Design and Development of the Power Generating System of a Solar Powered Cell Phone Charging Station

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Abstract: **This describes the design, and development of the evaluation system of a solar-powered cell phone generating system developed at the Lyceum of the Philippines University-Cavite Campus for the purpose of reducing the campus' electric energy consumption due to the unauthorized charging of cellphone by students from campus outlets. This study describes the components of the solar-powered charging station and explains the assembly, operation and testing of the solar charging station. IT also describes how this solar-powered charging station was evaluated using a survey questionnaire to determine the students perception of the performance and acceptability of the station.**

Keywords: **Cell Phone Charging Station, Solar Power, Solar cells, Photovoltaic Technology.**

1. INTRODUCTION

The Sun is a ball of energy located in the center of the solar system. The sun constantly gives off energy which is carried through space as electromagnetic radiation. Light and radio waves are examples of the types of electromagnetic radiation. It travels like waves in water with a series of ups and downs. Various types of electromagnetic waves may differ in their wavelength. This is the distance between two ups (or two downs) in a row. The wavelengths of radio waves are longer than those of light. Among the types of light, red has a longer wavelength than blue.

The range of electromagnetic energy emitted by the sun is known as the solar spectrum. The solar spectrum is composed of 40% of wavelengths of infrared, 50% at visible wavelengths and 10% at wavelengths of ultraviolet. This sunlight, when converted to electrical energy can be applied to irrigation, vaccination refrigerator system, and household lighting system.

Solar cells and solar panels have lots of uses. Solar cells are the building blocks of all photovoltaic (PV) systems because these are devices that convert sunlight to electricity. Individual PV cells are electricity-producing devices made of semiconductor materials. They are often connected together to form PV modules that may be up to several feet long and a few feet wide. Modules, in turn, can be combined and connected to form PV arrays of different sizes and power output. They are in everyday things like calculators, watches, flash lights, solar-powered toys, radios, and solar powered gadgets. Solar panels are also used to generate electricity to light up road signs. Even some automated teller machines have solar panels. Using solar power with devices like these means there is no need to worry about batteries being empty.

Solar energy is free although there is a cost in the building of collectors and other equipment required to convert solar energy into electricity. On the other hand, this energy does not cause pollution and can be used in the remote areas where it is too expensive to extend the electricity power grid.

According to Robert Foster of Solar Energy Renewable Energy and the Environment of 2012, the solar energy is the energy force that sustains life on Earth for all plants, animals, and people. It provides a compelling solution for all societies to meet their needs for clean, abundant sources of energy in the future. The source of solar energy is the nuclear interactions at the core of the sun where the energy comes from the conversion of hydrogen into helium. Sunlight is readily available, secure from geopolitical tensions, and poses no threat to our environment and our global climate systems from pollution emissions.

Advanced technologies have made solar energy more competitive with conventional energy fuels for generating electricity. Concentrating solar power technology produces much higher temperatures which can be used for heating and producing electricity. Large curved mirrors are used to reflect sunlight from a large area and focus it on a much smaller blackened area. Solar power plants use computer-controlled sun-tracking reflectors which move to face the sun's rays. The sun's thermal energy is reflected and focused on a large water boiler often on a tower. The fluid boils to produce steam which drives a turbine to generate electricity. Large solar power plants use new concentrating solar power technologies and are developing new polymer materials to replace the more expensive glass mirrors. Concentrating solar power is the most cost effective method to harness the sun's energy for generating electricity. (Diane Little (2009) *Solar Energy* 2009. EFMR Monitoring Group, Inc.)

Solar energy can be tapped directly (e.g., PV); indirectly as wind, biomass, and hydropower; or as fossil biomass fuels such as coal, natural gas, and oil. Sunlight is by far the largest carbon-free energy source on the planet. More energy from sunlight strikes the Earth in one hour (4.3 x 10^{20} J) than all the energy consumed on the planet in a year (4.1 x 10^{20} J). Although the Earth receives about 10 times as much energy from sunlight each year as that contained in all the known reserves of coal, oil, natural gas, and uranium, renewable energy has been given dismally low priority by most political and business leaders (Robert Foster (2010) *Solar Energy Renewable Energy and the Environment*, CRC Press: Taylor and Francis Group). The amount of energy radiated by the sun is unimaginably large. Solar radiation is absorbed in the atmosphere and at the earth's surface at a rate of around 10^{17} W. The global rate of energy consumption is approximately 10^{13} W, so the sun provides 10,000 times more energy than the world consumes. A solar converter of 10% overall efficiency could theoretically provide all the electricity generated by Asian Development Bank (ADB) country members within an area of approximately 5000km (Solar Photovoltaic Generator using PV technology.1996)

Based on the Department of Energy (DOE), biomass, solar and wind will be among the major sources of energy for the next decade, accounting for more than a third of the country's total energy demand. From 81.5 Million Barrels of Fuel-Oil Equivalent (MMBFOE) as compared to its 2002 aggregate of 129.5 MMBFOE. The same study also conducted a resource assessment of solar power potential. Results of previous ground-based measurements of the daily total number of hours of sunshine duration were combined with United States – National Renewable Energy Laboratory (US-NREL's) Climatologically Solar Radiation (CSR) model. The model converts information on satellite and surfaced-derived data to estimate the monthly average daily total global horizontal solar resource. The study showed that the country has an annual potential average of 5.1 kilowatt-hour (kWh)/m^2/days. Based on the 2001 inventory of solar technologies, a total of 5,120 solar systems have been installed, as follows: (i) 4,619 solar photovoltaic (PV) systems; (ii) 433 solar water heaters; and, (iii) 68 solar dryer systems. (http://www.doe.gov.ph/renewable-energy-res/biomass-solar-wind-and-ocean)

The Philippines' position just above the equator does not provide with vast potential for solar energy applications. However, the country's average solar radiation, based on sunshine duration, is 161.7 watts per square meter, with a range of 128 to 203 watts per square meter. (http://www.doe.gov.ph/renewable-energy-res/resource-maps/278-solar)

In the 1960s, the direct conversion of solar radiation into electricity through photovoltaic (PV) devices was understood only by a handful of scientists. By the late 1960s, PV energy conversion was still a little- known technology, but had established an important market in the US space program. PV was ideal as sunlight is constantly available in space. The fact that the cost of electricity was probably several thousand dollars per kWh was not a constraint since PV was the only viable power option, and the cost of a PV generator was small compared to the cost of building and launching satellite. (Solar Photovoltaic Generator using PV technology.1996)

Photovoltaic (or solar cells) shown in figure 1 is a solid-state semiconductor devices that convert light into direct-current electricity. These semi-conductors are most commonly made out of silicon crystal, which are used in many electronics and computer components. The top layer of the silicon portion of a solar panel is made from a mixture of this silicon and a small amount of phosphorous, which gives it a negative charge. The inner layer, which constitutes the majority of the panel, is a mix of silicon and a little bit of boron, giving it a positive charge. The place where these two layers meet creates an electric field called a junction. When light (or photons) hits the solar cell, before it gets to the silicon crystal to make electricity it passes through a glass cover on the panel and an anti-reflective coating, which stops photons from reflecting off of the panel and being lost. The photons are absorbed into the junction, which pushes electrons in the silicon out of the way (see illustration below). If enough photons are absorbed, the electrons are pushed past the junction and flow freely to an external circuit. When converted to alternating current electricity using what is called an inverter, this energy can be used to power anything that uses electricity. (Vince Lombardi (1990) *Solar 101*.Virginia Technology)

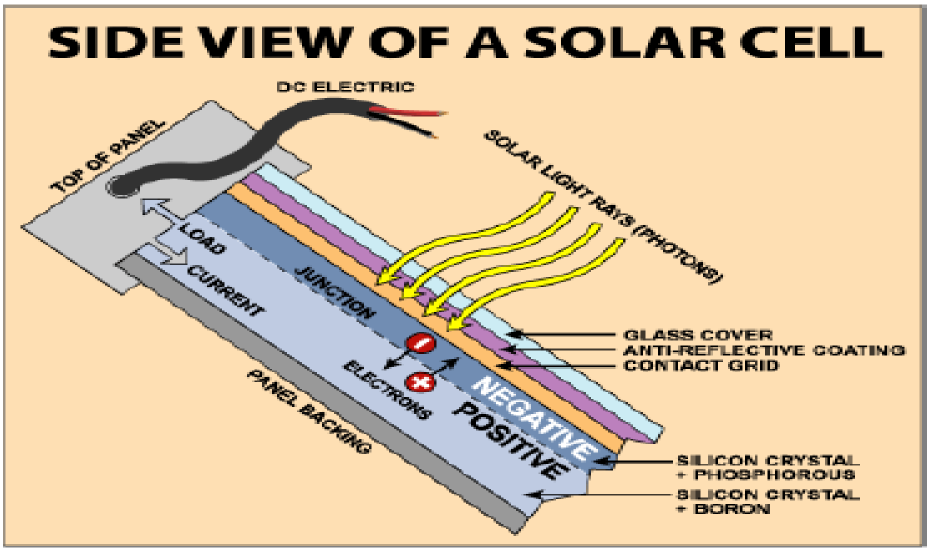

Figure 1: Side view of solar cell

Photovoltaic Energy:

Solar cells called photovoltaic (PV) cells convert sunlight directly into electricity. Semiconductor materials absorb sunlight energy and create an unbalanced flow of electrons from one side of the solar cell to the other. The sides are connected with a metal material which allows the electrons to travel. The flow of electrons produces electricity. Solar cells are often used in small devices such as calculators. Numerous photovoltaic cells can be interconnected to produce more power. Currently, the large-scale use of photovoltaic cells is not economically competitive in the market of electricity generation. The U.S. Department of Energy, along with non-government agencies and universities are working together on the Solar America Initiative (SAI). Their goal is to aggressively develop PV technologies making electricity from PV cells economically competitive with conventional electricity by the year 2015 (Solar Energy.2009.Pdf).

