Solar-Powered Automatic Watering System

Erlyn Mae Getino-Desamparado
Block 42 Lot 5, Providence Negros, Granada, Bacolod City
erlyn.getino@wnu.sti.edu

Abstract

This developmental and descriptive study is directed towards developing a solar powered automatic watering system, focusing on its design and development, determining the quality dimensions of the project, and evaluating the level of acceptability in terms of durability, performance, and serviceability. The questionnaire used was adapted from a researcher made questionnaire to gather information on the quality of the product among electrical, electronic, mechanical engineers and practitioners and the level of acceptability among local farmers. The means were used to analyze the data gathered to determine the quality of the project's dimension regarding durability, performance, and serviceability. The project was rated very satisfactory. As to the level of acceptability of the system as assessed by farmers regarding performance and serviceability, the product was rated as very satisfactory. In contrast, a rating in terms of durability earned satisfactorily. Based on these findings, a solar-powered automatic watering system can be developed. It is feasible, operational, and functional. The materials used are available in local markets and nearby cities and municipalities. Furthermore, there is a need to further enhance the project's durability since it was evaluated by the experts as satisfactory only.

***Keywords*:** Solar-powered automatic watering system, durability, performance, serviceability

Bionote:

Erlyn Mae Getino - Desamparado currently serves as Dean of the College of Engineering at STI West Negros University in Bacolod City holds a degree in Ph. D. in Technology Management, which she completed at Carlos Hilado Memorial State College in Talisay, Negros Occidental. Her research interest lies in solar powered automatic watering system.

Introduction

In the world where technology becomes the offshoot of fast and convenient, work simplification was the bywords. Man today, preferred to have everything in automation for it makes life easier, faster, and convenient. Using an automated system brings comfort to the users, particularly to the one racing with the fast pace changing world brought about by the demands of times. Everyone seems to likened automation. The automation of things today becomes a state of art of man's lifestyle. Even in using a sprinkler to water the plants on a summer basis, man wants to water the plant to be automated. For a plant enthusiast, plants are essential things to sustain human life for it provide nourishment and a means of food sources that makes the human body in good shape and good health. It is also the source of strength and energy and a good source of oxygen, for it acts as chambers for particular pollution in an environment where it was planted (Harishankar, Sudharsan, & Viveknath, 2011). Being a grower of plants for quite some time, experiencing watering the plants was tiring. Sustaining the plants repeatedly every day makes one very tired, especially if the one who did the watering was already old, just like my father, who was the one who inspired me to pursue this study. Though getting someone paid to do the task, undeniably, tiredness still lingers mainly if watering of the plants used the traditional approach in Ilonggo language we call "Manomano." This was the premise that prompted the researcher to design and develop a Solar Powered Automatic Watering System believing in what Harishankar et al. 2011, and beliefs that the sun's power is the future of the farmers and the solution for an energy crisis. Thus, watering the plants using an Automated Solar Powered System can be a means to resolve the traditional approach and might be a way to boost agriculture. Plus, designing and developing a watering system makes the task easier and convenient, user-friendly, and pollution-free, for it does not require human intervention. It is along with this basic premise that a study of nature was conducted.

Objectives of the Study

Generally, the study was to develop a Solar Powered Automatic Watering System. Specifically, it aimed to:

1. design a Solar Powered Automatic Watering System;
2. determine the quality dimensions of the project in terms of:
   a. Durability
   b. Performance
   c. Serviceability
3. Evaluate the level of acceptability of the Solar Powered Automatic Watering System in terms of:
   a. Durability
   b. Performance
   c. Serviceability

Scope and Limitations of the Study

The study was limited in the development of a Solar Powered Automatic Watering System and on the parameters specified in the specific objectives of the study. Hence, durability, performance, and serviceability were the variables mentioned that was evaluated by experts and farmers who were identified respondents of the study. Moreover, the study was confined with evaluation acceptability of the system using a demo farm of 4 feet by 20 feet planted with scallion (Allium *Cepa*) to ensure acceptability of the system (scientific+name+scallion+onion=scientific).

Review of Related Literature

According to James Marsh (2013), designing a plant watering system includes a control module. The control module is operable in at least one embodiment, receiving a signal from at least one weight sensor corresponding to a weight of a plant measured by at least one weight sensor. Store a low weight and a high weight associated with each of the at least one weight sensor, and communicate a control signal to at least one water valve that opens at the low weight and closes at least one water valve at the high weight. The current application is an automated plant watering system (APWS) that water a plant automatically based on its weight. This technique is designed for circumstances when a plant's weight is only affected by new growth, and water addition/evaporation in its container is required.

The APWS is coupled to a water source, a low-pressure water line from a container, or a municipal water supply. The water source may also be a container that can be refilled from rainwater manually, automatically, or any other adequate method. The APWS generally includes an electronic control module that contains a controller, a user interface or display, a memory, and any other circuitry to provide the functionality disclosed herein. One example is a timer circuit to maintain the current date and time, watering or testing schedules, etc. Another is an input device for users to enter data and various inputs and outputs for receiving signals from weight or other sensors, activating water valves, pumps, etc., and providing the additional functionality discussed herein. The APWS may also include one or more electronic weight sensors that produce a signal that corresponds to the weight of a plant. Depending on the particular application of the system, the sensor can be a piezoelectric sensor by itself, incorporated into a platform/mat or any other third-party sensor that meets APWS system requirements. The sensor may be integrated into a mat with a power source, such as a solar cell, and may also include a wireless transmitter that communicates the weight signal to the control module. Each of the sensors or mats may be uniquely identifiable by the module's control module to service a plurality of plants, each on individual sensors or mats. Data may be collected from 1 or more sensors or types of sensors (weight, humidity, barometric pressure, weather forecast, etc.) (*James Marsh, 2013).*

