IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 9, May 2023

Design and Development of Portable Solar Power Unit

Vaibhav V. Shelke, Ankit G. Nikhare, Shubham V. Gawande, Siddhaling S. Lingade, Vaibhav V. Pingle, Prof. Nikhil G. More
Department of Mechanical Engineering
Shri Sant Gajanan Maharaj College of Engineering (SSGMCE), Shegaon, India

Abstract: *This research paper proposes a novel solar power system comprising a sliding solar panel and a single-axis sun tracking mechanism, which can be coupled with a portable solar power unit for easy relocation based on power requirements. The system aims to optimize power generation potential by automatically adjusting the tilt angle of the solar panel based on the position of the sun, thereby increasing overall energy output. The sliding mechanism facilitates easy movement of the solar panel, making it an ideal solution for temporary installations or areas with limited space. The portable solar power unit offers flexibility in power requirements, allowing users to relocate the system as per their needs. The study presents a detailed analysis of the proposed system's efficiency and performance, with promising results that could potentially make it a cost-effective and sustainable solution for power generation in various settings. Furthermore, the proposed system includes a trolley- mounted portable solar power unit for ease of transportation, providing a stable and secure base for the solar panel and power unit, ensuring optimal performance and durability. The study highlights the potential of the system in promoting sustainable and cost-effective power generation in various settings*

Keywords: Solar Module, Solar Energy, Sun Tracking, Portable Solar Power Unit.

I. INTRODUCTION

Solar energy has emerged as a promising solution to meet the increasing demand for energy while reducing carbon emissions. Solar power can be harnessed and utilized in various sectors, including agriculture. With the growing demand for food and increasing pressure on natural resources, it has become imperative to explore sustainable solutions for farming practices. One such solution is the use of portable solar power units for agricultural purposes.

The proposed system, as described in the abstract, offers a sliding solar panel system with a single-axis sun tracking mechanism, coupled with a portable solar power unit. The system's design aims to optimize solar panel power generation by automatically adjusting the panel's tilt angle based on the position of the sun. This feature increases the overall energy output and efficiency of the system.

The sliding mechanism and portability of the solar power unit make it an ideal solution for power generation in temporary installations or areas with limited space. Additionally, the trolley-mounted portable solar power unit facilitates easy movement of the system to different locations as per the power requirements. This system offers flexibility in terms of power requirements, enabling users to relocate the system as per their needs.

The application of solar energy in agriculture, particularly for water pumping and irrigation, has gained significant attention in recent years. The use of solar power for these purposes offers a sustainable solution, reduces energy costs, and conserves valuable resources such as water. The methodology described in the abstract offers a promising solution for farmers with different income levels, including low and middle-income farmers who cannot afford high-cost integrated systems.

Overall, the proposed portable solar power unit for agricultural purposes offers a sustainable and cost-effective solution for power generation in various settings. With the increasing demand for food and the need for sustainable farming practices, this technology could play a significant role in the future of agriculture.

The use of solar energy as a clean and cost-effective source of power is becoming increasingly important for both industrial and household applications. Solar-based water pumping, in particular, is a crucial technology for conserving valuable resources like water and energy, with one of its primary uses being for crop irrigation in agriculture. While both DC and AC pumps are available in the market, the high cost per watt of integrated solar water pump systems has been a major hindrance to their commercialization, with low and middle-income farmers unable to afford them and

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instead relying on conventional power sources. In this study, we explore the possibility of utilizing existing AC water pumps owned by farmers and examine their performance in conjunction with solar panels. Use the enter key to start a new paragraph. The appropriate spacing and indent are automatically applied.

Photovoltaic Technology

Photovoltaic technology is the technology used to generate electricity directly from sunlight by converting light energy into electrical energy through the use of photovoltaic (PV) cells. PV cells are made of semiconductor materials, such as silicon, that can absorb photons of light and release electrons, creating a flow of electrical current.

Photovoltaic technology is commonly used in solar panels, which are installed on roofs or in large arrays to generate electricity for homes, businesses, and power grids. This technology has become increasingly popular in recent years due to its ability to generate clean energy without emitting greenhouse gases or other pollutants.

Solar Module

A solar module, also known as a solar panel, is a device that converts sunlight into electricity using photovoltaic technology. Solar modules are made up of multiple solar cells, which are made from semiconductor materials, typically silicon, and are connected together in series or parallel to increase the amount of power output.

