Enhancement Of the Solar Powered Burglar Alarm System with Two Flood Lights Implemented at Santa Barbara Elementary School Bacolor Pampanga

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Abstract: - As the education system in Philippines continues to improve, educational organization are tending to the schools in every part of the country to further improve the quality of education that student's needs, leading to renovation of old school buildings. The renovations that were carried out to the school of Sta. Barbara Elementary of Bacolor, Pampanga affected the system that was implemented by previous proponents. The goal of the study is to enhance a 12VDC Solar Powered Alarm System that is implemented in Sta. Barbara Elementary School Bacolor, Pampanga which focused on the sensitivity of the sensors, floodlights, and wiring for the system to continue in providing security and safety in the school. Components used for the system were designed and selected based on the evaluation made from the previous system and the practicality that is applicable in every component used. The system that was presented was enhanced effectively to the appropriate element needed as it was evaluated by the school faculty and caretaker.

Key Words: Alarm System, Flood Lights, Elementary School.

I. INTRODUCTION

Security is primary concern around the globe. Every person wants their home, buildings or infrastructure to be secured (Priyanka, 2015). According to Ahmad et al (2019), security alarm systems have become common. The increase in crimes, abductions, and robberies in the globe today is one of the reasons behind this. A criminal entry, breaching a window, entering by a cutting celling or even through a closed or occasionally open window is the most common method of invading houses, workplace, schools, and organizations today. Majority of offenders are frequently stopped by the sheer availability of an alert security system, based on different case studies. In addition, the concept of home automation and its safety has been known since the late 1970s. However, with the progress of technology, our notions of home have evolved dramatically, as has the concept of home automation and security systems.

In the past, home automation systems have always attempted to give inhabitants with dependable, simple, and secure methods to access their houses (Yadav et al, 2021).

In accordance to the study of Azid et al (2011), the selection of sensors is critical for high-quality home automation. If the sensors used to measure the required variables can transfer the measured values of variables to the controller, the control system is good. The sensors must give precise readings of the variables to be regulated at the control loop's reference point. The ARPN Journal of Engineering and Science (2015) stated that the most commonly used burglar alarm systems are Passive Infrared Detectors (PIR) due to their low cost and mass production. They've been most typically employed to detect presence and movement in buildings and residences. Unlike ultrasound rangers or infrared light distance sensors, the PIR consume extremely little electricity and need less maintenance than surveillance cameras. Infrared rays stimulate this sensor, which responds to the stimulus. Using a PIR sensor, every infrared emission is detected and analyzed, with the frequency of analysis taken as an input (Sukmana, 2015).

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As the pandemic currently strikes the country, during the 200-day community quarantine period, incidences of robbery and theft decreased by 60% across the Philippines, according to the Join Force Task Covid Shield. During the same time, it was also found that crime incidences were reduced by 46% across the country (Recuenco, 2020). Unfortunately, according to Calleja (2021), when the enhanced community lockdown was lifted, countless cases of theft and robbery have increased in our nation. Four persons were detained in the Philippines for breaking into a catholic church and taking donated money for COVID-19 victims. Moreover, two individuals were also caught in July for stealing and selling a sound equipment. “It may sound funny to many but these men stole the church’s microphones and speakers and sold them in a local store,” Dela Cruz said.

The Philippine National Police (PNP) of Bacolor, Pampanga (2016) reported that the crime rate has increased in related with burglaries, it specifically targeted public schools, neighbourhoods, and residences. Items included are Projectors and computers donated by the Department of Education (DepEd) were among the most regularly stolen devices according to school officials. Burglary incidence were reported at the Sta. Barbara Elementary School, Bacolor High School, and Bacolor Elementary School. Through the rigorous investigation, suspects' common point of entry was the rooms' window and doors wherein valuable items stated above are kept, they still allegedly entered and managed to steal the school property. Therefore, it was then seen the need of technical assistance and formulation of new technology which can be implemented on the principal’s office of Sta. Barbara Elementary school. As a result, professionals of Don Honorio Ventura State University from the Electrical Engineering and Electronics Engineering Departments responded and introduced Solar Powered Security System which were used to secure valuable items in the principal’s office. As solution to the encountered problem of power interruption, the system is powered by a solar panel installed on the roof of the principal’s office as the primary source of the alarm system and flood lights located outside the designated room (Alfonso et al, 2018).