An automated self-watering system for plants growing in containers, according to Yakoy Mordoch (1992), incorporates a water receptacle above the level of the container's growing material. The water container can be any shape and can be attached to or situated adjacent to the container's upper edge. Alternatively, the water container's legs might rest on or be implanted in the growing media, or they could be hooked onto the container's edge. The water receptacle can be made separately from the container or as part of it. An outlet in the side or base of the water receptacle is connected to a conduit for carrying water. The conduit is connected to a dryness sensor in the container's growing material. When the growing medium is fully hydrated, the dryness sensor automatically closes the conduit. When water is needed, it opens the conduit to allow water to drip onto the growing medium. The conduit's outlet is positioned such that water drips into the plant's root area growing in the container via gravity. A separate pot for a plant that fits in the container may also be stored in the container. A water receptacle above the growing material in the container is part of an autonomous self-watering system for plants growing in containers. The water container can be any shape and attached to or situated adjacent to the container's upper edge. Alternatively, the water container's legs might rest on or be implanted in the growing media, or they could be hooked onto the container's edge. The water receptacle can be made separately from the container or as part of it. An outlet in the side or base of the water receptacle is connected to a conduit for carrying water. A dryness sensor put in the container's growth media engages the conduit. When the growing medium is fully irrigated, the dryness sensor closes the conduit. When water is needed, it opens the conduit to allow water to drip onto the growing medium. The conduit's exit is positioned such that water drips into the plant's root area growing in the container via gravity. A separate pot for a plant that fits in the container can also be used in the container (Yakov Mordoch, 1992*)*.

With Tarun Agarwal (2015) watering the plants observe circuit that contains two probes, which will sense the soil's moisture and switch on the relay at the specific value of dryness. It is connected to any sprinkler system or pump with the relay to switch the circuit on automatically to water the plants. Two transistors act as switches in the circuit. If the probes fail to detect moisture in the soil, the resistance between the two probes will rise, causing the transistor to turn on. If the transistor turns on, the requisite voltage is applied to the transistor's base terminal, and the relay is actuated.

The variable resistor 50k is used to fine-tune the circuit so that the relay will turn on when the desired amount of dryness is reached. This circuit works with DC voltages of 6, 9, or 12 volts. It can be substituted by any steel nail, wire, or similar material for the probes. Put the probes a few inches under the soil and keep some gap between them for optimal results.

A step-down transformer in the power supply reduces the voltage to 12 volts AC. A bridge rectifier converts the AC voltage to DC, which is then regulated to 5V by a voltage regulator. This voltage is required for the microcontroller to function.

A microprocessor, a motor-driver circuit, and a sensor circuit are the three primary gears in this automatic plant watering system diagram. The sensor circuit compares the soil condition to the reference voltage of 5 volts when it detects it. A 555 timer does this process.

When the soil condition is less than 5V, the soil is declared dry, and the 555 timer transmits the microcontroller to the logic signal 1. The microcontroller then activates the motor driver circuit and instructs the motor to continue pumping water to the plants. The soil becomes wet when the soil condition exceeds 5V. The 555 timer then sends the microcontroller the logic signal 0 to turn off the motor driver circuit. Finally, the motor and soil conditions are displayed on the LCD *(Agarwal, 2015).*

S. Amardas1, R. A. Rahim1 (Malaysia, 2016) developed an automated solar watering system. The primary purpose of his project was to create a Solar Watering System capable of performing irrigation or watering tasks automatically and is powered by Photovoltaic (PV) panels. A moisture sensor in the soil is used to check the need for irrigation to operate a pump powered by the PV system and lead-acid battery. In addition to the input from the moisture sensor, the timer function within PIC18F4550 was also applied to prevent watering many times per day. This ensures that the crop or plant in the field will not have growth problems due to overwatering. A sun tracker in the form of a single axis was designed to increase energy harvesting from sun radiation. Horizontal Single Axis Tracker (HSAT) was built based on the feedback from two Light Dependent Resistors (LDR) and an opaque sheet dividing them so that shadow will be cast on either one of them the sun moves.

Solar Powered Automatic Irrigation System by Mr. M. A. Murtaza1, Mr. Mragank Sharma, Rohit Yadav, Rajvardhan Chaudhary, Kriti Rastogi Professor, Mechanical and Automation Department, Amity University (Lucknow Campus), India Assistant Professor, Mechanical and Automation Department, Amity University (Lucknow Campus), India UG Student, Mechanical and Automation Department, Amity University (Lucknow Campus), India came up with another design. The project was intended to cultivate an automatic irrigation system that controls the pump motor ON/OFF on sensing the moisture content of the soil. In the field of agriculture, the use of an appropriate technique of irrigation is essential. The study was to reduce human intervention and still certify proper irrigation. A software application was developed by predetermining the threshold values of soil moisture, temperature, and water level programmed into an arm controller. The project showed the controlling and monitoring the status of water and detecting the soil moisture content.

In this report, the soil moisture sensor, temperature sensors positioned in the plant's root zone, and opening unit handles the sensor info and transmit data to a web submission. One algorithm was developed to measure threshold values of temperature sensor and soil moisture sensor that was planned into a microcontroller to control water amount, for photovoltaic power panel was used. Another facto-like cellular internet interface used that allowable for data assessment and irrigation planning to be programmed through a web page.

The automatic system was tested for 30 days and save 90% compared with the modern irrigation system. Because of its energy autonomy and low price, the system can be valuable in a water-limited, geologically isolated zone. In this paper, soil moisture content has been sensed using an acoustic-based technique was developed. The main purpose of this technique is growth for measure soil moisture in a real-time method. The method is based on the association between two quantities, i.e., speed of sound and the degree of permeation with water in soils. This experiment found that the speed of sound reductions with the moisture content following was contingent on the soil.

This paper designs a model of automatic irrigation arrangement based on microcontrollers and solar power used only for power supply. Several sensors are placed in the paddy field. Sensors sense water levels unceasingly and give the data to the farmer through a cellular phone. The farmer controls the motor without going into the paddy field. If the water level reaches a dangerous level, the routine motor will be off without the confirmation of the farmer.

