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E-Switch: A Photovoltaic-Powered Automation Device For Optimizing Energy Using Pressure Plate

[1]Jules Genesis Magat, [2]Richard A. Cribello

[1]Pamantasan Lungsod ng Maynila,
julesgenesismagat@gmail.com

[2]University of Santo Tomas, University of the Philippines (Open University),
racribello@ust.edu.ph, racribello@up.edu.ph

Abstract – The accessibility of electricity is fundamental to modern life. This study launches an automation system that provides an efficient way of storing and using electricity from a non-vanishing source – Solar Energy. The prototype consists mainly of an SPDT relay, a Photovoltaic Module, and USB ports. The researchers seek to reduce the adverse environmental effects of how electricity is conventionally generated from non-renewable resources by introducing a universal prototype that lessens the likelihood of fire-causing incidents, can harvest and store energy simultaneously, and may also be used as an alarm. In addition, this study seeks to present a solution to the exponential growth of electric power that is increasing exponentially from time to time. The results were based on three trials with different instruments and prototype components. The series of tests to determine the unregulated voltage of the photovoltaic module was measured using a multimeter that changes from time to time and varies from the intensity of the sun's radiation. Besides, the force that activates the pressure plate system requires at least 23.83N, and the safety of the prototype was measured using an infrared thermometer, which detects the temperature of an object wherein the pressure plate hot spots were measured.

Keywords – Automation, Electricity, Pressure Plate, Solar Energy, Electrical-Fire prevention.

I. INTRODUCTION

The history of electricity is the history of the modern world. Electricity is undeniably one of the basic needs of every person in the world, and in the absence of it, modern society as we know it would not be possible as it strongly determines the living standard. Hitherto, almost every aspect of modern civilization depends on reliable and affordable electricity and the things that it powers, such as light bulbs to keep homes bright and well-lit, data centers that provide accessible internet, and smartphones to keep in touch with loved ones through communication – amongst countless others. Approximately 17% of the total secondary energy in the world is used as electricity, a form of energy that can be easily transferred with small losses through an electric grid (Beerepoot, 2016).

People are consuming electricity above the level of necessity, and energy uses have transmogrified as humans have revamped patterns of energy consumption reaching exponential demand in energy supply. As vast segments of the world start to increase a notch to the "energy ladder," it is highly expected that the dynamic growth continue to stretch throughout the succeeding decades. According to the International Energy Agency, based on recent data from 2019, about 65% of electricity is generated using fossil fuels, where coal is the dominant contributor with 39%, while oil and natural gas cover 3% and 23%, respectively. Though fossil fuels thumped technological advancements in many sectors, coal emits about twice as much CO_2 per generated kWh as natural gas, and coal power plants significantly contribute to global warming. Nuclear energy is responsible for 10% of the world's electricity generation. With 16%, hydroelectricity is the most significant contributor among renewable energy sources. However, it had the lowest growth rate among any other renewable electricity source from 1990 to 2018, while the solar photovoltaic cell, as a renewable electricity source, had a 40% average annual growth rate in the same period.

According to the Bureau, the Philippines had an estimated total record of 77,724 fire incidents, an average of 15,545 fire incidents in a year or 42 fire incidents in a day from the year 2013 to 2017, where thousands of people were killed or an average of 251 deaths every year. The Philippines' top 3 causes of fire incidents are open flame, lit cigarettes, and electric connections. Electric overload, electric arc, or electrical short circuit may trigger a fire originating from electric connections. Most of the houses in the Philippines are made from light materials, wherein a small amount of fire can spread or grow fast in just a second. Also, many people are pretty forgetful about removing any electric object's plug from the outlet that causes a fire. Several studies show that common fire causes are overloading, using substandard electrical materials, overheating, and failure to unplug sockets, extensions, and many more. Countless fire-related incidents have been recorded worldwide, in the worst cases, fatalities. In the Philippines, people experience rampant fire-related incidents in which the victims experience loss and even death. However, programs such as fire protection months and professionals inform and help people deal with fire; there is zero possibility that a fire cannot occur in a particular place. Above all, this research study should improve human lives through automation as researchers developed a system that produces energy with fewer fire-causing problems. The researchers' general objective is to launch a versatile device ensuring safety with regard to electrical fire incidents while using renewable energy sources, specifically solar energy, which can function as an alarm and lessen the energy consumption from the first line of generating electricity using non-renewable resources.