After years of usage of the burglar alarm system, there was an issue concerning the sensitivity of the system implemented that needed the recalibration of the sensors and the system, leading them to stop the system with its operation due to the inability of the school officials to maintain the system. Also, Sta. Barbara Elementary School was recently renovated and constructed a covered court that caused the tampering of the system that was installed. It is in this light that the researchers aimed to enhance and assess the burglar alarm system with flood lights specifically the sensitivity of the system and its two floodlights. Thus, this study will help and influence the environment, society, and economy, as sustainability has emerged in project management of the Solar Powered Burglar Alarm System.

The following are the specific objectives of the study proposed by the proponents:

- To assess and enhance the precision of the sensitivity of the burglar alarm.
- To enhance the wiring ampacity of the Alarm System according to the proper wire sizing in accordance with PEC.
- To enhance the components (Battery, Charge controller and Inverter) by selecting the suitable specifications for the alarm system.

After the enhancement, the system will run better and be more sustainable than the previous project.

II. METHODS

2.1 Research Design

The experimental method of research was adopted in the study. Experimental research is a study that follows a scientific research strategy to the letter. It consists of a hypothesis, a researcher-controllable variable, and variables that may be measured, calculated, and compared. Above all, experimental research is conducted in a controlled setting (Harland, 2011).

Experimental procedures are used in any research undertaken under scientifically acceptable settings. Researchers must confirm that the change in a variable is purely due to the alteration of the constant variable for experimental studies to be successful. Thus, the study should show a clear cause-and-effect relationship.

2.2 Research Framework

The following methods were employed in enhancing the solar-powered burglar alarm system with floodlights. The IPO model was adopted to identify the inputs, outputs, and required processing tasks required in transforming inputs into outputs. That asserts that a system's overall structure is as significant as its individual components in deciding how well it performed.

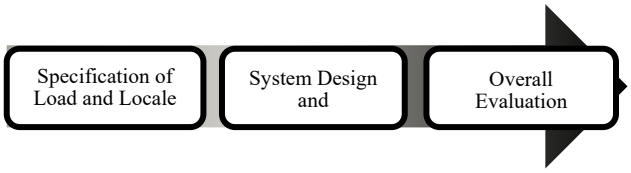


Figure 1. The research framework of the study

The framework in the figure 1, shows the procedure that describes the process in the enhancement of the solar powered burglar alarm system. It involves the specification of load and locale, system design and enhancement, assessment and evaluation.

2.3 Specification of Locale of the Study

As shown in Figure 2, the study was conducted in Santa Barbara Elementary School Bacolor which has two buildings. The computer room/principal's office is located in the first building of the school where the Burglar Alarm was installed.

Figure.2. The research framework of the study

2.4 Load Specification

In determining the specification of components that were used, previous materials, components, and characteristics of the location were considered. Loads were identified in accordance with the power consumption of each component that was used in the system which is shown in Tables 1 and 2. The computed watt-hour was based on the formula from the IEEE Magazine (2016).

Total watt-hour= (Total number of watts x total number of hours)

2.5 Load Schedule for the classroom

Table.1. Total watt consumed and watt-hour per day used by each load.

Components	Watts	Hour	Watt-Hour
Electric Bell**	7	0.5	3.50
Flood Lights***	50	12	600
Motion Sensor**	0.2	12	2.40
Magnetic Switch**	0.1	12	1.20
Arduino Uno*	0.2	12	2.40
Inverter*	5	12	60
Total	**62.5**		**669.5**

Note:
Operates at night only*
Operates only if there is an Intruder**
Operates as Outdoor lighting of the school***

The computed total watt-hour was used in selecting and sizing of the battery for the alarm system during the operating hours

2.6 AC and DC Loads

The computed power (watts) was based on the formula from the IEEE Magazine (2016).

Power(watts)= [Voltage(v)] [Current(I)]

Table.2. Load Schedule of AC and DC components.