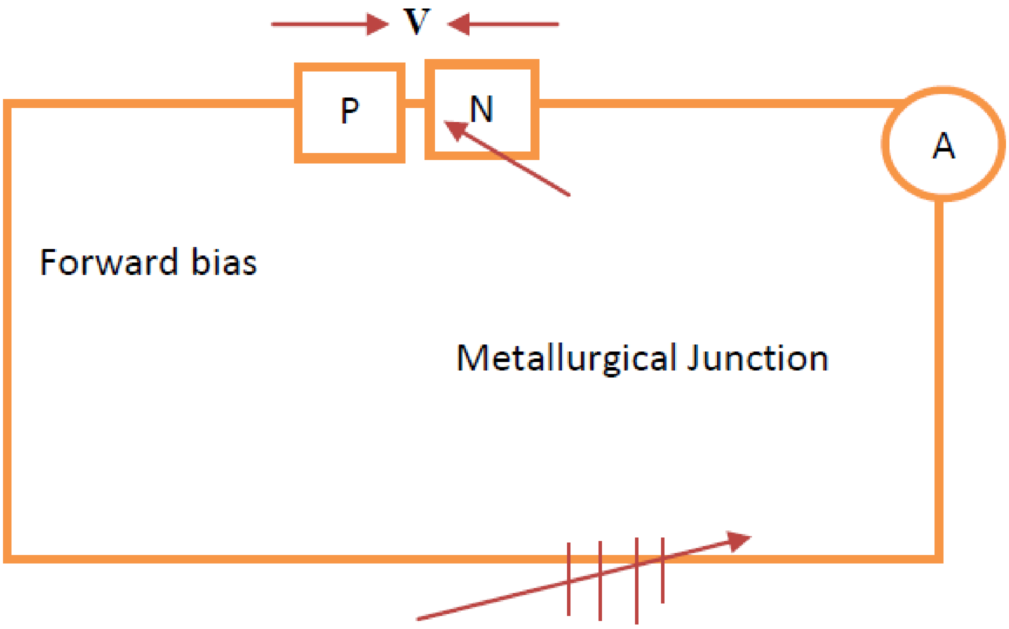

Figure 2. P-N junction in a simple circuit

Photoelectric effect and Photovoltaic effect:

The photoelectric effect was first noted by a French physicist, Edmund Becquerel, in 1839, who found that certain materials would produce small amounts of electric current when exposed to light. In 1905, Albert Einstein described the nature of light and the photoelectric effect on which photovoltaic technology is based, for which he later won a Nobel Prize in physics. The first photovoltaic module was built by Bell Laboratories in 1954. It was billed as a solar battery and was mostly just a curiosity as it was too expensive to gain widespread use. In the 1960s, the space industry began to make the first serious use of the technology to provide power aboard spacecraft. Through the space programs, the technology advanced, its reliability was established, and the cost began to decline. During the energy crisis in the 1970s, photovoltaic technology gained recognition as a source of power for non-space applications. (http://science1.nasa.gov/science-news/science-at-nasa/2002/solarcells/)

The photoelectric effect is the scientific principle which drives solar power production, research, and development. Without this important scientific principle, mankind would not be able to produce electrons from photons. The production of electricity from photons gives the fundamental ability to harness solar energy, capturing the power of the sun. This potential energy capture and conversion could completely power our world, and is thus pursued as the photovoltaic or solar industry.

The German physicist, Heinrich Hertz, noticed that certain materials exposed to sunlight and ultraviolet light reacted by giving off a current in 1887. Albert Einstein's mathematical description of the photoelectric effect appeared in one of his 1905 papers, named "On a Heuristic Viewpoint Concerning the Production and Transformation of Light". This paper proposed the simple description of "light quanta", or photons, and showed how they explained such phenomena as the photoelectric effect. His simple explanation in terms of absorption of discrete quanta of light explained the features of the phenomenon and the characteristics. Later, the same mathematical equations involved in Einstein's explanation of the photoelectric effect, won him the Nobel Prize in Physics in 1921.

Einstein's work predicted that the energy of individual ejected electrons increases linearly with the frequency of the light. Perhaps surprisingly, the precise relationship had not at that time been tested. By 1905, it was known that the energy of photoelectrons increases with increasing frequency of incident light and is independent of the intensity of the light. However, the manner of the increase was not experimentally determined until 1915 when Robert Andrews Millikan showed that Einstein's prediction was correct though stoppage voltage remains the same. In other words, by increasing the radiation the amperage or current increases, the voltage remains stable. (iv) for a given metal, increase in frequency of incident beam increases the maximum kinetic

Types of photovoltaic panel:

A photovoltaic panel is classified into four types. These are:

1. Monocrystalline (or multi-crystal) silicon panels. These panels are made from one continuous sheet of silicon with metal attached to the edges increasing conductivity. Their efficiency rates are in the 14%-18% bracket. They're more expensive and more efficient.

2. Polycrystalline silicon panels. These panels have an efficiency rate of around 12%-14% so they're not quite as efficient as the above. Metal is also attached on the edges to aid in conduction and also hold the cells together. When an individual cell is damaged it could theoretically replaced without replacing the whole panel. Their cost is less than the monocrystalline panels.

3. String ribbon silicon panels. These are put together very much like the polycrystalline panels but with added technological differences. Some people put the efficiency rate at around 12%-14%, some considerably higher. The difference in technology does allow for a lower manufacturing cost than the polycrystalline solar panels which should translate into a lower market cost.

4. Amorphous silicon panels. Last and least are the amorphous silicon panels with a 5%-6% efficiency rate, the lowest of any type of solar panel. They're made from a thin flat piece of conductive metal like copper with a thin layer of silicon film over the top. They're inexpensive to produce, relatively cheap to buy but aren't big on energy production. Amorphous silicon is being used in new ways such as in a metal roof application which has very interesting possibilities (http://www.simplesolarsetup.com/solarpanels.html).

Battery:

Battery is one of the best components in association with the solar panel. It lets the charging station to function even at night. Batteries also help loads to run at a constant voltage, while allowing the solar modules (or other power sources) to still charge as much as it can. When a battery is connected (you turn on a light for instance), this starts a chemical reaction between its sulfuric acid and the lead in the plates submerged in the acid. This reaction produces electricity (a flow of electrons from the chemicals) to run the light. The reaction also depletes the sulfuric acid and builds up a crust of sulfate crystal on the battery plates. When the battery is recharged (by PV modules, or other source), it reverses the reaction, electrons are introduced back at the plates, the sulfate is dissolved into acid again and the battery water becomes more acidic At full charge, the acid quits increasing in concentration, and further charging releases hydrogen gas. This battery gassing, in small amounts, stirs the electrolyte, knocks sulfate loose from the lead plates, and brings the battery to fuller charge. Too much gassing can boil the battery water dry, or because overheating both of which shorten a battery's life.

Chemical reactions usually slow down as the temperature drops, so this means a colder battery can't produce as much energy as a hot one. However, colder batteries will last much longer than ones that overheat (over 115°F) Also it is known that the greater the surface area of the lead plates, the greater the number of electrons that will be allowed to react at once, creating more current. But if the plates are thin, they can't react for very long before being drained or even damaged. This is how a relatively small starting battery can start a car. By increasing the surface area of its lead plates, a starter battery allows for a rapid flow of high amperage -- but they can't last as long because of their thinner plates. A deep cycle battery, the type used for energy storage in renewable energy systems, is the opposite of the starter battery -- it has much thicker plates with less surface area, and thus will produce power much more steadily over a longer period of time. (http://www.solarray.com/TechGuides/Batteries_T.php)

Charge Controller:

Since the brighter the sunlight, the more voltage the solar cells produce, the excessive voltage could damage the batteries. A charge controller is used to maintain the proper charging voltage on the batteries. As the input voltage from the solar array rises, the charge controller regulates the charge to the batteries preventing any overcharging (http://www.freesun power.com/chargecontrollers.php).

Most quality charge controller units have what is known as a three stage charge cycle that goes like this:

1) **Bulk.** During the Bulk phase of the charge cycle, the voltage gradually rises to the Bulk level (usually 14.4 to 14.6 volts) while the batteries draw maximum current. When Bulk level voltage is reached, the absorption stage begins.
2) **Absorption.** During this phase the voltage is maintained at Bulk voltage level for a specified time (usually an hour) while the current gradually tapers off as the batteries charge up.
3) **Float.** After the absorption time passes, the voltage is lowered to float level (usually 13.4 to 13.7 volts) and the batteries draw a small maintenance current until the next cycle.

Inverter:

Unless one plans on using battery power for everything, a power inverter will be needed. Since the majority of modern conveniences all run on 120 volts AC, the power inverter will be the heart of the solar energy system. It does not only converts the low voltage DC to the 120 volts AC that runs most appliances but also can charge the batteries if connected to the utility grid or an AC Generator as in the case of a totally independent stand-alone solar power system.

Types of Inverters:

Inverters are classified into four, these are:

1. Square wave power inverter. This is the least expensive and least desirable type. The square wave inverters produced are inefficient and is hard on many types of equipment. These inverters are usually fairly inexpensive, 500 watts or less, and use an automotive cigarette lighter plug-in.