Another project by Jia Uddin, Reza Taslim, Qader Newas, Jamal Uddin, Touhidul Islam, and Jong-Myon Kim, School of Electrical Engineering, University of Ulsan, Daehak-ro, Nam-gu, Ulsan, South Korea Dept. of Electrical and Electronic

Engineering. It is called an "automated irrigation system using solar power." The model was to automatically control and helps the farmers irrigate their fields properly. The model always ensures a sufficient water level in the paddy field, avoiding the under-irrigation and over-irrigation. Farmers can use remotely ON/OFF the motor by using cell phones even from away. The system is secured with a password for the restricted number of users. Solar power provides enough power to drive the system (Reza, Uddin, Islam, & Kim, 2012)

Another study investigated an automated self-watering system for plants growing in containers with a water receptacle above the level of the growing media. The water container can be any shape and can be attached to or situated adjacent to the container's upper edge. Alternatively, the water container's legs might rest on or be implanted in the growing media, or they could be hooked onto the container's edge. The water receptacle can be made separately from the container or as part of it. An outlet in the side or base of the water receptacle is connected to a conduit for carrying water. A dryness sensor put in the container's growth media engages the conduit. When the growing medium is fully irrigated, the dryness sensor closes the conduit, and when water is needed, it opens the conduit to allow water to drip onto the growing medium.

From A Solar Cell to a PV System

Photovoltaic modules https://en.wikipedia.org/wiki/Photonemploy the photovoltaic effect to create electricity https://en.wikipedia.org/wiki/Photovoltaic_effectfrom light energy (photons) from the sun. Wafer-based crystalline silicon cells or thin-film cellshttps://en.wikipedia.org/wiki/Dead_and_live_loads are used in the majority of modules. The top and back layers of a module can serve as structural (load-bearing) members. Mechanical and moisture damage to cells must also be avoided. Most modules are rigid, but semi-flexible ones based on thin-film cells are also available. The cells must be connected electrically in series, one to another.

A PV junction box is attached to the back of the solar panel, and it is its output interface. Externally, most photovoltaic modules use connector’s type to facilitate easy weatherproof connections to the rest of the system. Also, a universal serial bus (USB) power interface can be used.

Module electrical connections are made in series or parallel to achieve the desired output voltage or https://en.wikipedia.org/wiki/Parallel_circuitscurrent capabilities (amperes). Silver, copper, or other non-magnetic conductive transition metals may be used in the conducting wires that take the current away from the modules. In partial module shading, bypass diodes may be included or utilized externally to maximize the output of module areas that are still lighted.

Concentrators, which use lenses or mirrors to focus light onto smaller cells, are included in some unique solar PV modules. This enables the cost-effective usage of cells with a high cost per unit area (such as gallium arsenide). Metal frames with racking components, brackets, and reflector shapes are also used in solar panels.

History

Alexandre-Edmond Becquerel discovered that some materials can generate an electrical charge https://en.wikipedia.org/wiki/Alexandre-Edmond_Becquerelwhen exposed to light in 1839. This observation was not repeated until 1873 when Willoughey Smith found that light hitting selenium could create the charge. In 1876, William Grylls Adams and Day published "The action of light on selenium," outlining the experiment they conducted to repeat Smith's findings. Charles Fritts invented the first commercial solar panel in 1881, which he described as "continuous, constant, and of substantial force not only by exposure to sunlight but also by exposure to faint, diffused daylight." However, when compared to coal-fired power facilities, these solar panels were inefficient. Russell Ohl invented the solar cell concept that is used in today's solar panels in 1939. In 1941, he received a patent for his innovation. Bell Labs used this idea to develop the first commercially viable silicon solar cell in 1954.

Efficiency

Since 1976, there has been reported solar cell energy conversion efficiency (National Renewable Energy Laboratory). Photovoltaic modules, depending on their design, can generate power from a wide range of light frequencies. Still, they rarely cover the complete solar spectrum (specifically, ultraviolet, infrared, and low or diffused light). As a result, solar modules squander a significant amount of incident sunlight energy, and they can achieve significantly better efficiency if illuminated with monochromatic light. As a result, another design approach is to divide the light into six to eight different wavelength ranges, each of which produces a different light color, and then route the beams to other cells tuned to those wavelength ranges. This has been projected to be capable of raising efficiency by 50%.

Scientists at Spectrolab, a Boeing company, have developed multi-junction solar cells with 40 percent efficiency, setting a new world record for solar photovoltaic cells. According to Spectrolab researchers, concentrator solar cells could achieve more than 45 percent or possibly 50 percent in the future, with potential efficiencies of around 58 percent in cells with more than three conjunctions.

The best attainable sunlight conversion rate (solar module efficiency) in new commercial goods is now approximately 21.5 percent, which is often lower than the efficiencies of individual cells in isolation. Power density ratings of up to 175 W/m^2 (16.22 W/ft^2) are found in the most efficient mass-produced solar modules. According to Imperial College London research, the efficiency of a solar panel can be enhanced by studding the light-receiving semiconductor surface with aluminum Nano cylinders similar to the ridges on Lego bricks. The scattered light travels along a longer path in the semiconductor, meaning that more photons can be absorbed and converted into current. Although these Nano cylinders have been utilized before (gold and silver came before aluminum), the light scattering occurred in the near-infrared range, and visible light was significantly absorbed. The ultraviolet region of the spectrum was shown to be absorbed by aluminum.

Meanwhile, the visible and near-infrared parts of the spectrum were scattered by the aluminum surface. This, the research argued, could bring down the cost significantly and improve efficiency as aluminum is more abundant and less costly than gold and silver. The study also noted that the increase in current makes thinner film solar panels technically feasible without "compromising power conversion efficiencies, thus reducing material consumption."

Micro-inverted solar panels are wired in parallel, resulting in higher output than normal panels wired in series. The lowest-performing panel determines the series' output (this is known as the "Christmas light effect"). Because micro-inverters work independently, each panel provides its maximum output based on the amount of sunshine available.

