OPTIMIZED AND AUTOMATED SOLAR POWER CONVERSION AS SECURITY(AC) LIGHTING SYSTEM

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ABSTRACT

As a response to Colegio's advocacy regarding care for creation, this research project is focused on the design of a prototype of an Optimized and Automated Solar Power Conversion of Security (AC) Lighting the System. This study is conducted to help decrease the energy consumption in the school wherein its power is off the grid and enhance better security at the gate entrance at night where it is located. It is installed on the top of the guardhouse roof to maximize the light absorption of the solar power even during the rainy season utilizing the Monocrystalline material as the panel itself. This project is mainly allocated with the construction of the electronic hardware design using a battery and a Maximum Power Point Tracking (MPPT) charge controller to support the storage unit of electricity and a solar panel to harness solar energy. Its functionality was assessed by the accuracy of the cyclical charge and discharge time operations day and night. Power management aims to operate as a counter-measure to the effect of shortage in the storage of electricity during rainy days and cloudy days. It also uses an automation system for charging control and for the utilization of enough power in spotlights. The hardware design was embedded and specialized using the maximum power point tracking system to control the operation of the device which will act to assist in storing energy in the primary container. The study has concluded that charging full-time voltage during the rainy season accumulated to an average of 6.95 hours while in sunny weather conditions, accumulated only an average of 5.38 hours, and by this, the system was able to sustain enough amount of power storage at varying weather conditions. The discharging operations of the light that continuously illuminates at night accumulated into an average of 12 hours and 10 minutes. The researchers subsequently implemented the installation of this project study that will be used and utilized at the main entrance of the Colegio. The study is recommended for further improvement of the hardware feature employing a PIR automatic sensing technology to improve power optimization from time to time.

Keywords: *Photovoltaic Cell, MPPT, Circuit Breaker Module, Inverter*

INTRODUCTION

The energy demand across the globe has increased due to rapid advancement in the industry and even in household which led engineers to create more renewable or alternative source of energy like solar power as one of the abundant sources available within our environment's natural resources (Sharma and Goel, 2017). Solar photovoltaic cells can be an appropriate technology for a source of renewable electricity in developing nations, especially in remote rural areas (Shahsavari, A.,2018). Photovoltaic systems have been made essential and served as the best alternatives in renewable energy sources (Kumar and Sudhakar, 2015). According to the U.S. Department of Energy, the amount of sunlight that strikes the earth's surface in an hour and a half is enough to handle the entire world's energy consumption for a full year. Solar technologies convert sunlight into electrical energy either through photovoltaic (PV) panels or through mirrors that concentrate solar radiation. This energy can be used to generate electricity or be stored in batteries or thermal storage.

The place where the project was built, can manage hundreds of wattages from solar energy where it is exposed to sunlight due to the high land area within the vicinity. In this exposure, solar energy is unparallel, unsoiled and prospective energy source among all other nonconventional energy options (Ahsan, et.al., 2016). The research project worked on the electrical design unit as well as the safety features of the prototype and most importantly, the illumination at night using the alternating current power generated from the sun. The function of a supercapacitor will suffice the primary storage unit into the extent of a stand-alone system (Kouchachvili, L., 2018). In addition, a lead-acid gel battery combined with the sulfuric acid is mixed with finely divided silica, which forms a thick paste or gel. The freshly mixed gel is poured into the cell container before it sets. As the gel dries microscopic cracks form that allows the passage of gas between the positive and negative plates required for the recombination process (Spiers, 2018).

Capacitance builds up electricity, in common with a battery. The only difference is that an insulator device like a capacitor manages to rapidly switch the charging and discharging cycle at a fast rate, unlike batteries. The supercapacitor is an electronic component that has a high capacitance value of up to 500F or more which functions to collect a huge amount of electricity in a short period. The environmental aspect related within power generation with the harnessed solar energies from the solar panels which reduces carbon emission and carbon credits were considered also for the implementation and operation of the solar plant system in the location of its installation unit (Khatri, R., 2016).