Component	Watts	Volts	Ampere	Size of wire	Size of conduit
AC Loads					
1x Bell	7	220	0.03	2 sq.mm THHN Wire	20mm dia. PVC
DC Loads					
Lights (2x Flood 25W)	50	12	4.17	2 sq.mm THHN Wire	20mm dia. PVC
2x Motion Sensor	0.2	12	0.02	2 sq.mm THHN Wire	20mm dia. PVC

Table 2 shows the identification of the wire size and conduit for each components considering the ampacity of the selected wire according to the Table 3.10.2.6(B)(16) from the book, "Philippine Electrical Code Part 1 2017 ed. "

2.7 System Design and Enhancement

2.7.1 Selection and Sizing of Battery

The amounts of electrical energy produced by the solar panel is stored in the system using a deep cycle lithium-ion battery. This battery requires the maximum current supplied by the solar PV module. In addition, lithium-ion batteries can be recharged hundreds of times and are more stable. The basic idea of DC circuits is that while charging a battery, the charger must have a greater voltage than the battery because the current will follow the higher voltage component's direction.

To determine what kind of battery is sufficient (Formula from IIEE Magazine XLV 2016).

Battery Capacity (Ah) = (Total Watt-hour x Days of Autonomy)/ ((0.75 x nominal battery voltage))

Battery Capacity (Ah) = [(669.5Wh) (1)]/ [(0.75) (12V)]

The battery capacity calculated using the formula is 74.39 Ah. Since the next available battery ampere-hour after 75 Ah is 100

Ah, a 100 Ah, 12V, lithium-ion deep cycle battery was identified to satisfy the Ampere-hour requirement.

2.7.2 Enhancement of the Two Floodlights

In enhancing the floodlight, the researchers determined the relation of the angle and the illumination distance of the 25 watts floodlight used for its maximum efficiency in securing the visibility of the room during night time.

Outside the computer lab, a photo sensor automatically switches the lights on and off. When the sensor detects a lack of sunlight between 40 and 110 lux, the lights will automatically turn on, and when daylight between 150 and 250 lux is detected, the lights will instantly switch off.

2.7.3 Sizing Charge Controller and Power Inverter

The size of the charge controller and size of the inverter was calculated, based on the formula from IIEE Magazine XLV 2016.

$$Current\ Rating = \frac{Power\ output\ of\ the\ solar\ panel}{Voltage\ of\ the\ battery}$$

$$Current\ Rating = \frac{100\ Watts}{12\ Volts} = 8.333\ A$$

Size of Inverter = (Total Load+(1+Addition Further Load Expansion))/ (Efficiency of the Inverter)

Size of Inverter = (62.5 +(1+20%))/80%

Size of Inverter = **79.63 watts inverter**

A power inverter is another component that was added to the system. It is an electronic device or circuit that transforms DC to AC. The input voltage, output voltage, frequency, and total power handling are all determined by the architecture of the specific device or circuitry. The inverter does not generate any electricity; the power is supplied by the DC source. A power inverter can be wholly electronic or a combination of mechanical effects and electronic circuitry.

Since there is no 80 watts inverter, 200 watts modified sine wave, 12VDC/230VAC was used in the system for the ac load.

2.7.4 Sizing and Selection of Wire

In determining the size of wire used, the book "Philippine Electrical Code Part 1 2017 ed," will serve as the reference.

$$I = \frac{Total\ Watts}{12\ Volts}$$

$$I = \frac{100\ Watts}{12\ Volts} = 8.333\ A$$

Based on calculations, a 2-mm. sq. with a maximum ampere rating of 25 Amperes is sufficient to meet the 8.333 A and a 15A circuit breaker was used. The wire size and safety switch used for the system was based on the Table 3.10.2.6(B)(16) from the book, "Philippine Electrical Code Part 1 2017 ed. “

2.7.5 Enhancing the Sensor’s Precision

In enhancing the precision of the sensors, the researchers tested the previous sensor that was installed inside the computer room (as shown in Figure 3) and found out that they are no longer in proper working condition. Therefore, the researchers changed the installed sensor with a new one and protected with the adjustable angle case. It was built using 3D printer and polylactic acid. In determining the precision of the sensor, it was tested in different situations to determine the certain sensitivity for its precise working condition. The PIR sensors are installed using 2-mm squared thermoplastic high resistant nylon coated stranded wire at 90°C of its operating temperature.