2. Modified sine wave power inverter. This is probably the most popular and economical type of power inverter. It produces an AC waveform somewhere between a square wave and a pure sine wave. Modified sine wave inverters, sometimes called Quasi-Sine wave inverters are not real expensive and work well in all but the most demanding applications and even most computers work well with a modified sine wave inverters. However, there are exceptions. Some appliances that use motor speed controls or that use timers may not work quite right with modified sine wave inverter. This inverter is only recommended for smaller installations such as camping cabin.

3. True sine wave power inverter. It produces the closest to a pure sine wave of all power inverters and in many cases produces cleaner power than the utility company itself. It will run practically any type of AC equipment and is also the most expensive. Many true sine wave power inverters are computer controlled and will automatically turn on and off as AC loads ask for service. Most appliances run more efficiently and use less power with a true sine wave power inverter as opposed to a modified sine wave power inverter.

4. Grid tie power inverter. This is used to complement the generated solar power with grid power. In addition to regulating the voltage and current received from the solar panels, a Grid Tie Power Inverter ensures that the power supplied to the distribution panel of the house will be in phase with the grid power.

Based on the types of photovoltaic cell, the study should have a monocrystalline solar panel so that it can have higher efficiency. This also helps to get more photons from the light which can easily energize the panel and supply the loads connected. Batteries are also important in this study because this component helps in supplying power even at night or cloudy weather conditions. The best battery can be used is the lead antimony deep-cycle batteries that will store the energy. Charge controller is another component that helps in regulation of the voltage and current supplied to the battery. This helps the battery to prevent damage because of overcharging. Lastly, inverters are another component needed in this study. AC loads now can be used by having inverters. True sine wave inverters are much better other than any types of inverters because it provides a pure sine wave form just like an alternating current waveform. AC loads also run efficiently with this inverter rather than those other types of inverters.

Statement of the Problem:

Lyceum of the Philippines University-Cavite (LPU-C) is a university located in General Trias Cavite which started operating in 2008. It began by offering with ten (10) initial undergraduate programs and admitting almost 1500 enrollees. To date, the university has a total population of 8650 students with 25 undergraduate programs being offered. The increase of total population of the university leads to the increase of the power consumption of the university. Students have been a big factor contributing in the increase of power consumption of the university.

Article 2.1 in the student handbook, A.Y. 2012 - 2013; page 40 states that "The use of cellular phones and similar gadgets during classes or lectures and *unauthorized use of electric outlets of the university* "is prohibited. This regulation prohibits the student from charging their mobile phones inside the school premises. In spite of this policy stated, however students tend to charge their electronic gadgets from campus outlets secretly.

The unauthorized use of outlet is one factor that contributes to the large power consumption of the university. The development of the power generating system of a solar powered cell phone charging station might directly help the university to lessen its electrical energy consumption. The development might prevent the unauthorized use of electric outlets. The cell phone charging station used a photovoltaic technology which converts solar energy to electrical energy. Photovoltaic device is run by a photovoltaic effect which causes the device to absorb photons of light and release electrons. When these free electrons are captured, electric current is produced and is used as electricity.

Objectives of the Study:

The general objective of the study was to develop the power generating system of a solar powered cell phone charging station. Specifically, the study aimed to:

1. Design the power generating system of a solar powered cell phone charging station
   - Determine the viability of the specific site.
   - Determine the solar irradiance at LPU – C.
   - Identify the rating of the solar panel that will cater the load.
   - Design the electrical system.
2. Construct the power generating system of a solar powered cell phone charging station
3. To evaluate the performance of the system.

Significance of the Study:

This study is because from an environment perspective became it could help reduce greenhouse gases as it did not emit any carbon foot print. In particular, this study benefited the following:

1. Lyceum of the Philippines University – Cavite community, for it gave a new source of power that might help lessen the power consumption of the university;
2. Local Government Unit (LGU), for the ideas and concepts about solar energy for their future projects;

3. Department of Environment and Natural Resources (DENR) and Department Of Science and Technology (DOST), for this study promoted renewable energy that helped lessen the continuous perforation of the ozone layer and increase the awareness of people about the technology.
4. Future researchers, as the study may serve as a reference for the further studies about solar technology.

Conceptual Framework of the Framework:

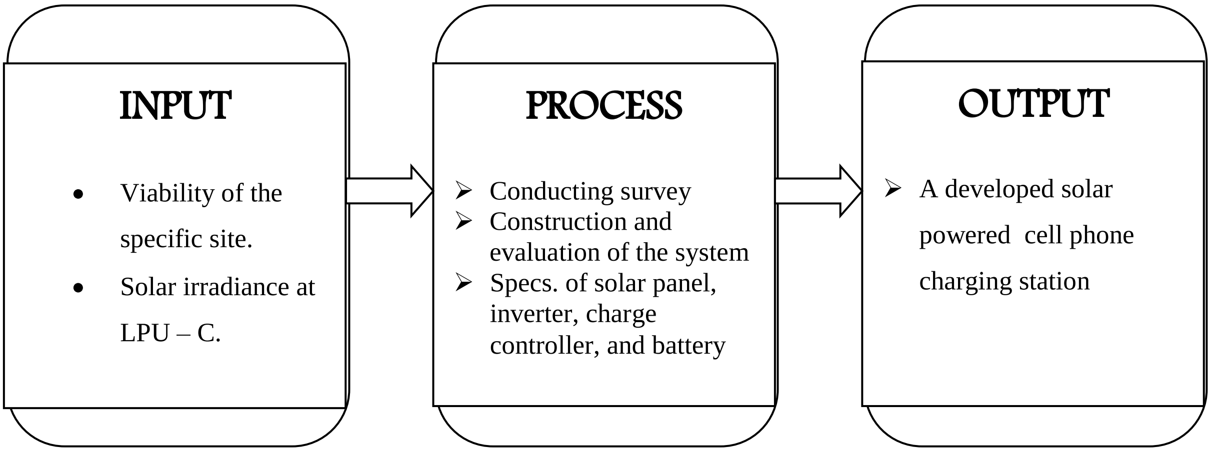

Figure 3: Conceptual framework

Scope and Delimitation:

This study covered the design and construction of the system. The solar charging station was placed at the rooftop of the phase 2 building of LPU-Cavite. The study used C2430 20A model of charge controller and a 300P model of pure sine wave power inverter. The battery used was rated 100AH motolite deep – cycle antimony lead battery. This study also used a 100-Watt Solar Panel as source of electrical energy. These components were not covered by the study instead was bought from Solar Power Corporation (SPC). The production of solar panel and mobile chargers were not also covered in this study.

Definition of Terms:

To understand the design and assembly of the power generating system, the following technical terms must be clarified:

Charge Controller. It limits the rate at which electric current is added to or drawn from electric batteries. It prevents overcharging and may prevent against overvoltage, which can reduce battery performance or lifespan, and may pose a safety risk. It may also prevent completely draining ("deep discharging") a battery, or perform controlled discharges, depending on the battery technology, to protect battery life.

Electromagnetic Radiation: This is radiation produced by the motion of electric changes.

Fuel Cell: It is a device that converts the chemical energy from a fuel into electricity through a chemical reaction with oxygen or another oxidizing agent.

Maximum Power: It is the highest power output levels a component, circuit, device, piece of equipment, or system can handle safely.

Maximum power current: It is the highest current output level of a component, circuit, device, piece of equipment, or system can handle safety.

Maximum power voltage: It is the highest voltage output level of a component, circuit, device, piece of equipment, or system can handle safety.

Open circuit voltage. It is the maximum voltage available from a solar cell, and this occurs at zero current.

Photon: It is a fundamental particle of an electromagnetic radiation. It has no mass nor charge and which composes light and other forms of electromagnetic radiation.

Renewable energy: It is generally defines as energy that comes from resources which are naturally replenished on a human time scale such as sunlight, wind, rain, tides, waves and geothermal heat.

Solar Irradiance: It is the measurement of solar power and is defined as the rate at which solar energy falls onto a surface.

Short circuit current: It is the current through the solar cell when the voltage across the solar cell is zero (i.e., when the solar cell is short circuited).

Tolerance: It is an allowable amount of variation of a specified quantity, especially in the dimensions of a machine or part.

Working temperature: It is the temperature range where the machine has the capacity to work in full power.

Review of Related Literature:

This chapter focuses on the study of components needed to the design such as the solar panel, battery, charge controller and inverter for the charging station. This also explains how the photovoltaic cell technology works, the conversion of solar energy to electrical energy as well as its parts and characteristics.

2. RESEARCH METHODOLOGY

This section presented the research's methodology and design in attaining the objectives of the study. The design of the system involves a cell phone charging station as an application for the solar energy source.

Time and Place of the Study:

The study was conducted at the Lyceum of the Philippines University – Cavite from June 2012 to February 2014.

The proposal was done last June 2012; the title defense was concluded last October 2012. The data gathering, design, and construction were made from November 2012 to May 2013. The evaluation was conducted from August 2013 until February 2014. The testing procedures and evaluation were conducted at the roof top of the phase 2 building of the university.

Project Development:

The charging station is composed of different components. These are the solar panel, battery, charge controller, inverter, and the charging station. Proper sizing of the components is very important to achieve a high efficiency of the system.