Technology

The majority of solar modules are currently composed of crystalline silicon (c-Si) solar cells, which can be multi-crystalline or monocrystalline. In 2013, crystalline silicon accounted for more than 90% of all PV output in the world. Thin-film technologies based on cadmium telluride and amorphous silicon make up the rest of the overall market.

Advanced thin-film cells are used in upcoming third-generation solar technology. In comparison to other solar technologies, they produce a relatively high-efficiency conversion at a low cost. Also, for solar panels on spacecraft, high-cost, high-efficiency, and close-packed rectangular multi-junction (MJ) cells are preferred. They provide the highest ratio of generated power per kilogram lifted in space. https://en.wikipedia.org/wiki/Compound_semiconductorGallium arsenide (GaAs) and other semiconductor materials make up MJ-cells, which are compound semiconductors. Concentrator photovoltaics are another new PV technique that uses MJ-cells (CPV).

Thin Film

https://en.wikipedia.org/wiki/Thin-film_moduleThe cell and the module are made on the same production line in rigid thin-film modules. The cell is built on a glass substrate or superstrate, with the electrical connections made *in situ*, in a process known as "monolithic integration." The substrate or superstrate is bonded to a front or back sheet, usually another sheet of glass, with an encapsulant. CdTe, a-Si, a-Si+uc-Si tandem, or CIGS are the most common cell technologies in this category (or variant). Amorphous silicon converts sunlight at a rate of 6–12%. The photoactive layer and other required layers are deposited on a flexible substrate to construct flexible thin-film cells and modules on the same production linehttps://en.wikipedia.org/wiki/Photoactive_layerhttps://en.wikipedia.org/wiki/Flexible_substrate. Monolithic integration can be employed if the substrate is an insulator (e.g., polyester or polyimide film)https://en.wikipedia.org/wiki/Die_(integrated_circuit). If it's a conductor, you'll need to use a different method of electrical connection. The cells are laminated to a transparent colorless fluoropolymer on the front side (typically ETFE or FEP) and a polymer suitable for bonding to the final substrate on the other side to create modules.

Smart Solar Modules

Several companies have begun to incorporate electronics into solar panels. This provides maximum power point tracking (MPPT) for each module separately and measures performance data for module-level monitoring and problem identification. Power optimizers, a DC-to-DC converter technology created to optimize the power harvest from solar PV systems, are used in several of these solutions. As of around 2010, such electronics can also correct for shading effects. A shadow falling across a piece of a module causes the electrical output of one or more strings of cells in the module to drop to zero, but not the entire module's production.

Performance and Degradation

Module performance is generally rated under standard test conditions STC, irradiance of 1,000 W/m^2, solar spectrum, and module temperature at 25°C. Electrical Characteristics include nominal power, open-circuit voltage, short circuit current, maximum power voltage, maximum power current, peak power, and module efficiency. This is a word from the days when solar modules were solely used to charge batteries; it refers to the nominal voltage to the battery's voltage that the module is best suited to charge. As lighting, temperature, and load conditions fluctuate, the module's actual voltage output varies; therefore, there is never a single voltage at which it functions. The nominal voltage allows users to quickly determine whether or not a module is compatible with a particular system.

The greatest voltage that the module may produce when it is not attached to an electrical circuit or system is known as the open-circuit voltage or VOC. A voltmeter can be used to measure VOC directly on an illuminated module's terminals or its detached connection.The peak power rating is the maximum output under standard test conditions (not the maximum possible outcome).

Maintenance

Solar panel conversion efficiency, typically in the 20% range, is reduced by dust, grime, pollen, and other particulates that accumulate on the solar panel. "A dirty solar panel can reduce its power capabilities by up to 30% in high dust/pollen or desert areas", says Seamus Curran, associate professor of physics at the University of Houston and director of the Institute for Nano Energy, which specializes in the design, engineering, and assembly of nanostructures.

According to researchers, solar panels that had not been cleansed or rained on for 145 days during a California summer drought lost only 7.4% of their effectiveness. Paying to clean the solar panels is considered not a good investment. Overall, cleaning panels midway through the summer would result in a $20 increase in power generation until the summer drought ends in around 2 12 months for a typical domestic solar system of 5 kW. The financial losses are greater for larger commercial rooftop systems, but they are rarely enough to justify the cost of cleaning the panels. On average, panels lost a little less than 0.05% of their overall efficiency per day. Pollution and Energy in Production

The solar panel has been a well-known method of generating clean, emission-free electricity. However, it produces only direct current electricity (DC), not typical appliances. Solar photovoltaic systems (solar PV systems) are often made of solar PV panels (modules) and inverters (changing DC to AC). Solar PV panels are mainly made of solar photovoltaic cells, which have no fundamental difference to the material for making computer chips. Producing solar PV cells (computer chips) is energy intensive and involves highly poisonous and environmentally toxic chemicals. There are few solar PV manufacturing plants around the world producing PV modules with energy produced from PV. This measure dramatically reduces the carbon footprint during the manufacturing process. Managing the chemicals used in the manufacturing process is subject to the factories' local laws and regulations.