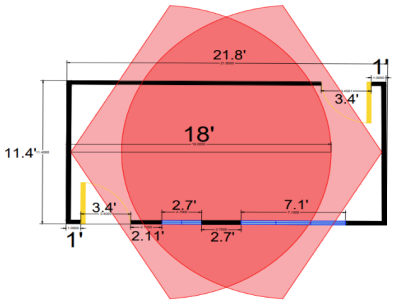


Figure.3. Location of PIR sensors

2.8 Overall Evaluation

After the enhancement and installation processes, the researchers evaluated the final system and compared its initial performance goals, and performed testing to see if the system would continue to meet the goals or perform better than the initial one. The system was assessed focusing on the reliability of the alarm system to trigger, audibility of the alarm and the ability of the installed floodlights in securing the visibility around the classroom at night.

The researchers evaluated the alarm system's capacity to activate when there is an intruder inside the computer laboratory by walking inside the sensor's coverage area and making motions to prove that the system triggers the alarm system to inform the neighborhood if an intruder is detected. While, the audibility of the alarm was tested by designation

different areas around the school, the alarm was then triggered and tested if it was audible in the nearby neighbors.

The two floodlights that are connected to the system runs only during night time, it is connected to a photo sensor that will automatically turn on the floodlights at night. The floodlights were assessed during the night to prove that it gives satisfactory amount of vision around the designated room where the system is installed during the night.

IV. Data And Results

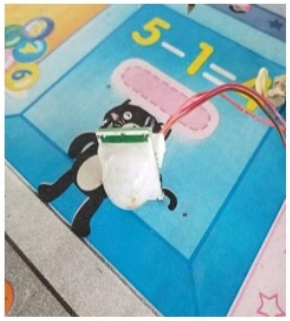
4.1 Comparison Between the Old and New System Specifications

Comparison of specifications were made to prove that the system was enhanced and better than the previous system that was implemented.

4.1.1 PIR Sensor

The enhancement applied with the sensor was the changing of the sensor with the latest product release of it the specification is still the same because the type of sensor used is also a PIR sensor. The only modification of the new sensor was the added case for the safety and reduction of the sensor's exposure to hazards.

NEW SENSOR



OLD SENSOR

4.1.2 Flood Lights

The floodlights were upgraded over the previous system, which was 12V, 20 watts, 120 degrees, and IP66. The proponents used 25W led outdoor floodlights with a DC voltage of 12V, which is extremely safe and won't cause electric shock or fire.

Advanced light control sensor that saves energy, has a long service life and waterproof at IP65 specifications. The waterproofing was not an issue due to the no possibility of a high-pressured water to be directed to the floodlights.

NEW FLOODLIGHTS

OLD FLOODLIGHTS

4.1.3 Alarm Bell

In comparison to the previous system, they used a 12V, 35 watts buzzer beep sound reversing alarm siren horn with a high pitch sound frequency, whereas the proponents used a 220V AC hallo electric bell with a decibel level of 95 that is far louder than the prior system.

NEW ALARM BELL

OLD ALARM BELL

4.2 The result of the PIR sensor's actual specification and manufacturer's specification

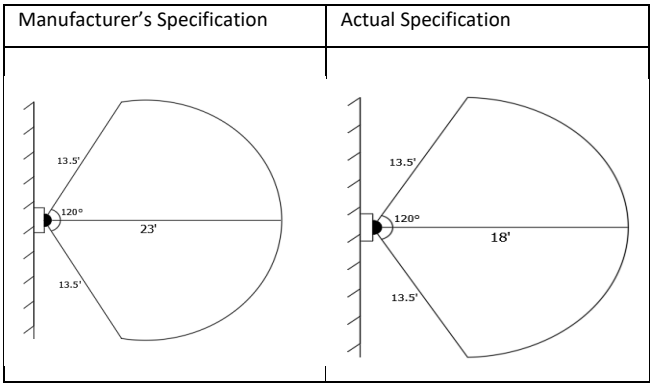


Figure.4. Manufacturer and Actual PIR Specification

Comparison of the PIR sensor's actual specification (right) and the manufacturer's specification (left).