Capacitors were commonly constructed in use of storing electrical charges between central layers of non-conductive materials. The activated carbon which is the unique material used to cover the storing capability of this device acts as the physical super barrier to making charging quick and huge. That is why the fast-charging capability supports the storage unit which is enhanced the network of supercapacitors of 500F each that produces a maximum output of up to 18VDC in its full charged condition during the daytime. This might extend the battery life because its usage is not stressed due to this component that gives the aid or support

Table 1. Power Consumption Efficiency Comparison for Lighting Systems

Features	LED	Fluorescent	Incandescent
Light bulb projected lifespan (hours)	25,000	10,000	1,200
Watts per bulb (equivalent 60 watts)	8.5	14	60
Cost per bulb	₱5	₱2	₱1
KWh of electricity used over 25,000 hours	212.5	350	1500
Cost of electricity (@ 0.10 per KWh)	₱21.25	₱35	₱150
Bulbs needed for 25,000 hours of use	1	2.5	21
Equivalent 25,000 hours bulb expense	₱5	₱5	₱21
Total cost for 25,000 hours	₱26.25	₱40	₱171

Source: (US Department of Energy, 2018)

The loading system deployed uses an AC lighting or the alternating current (AC) source employed to drive the LED lighting system. An alternating current of a light-emitting diode that operates directly out of the alternating current line voltage instead of utilizing a driver to transform the line voltage to direct current power. An alternating current LED chip has a plurality of LED units formed on one chip and is assembled into a circuit loop to be directly used in an alternating current field. An AC LED is also referred to as a high voltage light-emitting diode since it is clear of a current conversion driving component and can be directly employed in mains electricity which is a high voltage (https://www.manufacturer.lighting).

The study determined the construction process of the electrical design of an Optimized and Automated Solar Power Conversion as Security (AC) Lighting System that fabricated a prototype with the safety features embedded in a control room for monitoring and control purposes of the lightings and the light sensor device. MPPT was also used to take advantage of its fast-charging properties. It is because it will serve as an intermediate system that mainly uses a PowerPoint tracking system to save more energy in the peak hours in the battery while it can also accumulate energy directly from the solar panels. This increases a more current flow that will make the system charge more rapidly. In the absence of sunlight due to rainy seasons, the charging process might resume charging the energy in aid of these supporting devices.

The construction built of the hardware features a maximum power-point tracking solution, a light-emitting diode lamp, a Gel type 12VDC battery, and two monocrystalline solar panels that correspond to the operation from charging up to its lighting functionality. The assessment of the performance was evaluated in terms of the charge and discharge rate records within the vicinity of the installation. The lighting system is currently utilized at the gate entrance, which acts as the only illuminating unit in front of the school vicinity can spontaneously enhance security and will continue to support security personnel duties at night that somehow sustains its power which is generated by its own and acts as an OFF grid within the system operations cycle. By these, it can lessen power consumption as a means of illumination during nighttime. The hardware design was continuously developed and inspired by the previous projects which were the charging station unit and the streetlights. Operating with the aid of solar powers in generations of renewable and alternative sources of energy that will support, maximize, and conserve natural resources.

This case study will be an essential reference, guide, and related literature for providing consistent information regarding the Optimized and Automated Solar Power Conversion as Security (AC) Lighting the System and about renewable alternative energy sources or another related environmental energy project. As in the field of electrical engineering, the innovation of technology for power generation will be installed at the school to provide an alternative source of energy to utilize the spotlight energy at night. In the field of electronic devices, the researcher wants to emphasize one of the unique features of this project which is the function of a control system through combining the property of a supercapacitor as an automated fast charging device to aid the battery in its function as a primary storage unit. By the future implementation of this study, an alternative source of renewable energy will be developed to generate electricity without degrading the environment and natural resources in its process.