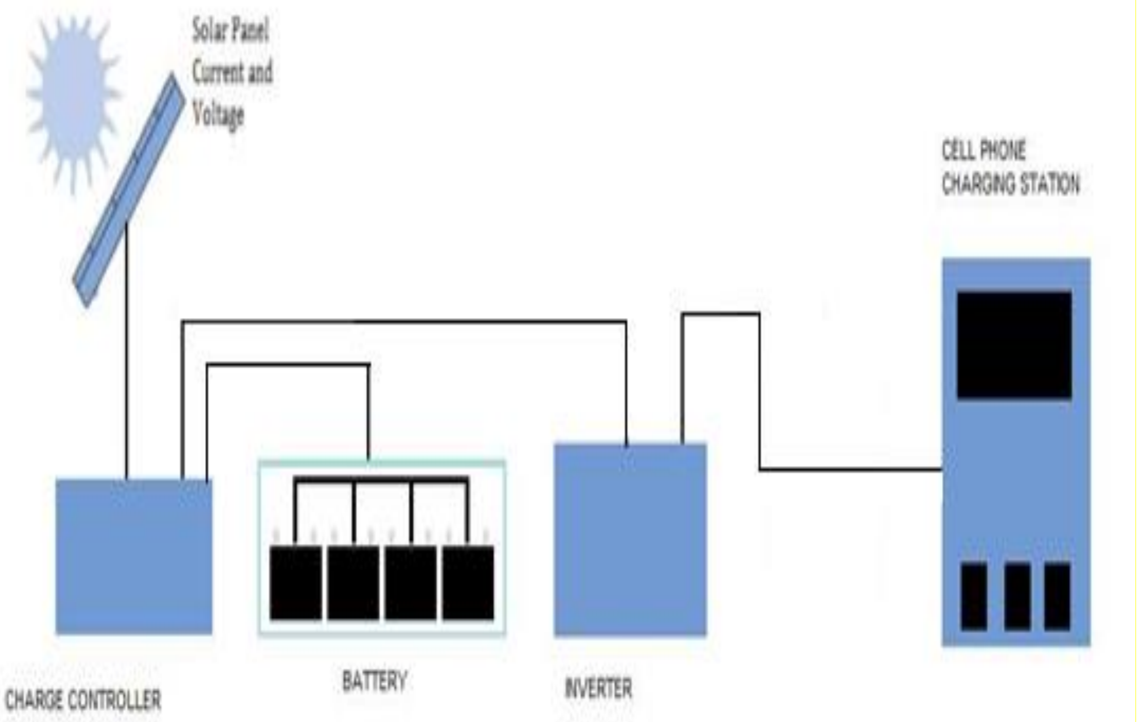

Figure 4: Project development

Identifying the rating of the Solar panel:

There are several factors to consider in installing a solar panel. These are (a) surface position and orientation, (b) atmosphere and shading, (c) effect of irradiance to output power and (d) effect of temperature to output power.

Viability of the site is one important factor in the efficiency of the performance of the solar panel. The location of the solar panel should have at least complete exposure to sunlight for 6 hours per day. There should be no obstruction so as the panel will really be exposed directly to the sun. The location should not be accessible to by-passers. Correct positioning of solar panel should be considered in order to obtain the maximum power output. Its importance is to make sure that panels are installed in its optimal position to capture most light coming from the sun. Philippines is located at the northern hemisphere, therefore, solar panels should be facing true south.

Voltage mismatch is the condition in which two parallel strings are outputting different voltages when measured independently. This is because part of a string is being shaded while another part is being exposed in the sun, thus, creating a voltage mismatch, while current mismatch is the condition where the output of each module is varied. Thus, atmosphere and shading is another factor to be considered for voltage and current matching.

Irradiance affects the output power produced by the solar panel. As the solar irradiance increases, the open circuit voltage and short circuit current also increases; hence, maximum power point varies. The solar irradiance of the site will be taken from the data of the Department of Science and Technology (DOST).

When temperature increases, the rate of photon generation increases. Thus, reverse saturation current increases rapidly and this result on reduction on band gap hence this leads to marginal changes in current but major changes in voltage.

The solar panel in this study was 100 Watts so that the charging time of the battery to supply power during night or other weather conditions will be less. Larger power rating of the panel means having large maximum voltage and current that will be stored to the battery in a short period of time.

Battery Sizing:

The power conditioning unit consist of batteries, charge controllers, and inverters. Batteries are electrochemical devices that store chemical energy that can be released as electrical energy. PV batteries must have the ability to be repeatedly charged and discharged without damaged, to hold charge when not in use and can operate for long period of time. Two principal types of batteries are lead-antimony batteries and nickel cadmium batteries. Lead antimony batteries have a range of 80 Ampere-hours to over 1000 Ampere-hour which requires the addition of water to maintain electrolyte levels. Nickel-Cadmium batteries are adapted for deep cycling and manufactured as either sealed types with a pressure relief valve built into the cell or vented types with a resealable vents that open and close under small pressure changes. Battery size and capacity used by the system was based from the 1 watt: 1 ampere-hour ratio. The general rule of how many watts might need in relationship to the battery size is approximately 1 watt of solar panel for every amp hour of battery. The sizing of the battery is based from (http://www.simplesolarsetup.com/solarpanels2.html).

Charge Controller and Inverter Sizing:

Charge controllers were used to regulate the voltage from solar panel to batteries. It also protects the batteries from any potential damage. Inverters were used to convert electricity from DC to AC.

The rated working current and voltage of the charge controller were based from the solar panel voltage. Thus, the over discharge protection was 25% and the over charge protection was 95%.

Selection of Wires and Cables:

Wires and cables provide the connection from the solar panel to the load and conduct electricity to the system so that it will work. The solar panel was rated a short circuit current of 6.17 Amperes. If the sunlight strikes the panel, heat from the sun also transfers to the panel which can affect the efficiency of the system. Higher size of cables can handle high temperatures which can prevent losses. The size of wire was based from the short circuit current with 25% allowance. The size was in accordance with the Philippine Electrical Code.

Operation and Testing Procedures:

The following procedure must be performed before and after any maintenance, adjustment, repair or modification to the solar charging station. This is to check whether the system is in good condition and working properly. The solar panel should be check for cracks, while the battery should be check for leaks and bumps. This two is the most critical equipment of the system because they are the things that always need maintenance.

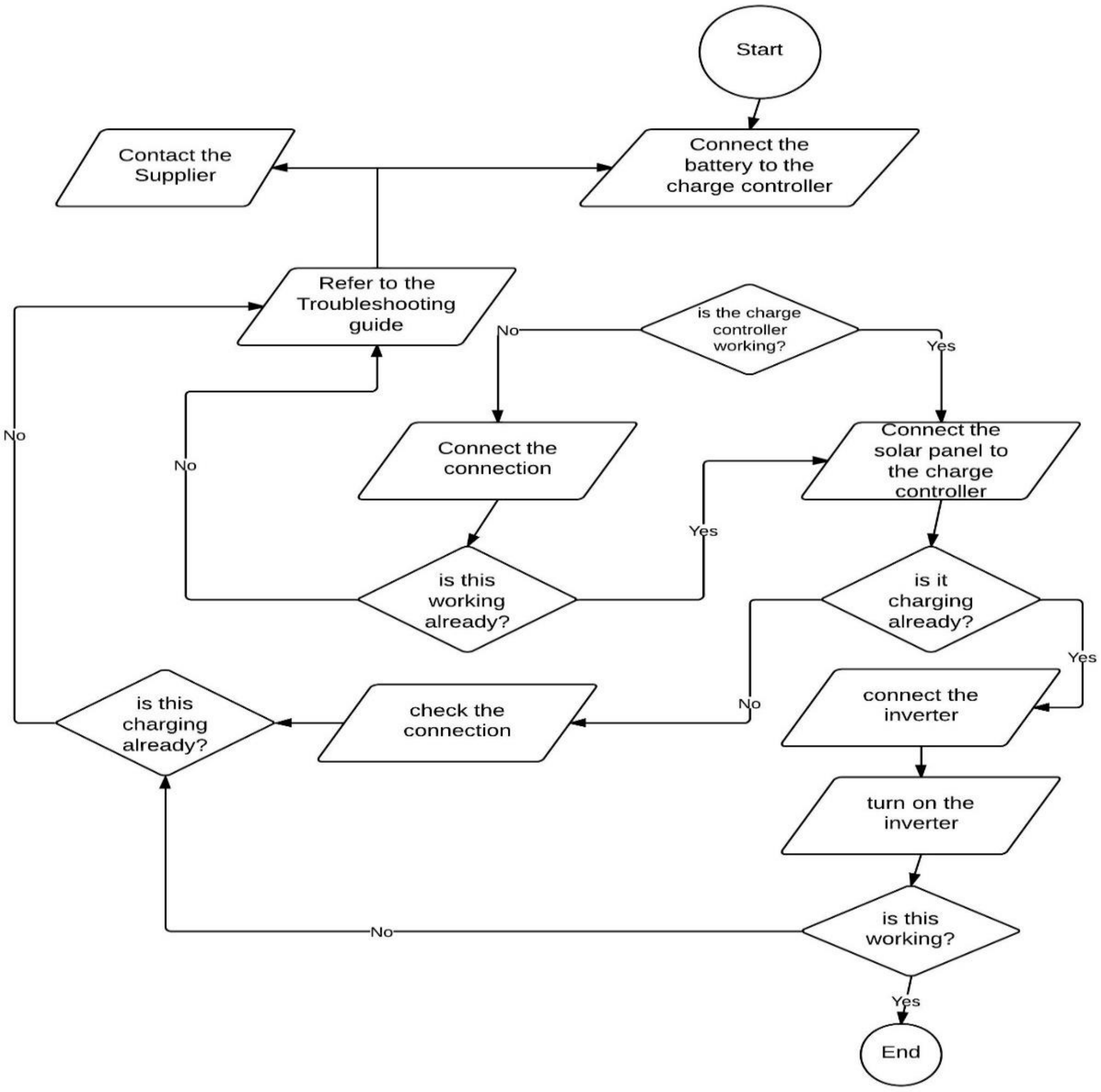

Figure 5: Operation flow chart

When it comes to assembly and operation, these steps should be strictly followed:

- Connect the battery to the charge controller, and wait for the screen to turn on.
- Connect the solar panel to the charge controller.
- Put the solar panel into direct sunlight and check the charge controller to see whether it is charging or not
- Connect the inverter to the charge controller.