Impact on Electricity Network

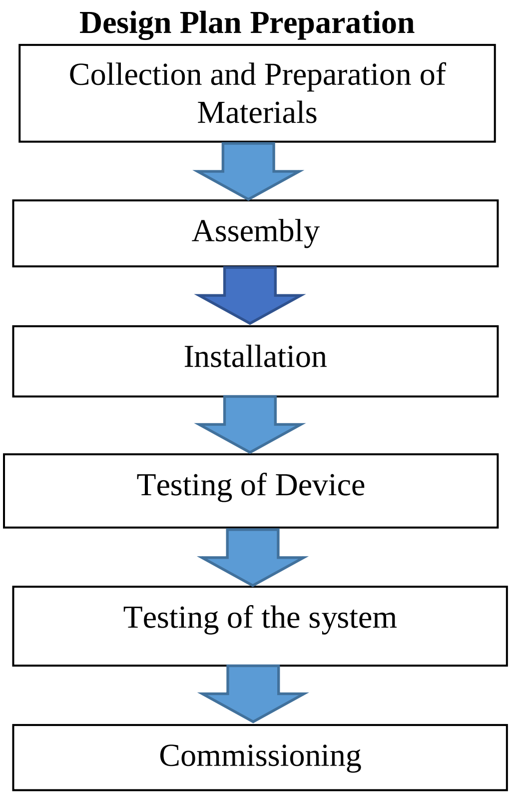
The energy flow becomes two-way as the number of rooftop solar systems grows. Electricity is exported to the grid when local generation exceeds usage. The power network, on the other hand, is not intended to handle two-way energy transfer. As a result, some technical difficulties may arise. For example, in Queensland, Australia, there have been more than 30% of households with rooftop PV by the end of 2017. The famous Californian 2020 duck curve appears very often for a lot of communities from 2015 onwards. An over-voltage issue may come out as the electricity flows from these PV households back to the network. Overvoltage can be managed in a number of ways, including controlling PV inverter power factor, installing new voltage and energy control equipment at the electricity distributor level, re-conducting electricity wires, and implementing demand-side management. These solutions frequently have restrictions and costs associated with them.

Implication onto Electricity Bill Management and Energy Investment

There is no silver bullet in electricity or energy demand and bill management because customers (sites) have different specific situations, e.g., different comfort/convenience needs, different electricity tariffs, or different usage patterns. Electricity tariff may have a few elements, such as daily access and metering charge, energy charge (based on kWh, MWh), or peak demand charge (e.g., a price for the highest 30min energy consumption in a month). PV is a promising option for reducing energy charges when the electricity price is reasonably high and continuously increasing, such as in Australia and Germany. However, for sites with peak demand charge in place, PV may be less attractive if peak demands mainly occur in the late afternoon to early evening, for example, in residential communities. Overall, energy investment is essentially an economic decision. It is better to make investment decisions based on a systematical evaluation of options in operational improvement, energy efficiency, onsite generation, and energy storage.

Methodology

Figure 1.
Production Flow



Collection and Preparation of Materials

This process was done by canvassing the materials needed from the local electronics shop, and online shopping was the last option on materials not available locally.

Assembly

Assembly of the watering system involves the housing, fixture, and interconnection of electronic, electrical, and mechanical components, printed circuit board of the microcontroller, and sub- assemblies. All the parts and materials needed for the project were already checked and tested before doing the project's assembly.

Installation of the Parts

After the working drawing of the design, installation of the watering system was made based on the established design, and quality features were evaluated regarding parameters such as durability, performance, and serviceability to ensure that the system can be accomplished according to its expected output and outcome.

After assembling the components, installing the solar panel, charging circuit, battery, inverter, and the motor pump was done. The electrical connection of the watering system was made, checked, and tested.

Testing of the System

Operation and Testing Procedures

After the design was made, the system was made to function for a definite period. The wiring was connected to ensure that there is no loose connection or cold solder. Unyielding analysis was conducted to guarantee the even and uninterrupted operation of the project.

Following procedures tested the watering system to maintain the device's regular operation, testing the circuit controller and soil moisture sensors connected to the circuit is placed into the soil. The soil moisture sensors will sense the resistance of soil if the soil is wet (resistance is low), there will be current flowing, and if the soil is dry due to high resistance, current will not flow. When soil is dry, it will produce a large voltage drop due to increased resistance. This will trigger the transistor and makes the pump turns on. When the pump turns on, it supplies water from the tank to the plants until the two probes will conduct low resistance (soil is wet). When the water content in the soil is increased, the resistance in the soil will decrease, and conduction of the probes will start, making the transistor stop the triggering of the transistor, and automatically the pump turns off.

The circuit was tested in an open field where the sun's heat is at its maximum for testing the solar panel. To obtain the rated output, it needs full, bright sunlight falling directly onto the panel. The solar panel was placed directly to sun rays slanting approximately 45 degrees. Then it is connected to the controller to ensure the battery will not be an overcharge. It was observed for a day and continuously checked the battery's output voltage every hour until the battery is fully charged.

Commissioning

The process by which the system after installing all equipment from the solar panel, inverter, motor, tank, moisture sensor, solenoid valve and the program was tested to verify if it will perform according to the desired objectives. This process was repeatedly done to ensure the system was durable, function well, and serviceable.

Table 1
Parts of the Solar-Powered Automatic Watering System and their Functions

Parts	Functions
Battery pump	Absorbs the energy from the solar panel to power the motor
Charge Controller	Makes sure that battery is not over or under charged
Moisture Sensor	Measures the volumetric water content in soil
Motor pump	Use to move the fluid
Solar Panel	Source of energy to provide power to the motor pump
Solenoid Valve	Use to regulate the opening of the fluid in a valve
Micro Controller	Is a computer present in a single integrated circuit which is to perform one task and execute

The interrelationships of the automatic watering system parts were utilized to systematically install and assemble all its primary connections and /or all system components for it to perform efficiently and may deliver the services expected as determine. All components are integrated neither based on the construction procedures or steps in neither installing nor commissioning the watering system. The parts of the watering system were primarily available in the local market. If it was not available locally, an online system of purchasing the parts of the watering system was made to ensure that quality materials, tools, and equipment were considered.