METHODOLOGY

This study used a descriptive research design that supports necessary information from the device's performance and operations efficiency, accuracy, and effectivity of the variables involved within the study (McNeill, 2018). Data was collected and compared with the existing studies and platforms to exemplify the performance evaluations of the system unit developed initially. In this method, the collected parameters of measurements were carefully analyzed from the digital readings of the lighting system to specify the actual rate versus an ideal rate of performance. Charging time at rainy and sunny weather conditions were the gathered data as well as the discharge rate at night of the battery. The electrical characteristics limitations, capabilities of components' hardware, literature, and facts were found through minor sources such as books, published and unpublished journals, and mostly on websites.

General Method Used

The researcher conceptualized the project by having the Rapid Android Application Development RAAD model as a guide in the development of the proposed system. The following are the processes that were followed.

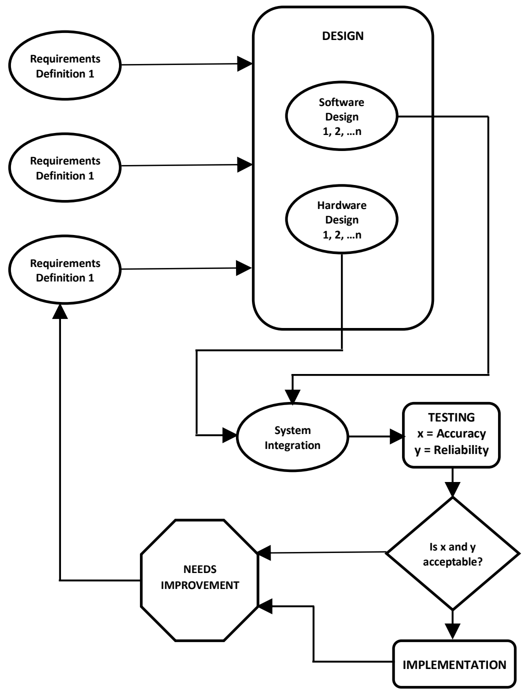

Figure 1. Rapid Android Application Development

Requirement Definition

With the initial development of the study, a simplification of the overall process from the existing spotlight of the school was considered. To get the relevant information, the researcher will obtain the following information such as the power consumption and the illumination system span coverage of the lighting unit in the vicinity of the area. The gathered data for the proposed system will be recorded to expand the process flow of the system.

System Design

This part comprises the composition of the structures to build the hardware and software. It will serve as a complete guide for visual analysis and interaction of the system electrical unit built integrating within the platform and software's Maximum Power Point Tracing System. The user interface that will be provided will have a current list of all security personnel that can be customized by the system user itself.

In the early development of this project, the Rapid Android Application development was used. This technique allows determining the requirements to be included in the design so that the desired characteristics of the system can be tested. It will also provide an opportunity to identify the necessary improvements in the design and functionality of the system as recommended by the end-user.

Hardware Design

The representation of a pictorial block for each module to the entire hardware is linked to exemplify the interactions between all the components used. The schematic diagrams formulated show the interdependencies and interconnectedness of the electronic components used.

A series of testing will be done on the system receiver to stabilize the performance of the system. The series of hardware modules will be used on the platform for their compatibility testing and evaluation. The components will be carefully evaluated by noting their weaknesses and strengths. Then the evaluations will be analyzed and considered using Computer-Aided Design (CAD) and other electronic simulation software like DIP TRACE, EAGLE, and PROTEUS. In this period, the components, process orders, and input data will also be finalized within the system.

System Integration and Testing

The project will be designed using IEE802.15b Bluetooth technology that will be combined with a wireless communications transceiver. As a result, the data signals will be sent and saved in a central database server through a local network Wi-Fi Service transceiver application.

In testing the functionality of the system, numerous units of testing will be done to test for the reliability and accuracy of the system. This process also includes system compatibilities for hardware modules embedded with software drivers. Upon the installation and activation of devices, the network functionality will be configured along with the database server and Android devices. Integrating the hardware and the software of the system is the most important key factor to identify the errors in the project.