The process by which solar modules generate electricity starts with photons from the sun's light hitting the solar cells within the module. The photons then cause electrons within the solar cells to become excited, creating a flow of electrical current. This electrical current is then collected by the wiring within the module and transferred to an inverter, which converts the direct current (DC) electricity into alternating current (AC) electricity that can be used to power homes and businesses.

Solar modules are commonly used in residential and commercial solar power systems to generate clean, renewable electricity. They are typically installed on rooftops or in open fields where they can capture the maximum amount of sunlight possible. Solar modules are also often used in off- grid applications such as remote cabins and RVs, where they provide power without the need for a traditional power grid connection.

The efficiency of solar modules is constantly improving, with newer modules often boasting efficiencies of over 20%. The cost of solar modules has also decreased significantly in recent years, making solar power more accessible to homeowners and businesses. Solar modules are a critical component in the transition to a more sustainable energy future, as they provide a clean, renewable source of electricity that can help reduce greenhouse gas emissions and mitigate climate change.

II. METHODOLOGY

2.1 Design and Development

The design and development of the portable solar power unit was carried out by a team members of the project who carefully analyzed the different components and factors involved in the project. The system consists of three panels, each with a capacity of 15 watts. The middle panel was kept stationary while the other two panels were allowed to slide in opposite directions using a rack and pinion mechanism.

Fig. 1. Portable Solar Power Unit

The sliding mechanism was designed to be smooth and efficient, and to reduce friction, a channel slider with bearings was incorporated. The solar panels were attached to the sliders using the screw. The sliders helped the panels to move easily and smoothly, ensuring that the system would remain stable and functional. We got the idea to slide the panels using the channels which are used in modular kitchen. The slider channels were fitted in the wooden frame which held the whole set of panels firmly. To provide the additional support, we used the strips of the iron and attached it to the wooden frame using the nuts and bolts. At this stage the assembly of the upper part of the system was complete.

2.2 Sliding Mechanism

To move the panels along with the sliders, the DC geared motors were used. As the middle panel was kept stationary, we only needed to move the other two panels in the opposite directions which was done using two motors. One motor was fixed in upper side and the other was on the lower side. Pinion was attached to the shaft of the motor and was placed on to the rack. Both the motors were controlled using the motor driver. The directions of the rotation of the motors were opposite. The signal to the motors was given using the micro- controller Arduino UNO which controlled the whole system. To automate the sliding mechanism, we used the Infra-Red sensors that detected the presence of the panels in the area. At this stage the sliding mechanism was complete, now we needed to mount the system on the trolley.

Fig. 2. Panel assembly in an unfolded position

2.3 Trolley Mounting

To make the system portable, a trolley was designed and fabricated. The trolley was made of mild steel and had two wheels that made it easy to transport the solar power unit. The trolley was designed to be stable and sturdy, ensuring that the system would remain secure during transportation. While transporting, the system will get fold. To mount the system, we had to extend the base of the trolley upwards, so we welded the two columns on the both sides and made the casing accordingly so that the mechanism will get mounted on it properly. We wanted to reduce the friction that would occur during the sun tracking, so we used the ball bearings. The shafts of the upper part of the system were made to go through the ball bearings. The ball bearings were fixed on the columns of the trolley. Now the mounting part was complete.

2.4 Sun Tracking Mechanism

The sun tracking mechanism was designed to increase the efficiency of the system. It was a single-axis mechanism that used an LDR (Light Dependent Resistor) sensor to detect the intensity of light. The panels were mounted on a shaft using the ball bearings that rotated to track the movement of the sun throughout the day. A DC geared motor was attached to the one side of the shat that was used to rotate the panel assembly, which increased the efficiency of the solar panels. The movement and the speed of the motor was controlled using the same motor driver. The input from the LDR sensors would go to the Arduino and it will send the signals to the motor driver to actuate the motor accordingly. The entire mechanism was controlled using an Arduino UNO, which allowed for precise and accurate tracking of the sun's movement.

Fig. 3. Inclination of panel assembly to demonstrate sun tracking

2.5 Power Supply

The power supply for the system was a 12V 7A battery. This battery was selected for its ability to provide sufficient power to the system while being compact and portable. The battery was connected to the motor driver and the Arduino UNO, which controlled the sliding and sun tracking mechanism. The battery was mounted at the base of the trolley.