Figure 2.
Interrelationship of Parts

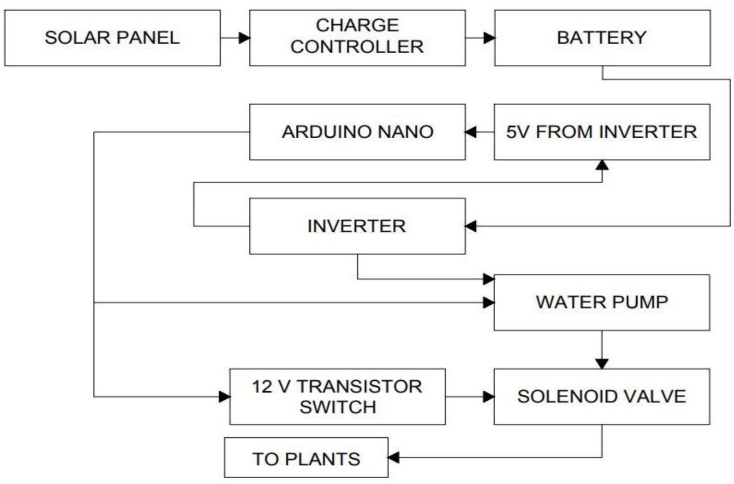


Table 2
Tools Used

Name of Tools	Functions
Cutter	Used to remove material from the work piece by means of shear deformation
Hammer	Handheld tool used to strike another object
Hand Drill	Hand drill is a fastening tool used to secure screws or bolts. It can also be used to drill bit to tighten fasteners, and can be used with stirring attachments to mix paint and joint and other liquid materials, such as glazing materials for ceramic
Multitester	Test tool used to measure two or more electrical values principally voltage (volts), current (amps) and resistance (ohms)
Pliers	Used for gripping something round like a pipe or rod, some are used for twisting wires, and others are designed to be used for a combination of tasks including cutting wire
Soldering Iron	Soldering iron is a hand tool used in soldering. It supplies heat to melt solder so that it can flow in the joint between two work pieces
Saw	Used to cut pieces of pipe into different shapes
Tape Measure	A flexible ruler and used to measure distance. It consists of a ribbon of cloth, plastic, fiber glass, or metal strip with linear-measurement markings. It is a common measuring tool.
Wire Stripper	A small, hand-held device used to strip the electrical insulation from electric wires

The tools used in this project were available in the local market and were commonly used in designing and developing the system. The tools were used to hold, operate and perform a simple task (like moving, lifting, breaking, holding, turning, and bending). Using the following tools, it will function as expected, for it was utilized to install and assemble all the needed materials in developing the Solar Powered Automatic Watering System.

Table 3
Item Specifications

Items	Specifications
Solar Panel	Power Rating: 50Watts
Battery type	Voltage Rating: 12 VDC, 70AH, N70
Inverter	Input: 12 VDC Output 220VAC
Water Pump	Voltage Input 220VAC Power ½ HP
Solenoid Valve	Voltage 12 VDC Pressure Rating 0.02 – 0.08 MPa
Moisture Sensor	Voltage Input 3 VDC Weight 100g
Arduino Nano	Operating Voltage 5 VDC Voltage Input 7-12 VDC

Table 3 are the list of Tools and Materials and the corresponding specification to make sure that all the parts of the solar powered automatic watering system can met the minimum requirements for quality dimensions and for ease of operation

Table 4
Bill of Materials

Items	Specifications	Quality	Price
Solar Panel	Power rating: 50 watts	1	Php 3899.00
Battery	12VDC 70AH	1	Php 5000.00
Inverter	Input: 12 Vdc, Output 220Vac	1	Php 2500.00
Pump	½ HP	1	Php 1500.00
Solenoid Valve	Voltage input 12 Vdc	3	Php 1303.00
Moisture Sensor	Voltage input 3 Vdc	10	Php 681.00
Arduino Nano	Operating Voltage 5Vdc	1	Php 400.00
PVC	¾ inch	4	Php 480.00
	Elbow ¾	4	Php 64.00
	Tee ¾	2	Php 34.00
	Adapter	6	Php 96.00
Solvent		1	Php 38.00
Caps	¾	3	Php 45.00
Diode	1N4001	4	Php 24.00
Transistor	BD139 NPN	7	Php 175.00
Lead		1	Php 40.00
PCB		1	Php 50.00
Box		1	Php 1000.00
Use of machines and tools			Php 2000.00
Transportation			Php 3000.00
Miscellaneous Cost			Php 3000.00
	Total		Php 25,329.00

Materials used in this project are all available from the local market. Its affordability ensures that the research study was made with due diligence. Prices vary depending on the choice of the brand selected. In this research study, quality tools and equipment were considered to guarantee performance, durability, and serviceability in terms of quality dimensions.

Design Calculations

Sizing the Solar Panel

The size of the solar panel can be determined based on the daily watt-hour consumption and the number of hours of peak sunshine. The power rating on solar panels is listed in Watts and gives the maximum power a solar panel will generate in bright sunlight. To calculate the amount of power it can supply to the battery, multiply:

(The rated power of the solar panel) x (the number of hours of direct sunlight) x (An estimated percentage of time it will receive direct sunlight (no clouds)) x (the efficiency of the charge controller)

The solar panel will have the number of hours of direct sunlight but also other hours of indirect sunlight. *Within* the hours of direct sunlight, clouds may obscure the sunlight. During the test, 30% of the time, the panel is in shadow (70% in full sunshine). For the charge controller, 85% efficiency is a typical value for a charge controller.

Sizing the Battery

Solar battery sizing (otherwise known as battery bank sizing) is one of the most important considerations when choosing the specifics of the solar electric system. The main purpose of sizing a battery bank is to get one that can handle the load from the PV panel and provide enough stored power. Most batteries will last longer if they are shallow-cycled, discharged only about 50% of their capacity. This implies that the battery bank should be about two times the daily load. The first thing to do is to determine the average daily Watt-hour consumption of the system. Next is to assume a number of days between two and six, called "days of autonomy," of storage capacity without recharging, which will allow the system to sustain energy even in nighttime conditions.

Sizing the Charge Controller

Another important consideration of this system is the charge controller. The purpose of the charge controller is to regulate the current from solar panels to prevent batteries from overcharging. A charge controller senses when the batteries are fully charged, also prevents the battery from feeding back into the solar panel at night when it is dark.

Charge controllers are rated by the amount of current they can receive from the solar panel. It should be chosen in such a way that it can be capable of handling the maximum amount of current that the solar panel can produce.