A manual of operation is provided for proper usage of the system. The manual of operation should contain the parts of the system, proper electrical connection, and troubleshooting.

Data Gathering:

The data for this research were collected using a survey questionnaire. The survey was created using suitable questions modified from related research and individual questions formed by the researches. The survey comprised five questions, which were related to the participant's perception regarding the need of a charging station inside the campus. In the questionnaire, respondents answered yes or no to determine if the respondent agreed or disagreed in a statement. After the professor validated the questionnaire, it was distributed to the students, faculty and employees of Lyceum of the Philippines University – Cavite. The researchers also understood that people's consciousness may also affect their honesty and effectiveness in answering the survey, and so, the researchers gave the respondents the option of being anonymous. Participants were given enough time to respond and there were no incentives offered. After sampling had been done, the researchers studied whether or not the solar energy is feasible within the campus; thorough observation was conducted to identify the location where they can put the prototype. They also acquired data from the Department of Science and Technology that provided the exact solar irradiance within the campus which further helped them in this research.

Evaluation Procedure:

The system was evaluated according to the performance and acceptability of the users in terms of the performance, appearance, and safety for users which is important in this research. The researchers measured the performance of the system by observation and acquiring data through actual measurement and computation. Second, another survey was conducted to the users to assess the acceptability of the students, faculty and employees to the solar charging station. The estimated number of students was approximately 200; this was to asses in how they evaluate the operation of the study and to see if it is viable and able to maximize the production of power to the charging station, appearance and if safety criteria's will be met. The criterion was based on the most common questions considered.

3. RESULTS AND DISCUSSION

This chapter deals with the gathered data and interpretation of the results in relation to the objectives of the study. This chapter discusses the result of the produced power from the solar panel which supplies the charging station. This section is organized in six sections; (a) Viability of the specific site; (b) Solar irradiance of the location; (c) Specifications of the solar panel; (d) Design of the electrical system; (e) Development of the system; and (f) Evaluation of the system.

Viability of the specific site:

One of the important things to consider when putting up a solar system is choosing a proper place. It must be placed in an open area which is not obstructed by trees, houses, mountains or any objects that will form shadows. The study should have an area where the sun can directly hit the solar panel. Lyceum has high buildings surrounded by trees, so putting the panel on the ground was not feasible.

The solar panel was placed on the roof deck located above the gym of the university shown in figure 6. The site was not obstructed by any kind of things that can form shadows. The site was also perfect because the sun directly hits the panel which can maximize the output power produced by the panel. The site gave the panel a complete exposure to sunlight for at least 6 hours per day.

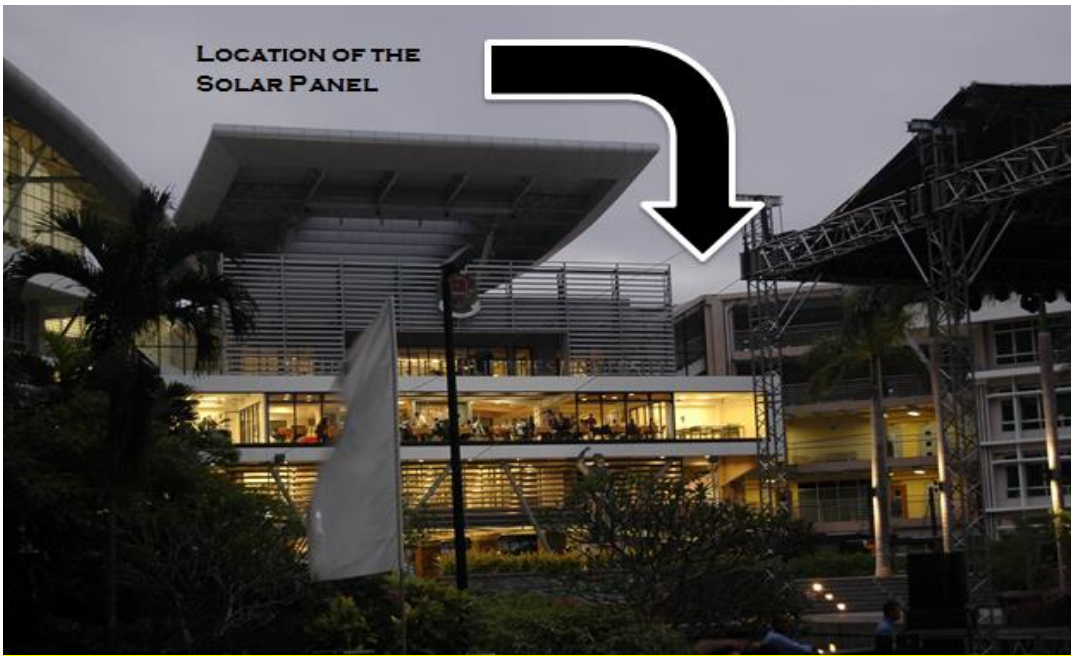

Figure 6: Location of the solar panel

Figure 7: Location of the solar panel

Solar Irradiance of the Location:

Another important factor to be considered in putting up a solar system is the solar irradiance, which is the amount of light that is hitting on the surface of the earth. This gave the solar panel the opportunity to harvest the average solar irradiance of Cavite which is equal to 5.71 kilowatts per square meter (based from the Department of Science and Technology' data last 2012).

Design and Development of Electrical System:

Specifications of the Solar Panel:

The solar panel shown in figure 7 which was used in the system is rated 100W. The open circuit voltage is 22.36 V and the short circuit current is 6.17 A. The open circuit voltage, Voc, is the maximum voltage available form a solar cell and this occurs at zero current. The open circuit voltage corresponds to the amount of forward bias on the solar cell due to the bias of the solar cell junction with the light generated current. The short circuit current, Isc, is the current through the solar cell when the voltage across the solar cell is zero. The short circuit current is due to the generation and collection of light generated carriers. The short circuit current is the largest current which may be drawn from the solar cell. The maximum power voltage and current are 18V and 5.56 A, respectively. The power voltage and current output of the solar panel cell are approximately proportional to the suns intensity. At a given intensity, a solar panels output current and operating voltage are determining by the characteristics of the load. If the load is the battery, the battery's internal resistance will dictate the modules operating voltage. The working temperature is -45 degree Celsius to 55 degree Celsius and the tolerance.

Specification of the Inverter:

The model of the inverter used by the system is 300P at rated of 300W. The overload protection is 360W. Overload protection is used in reference to electrical systems. It is a safety mechanism intended to prevent or minimize damage that can occur from electrical malfunctions. The rated output voltage is 220V/230V AC with ± 10% tolerance. The input voltage is 12V DC which came from the solar panel. The output waveform produced by the inverter was a pure sine wave.

Specification of the Charge Controller:

The model of the charge controller is C2430. The rated voltage is 12 V with automatic voltage recognition. The maximum load current is 20 A. The temperature compensation is 3mv / °C / cell. Temperature compensation is the adjustment in performance of a system to compensate for changes in temperature. The no load loss is less than or equal to 20 mA. The maximum wire diameter that can be installed is $6mm^2$. The Ambient temperature is 25 °C - 55 °C. Ambient temperature is the temperature which surrounds an object. The solar panel input voltage required for the charge controller was 12 V to 20 V DC.

Specification of the Batteries:

The solar power battery is designed specifically for solar power installations, particularly those in which it is desirable that maintenance be kept to a minimum. The size of the battery is 100AH deep cycle. A deep-cycle battery is a lead-acid battery designed to be regularly deeply discharged using most of its capacity. The battery used in the system generates a 12 Vdc. The area of the battery is 392 x 180 x 200 mm and the temperature of the battery was approximately 230°C.