2.6 Testing and Analysis

Once the system was designed and fabricated, it was tested and analyzed under the different timings of the day to evaluate its performance. To check if the system is working, we connected the DC pump which was directly connected to the supply from the solar panels. The solar panels were tested for their efficiency, and the data was collected and analyzed to determine how well the system was performing. The testing and analysis were critical in identifying any potential issues with the system and making necessary modifications to ensure that the system would function correctly.

The portable solar power unit that uses a rack and pinion mechanism to fold and unfold, along with a single-axis sun tracking mechanism, is a valuable asset for outdoor activities or in areas without electricity. The system was carefully designed and developed to ensure that it was efficient and functional, and the incorporation of a channel slider with bearings, an LDR sensor, and a DC geared motor ensured that the system was smooth and efficient. The system was controlled using an Arduino UNO and was powered by a 12V 7A battery, making it portable and easy to transport. The testing and analysis of the system demonstrated its stability and efficiency, making it an excellent solution for outdoor activities or in areas without electricity.

III. WORKING AND COMPONENTS

3.1 Working

The system works by using 12V 7amp battery, Arduino UNO, L298N Motor driver, DC motors and Servo Motor. System works with the help of switches as well as sensors including IR sensor, LDR sensor.

1. The mechanism for the automatic folding and unfolding of solar panels operates in the following manner:

To power the system, a 12V 7A lithium-ion battery is utilized. The battery is connected to the Arduino Uno using wires, providing the necessary power to the board. The L298N motor driver and Uno Arduino board work collaboratively to govern the speed and direction of the motor through the use of PWM and direction signals. Precise control of the motor is achieved by the PWM signal generated by the Uno board, which acts as a control signal for the L298N motor driver. The driver regulates the voltage applied to the motor based on the PWM signal, thereby regulating its speed. The direction in which the motor rotates is determined by the direction signal, also generated by the Uno board, and received by the L298N motor driver. The driver uses this signal to control the flow of current to the motor, which can be reversed to alter the motor's direction of rotation. This capability is beneficial for numerous applications.

The L298N motor driver features a set of input pins for each motor, denoted as IN1, IN2, IN3, and IN4. The IN1 and IN2 pins manage the motor's rotation direction, while the IN3 and IN4 pins control its speed. To set the motor in motion, the IN1 and IN2 pins should be set to HIGH and LOW, respectively, for one direction, and LOW and HIGH, respectively, for the opposite direction. Meanwhile, the speed of the motor can be regulated by the IN3 and IN4 pins, which utilize a Pulse Width Modulation (PWM) signal to adjust the amount of power transmitted to the motor. Altering the duty cycle of the PWM signal enables the adjustment of the motor's speed.

Automating the process of folding and unfolding solar panels can be achieved through the use of a rack and pinion mechanism with a 12V 60 rpm motor. The pinion gear of the rack and pinion mechanism is connected to the motor, such that rotation of the motor causes the pinion gear to turn. The rack, which is a toothed bar, meshes with the pinion gear and moves in a linear direction as the pinion gear turns. By attaching the rack to the solar panels, the movement of the rack causes the panels to fold or unfold. To control the direction and speed of the motor and the rack movement, an Arduino board and L298N motor driver are utilized. The motor is connected to the motor driver, which is in turn connected to the Arduino. The Arduino sends signals to the motor driver to regulate the motor speed and direction, which ultimately controls the movement of the rack and solar panels.

2. A solar tracking system using an Arduino UNO, DC geared motor, and LDR sensor works as follows:

The Light Dependent Resistor (LDR) sensor is employed for gauging the luminous intensity falling on the solar panel. The resistance of the LDR varies as the light intensity changes. The analog output of the LDR sensor is linked to an input pin on the Arduino UNO. The voltage level from the LDR sensor is interpreted by the Arduino, utilizing an Analog to Digital Converter (ADC), and transformed into a digital value. Based on the digital value from the LDR sensor, the Arduino governs the movement of the solar panel's DC geared motor. For instance, when the LDR sensor indicates a low intensity of light, the Arduino can command the solar panel to turn towards the direction of the sun. The DC geared motor is connected to the mount of the solar panel and enables rotation on two axes: azimuth (east-west) and elevation (north-south). The motor driver, like the L298N, controls the motor. The Arduino UNO incorporates a program code that computes the solar panel's sun position based on the time of day and location. The code uses the output of the LDR sensor to fine- tune the position of the solar panel, maximizing the sunlight it receives.