Cost Analysis

The system's total cost includes the cost of supplies and materials, labor cost, and overhead cost. The labor cost and overhead cost constitute 40% and 10%, respectively, of the cost of the supplies and materials, tools, and equipment used. As reflected in Table 4, the supplies, materials, tools, and equipment cost was P25, 329.00. This amount provides a reason for the researcher to carefully install, assemble, and construct the research study to achieve the durability, performance, and serviceability desired for the system.

Presentation, Analyses, and Interpretation of Data

Design of the System

The first objective of the study was to design and develop a Solar Powered Automatic Watering System. The components in a solar-powered automatic watering system include the PV array, charge controller, inverter, battery, microcontroller, solenoid valve, and motor pump.

It is essential that the component is designed as part of an integrated system to ensure that all the equipment is compatible and operates as intended.
The design of this project was made suitable for the scallions' plants located at Purok Paraiso, Barangay Taloc, Bago City. The size of the box is 1.5 x 2 ft, where the

scallions were planted. Then it was embedded on a table made of steel for elevation purposes given by the Department of Agriculture. The dimension of the rectangular steel is 20 feet long by 4 feet wide with a height of 3 feet. The mechanical and electronics parts were enclosed in a box at the side of the steel table. The components enclosed in the box are the motor, battery, Arduino kit circuit, and charge controller. There are 3 PVC pipes connected to the solenoid valve with holes that water the plants, and it can be expanded for more plants to water. It was solar-powered so that farmers in the mountainous area that has not been reached by electricity can still use the design.

Evaluation of Quality Features by Experts

The study's second objective was to evaluate the quality of the design in terms of durability, performance, and serviceability, as rated by the ten experts considered respondents of the study.

Table 5
Mean Score on the Quality Dimension of the Solar-Powered Automatic Watering System in terms of Durability

Items	Mean	SD	Verbal Interpretation
1. Quality of materials	3.50	0.53	Very Satisfactory
2. Quality of workmanship	3.20	0.42	Satisfactory
3. Quality of design	3.20	0.42	Very Satisfactory
4. Overall quality of the equipment	3.40	0.52	Satisfactory
Total	3.33		Satisfactory

5	4.21 - 5.00	Excellent
4	3.41 - 4.20	Very Satisfactory
3	2.61 - 3.40	Satisfactory
2	1.81 - 2.60	Fair
1	1.00 - 1.80	Poor

Table 5 presents the total mean score on the quality dimension of the system in terms of durability. The average mean score was 3.33, interpreted as satisfactory. This implies that the researcher should look into the quality and quality of the design. These are the items in durability that need enhancement since it is adjudged as satisfactory. The lowest obtained mean score was 3.20, interpreted as satisfactory. Quality materials obtained the highest mean score of 3.5, interpreted as very satisfactory. This implies that in terms of the quality of the materials, the solar-powered watering system was durable.

Table 6
Mean Score on the Quality Dimension of the Solar-Powered Automatic Watering System in terms of Performance

Items	Mean	SD	Verbal Interpretation
1. Ease of operation	4.00	0.47	Very Satisfactory
2. Safe to use the equipment	4.20	0.63	Very Satisfactory
3. Satisfies the basic needs of the user	4.20	0.42	Very Satisfactory
4. Reflects the ultimate use and function	4.40	0.52	Excellent
Total	4.25		Excellent

Legend		
5	4.21 - 5.00	Excellent
4	3.41 - 4.20	Very Satisfactory
3	2.61 - 3.40	Satisfactory
2	1.81 - 2.60	Fair
1	1.00 - 1.80	Poor

Table 6 shows the mean score on the quality dimension of the Solar Powered Automatic Watering System in terms of performance. The obtained total mean score was 4.25, interpreted as excellent, which implies that in terms of the system's overall performance, its performance can easily be operated, safe to use, satisfies the user's basic needs, and can be used and ultimately function well. The highest obtained mean score was 4.40, interpreted as excellent with a standard deviation of 0.52 on the item, "reflects the ultimate use and function'. The lowest mean score was 4.00, interpreted as very satisfactory, with an SD of 0.47. This implies that the performance, though on the lowest rating, can still be relied upon since it was still in its very satisfactory evaluation.

Table 7

Mean Score on the Quality Dimension of a Solar Powered Automatic Watering System in terms of Serviceability

Items	Mean	SD	Verbal Interpretation
1. Availability of local materials	4.50	0.53	Excellent
2. Availability of technical expert	4.20	0.42	Very Satisfactory
3. Availability of tools and machines	4.30	0.48	Excellent
4. Ease of maintenance	4.00	0.47	Very Satisfactory
Total	4.25		Excellent

Legend		
5	4.21 - 5.00	Excellent
4	3.41 - 4.20	Very Satisfactory
3	2.61 - 3.40	Satisfactory
2	1.81 - 2.60	Fair
1	1.00 - 1.80	Poor

Table 7 shows the mean score on the quality dimension of the Solar Powered Automatic watering System in terms of serviceability. The table reveals that the total mean score was 4.25, interpreted as excellent. This implies that the quality dimension of the system can provide continuous service since materials were available locally. The highest obtained mean score was 4.50, interpreted as excellent with an SD of 0.53. The lowest accepted mean score was 4.00, interpreted as very satisfactory in the item "ease of maintenance." These findings imply that the third quality dimension in terms of serviceability was serviceable, as seen in the evaluation results.

Table 8

Summary of the Mean of the Evaluation of the Quality Dimensions

Items	Mean	Verbal Interpretation
1. Durability	3.32	Satisfactory
2. Performance	4.25	Excellent
3. Serviceability	4.25	Excellent
Total Mean of the Mean Score	3.94	Very Satisfactory

Table 8 reflects the summary of the mean score on evaluating the dimensions of the Solar Powered Automatic Watering system. Performance and serviceability obtained the highest mean score of 4.25, interpreted as excellent respectively on the hand, and the lowest obtained mean score was 3.32 was durability interpreted as satisfactory. The finding implies that the system was serviceable and can perform well; however, there is still a need to further enhance the system's durability for it to stay longer through the years since durability was evaluated to be one of the lowest among the three quality dimensions.