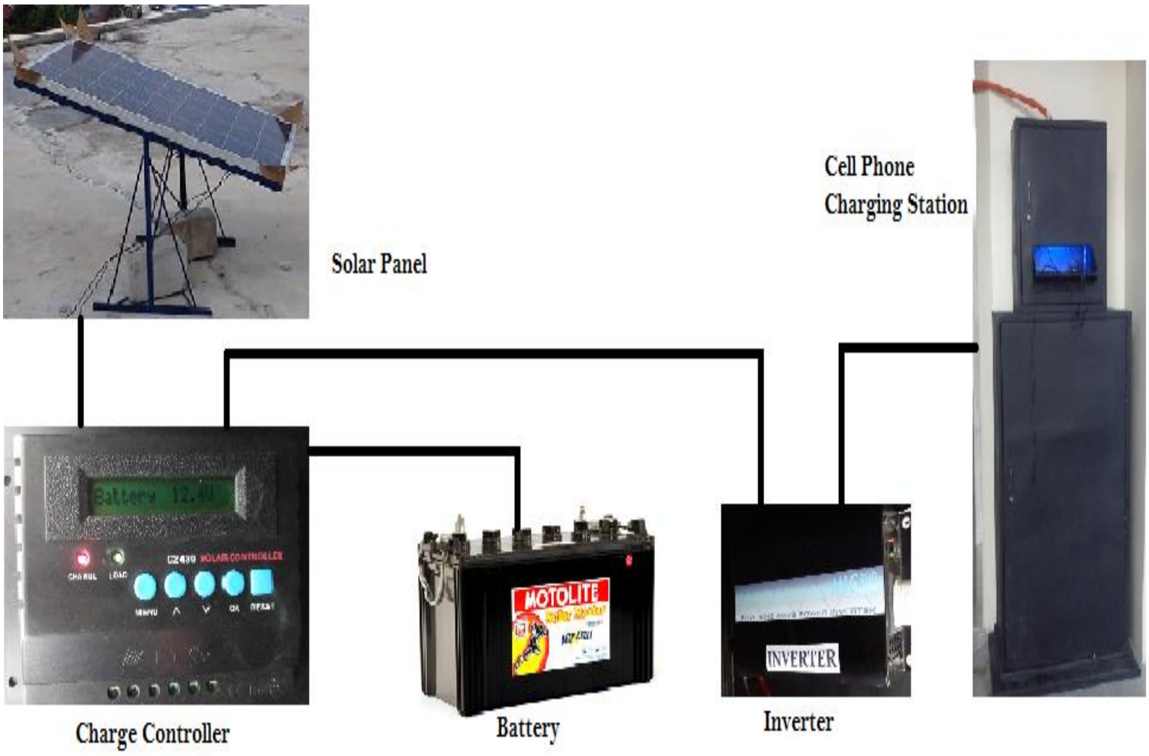

Figure 8: Design and development of electrical system

Solar panels convert sunlight into electricity. The current will flow from the solar panel to the charge controller to regulate the voltage and current that will flow to the batteries. Batteries are needed because the application requires an electric supply at times when no electricity is being produced by the module. Photovoltaic batteries must have the ability to be repeatedly charged and discharged without damage, to hold charge when not in use, and to operate for long periods with little maintenance. After the battery, next phase will be on the inverter, which is a solid state electronic component that will convert electricity from DC to AC. The system is shown above in figure 8.

The power conditioning unit consist of batteries, charge controllers, and inverters. Batteries are electrochemical device that stores chemical energy that can be released as electrical energy. PV batteries must have the ability to be repeatedly charged and discharged without damaged, to hold charge when not in use and can operate for long period of time. Two principal types of batteries are Lead-antimony batteries and nickel cadmium batteries. Lead antimony batteries have a range of 80 Ampere-hours to over 1000 Ampere-hour which requires the addition of water to maintain electrolyte levels. Nickel-Cadmium batteries are adapted for deep cycling and manufactured as either sealed types with a pressure relief valve built into the cell or vented types with a resalable vents that open and close under small pressure changes. Charge controllers are used to regulate the voltage from solar panel to batteries. It also protects the batteries from any potential damage. Inverters are used to convert electricity from DC to AC.

Cable is another thing to consider in building this system. Cables should last for at least the lifetime of the PV modules. Cables to be used for the connection of the load to the charge controller will be $14mm^2$ will be THW and the cables from the solar panel to the charge controller will be 3.5 mm2 THHW.

Evaluation of the Performance of the System:

On the start of the study, a survey was conducted to determine whether a cellphone charging station is needed and also to determine what kind of apparatus should be put in the prototype.

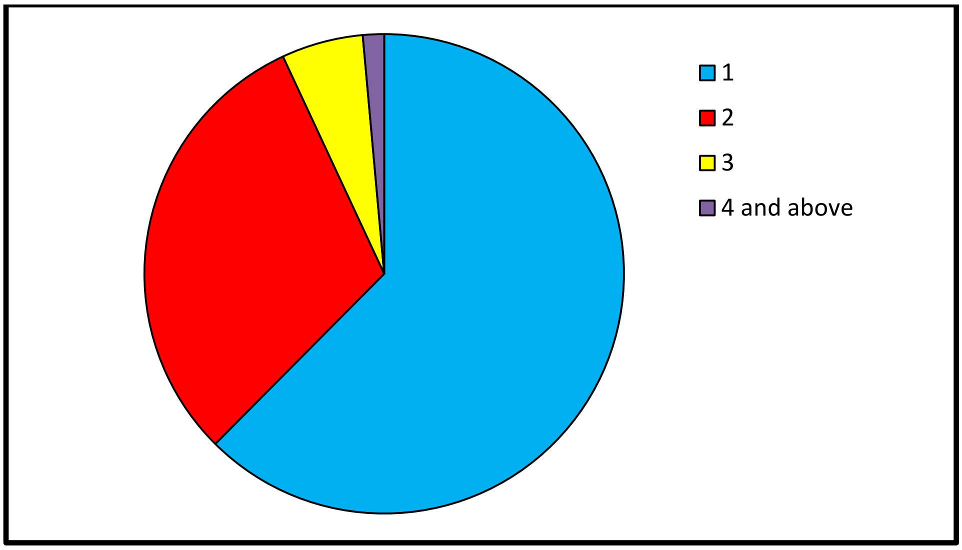

Figure 9: Number of cellphones

According to the survey, with 908 respondents shown in the figure 9, 62.44% of the sample that is equivalent to 567 people have only one cellphone, 32.62% has two cellphones 5.51% has three cellphones and 1.43% has four and more cellphones. This shows that in average, every person has at least two cellphones.

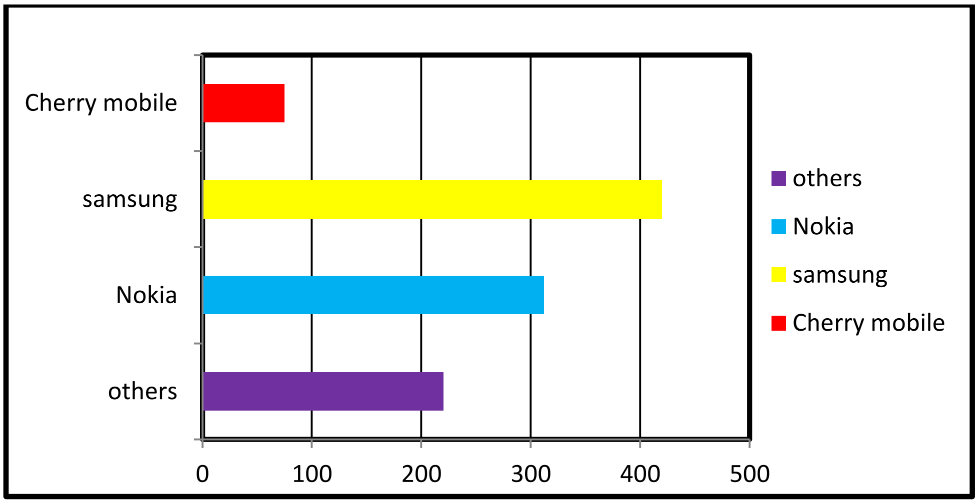

Figure 10: Cellphone brands that is commonly Use by the students, employees and faculty

Another question in the survey was to determine the brand of the cellphone that is widely used by the people inside the university. As shown in figure 10, Samsung is the most widely used brand inside the university followed by Nokia and other brands.

Based also on the survey, at least half of the respondents charge their cellphones twice or thrice a day but 77.97 % of the total respondents don't bring their chargers with them. In this case, the survey showed that 86.67 % has said yes on the survey if installing a charging station in the university would be beneficial.

Testing procedures were also conducted in this study to evaluate the accuracy and the proper functionality of the design. Testing of certain devices is one of the most important things to be considered. This indicates how this device is reliable and contributes in the benefit of others. This was done by identifying the different ways until it attains its objectives and its purpose. After obtaining the data, the test was conducted with several trials at different time and date at different conditions of the environment. Moreover, before the testing and acquiring data were conducted with this system, choosing a proper place is needed. It must choose an open area, not obstructed by trees, houses, mountains etc, establish the direction of the sun and must consider the environmental disaster.

The testing for PV panel was conducted at Lyceum of the Philippines University Cavite Campus to acquire sufficient radiance for solar panel to produce power.

Since these systems already produced power, the next testing procedure conducted was to obtain the data results of usual method (manual measurement) with the proposed study acquired by the renewable energy source.

After the installation and testing, a survey – questionnaire was given to the users. Two hundred students who used the charging station were given the questionnaire and as the statistical results show, the performance, appearance and safety of the system was good having a mean of between four and five.

Troubleshooting:

During a failure in the charge controller, these steps can be followed for troubleshooting purposes:

Table 1: Troubleshooting Procedure

PROBLEM	CAUSE	SOLUTION
Green light goes out, the loads stop working, and LCD shows Battery Low.	Low voltage charging	A. Cut off the loads and restart the controller by pressing Button Reset. After the battery finished charging, reconnect the loads. B. Increase solar panel's power or change battery.
Green light goes out, the loads stop working, and LCD shows Overload	Overload	Reduce the quantity of loads and then press Button Reset
Green light goes out, the loads stop working, and LCD shows Short Circuit	The loads Short circuited.	Eliminate the malfunction and then press Button Reset.
• Green LED is on ----- Loads are normally working • Red LED is on ----- Battery is fast charging • Red LED is flickering --- Battery is charging in constant voltage (or floating) condition.	Red LED goes Out of power	It is common during the night. If it doesn't charge for a long time, please carefully check the connection of solar panels, controller and battery to avoid loose-connection or disconnection.

Special Note: It is a normal phenomenon that the red LED indicator is on when the controller is connected to the battery; the red LED indicator is charging – allowed indicator, if the solar panels meet the changing conditions, the LCD will display the charging current, and the red LED indicator is off only when the battery is full.

