the control of the electrical loads, and four 20-ampere breakers for the protection and override of the electrical loads. The researcher installed MCB breakers instead of bakelite-type circuit breakers for three reasons; MCB is aesthetically appealing, cheaper but durable, and compact.

For the control circuit, the system has Sino Timer Programmable Device installed. This device is capable of 17 pairs of ON/OFF modes for each day or a total of 119 slots from Monday to Sunday schedules. The researcher installed this device instead of using other microcontroller circuits (e.g, Arduino, PIC, Raspberry Pie, and others) for economic reasons. It is cheaper to use Sino Timer Programmable Device.

The system has two override systems. The Sino Timer Programmable Device has a built-in override system. It can be used by pressing the "Manual" button until the "ON" setting can be seen on the LCD Display. The main override feature can be accessed via the control panel by pulling up the MCB lever with the "Override" label.

Tests and Modifications

What tests and modifications may be necessary to optimally operate the system?

The researcher constructed a mock-up board that mimicked the electrical circuit of the Alvarado Hall academic room. The board is constructed using the materials that can be found in a typical academic room. It has two separate electrical circuits, one for convenience outlets and one for lighting outlets.

During the fabrication and testing of the prototype, the researcher experienced an exceedingly difficult problem. The Sino Timer Programmable Device resets itself when the contactor coil de-energizes, the contactor coil produced a "kickback" current or the counter-EMF that affected the normal operation of the system. To solve the encountered problem, the researcher has two options, replace the contactor with a direct-current (DC) coil and use a simple damper-diode or retain the existing 220-volts coil contactor and use other methods of countering the interference. Economic factor and circuit complexity, the researcher decided to retain the 220-volts contactor and install a device that could remove the interference caused by it.

The researcher slightly modified the system by integrating noise suppressing circuits. The first filter used in the prototype was an EMI filter circuit that filters out the undesirable electronic noise entering the Sino Timer Programmable Device. The "Snubber Circuit" is the second filter connected across the contactor coil. These circuits eliminate the problem encountered during the testing of the system.

Cost-benefit Analysis

How may a cost-benefit analysis be conducted to determine the viability of the system?

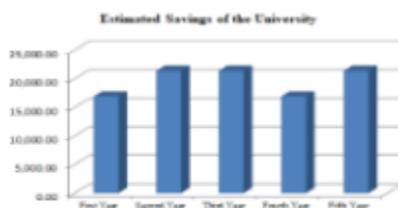
The estimated unauthorized electricity use of the academic room is around 9 KW which translates to ₱2,760 electricity costs if multiplied by ₱10 per KW (average rate per kilowatt).

Table 4. Estimated Annual Savings of the Alvarado Hall in one Academic Classroom

Parameters	Data
Total Loss per day (table 12)	8,953.2 watts
Control Panel Electricity Consumption per day (table 11)	51.36 watts
Electricity Savings per day (system installed in the academic room)	8,901.84 watts
Monthly Savings on Electricity (24 school days)	213, 644.16 watts
Electricity cost as of 2022 (estimated to flat rate 10 pesos per KW)	₱2,136.44
School Calendar (in 10 months)	₱21,364.42
System's costs (table 8)	₱4,486
Estimated Alvarado Hall Savings in 10 months	₱16,878.41

The efficiency of the system can be expressed in terms of the electricity consumption during normal operation and the construction cost of the device. The device consumes an estimated 51.36 watts while the energy loss in the academic room due to unauthorized use is estimated to 8,953.2 watts each day. The device consumes minimal electricity. In terms of the construction cost of the system, the system can be constructed in just less than five thousand pesos based on the 2022 inflation rate.

In a year, the college could save up to ₱21,364.416 pesos per academic room (2,136.44 multiplied by 10 months). It is still favorable to the university even if the device is being replaced every year for its maintenance considering that the device itself could be used for more than 3 years.



Graph 1. The Estimated Savings of the University in Five Years

Graph 1 shows that the University could save an estimated amount of ₱16,000.00 in the first year of implementation of the system. In the second and third year of implementation, the savings can increase to more than ₱20,000.00 but will decrease in the fourth year of implementation. In the fifth year of implementation, the savings return to the same amount as in the second and third year of implementation. The first year of implementation has only ₱16,000.00 in savings because the cost of the system was deducted from it. Hence, the fourth year of implementation decreased the savings due to the maintenance cost of the system.

System Acceptability

How may the system acceptability be measured in terms of the following construct; Functionality, Reliability, Usability, Efficiency, Maintainability, and Safety?

Table 5. Summary of the Acceptability of the System

Criteria	Mean	Verbal Interpretation
Functionality	4.28	Very Acceptable
Reliability	4.49	Very Acceptable
Usability	3.97	Very Acceptable
Maintainability	4.28	Very Acceptable
Workability	4.49	Very Acceptable
Safety	4.09	Very Acceptable
Overall Mean	4.28	Very Acceptable

The system was evaluated in the following indicators: functionality, reliability, usability, efficiency, and portability to determine the outcome of assessing the **Development and Acceptability of an Official Schedule-Based Control of Electrical Circuits**. The evaluation described the system as *Very Acceptable*, with a mean of 4.28.

DISCUSSION

The system employed the cheapest materials available in the local market. The researcher used a mock-up board to test the functionality of the prototype. In this stage, the researcher found the flaws in the design and applied remedies to address the problem. The researcher installed a snubber circuit to eliminate the problem created by the kickback voltage during the de-energized period of the contactors.

The cost-benefit analysis was conducted by estimating the amount of consumed electricity with and without the installed system. The system was evaluated by the respondents who are experts in the field of electronics and electricity and those who are directly affected by the installed system.

Conclusions

The following conclusions were drawn in light of the study's observations and the results presented.

The system was implemented using the high current control, programmable control, override, and electronic noise filter sections. The system was tested and modified to achieve optimum performance. Based on the cost-benefit analysis conducted, the system can significantly reduce the electric consumption of the University if fully implemented. The system was deemed to be very acceptable by its potential end-users.

Recommendations

Based on the findings and conclusions, the following recommendations were derived:

1. To ensure optimum operation of the system, a technician may be assigned for its regular maintenance.
2. The system should be installed in each academic room in the college to save electricity due to unauthorized use.
3. The future researchers may modify the system by adding more features like a remote control to easily program the schedules.
4. The device may be installed inconspicuously to avoid unauthorized handling.

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