Level of Acceptability of the System as assess by Farmers

The third objective of the research study was to evaluate the level of acceptability of the system. Based on the results of the evaluation of the farmers' respondents, results were presented on the next page based on the following parameters: Durability, Performance, and Serviceability.

Table 9

Mean Score on the Evaluation of Solar Powered Automatic Watering System in terms of Durability

Item	Mean	SD	Verbal Interpretation
1. Quality of materials	3.80	0.61	Very Satisfactory
2. Quality of workmanship	3.20	0.41	Satisfactory
3. Quality of design	3.40	0.56	Satisfactory
4. Overall quality of the equipment	3.20	0.41	Satisfactory
Total	3.40		Satisfactory

Legend

5	4.21 - 5.00	Excellent
4	3.41 - 4.20	Very Satisfactory
3	2.61 - 3.40	Satisfactory
2	1.81 - 2.60	Fair
1	1.00 - 1.80	Poor

Table 9 shows the mean score on the level of acceptability of the system in terms of durability. Based on the findings, the total mean score was 3.40, interpreted as satisfactory. This implies that in terms of the total summation of durability, the farmers' respondents were not so satisfied whether the system would last longer since the equipment's workmanship and overall quality. The lowest obtained mean score was 3.20, interpreted as satisfactory with an SD of 0.41 respectively among farmers' respondents in terms of materials and design. The highest obtained mean score was 3.8, with an SD of 0.61 interpreted as very satisfactory. The finding shows that in terms of workmanship, design, and overall quality of the equipment should be considered considering the durability of the system.

Table 10

Mean Score on the Evaluation of a Solar Powered Automatic Watering System in terms of Performance

Items	Mean	SD	Verbal Interpretation
1. Ease of operation	4.00	0.69	Very Satisfactory
2. Safe to use the equipment	4.50	0.63	Excellent
3. Satisfies the basic needs of the user	4.50	0.51	Excellent
4. Reflects the ultimate use and function	4.60	0.50	Excellent
Total	4.40		Excellent

Legend

5	4.21 - 5.00	Excellent
4	3.41 - 4.20	Very Satisfactory
3	2.61 - 3.40	Satisfactory
2	1.81 - 2.60	Fair
1	1.00 - 1.80	Poor

Table 10 shows the system was evaluated in terms of its performance with a total mean score of 4. 40 interpreted as excellent. This implies that farmers' respondents considered the performance of the solar-powered automatic watering system in response to ease of watering operation, safer to use the equipment when compared to other automated devices, satisfying the basic needs of the users, and reflects the ultimate use and function of the system. The farmers' respondents evaluated the system's performance as very satisfactory, obtaining the lowest mean score with a rating of 4.00 with an SD of 0.69. The highest obtained mean score was 4.50 with an SD of 0.63 and 0.51 interpreted as excellent on the items "safe to use the equipment "and "satisfies the user's basic needs."

Table 11

Mean Score on the Evaluation of a Solar Powered Automatic Watering System in terms of Serviceability

Items	Mean	SD	Verbal Interpretation
1. Availability of local materials	4.00	0.53	Very Satisfactory
2. Availability of technical expert	4.00	0.64	Very Satisfactory
3. Availability of tools and machines	4.00	0.50	Excellent
4. Ease of maintenance	4.00	0.64	Very Satisfactory
Total	4.15		Very Satisfactory

Legend

5	4.21 - 5.00	Excellent
4	3.41 - 4.20	Very Satisfactory
3	2.61 - 3.40	Satisfactory
2	1.81 - 2.60	Fair
1	1.00 - 1.80	Poor

Table 11 presents the total mean score in terms of serviceability, with a total rating of 4.15 interpreted as very satisfactory. Out of four items," availability of tools and machines" was evaluated excellent with a mean score of 4.60 with an SD of 0.50 that tools and machines used were serviceable. In comparison, the three items were rated very satisfactory for they garnered total mean scores of 4.0 with SD of 0.52, 0.64 respectively. This implies that farmers' respondents were also satisfied with the materials, availability of technical experts, and ease of maintenance of the system.

Table 12

Summary of the Mean of the Mean Scores Evaluation of the Solar-Powered Automatic Watering System according to the aforementioned variables as evaluated by Farmer-Respondents

Items	Mean	Verbal Interpretation
1. Durability	3.40	Satisfactory
2. Performance	4.60	Excellent
3. Serviceability	4.15	Very Satisfactory
Total mean of the mean score	4.05	Very Satisfactory

Table 12 reflects the summary of mean scores evaluated by farmers on the level and acceptability of the watering system in terms of the variables mentioned, such as; durability, performance, and serviceability. It shows that out of the variables mentioned by Farmers' respondents rated performance with the highest mean score of 4.60 interpreted as excellent. Durability earned the lowest mean score of 3.40, interpreted as satisfactory by the farmers' respondents. It implies that the respondents were not satisfied whether the system can last longer, thus enhancing the system.

Conclusion

In this paper, a solar-powered automatic watering system was designed and developed, determined the project's quality dimensions, and evaluated the level of acceptability in terms of durability, performance, and serviceability. It adopted the developmental and descriptive method and used a researcher-made questionnaire to gather information on the quality and acceptability of the product among electrical, electrical, and mechanical engineers and practitioners, and local farmers. The materials used were available in the community and online, particularly on materials not available locally. The quality dimensions of the project in terms of performance and serviceability were very satisfactory, which reflects the ultimate use and function. The result on the level of acceptability among farmers in terms of performance and serviceability was very satisfactory.

On the other hand, durability was evaluated as satisfactory. In terms of the quality of the project, a need to further enhance the durability of the system since it was evaluated by the experts satisfactory, a thorough examination in the light of the standardized tools and materials for the system to stay longer. For future studies, I recommend that researchers focus on improving the design based on its capacity and the durability of the watering system to be utilized by the farmers.

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