Average Actual Measurement of Current for Five days:

Table 2: PV Panel Parameters

PV PANEL PARAMETERS ACTUAL MEASUREMENT						
TRIAL NO.	**TIME**	**DAY 1 09/25 AMPERE A**	**DAY 2 09/26 AMPERE A**	**DAY 3 09/29 AMPERE A**	**DAY 4 09/30 AMPERE A**	**DAY 5 10/03 AMPERE A**
1	8:00 AM	0.1	0.1	0.1	5.2	5.4
2	8:30 AM	0.4	0.4	0.4	5.2	6.4
3	9:00 AM	0.8	0.8	0.8	5	2.2
4	9:30 AM	5.4	1.1	0.7	4.8	1.4
5	10:00 AM	4.7	0.8	4	4	4
6	10:30 AM	4.8	5.2	4.2	6.7	3.6
7	11:00 AM	1.3	5.2	4.7	6.5	4
8	11:30 AM	1.2	5	4.8	6.6	3.5
9	12:00 PM	1.3	4.8	5.2	7.4	3.4
10	12:30 PM	1.5	4	6.7	6.9	3.3
11	1:00 PM	0.7	6.7	6.5	1.2	4.1
12	1:30 PM	5.3	6.5	6.6	6.7	5.3
13	2:00 PM	4.6	6.6	6.3	5.8	5.8
14	2:30 PM	5.4	6.3	7.2	5.7	5.7
15	3:00 PM	6.4	7.2	1.3	5.7	5.7
16	3:30 PM	2.2	7.3	7.4	5.9	5.9
17	4:00 PM	1.4	7.4	7	5.4	5.4
18	4:30 PM	1.5	7		4.4	4.4
19	5:00 PM	1.3	6.9		4.4	4.4
20	5:30 PM	1.2	6.8		4.5	4.5

The Table 2 was converted to figure 11 to show the relationship between current and time to determine the peak hours.

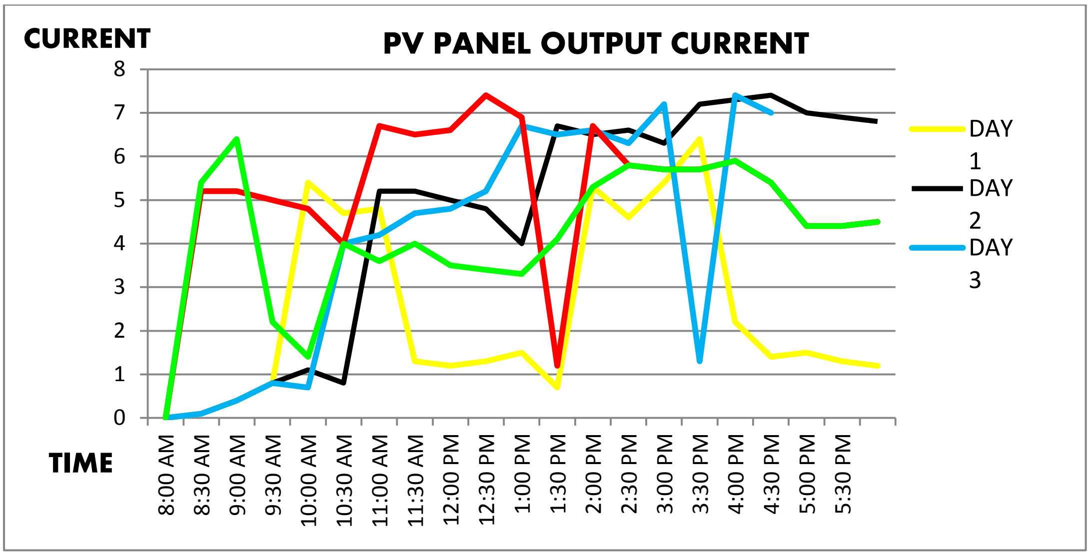

Figure 11: PV panel output current

The Figure. 11 shows that current produced is high when the PV panel is hit by the solar irradiance at peak hours. On 25th day of September 2013, the gathered value of the current from the solar panel during the time between 8:00am – 9:30 am increased with the value of 0.1 – 5.4 ampere. During the time of 9:30 – 1:00 pm current decreased from 5.4 – 1.5 ampere, while at the time of 1:00 – 3:00 pm the current increased to 1.5 – 6.4 ampere. At 4 o'clock onwards, the current slowly decreased as the sun sets. On 26th day of September 2013, the gathered value of the current from the solar panel during the time between 8:00am – 9:30 am increased with the value of 0.1 – 5.4 ampere. During the time of 10:30 – 12:30 nn current decreased from 5.2 – 4 ampere, while at the time of 12:30 – 4:00 pm the current increased to 4 – 7.4 ampere. And at 4:30 – 5:30pm the current slowly decreased. On the 29th day of September 2013, the gathered value of the current from the solar panel during the time between 8:00 – 10:00 am increased with the value of 0.1 – 4 ampere. During the time of 10:00 – 12:30 nn current increased from 4 – 6.7 ampere, while at the time of 12:30 – 2:30 pm the current slowly decreased to 6.7 – 6.3 ampere. On the 30th day of September 2013, the gathered value of the current from the solar panel during the time between 8:00 – 9:00 am is decreasing with the value of 5.2 - 5 A. During the time of 10:00 – 1:00 pm, the graph fluctuate because a cloud was formed that covered the sun and never allowed the sunlight to reach the solar panel. This affected the current produced by the solar panel. At the time of 2:30 – 5:30 pm the current decreased by 5.7 – 4.5 ampere. On the 3rd day of October 2013, the gathered value of the current from the solar panel during the time between 8:00 to 8:30 is increased from 5.4 to 6.4. The current decreased during the time between 9:00 - 9:30 am because of the weather condition. Current increased from 10:00 onwards and continued to supply the charging station. When clouds were formed obstructing the sun light, the power produced was less compared to the weather with a clear sky. Based on the following results, the weekly average current was 4.31 ampere. If the weekly average current will be, the basis the charging time will last for about 2.57 days before the battery will be fully charged.

Average Actual Measurement of Voltage for Five days:

Table 3: PV Panel Parameters

PV PANEL PARAMETERS ACTUAL MEASUREMENT						
TRIAL NO.	**TIME**	**DAY 1 09/25 VOLTAGE V**	**DAY 2 09/26 VOLTAGE V**	**DAY 3 09/29 VOLTAGE V**	**DAY 4 09/30 VOLTAGE V**	**DAY 5 10/03 VOLTAGE V**
1	8:00 AM	12.7	12.7	12.7	13.2	13.3
2	8:30 AM	12.7	12.7	12.7	13.5	13.4
3	9:00 AM	13.7	13	13	13.6	13.2
4	9:30 AM	13	13.1	13	13.7	13.1
5	10:00 AM	13.1	13.1	13.1	13.7	13
6	10:30 AM	13.2	13.2	13.1	13.8	13.1
7	11:00 AM	13	13.5	13.2	13.8	13.2
8	11:30 AM	12.9	13.6	13.7	13.9	13

9	12:00 PM	13	13.7	13.7	13.7	13.1
10	12:30 PM	13	13.7	13.8	13.7	12.9
11	1:00 PM	12.9	13.8	13.8	13.6	13.3
12	1:30 PM	13	13.8	13.9	14.1	13.6
13	2:00 PM	13.2	13.9	13.9	14.1	13.9
14	2:30 PM	13.3	13.9	13.9	14.1	14.1
15	3:00 PM	13.4	13.9	13.9	14.1	14.1
16	3:30 PM	13.2	13.9	13.7	14.1	14.1
17	4:00 PM	13.1	13.7	13.5	13.9	13.9
18	4:30 PM	13.1	13.6		14.4	14.4
19	5:00 PM	13	13.5		14.4	14.4
20	5:30 PM	12.9	13.4		14.5	14.5

The Table 3 was converted to figure 12 to show the relationship between voltage and time to determine the peak hours.