Testing

The application will be installed into the Android version 6.0 Marshmallow and will meet the software and hardware requirement in a complete network set-up configuration using the receivers and transmitters that will be embedded within the device. Hardware and network connectivity speeds also vary based on the user's location and distances.

Response Time, Reliability, and Accuracy

Since most mobile applications rely on network connections, measuring the performance of the mobile network is very important for the system's functionality of the project. The response time measurements will be calculated in the tests that will be administered on the device with ten samples. Moreover, testing the illuminations span and coverage and utilization of the power throughout the device efficiency will perform its reliability.

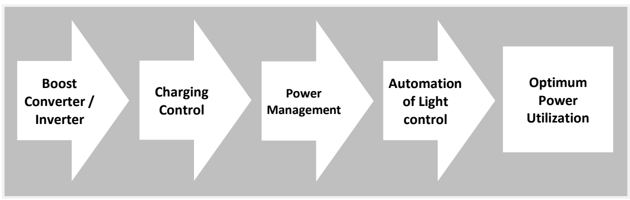

Figure 2. Conceptual Diagram

Optimizing the power consumption will be mainly utilized through the use of PIR (passive-Infrared) sensors which will automatically detect human presence to control the light intensity of the spotlight throughout its operations. If a human or any sudden movement is detected, maximum illumination will be activated, and it will return to its normal illumination when there is no more motion trace. The charging sequence at daylight will be maximized because of the additional storage units provided by capacitors. The sunlight also at the daytime will be used simultaneously to control the sensor supplying the power that acts as a stand-alone system. This is not consuming any amount of power from the gridline to utilize the security lighting system at night. The automatic control will be supported by the mode set-up which has the remote sensing monitoring system and the android application monitoring system which has the capability of controlling the device through wireless technology-Internet of things.

The project will include the development of the lamp post above the rooftop that will be installed in an enclosure protected from dust, rain, and direct heat of sunlight to ensure its components' life span maintenance and functionality. The whole device set-up consists of the interface between the hardware and the software of the prototype to test for its power and the cost efficiency in its implementation.

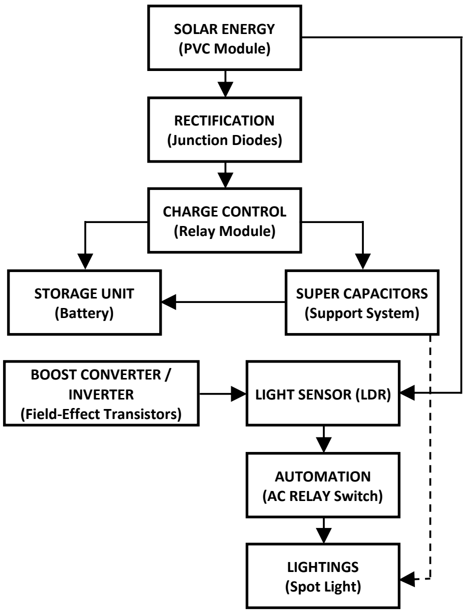

Figure 3. Block Diagram

The hardware design will be constructed mainly from a module controller board that operates to optimize the function of the automatic charging and discharging sequence by light and the electric energy conversion from the prototype. The whole set-up and composition of the following list of components were taken down below which considers the design to consume less power throughout the system operations.