II. METHODOLOGY

A. Pressure plate

Cut out three pieces of cardboard measuring 12 inches by 9 inches, wrap one side with aluminum foil, and tape the excess aluminum foil at the edge. Do this with two pieces of cardboard. Cut the middle portion of the remaining cardboard, leaving 3 inches on each side from the edge. Connect one 12V insulated wire to one covered cardboard at the edge, and do this to the remaining covered cardboard. Place the hollow cardboard between the two covered cardboard facing each other. Cover the cardboard with hydrophobic fabric while leaving the wires uncovered by the fabric.

B. USB ports

With 4 USB ports, create two outputs or sockets with each of the terminals of the SPDT relay, and label it with NO and NC, NO for normally open and NC for normally closed. Connect the negative terminal of the NO USB ports and the positive terminal; repeat this step for the NC USB ports. Next, connect the negative terminal of the NC USB ports to the NO USB ports.

C. Insulation Housing

Insert the USB ports into the 4 square holes of the casing and the wires of the pressure plate. Connect the wires of the pressure plate to the coils of the terminal of the SPDT relay, and set up the position of the battery and controller, which is used to regulate the power source, particularly the solar panel and the battery. Connect the battery and the solar panel to the controller and connect the negative terminal to the common terminal. Then, connect the negative terminal of the NO USB ports to the normally open terminal of the relay and the negative terminal of the NC USB ports to the normally closed terminal of the relay. Connect the USB ports' positive terminal to the controller's positive terminal.

D. Weight and Unregulated Solar Energy

Fifteen trials were conducted and recorded with a pitcher with a constant weight of .822 Kg filled with water of different weights.

$$F = M * a$$

Where a is equal to gravity.

After measuring the mass of the pitcher filled with water using the triple beam balance, the force exerted by the pitcher will be calculated using the formula above to obtain samples. The solar panel will be set up in a high open area, directly facing the sun, and the alligator clip will be clamped at the end of the multimeter or multitester. It will be set higher than the recorded maximum voltage the manufacturer sets.

The unregulated solar energy will be gathered and categorized according to the time they were collected. The time will vary at 8 am, 12, 3 pm, and 5 pm, with five trials each at the exact location directly facing the sun

E. Temperature of the Pressure Plate

Plug the 12-volt adapter into the outlet and energize the system by applying force to the pressure plate system, using an alarm, and setting time intervals for monitoring potential hotspots or increases in temperature in the pressure plate. When checking the pressure plate's temperature, unplug the adapter to avoid electrocution, take off the hydrophobic fabric of the pressure plate, flip one side of the pressure plate, aim at the surface of the pressure plate, and pull the trigger-like button, hold and release after 1 second.

F. Discharging the DC

The data will be gathered as the researchers employ the prototype for non-stop charging cell phones from drained to fully charged batteries. For the researchers to analyze the prototype's performance, an Android mobile phone with a 2000 mAh/7.400 Wh battery was checked and charged from the drained battery into the device until it was fully charged.

G. Charging the DC

Set up the photovoltaic module and measure its current by connecting the panel's positive terminal to the multimeter's positive terminal. Do this to the negative terminal of the panel and the multimeter. Measure the current by setting the range of the multimeter to the ampere. Connect the module to the regulator, and connect the discharged battery. Record the time of charging until the battery reaches its maximum capacity.

The formula for calculating the estimated hours of charging is:

$$T(Estimated\ Charging\ Time) = \frac{Ah\ (battery)}{A\ (Solar\ Panel)}$$

H. Equivalent amount of Energy Consumption for 12V DC Appliances

Since the E-switch system works for devices having 12V, appliances that are used in running the whole proposed system are also utilized using electricity from the electric grid system to compute the total consumption of the appliances and their percentage in the entire monthly bill amount. To compute the total cost of energy consumption of a specific device, the following were used:

$$P = I\ x\ V$$

Where power P is in watts, current I is in amperes, and voltage V is in volts.