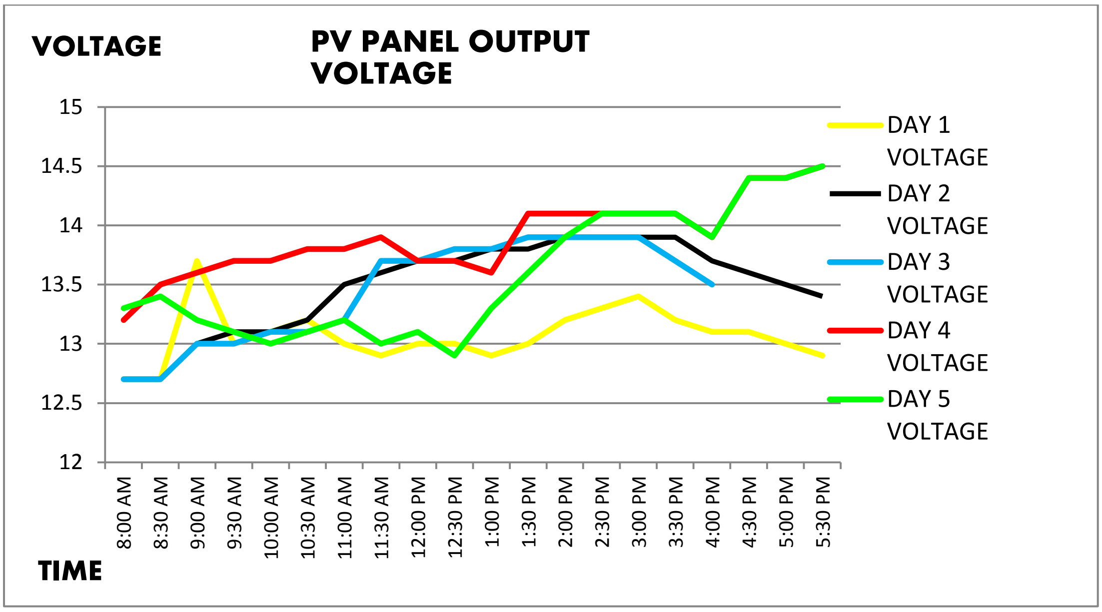

Figure 12: PV panel output voltage

The Figure 12 shows that voltage produced is high when the PV panel is hit by the solar irradiance at peak hours. On 25th day of September 2013, the gathered value of the voltage from the solar panel during the time between 8:00am – 9:30 am increased with the value of 12.7 – 13 volts. During the time of 9:30 – 1:00 pm current decreased from 13 – 12.9 volts, while at the time of 1:00 – 3:00 pm the current increased to 12.9 – 13.4 volts. At 4 o'clock onwards, the current slowly decreased as the sun sets. On 26th day of September 2013, the gathered value of the voltage from the solar panel during the time between 8:00am – 9:30 am increased with the value of 12.7 – 13.1 volts. The time of 10:30 – 12:30 pm, the voltage increased to 13.2 – 13.7 volts and at 4:30 – 5:30pm, the voltage slowly decreased. On the 29th day of September 2013, the gathered value of the voltage from the solar panel during the time between 8:00 – 10:00 am increased with the value of 12.7 – 13.1 volts. During the time of 10:00 – 12:30 nn the current increased from 13.1 – 13.8 volts. On the 30th day of September 2013, the gathered value of the voltage from the solar panel during the time between 8:00 – 11:30 am increased with the value of 13.2 – 13.9 volts. During the time of 12:00 – 1:00 pm, the graph fluctuated because a cloud was formed that covered the sun and never allowed the sunlight to reach the solar panel. This affected the voltage produced by the solar panel. At the time of 2:30 – 4:00 pm, the voltage decreased by 14.1 – 13.9 volts. On the 3rd day of October 2013, the gathered value of the voltage from the solar panel during the time between 8:00 - 8:30 am was increased from 13.3 – 13.4 volts. The current voltage decreased during the time between 9:00 – 12:30 pm because of the weather condition. Voltage increased from 1:00 pm onwards and continued to supply the charging station. When clouds were formed obstructing the sun light, power produced was less compared to clear sky. Based on the following results, the weekly average voltage is 13.5 volts.

Computation for Finding the Solar Irradiance and Efficiency

This computation presents the solar irradiance and efficiency of the solar panel. The latitude and the longitude of the Lyceum of the Philippines University Cavite are 14.290844 and 120.915554 respectively.

The solar irradiance is a measure of the rate of solar energy arriving at the earth surface from the sun's direct beam, on a plane perpendicular to the beam. The zenith angle is the angle the sun makes with the ground. It is used to calculate the incoming solar radiation. On the other hand, the declination angle is the angle between the equator and a line drawn from the center of the earth to the center of the sun.

Location: Lyceum of the Philippines University Cavite

Latitude: 14.290844

Longitude: 120.915554

(Latlong.net)

Finding solar irradiance for January 25, 2014

Solar Irradiance = normal solar irradiance * cos z

Where:

Normal irradiance = 1400 W / m^2

Z = Zenith angle

Cos Z = (sinδ)(sinϕ) + cosδcosϕcos[(L.T.-12)*15

Where:

δ= sun declination

ϕ= latitude

L.T.= local solar time in hours

Computation for sun declination

δ= 23.45˚ sin[360 / 365 (d - 81)] ; d = number of days

= 23.45˚ sin[360 / 365 (25 - 81)]

δ= 19.26 South

Computation for L.T.

A = latitude * Difference between Pacfic standard time, local time and greenwich mean time

= 14.290844 * -8

A = -144.326752

B = 360/365 [d – 81]

= 360/365 [25 – 81]

B = -55.23287671

C = 9.87 (sin2B) – 7.53 (cosB) – 1.58 (sinB)

= -12.2430104

L.T. = 4 (local solar time meridian (A) – longtitude) + C

= 4 (-144.326752 – 120.915554) + (-12.2430104)

= -953.21 minutes [1 hr / 60 min]

L.T. = -15.89 hours

Solving for Zenith

Cos Z = sin (19.26) sin (14.290844) + cos (19.26) cos (14.290844) cos [(-15.89 – 12)(15)]

Cos Z = 0.5620925668

Solving for solar irradiance

Solar irradiance = (1400 W / m^2) (0.5620925668)

Solar irradiance = 786.9295935 W / m^2

Solving for Efficiency

$$\eta max = \frac{Pmax}{(irradiance)\ (Area)}$$

$$= \frac{100\ W}{(786.9295935)\ (0.73209531)}$$

$$= 17.3578$$

Computation of wires to be used

From solar to charge controller – battery

Short Circuit Current = 6.17A

Source Circuit Current = 1.25 x Short Circuit Current

= 1.25 x 6.17

= 7.71 A

*Based on the Philippine Electrical Code (PEC) Article 6.90.2.2 (a) through (a) (4) the Ampacity should not be 1.25 less than source circuit current therefore

Size of wires will be = 1.25 x 7.71

= 9.64 A

Correction Factor = 0.67 – based on the table 6.90.41

Size of wire will be $= \frac{9.64}{0.67}$

= 14.39A

*size of wire is 2.0 mm^2 but base on the manual of the solar panel 3.5mm^2 should be used

From battery to inverter

Efficiency of the inverter = 0.85

Inverter input nominal voltage = 12

Minimum Input Voltage = 9.05

Maximum Input Voltage = 15.05

Wattage = 300W

Current $= \frac{300W}{9.05 \times 0.85}$

= 40A

Size of conductor = 40 x 1.25

= 50 A

*size of wire is 14mm^2

From inverter to load

Efficiency of the inverter = 0.85

Inverter output nominal voltage = 230V

Minimum output voltage = 207 V

Maximum output voltage = 253 V

4. SUMMARY, CONCLUSION AND RECOMMENDATION

Summary:

The study was conducted for the purpose of developing a power generating system of a solar powered cellphone charging station. It was conducted from June 2012 to February 2014 and was installed at the Lyceum of the Philippines University – Cavite located at General Trias.

This study started by performing a sampling to the students of the university. This is to know how many chargers should be placed in consideration of the population within the university and to identify if this study would be beneficial to the users out of 908, 708 students which is 80% of the respondents of the survey said that they don't bring their chargers.

After having the sampling, the components needed for the study were bought. A polycrystalline solar panel was used. Deep cycle batteries were also bought to store the energy and to supply the system during night time. A charge controller and an inverter were also part of the system which play an important role in the system. Charge controllers are used to regulate the voltage from solar panel to batteries and also protect the batteries from any potential damage. Inverters are used to convert electricity from DC to AC supplying 220 or 230 V rating of the chargers. This study used a true sine wave power inverter which produces the closest form of sine wave among the types of power inverters and in many cases this inverter produces cleaner power to be produced.

The data of solar irradiance the gathered from the DOST and was computed for the year of 2013 and 2014. The data gathered made the charging station worked which received enough photons from the sun by having the correct position of the solar panel. The position of the sun was also computed and able to be place the solar panel 15 degrees facing south.

The testing of the system was performed by gathering the voltage and current data daily from the system. The parameters gathered shown in figure 8 that at 12 to 3:00 pm was the peak hours of the day in which the sun produced high irradiance without any distractions from the environment as well as the weather conditions.

The survey questionnaire was also used to gather data about the performance and acceptability of the system. The gathered survey results from a sample of 200 students respondents who used the charging station shown in page 104. They answered the questionnaire and as the statistical results show the performance, appearance and safety of the system were good having a mean of between four and five.

Conclusion:

The series of testing conducted on the system proved that this study was able to generate power and supply a Cellphone charging station in the LPU - C using a PV panel as an alternative source of electrical supply. The survey conducted on the study was successfully completed and majority of the students agreed to have a Cellphone charging station. This sampling therefore, attests that the study was beneficial to them especially during emergency situations.

The viability of the site where the solar panel was placed was a good place because it was directed to the sun without any hindrances that can lessen the efficiency of the system. It received enough amount of photons to supply the charging station and charge the battery to its full capacity.

The efficiency of the system was good which falls in the 13-15% range of the said efficiencies based on theories. This shows that the system was efficient enough to cater many Cellphones without having any problems as well as no having large amount of losses from the system.

The survey-questionnaire results showed that a good performance and acceptability of the system was attained by the users. The safety of the system was also guaranteed based on the results from the questionnaires. This also shows that the charging station was beneficial to the students and was able to reduce the students that using the outlet for charging purposes. As a result, the power consumption of the university will be less because of the reduced usage of power from the outlets.

Recommendation:

The solar powered cellphone charging station is recommended to the students, faculties and other staff of the Lyceum of the Philippines University – Cavite (LPU-C) for them to use the charging station. This will help to lessen the university violators and reduce the power consumption caused by unauthorized use of the outlets.

For further improvement, the researchers highly recommend the future researchers to study about the reflectors or mirrors to intensify the amount of solar irradiance produced by the sun. This will help to maximize the amount of power that will supply the charging station. The use of sensors for the PV panel should be studied and applied also so that the panel will move depending on the movement of the sun. Another recommendation is to hybrid other source of renewable energy like hydro, wind, etc. that will supply during night time. This will make the system to function efficiently especially during night time and when higher loads are installed.

For further studies, it is recommended to put an additional outlet for laptop and tablet chargers as well as some AC loads. The most suitable connection is to install a panel board for the AC loads with a circuit breaker installed for protection.

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