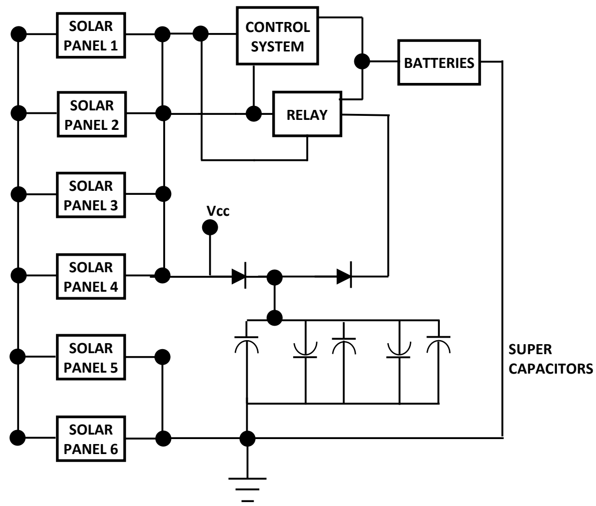

Figure 4. Electronic Hardware Schematic Diagram

RESULTS AND DISCUSSION

Technical Computation Electrical Design Analysis

Daily Power Consumption

$$Device\ Wattage\ x\ Number\ of\ Hours\ Used$$

$$50\ watts\ x\ 12\ hours = 600\ Watts$$

Solar Battery Deep Cycle (Gel Type)

Among other renewable alternative electrical energy sources, solar energy is free and abundant in the surrounding environment that can manage long-term issues in energy crisis (Kannan, 2016). The initial process will be coming from the harnessing of solar energy at daylight with the use of Photovoltaic cells or solar panel arrays designed to sustain enough amount of electricity for the storage of energy and operation of the control system. The control system consists of automation in charging, energy conversion, and light activations. With the continuous flow of energy, this simultaneously supplies power to activate the light sensors and the control system intended to optimize the power consumption of the prototype.

An enhanced storage system will be supported by supercapacitors that have high capacitance values to store more energy and to be fully charged in a short period. It will have the advantage of quick charge, large power density, and long-life cycle. The stored energy will be transferred to the battery which repeats the cycle until the battery will also attain its full charged condition. In terms of recharging rate and life span, a supercapacitor will have a greater advantage than a battery for generating and utilizing the energy of the system even in considering cloudy or rainy days. Then the reserved battery capacity should be 50-60 percent, so therefore there will be an amount of power rating of 600 Watts coming from the initial input power compared to the output. Taken into consideration by Ohm's Law, a rating of 100 ampere-hours by a 12 volts direct current rating will produce a specified amount of 1200 watts of electrical power. In conclusion, there is a fifty percent battery capacity coming from the 600 watts over a 1200 watts initial capacity.

Solar Panel

Using the average 100 Watts mono crystalline at 80 percent efficiency output at 5 hours average sun hours in the Philippines results into 100 X 5 hours equal to 500W multiplies to 80 percent equals to 400 Watts then;

$$\frac{600W}{400W} = 1.5$$

which results into two pieces of 100 Watts solar panels within the design made.

Solar Charge Controller

One of the automated operations will be coming from the charged control sequence of the battery. During the discharged operation at night of the storage unit, an inverter module will be constructed to deliver enough power in lighting up the spotlight until the energy will be drained. The operation will repeat the cycle from charging in the daytime and discharging at the t-time. The limitation of the charge control system was built to have 12A from two parallel mixtures of photovoltaic cells in 12VDC amount produced wherein the maximum power point tracker is a device that chops up and down direct current voltages format. This preserves the match between the panels and the storage units. It would transform a higher scale of energy voltage product from solar panels gong small scales energy voltages needed to charge up the storage units. These are sometimes called "power point trackers" and are not to be confused with panel trackers, which are solar panel mount that follows, or track, the sun.

The optimization characteristics of this control system unit are because photovoltaic cells are spotless wherein panel tracking is where the mount accurately follows the sun. These sums up to enhance the product output captured from the sun across the clouds for maximum sunlight filtering. These normally absorb about a 35 percent increase in summer for tropical countries like the Philippines. In aid of maximum power point tracking solutions, panel temperatures are much lower on rainy days that might put out greater energy, wherein it is the time that the device needs to power up more from the solar panels due to shorter days of sunlight covers.