When PIR sensor was tested, it was determined that the actual length of the sensor was 5 feet shorter than the manufacturer's specification as shown in Figure 4. This data was used as an advantage during sensor. installation to avoid sensor overlap

and eliminate blind spots in the coverage area, hence enhancing the security of the computer lab. Using the pull-push rule, the coverage of the sensor was measured from the position of the component up to the area of coverage. The actual length and range were 18'. The verification was conducted by entering and creating movements inside the room for the reliability of the sensors.

4.3 The alarm system's ability to detect an intruder

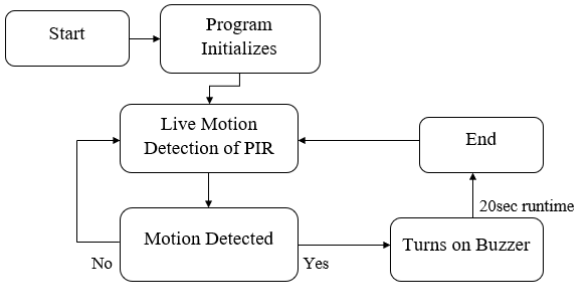


Figure.5. Flow chart of PIR-based motion detection syste*m*

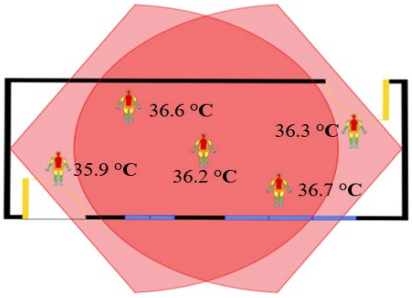


Figure.6. Area of Coverage

A PIR sensor regularly detects temperature differences without trouble. At high temperatures, approximately 36 °C, close to body temperature which is 37 °C. Moving inside the area covered by the sensor in different locations, as illustrated in Figure 6, was used to test the alarm system's ability and accuracy in case there is an intruder. All movements in each position in the coverage area were effectively identified by the sensors, which triggered the alarm system. A magnetic switch was installed on the classroom door to detect illegal entry. If the door was opened, the magnetic switches transmit a signal to the control system, which activates the alarm system.

An infrared thermal scanner was used during the simulation to test the body temperature of the person that represents the intruder.

From the data gathered this shows that the average body temperature of a person entered inside the classroom during the simulation was 36.3 °C. This indicates that PIR Sensors is effective in detecting an intruder.

4.4 Photo sensor's turn-on and turn-off time

Table.3. Flood lights turn-on and off time

Day	Turn On (Time)	Turn Off (Time)
1	6:18 PM	
2	6:21 PM	5:28 AM
3	6:19 PM	5:32 AM
4	6:25 PM	5:29 AM
5	6:18 PM	5:30 AM
		5:29 AM
Average Time	**6:20 PM**	**5:29 AM**

The photo sensors' turn-on and turn-off intervals were recorded during the 5-day monitoring of their operation. The photo sensor's average turn-on and turn-off time were determined to be 6:20 pm and 5:29 am, respectively. It is observed that there's an interval of 11hrs and 9mins in turning and off of the flood lights. The calculated time interval was used to determine the time needed for the computation of the total watt-hour.

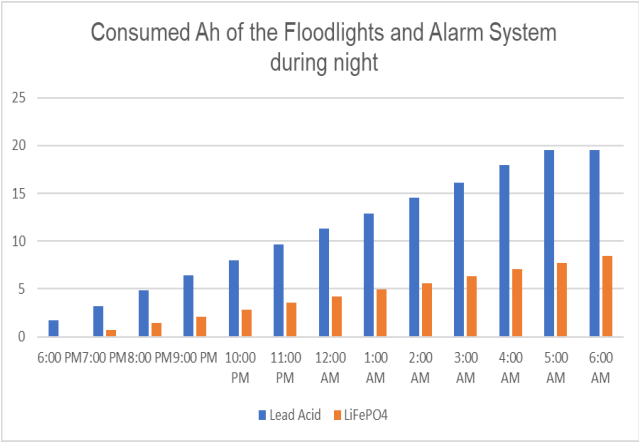


Figure.7. Consumed Ah of the alarm system and flood lights at night
Note. Adapted from Technical assessment of DC supply Burglar Alarm System in Sta. Barbara Elementary School, by J. Bagtas et al 2022, p. 10-11, Installation of Solar Powered Security System for Santa Barbara Elementary School