$$kWh = \frac{(wattage)(hours\ used)}{1000}$$

$$Daily\ bill = (kWh)(cost\ per\ kWh)$$

$$Monthly\ bill = Daily\ bill\ x\ 30\ days$$

$$\% = \frac{monthly\ bill\ of\ the\ device}{total\ monthly\ bill\ amount}$$

Charging using the system and the normal socket

For the researchers to examine the prototype's efficiency, an Android mobile phone with a battery of 2000 mAh/ 7.400 Wh was tested and charged in the system from the drained battery until it was fully charged. and was also done in a standard socket with the use of a 5V-2.0A Android charger

III. Data Analysis

Samples were analyzed by the researchers with the guidance of studies and were tested according to the recommended conditions (standard), such as the expected sun peak hours. The data were compared with one another, considering the environmental changes that caused phenomenal changes to the results. There are different ways of analyzing data from two system parts separately. In the solar panel, measures of central tendency will be utilized to get the mode in every trial. The mode will serve as the most frequent value of voltage the solar panel can gain from the sun at a particular time or peak sun hour.

Data for the pressure plate will be determined using the formula:

$$f = mass\ x\ acceleration$$

which will provide the required amount of force for the pressure plate to be an efficient automation for the whole system. The calculated force is the minimum weight the pressure plate needs to work, which means that the pressure plate will work with weight above the calculated force placed on it.

IV. Results

A. Pressure plate

The researchers tested the force required for the pressure plate to function as expected. First, the researchers tried to place a glass pitcher weighing 0.822 kilograms, which was assumed to be enough for a pressure plate to produce electricity but proved insufficient. In trial 2, a glass pitcher weighing 0.822 kilograms and a coffee cup weighing 0.458 were put down at the top of the pressure plate, which proved inadequate. For the third trial, a glass pitcher weighing 0.822 kilograms with 0.912 kilograms of water inside it was placed in the pressure plate, but resulted in an insufficient weight for the pressure plate to work. The researchers have done many trials, shown in the table below, that resulted in the plate not functioning adequately. However, it worked when the 0.822 kilograms of pitcher was loaded with 1.610 kilograms of water and then placed or applied at the top, giving the sum of 2.432 kilograms. This implies that using force below 2.4 Kilograms to the pressure plate will not be sufficient for the device to produce energy. On the contrary, using force above or equal to 23.52 kilograms to the pressure plate will have the same amount of electricity as when using 2.4 kilograms because the energy exerted doesn't vary depending on the force applied to the pressure plate.

Trials	Mass	Activated or not?	Force
1	0.822 kg	NOT	8.056 N
2	1.28 kg	NOT	12.544 N
3	1.738 kg	NOT	17.032 N
4	1.834 kg	NOT	17.973 N
5	1.908 kg	NOT	18.698 N
6	1.992 kg	NOT	19.522 N
7	2.01 kg	NOT	19.698 N
8	2.2 kg	NOT	21.56 N
9	2.432 kg	ACTIVATED	23.834 N
10	2.837 kg	ACTIVATED	27.8026 N
11	3.84 kg	ACTIVATED	37.632 N
12	4.513 kg	ACTIVATED	44.227 N
13	6.692 kg	ACTIVATED	65.582 N
14	7.18 kg	ACTIVATED	70.364 N
15	9.891 kg	ACTIVATED	96.932 N

***Table 1**. testing for the force needed to activate the pressure plate*

Determining the fire safety of this prototype depends on the pressure plate's temperature, as it provides automation for the whole electrical system. To measure heat generated from the pressure plate, the researchers used an Infrared Thermometer. The testing comprised five trials varying in the time frame of fifteen minutes. It can be seen in the table above that from the first trial up to the last trial, the resulting temperature of the pressure plate was stable at 23°C even when it was tested five times every fifteen minutes for a total of 1 hour and 15 minutes of testing duration. Moreover, it was tested in an air-conditioned room, which influenced the temperature of the pressure plate but had nothing to do with the accuracy of the data collected. This implies that the pressure plate is a safe automation that can prevent electrical fire as it was proven to have a constant heat temperature that is safe to avoid fire.

Trials	Temperature
15 mins	23°C
30 mins	23°C
45 mins	23°C
60 mins	23°C
75 mins	23°C

***Table 2**. Resulting temperature of pressure plate while operating*

B. Solar Panel

Results of the tested voltage the solar panel has gained varying times for this research's data have been summarized in the Table below. The researchers presumed to collect reliable, efficient data compared to the specific chosen time as the sun produces discrete light intensities at different times.