Maximum Power Point Tracking (MPPT) is a digital tracking device that controls the charging that simultaneously monitors the output of the panels and compares it to the amount of battery voltage. It will detect out what is the perfect fit of power that the panel can put out to charge the primary storage units within the system. Commonly, maximum power point trackers are ranging at 93-97 percent in their power conversion efficiency. It harnesses a 20 to 45 percent power gain in colder days and 10-15 percent in summer days of operations and a continuous cycle of repetition over a while. Actual gain can change possibly due to temperature, weather, charge cycle of battery, and other natural extrinsic and intrinsic factors.

Inverter

The specification included in this device has a 300Watts of load power consumption in maximum range, therefore the load or bulb in the spotlight is rated for 50W. The amount of voltage generated from multiple arrays of solar panels within the storage units will be in the DC form which will require the specification of higher voltage into the high bright lamps. From the battery, a boost converter will amplify the voltage to match the amount needed in the input of the inverter circuit. This design will be adapted from elctroschematics.com and might be modified for some compatibility and availability issues.

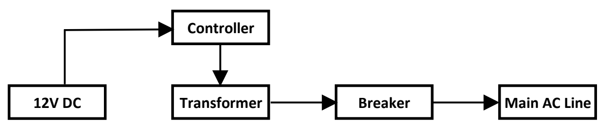

Figure 5. Inverter Hardware Design-DC to AC Converter

DC Breakers

Circuit breakers were included for safety purposes of the system which has the panel to control set-up in 25 Ampere rates, the controller to Load the pathway into 25 Ampere rates, the battery to load set-up with a 32 Ampere rate, and the manual mode set-up with 40 Ampere rates.

Final Hardware Design

The system prototype was built in this wooden platform below with the following components, namely: the solar panels, Gel type 12VDC battery, the maximum power point tracking device which is digital in purpose by its monitoring and control functions, the circuit breakers for safety routing of connection all through-out the circuit hardware design built, the inverter and the lighting system.

Figure 7. Spot Light Set-up with Solar Panels

Figure 6. Prototype Construction Set-up

The loading system is utilized with a light-emitting diode 50 watts rating of the lamp. It initially harnesses solar energy from two (2) parallel solar monocrystalline, photovoltaic cells and transfers energy directly to the controller where the Gel-type battery is connected.

In reference to the data on table 2, the parameters taken into consideration were the readings for the temperature in degree Celsius, Photovoltaic Voltage input ratings as well as the current capacity in ampere-hour rating, the initial charging time, the full-charged time voltage, and the date of conducted trial. These variables were commonly referred to as the common specifications of the charging system for normality check of the hardware and the software functionality. As the average rating is computed over the ten trials, this accumulated an amount of 6.95 hours which represents the rate at which the charging operates at a cloudy day set-up.

Table 2. A 13.7V Full Charging Sequence at Daylight with Rainy Weather Condition

#	Device Temperature Degree Celsius	Solar Panel Voltage(V)	Solar to Battery Current (Ah)	Time Started	Fully Charged Time (Hours)	Date
1	32	18.1	34	5:43:16 am	6.4	11/26/2020
2	37	17.6	38	5:36:11 am	7.1	11/27/2020
3	39	19.2	32	5:41:02 am	7.7	11/28/2020
4	31	20.3	36	5:27:55 am	6.6	11/30/2020
5	36	17.4	29	5:18:09 am	7.3	12/14/2020
6	39	18.5	26	5:22:13 am	7.2	12/15/2020
7	40	19.3	33	5:17:05 am	6.8	12/16/2020
8	33	17.9	34	5:21:08 am	6.7	12/17/2020
9	37	18.7	38	5:13:29 am	7.2	12/19/2020
10	31	17.5	40	5:25:16 am	6.5	12/21/2020
Average	35.5	18.45	34		6.95	