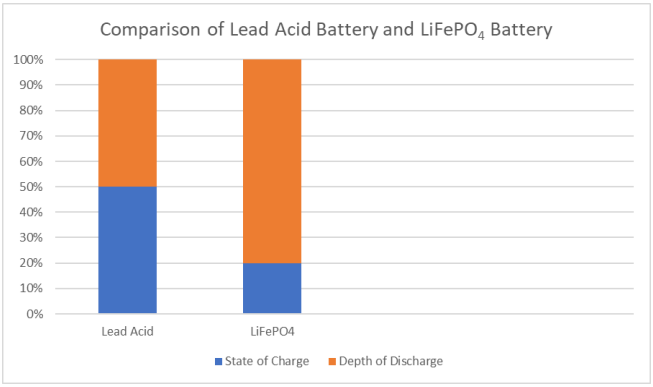


Figure.8. Lead-Acid Battery vs. LiFePO4 Battery

Figure 8 shows the difference between a lead-acid used by the previous proponents in 2018 and LiFePO4 that was used during the enhancement program. The depth of discharge of a battery is the capacity used before recharging it. Lead-acid batteries run to only 50% depth of discharge, beyond the recommended point, is risking the negative effect onto the lifespan of the battery.

Lithium Iron Phosphate batteries, also known as LiFePO4 or LFP batteries, are the finest lithium battery chemistry for solar applications. It is more durable and can withstand longer cycles. Counter to the lead-acid, lithium batteries can hold 80% or more depth of discharge without affecting the lifespan of the battery.

In addition, unlike lead-acid batteries, they do not require maintenance or venting.

4.5 The alarm system's audibility

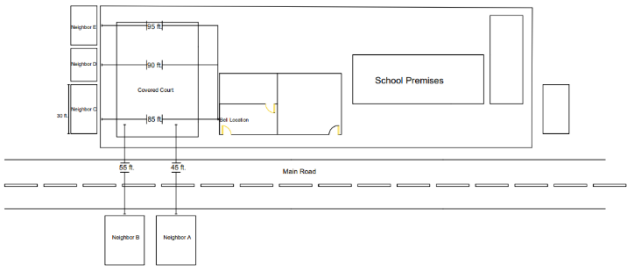


Figure.9. Distance of the alarm to the neighbors

Neighbor A, the nearest neighbor around the school (shown in figure 9), obtained a 95 dB at 45 ft., which is equivalent to a motorcycle engine running, vehicle horn, and power mower sounds. Neighbors B with a distance of 55 ft. received a 90 dB equal sound to a subway and motorcycle. Neighbor C with a distance 85 ft. received an 80 dB equivalent sound to a garbage disposal and dishwasher. Standing 90 ft. away from the alarm system is the neighbor D that received a 78 dB equivalent to sound of a food blender and car wash shop. Lastly, for the neighbor E the farthest neighbor around the school received a 65 dB at 95ft that's equivalent to passenger car and vacuum cleaner.

V. CONCLUSION

The primary goal of enhancing the precision of the sensor was achieved through different situations. With the use of a thermal scanner, the temperature of persons entering the room was monitored, where the person can be detected at a certain body temperature. During the simulation, it was proven that in moving inside the coverage area of the PIR sensors, the precision of the sensor was successful in detecting an intruder accurately.

For the objective of enhancing the wiring ampacity, computations were depicted and based on the enhancement of the wire size which was applied in the procedure considering different factors such as the temperature. The researchers used a Thermoplastic High Heat-resistant Nylon-coated wire with a 90° C as its operating temperature. This type of wire is applicable for tropical countries like the Philippines.

While the enhancement of the components was based on the specification of the previous project better components were chosen, then comparing to the newly installed components from the old system proving that the system was improved.

VI. RECOMMENDATION

Further enhancement of the system can still be made as it is not a perfect project. A surveillance camera can be added to monitor entry and exit in the institution as there are CCTV's today that runs through solar energy. A 200w power inverter can be improve by using a pure sine wave and with a higher power rating for future load expansion.

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