3.2 Components

- Arduino UNO
- DC Geared Motor
- DC Wiper Motor
- L298N Motor Driver
- LDR Sensor
- Rack and Pinion
- Ball Bearing
- IR Sensor
- SPST Switch

IV. DESIGN AND CALCULATIONS

4.1 Calculations for sliding mechanism

-Maximum Load required to push and pull the solar plate F = Weight of plate

F = 1.704

= 1.704

= 16.72 N

-Rack and pinion dimension

Length of Rack = 40 cm =400mm

Outer diameter of Pinion = 4 cm = 40mm Weight of Rack and pinion = 125 gm Pitch of rack and pinion = 3 mm

-Torque of motor required for the sliding

= F X R

= 1.704 X 2

= 3.408 kg.cm
-For the above torque C-29650 motor is selected having following specification
Operating voltage = 12 V Torque = 4 kg.cm
Speed = 100 RPM Current = 700 mAh Power = 8.5 watts
-Calculation for sliding time.
Motor RPM = 100
RPS = 100/60 = 1.67 RPS
Number of Revolution required for the opening of array Number of teeth on rack = 400/3
= 134
Number of teeth on Pinion = 40 X 3.14/3 =41 Therefore,
134/41 = 4 revolution are required 4 / motor speed = 4 / 1.67
Approximately = 3 second

Calculations for tracking motor
Weight is uniformly distributed and acted on both side, therefore for self-balancing
Motor is required only to turn the array of the solar plate. So, we used geared DC motor having following specification,
Motor voltage = 12 V Speed = 45 RPM Current = 1.5 A Power = 18 Watts Torque = 45 kg.cm

Calculations for Water pump
Supply from Solar plate = 15 Watts Total = 45 Watts
Pump rating = 12 V Current = 3 Amp Power = 36 Watts Flow = 4.5 LPH

V. OBSERVATIONS AND RESULT

We know that the angle between the sun's rays and the solar panel is crucial for achieving maximum efficiency. We can conduct an observation by changing the angle of the solar panel at the same time with the same load to determine how the output changes in relation to the position of the solar panel.

TABLE I. CHANGE IN CURRENT, VOLTAGE ACCORDING TO CHANGE IN ANGLE OF SUN TRACKING

Angle (Degree)	Current (Amp)	Voltage (V)	Time
30	0.8	15	12:26 PM
60	2	18	12:28 PM
90	2.4	19	12:30 PM
120	2.05	18	12:32 PM

TABLE II. CHANGE IN CURRENT, VOLTAGE ACCORDING TO CHANGE IN ANGLE OF SUN TRACKING

Angle (Degree)	Current (Amp)	Voltage (V)	Time
30	0.8	11	2:55 PM
60	1.4	15	2:57 PM
90	1.9	18	2:58 PM
120	2.2	18.5	3:00 PM

VI. CONCLUSION

The proposed solar power system comprising a sliding solar panel and a single-axis sun tracking mechanism, coupled with a portable solar power unit, offers a sustainable and cost-effective solution for power generation in various settings, including agriculture. The system's design optimizes solar panel power generation potential, increases efficiency, and facilitates easy movement to different locations as per power requirements. The system's portability and flexibility make it an ideal solution for temporary installations or areas with limited space, and the trolley-mounted portable solar power unit provides a stable and secure base for the solar panel and power unit, ensuring optimal performance and durability. The study highlights the potential of the proposed system in promoting sustainable and cost-effective power generation, particularly for low and middle-income farmers who cannot afford high-cost integrated systems.

VII. FUTURE SCOPE

The future scope of the portable solar power unit in agriculture, especially for water pumping, is very promising. The versatility of the system allows it to be easily moved to multiple locations, meeting the needs of farmers and increasing access to sustainable power solutions. The use of the portable solar power unit also offers potential income- generating opportunities for farmers through renting the system to other farmers. In addition to water pumping, the portable solar power unit can serve as a portable power station for charging electric machinery commonly used in rural areas and agriculture, such as mini E-tractors, power tillers, grass cutters, and spray pumps. This multi-functional use of the system can help to reduce energy costs, increase efficiency, and promote sustainable farming practices in rural areas.

In conclusion, the future scope of the portable solar power unit in agriculture is vast, and its potential benefits are numerous. With the increasing demand for sustainable and efficient farming practices, the use of renewable energy in agriculture is more critical than ever. The integration of AI and energy storage systems into the portable solar power unit can help improve efficiency, increase reliability, and promote sustainable farming practices.

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