Table 3. A 13.7V Full Charging Sequence at Daylight with Sunny Weather Condition

#	Device Temperature Degree Celsius	Solar Panel Voltage(V)	Solar to Battery Current (Ah)	Time Started	Fully Charged Time (Hours)	Date
1	34	19.9	46	5:33:22 am	5.2	11/24/2020
2	36	18.7	51	5:23:47 am	5.5	11/25/2020
3	38	19.5	48	5:28:13 am	5.1	11/29/2020
4	42	18.6	46	5:11:16 am	5.4	12/11/2020
5	46	21.2	52	5:26:12am	5.8	12/12/2020
6	45	20.6	55	5:09:21 am	5.5	12/13/2020
7	38	20.3	47	5:36:14 am	5.1	12/18/2020
8	39	19.6	44	5:12:24 am	5.2	12/20/2020
9	41	19.8	46	5:22:38 am	5.6	12/22/2020
10	38	18.8	49	5:14:37 am	5.4	12/23/2020
Average	39.7	19.7	48.4		5.38	

As the same parameter applies in reference to the data on table 3, the accumulated average time resulted in 5.38 hours only in the operation of a normal sunny weather condition. This is faster than the rainy condition and still can store energy in varying weather conditions. This generated power from Solar energy maximizes and sustains the cycle of charging simultaneously with the lighting operations at night.

Table 4. Efficiency test of the Light during nighttime

Number of Testing	Date	Time Started Automatic Lights ON	End of Discharge Time Record	Battery Leftover Voltage
1	12/15/2020	6:11:31 pm	6:21:03 am	12.6
2	12/16/2020	6:14:26 pm	6:23:15 am	12.3
3	12/17/2021	6:10:45 pm	6:22:44 am	12.4
4	12/18/2021	6:09:21 pm	6:19:01 am	12.2
5	12/19/2022	6:13:11 pm	6:23:11 am	12.4
6	12/20/2022	6:09:21 pm	6:27:48 am	12.6
7	12/21/2023	6:12:46 pm	6:31:04 am	12.7
8	12/22/2023	6:17:01 pm	6:30:51 am	12.5
9	12/23/2024	6:21:02 pm	6:22:37 am	12.7
10	12/24/2024	6:17:05 pm	6:19:56 am	12.5
	Average	13.3	23.7	12.49
	Average Time	6:13 pm	6:23 am	
Average Operating Hours		**12 hours and 10 minutes**		

In reference to the table 4, the parameters taken into consideration were the date for the conduct of the trials, the initial discharging time at when the light is initially turned ON consuming the stored energy at daylight, the end of the discharging period when the light will be turned off automatically as it already sensed a sunlight t daytime and lastly, the battery left over-voltage these parameters taken were referred to as safety limit for the device life span and capacity limit to operate continuously. Acquiring the average value from the rest of the ten trials, the system continuously operates at night at an average of 12 hours and 10 minutes.

CONCLUSION

Based on the findings, the prototype was built using the MPPT control system, monocrystalline, solar PV cells which can harness energy even when the weather has variated from rainy to sunny days, and a Gel type lead acid 12VDC battery. MPPT control was designed for appropriate functions of the sequence of charging, and the automation that supports turning ON and OFF of the light. The functionality of the system was tested and evaluated in terms of its charging time and accuracy based on the result of charging the full-time voltage of the system when it is on a rainy day set up that has resulted in an average of 6.95 hours. While in the set-up of sunny weather conditions, it got an average of 5.38 hours only, and still, it considers that the system was able to sustain enough power of storage at varying weather conditions.

The discharging sequence wherein the spotlight continuously lights up at night has resulted in an operating full hour of 12 and 10 minutes with an excess average value of voltage into 12.49 Volts. The power output delivered from a photovoltaic module highly depends on the amount of irradiance, which reaches the solar cells wherein many factors determine the ideal output or optimum yield in a photovoltaic module. However, the environment is one of the contributing parameters which directly affects the photovoltaic performance as one observed here was the location of installation wherein the direct exposure of sunlight varies from time to time.

RECOMMENDATION

The operating hours of the spotlight might be maximized in power consumption throughout the use of PIR sensor technology which can only act to consume power when human intervention is detected within the surface covering the area of the facility within the range of the spotlight.

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