Conducting five (5) trials, the researchers collected data as the solar panel gained energy from the sun ranging from 21 V to 21.7 V at 8:00 am, which is lower compared to the energy gained when the solar panel was directly faced the sun at noon providing a data varying from 22.9 V to 21 V that is considered to be the most sun peak hour. However, as seen in the table above, the energy obtained from the sun at 3:00 pm has a voltage of 21.7 V, decreasing to 21 V, which has the nearest energy result to noon. Lastly, 5:00 pm has the lowest energy result, giving data varying from 20.9 to 20.5.

Time	Trial1	Trial2	Trial3	Trial4	Trial5
8:00am	21.7V	21.5V	21.3V	21.1V	21 V
12:00nn	22.9V	22.7V	21 V	22.5V	21 V
3:00 pm	21.7V	21.5V	21.3V	21.1V	21 V
5:00 pm	20.9V	20.8V	21 V	20.7V	20.5V

***Table 3**. Unregulated solar energy voltage*

C. The DC Battery

Testing the time the battery can take when discharging as the system was used is a significant help in measuring the efficiency of this prototype. The researchers conducted fifteen trials through a cell phone charger to get an accurate result, but as seen in the table below, there are chances that the hours are the same as when it was used coincidently. As can be noticed in the table, the voltage and the wattage are constant. At the same time, values on a kilowatt per hour vary as obtained when the wattage is multiplied by the given hours used and then multiplied again to one thousand (1000) because the needed answer is in kilowatts. On the other hand, ampere-hour was acquired when kilowatt per hour was multiplied by one thousand (1000) and then divided by the voltage.

Conducting a trial at 5 hours of charging resulted in 33.6 hours, equivalent to a day and nine hours. Determining the discharging time of the system as an android mobile phone with a battery containing 2000 mAh/ 7.400 Wh when the system was used nine hours for charging was ascertained to discharge at 18.7 hours. Moreover, charging at 10 hours will have 16.8 hours to discharge, while it has a discharging time of 15.3 hours when charged at 11 hours. This gathered data proves that charging a cell phone in the researcher's prototype is more effective than using electricity in an electric grid, which can lessen electric bills.

Ampere Hour	Ampere of the Module	Estimated Hours	Actual Hours of Charging Time (Testing)
7 Ah	1.11 A	6.31 Hours	6 Hours and 48 Minutes

***Table 5**. Actual charging of DC*

6	8	12	10	0.08	6.7	21.0
7	5	12	10	0.05	4.2	33.6
8	6	12	10	0.06	5.0	28.0
9	9	12	10	0.09	7.5	18.7
10	9	12	10	0.09	7.5	18.7
11	11	12	10	0.11	9.2	15.3
12	10	12	10	0.1	8.3	16.8
13	8	12	10	0.08	6.7	21.0
14	9	12	10	0.09	7.5	18.7
15	7	12	10	0.07	5.8	24.0

***Table 4**. Discharging the DC*

The table shows the amount of electricity discharged by the battery. It also shows the ampere of the module, which is a load of electricity harvested by the solar panel, wherein it is estimated to fill the battery to maximum load. Hence, the last column shows the actual result of the trial.

D. Amount of energy consumption

Shown in Table 6 is the amount of energy consumption of devices that the prototype can power up, including its cost in terms of daily, monthly, and yearly bill amount. Furthermore, the cost of a kWh is Php 9.4523 and was obtained from a reliable source of electricity in the country-Meralco.

Appliance	Wattage	Hours used	Per day	Kwh	Php/day	Php/month	Php/year	Monthly Bill Amount	Percentage
Cellphone Charger	10 watts	9	90 watts	0.09	0.85	25.5	306	1000	2.6
								2000	1.3
								3000	0.9
								4000	0.6
								5000	0.5
Fire Alarm	60 watts	1	60 watts	0.06	0.57	17.1	205.2	1000	1.7
								2000	0.9
								3000	0.6
								4000	0.4
								5000	0.3
Coffee Maker	650 watts	0.35	227.5 watts	0.23	2.17	65.1	781.2	1000	6.5
								2000	3.3
								3000	2.2
								4000	1.6
								5000	1.3
LED Lights	12 watts	10	120 watts	0.12	1.13	33.9	406.8	1000	3.4
								2000	1.7
								3000	1.1
								4000	0.8
								5000	0.7

***Table 6**. Amount of the energy consumption of specific devices*

E. Testing of the prototype by charging

The researchers conducted an experiment to test or examine the system's efficiency or prototype by charging an Android mobile phone with a battery that contained 2000 mAh/ 7.400 Wh in the system. As a result, with the use of the researcher's prototype, it took 5 hours time duration for the battery percentage of the drained (battery) Android mobile phone to reach 100% or be fully charged compared to the time duration when the drained (battery) android mobile phone is charged in a standard socket with the use of 5V- 2.0A android charger, it only took 2 hours for the mobile phone to be fully charged.

	Time	Battery %
System	5 hours	0 to 100%
Normal socket	2 hours	0 to 100%

V. Discussion

The results in the previous section imply that the pressure plate will be activated if the weight acting on it is greater than or equal to 2.4 kilograms. Hence, the magnitude of the electricity does not vary from the magnitude of the force acting on the pressure plate. Second, the results that the researchers gathered in the unregulated voltage generated by the solar panel imply that the magnitude or the strength of the harvested solar energy varies from time to time. Thus, the efficient harvesting of solar energy is from 12 noon to 3 pm, the peak sun hour in which the sunlight offers 1,000 watts of photovoltaic power per square meter.

In discharging the DC, the battery was used non-stop in every trial to see how long it could function. The relation between the ampere-hour and the discharging time is that: when the ampere-hour is higher, the tendency for the battery is to discharge faster, and when the ampere-hour is lower, the discharging time is slower. This implies that the two are inversely proportional. On the other hand, the result of charging the battery shows the estimated hours of charging, wherein it is also expected to experience constant and ideal situations. However, as a result of different factors affecting the current harvested by the solar panel, the actual hours of charging are different from the estimated hours of charging, such as the regulator also using energy from the battery. The angle of the solar panel also affects the magnitude of the harvested energy; the sun's photovoltaic voltage also affects the solar panel's harvested energy, etc. Whereas it took 1.11A in 6 Hours and 48 Minutes to fully charge a battery with 7Ah capacity, the battery level is also shown on the LCD of the regulator for monitoring purposes.

Considering that the system can power up to 12V, it has a promising ability to save significant amounts of money, thus benefiting from it financially and, at the same time, lessening the consumption of electricity from non-renewable resources. A cellphone charger has a total cost of energy consumption of Php 25.5 monthly. To note, that is just one charger being used daily, which means that in a household set-up, the amount of consumption using chargers will increase as other members also use cellphone chargers daily and in a household that has an estimated total monthly bill of Php 5000, the percentage of a cellphone charger is roughly less than 1% meaning if the system is improved in the future, significant changes in terms of energy conservation and less amount of money will be used to pay for bills of electricity will become possible.

An android mobile phone with a battery containing 2000 mAh/ 7.400 Wh took 5 hours to be fully charged from a drained battery using the researcher's system or when charged to the system. Compared to when charged in a standard socket, it can only take 2 hours for it to be fully charged using an android charge of 5V-2.0A. It implies that charging from a standard socket is faster than charging in the researcher's prototype or system. However, the benefit or advantage of our system compared to a standard socket is saving energy and reducing expenses for electric bills.

Moreover, the prototype serves not only as an automation system that can prevent electrical fire incidents but also as an alarm and can function even without the pressure plate; nevertheless, only the normally closed terminal or socket will work. Furthermore, with proper components, the prototype can serve as an alarm for security purposes; it can act as a doorbell which, when a living entity exerts a force upon the pressure plate, notifies nearby person/s and serves as an alarm for intruders.

However, since the prototype is composed of weak and inefficient material to produce and sustain high voltage, specifically the solar panel that can only harvest 22.9 V maximum and the SPDT relay that can sustain ranging from 12 volts-24 volts, appliances such as TV and air conditioning unit requires and may only work with sufficient and efficient components that can sustain and can produce extremely high voltages that can support the specific appliance. It is highly recommended that future researchers use higher qualities of components. It is also highly advisable to conduct a further and long-term study to maximize the capabilities, suggesting amalgamation of electrical and electronic equipment such as sensors.

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APPENDIX