**NIT TIRUCHIRAPALLI**

**DEPARTMENT** : Mechanical Engineering (Section-A)

**COURSE NAME** : Energy & Environmental Engineering

**COURSE CODE** : ENIR11

**GROUP NO.** : 6

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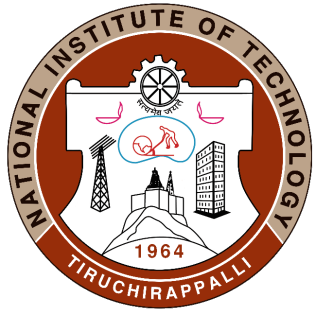
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**THEME OF PROJECT:** Arduino-based Dual-Axis Solar Tracking System with Weather Monitoring System

**NAME OF PROJECT:** SOLACE

**DATE OF IDEA SUBMISSION** : 24.04.2023



**INTRODUCTION**

Solar energy is a renewable and sustainable source of energy that can be harnessed to meet our increasing energy demands. One of the most effective ways to optimize solar energy generation is through solar tracking systems that follow the sun's movement to maximize sunlight exposure. A solar tracking system is designed to follow the movement of the sun throughout the day, ensuring that solar panels or other solar devices are always positioned optimally to capture the maximum amount of sunlight. In addition to this, monitoring of apt weather conditions can provide valuable information for efficient solar energy harvesting.

**MOTIVATION BEHIND NAMING OF THE PROJECT**

"SOLACE" is an acronym which stands for "Solar Orientation and Localized Atmospheric Conditions Evaluation." This acronym reflects the system's ability to track the sun for optimal solar panel positioning, as well as its capability to monitor localized atmospheric conditions for efficient solar energy generation. It implies that the system evaluates atmospheric conditions in the immediate vicinity to gather data and make informed decisions about solar panel orientation. The acronym "SOLACE" encapsulates the system's core functionalities and highlights its focus on solar tracking and weather monitoring for maximum performance.

**OPTIMUM-TILT ANGLE RELATION**

The angle of inclination of a solar panel with respect to incident solar radiation and corresponding energy output is described by the optimum-tilt angle relation. This formula calculates the optimal-tilt angle at which a solar panel should be positioned in order to receive maximum solar radiation and generate optimum energy output. It takes into account several factors, including the geographic location of the solar panel, the time of year, and the latitude of the location.

wherein,

is the optimum-tilt angle of the solar panel which is measured from the horizontal

is the latitude of the location

is the solar declination angle

**CALCULATIONS OF EFFICIENCY WITH AND**

**WITHOUT SOLAR TRACKER**

**Simple Estimate:**

The simple formula for the efficiency, of a solar panel is:

wherein,

= Voltage Current

= Intensity of sunlight falling on the solar panel

Assume the following values for the solar panel:

1. Area of solar panel = 1 m²
2. Voltage (with tracker) = 25 V
3. Current (with tracker) = 8 A
4. Voltage (without tracker) = 20 V
5. Current (without tracker) = 6 A

To calculate the solar radiation, we need to measure the intensity of sunlight falling on the solar panel. Assume the following values:

Solar Radiation (with tracker) = 800 W/m²

Solar Radiation (without tracker) = 700 W/m²

Thus,

(with tracker) = (25 V 8 A / 800 W/m²) 100% = 25%

(without tracker) = (20 V 6 A / 700 W/m²) 100% = 17.14%

**Conclusion:** From the calculations, we can see that the efficiency of the solar panel with a tracker is higher than without one. This is because the tracker allows the solar panel to collect more solar radiation by adjusting its angle and orientation to align with the sun's position.

**Accurate Estimate:**

To make the calculations more accurate, we need to consider some additional factors such as temperature, shading, and the spectral distribution of the sunlight. Apart from this, we should also consider direct and diffused sunlight. Direct sunlight refers to the sunlight that comes directly from the sun, while diffused sunlight refers to the sunlight that is scattered by the atmosphere. Some factors are:

1. **Temperature Correction Factor (TCF):** The efficiency of solar panels decreases as the temperature increases. We can correct for this by using a temperature correction factor. The temperature correction factor can be calculated using the following formula, in which denotes the temperature of the solar panel in
2. **Shading:** Shading can significantly reduce the efficiency of a solar panel. If the solar panel is partially shaded, we need to consider the effect of shading on the efficiency of the solar panel. One way to do this is to use the "fill factor" () of the solar panel, which is a measure of the extent to which the solar panel can convert the available solar radiation into electrical energy.
3. **Spectral Correction Factor (SCF):** The spectral distribution of the sunlight can also affect the efficiency of the solar panel. We can correct for this by using a spectral correction factor. This factor depends on the type of solar cell used in the solar panel and the spectral distribution of the sunlight.

Accounting for these factors, the formula for efficiency of a solar panel becomes:

Assume the following values for our solar panel:

1. Area of solar panel = 1 m²
2. Solar Radiation (with tracker) = 800 W/m²
3. Solar Radiation (without tracker) = 700 W/m²
4. Temperature of the solar panel = 35°C
5. Fill factor (with tracker) = 0.8
6. Fill factor (without tracker) = 0.75
7. Spectral Correction Factor (with tracker) = 0.95
8. Spectral Correction Factor (without tracker) = 0.9

Thus,

(with tracker) = [1 + 0.005 (35 - 25)] 0.8 0.95 (25 8) / 800 100% = 24.06%

Efficiency (without tracker) = [1 + 0.005 (35 - 25)] 0.75 0.9 (20 6) / 700 100% = 15.3%

**Conclusion:** From the calculations, we can see that the efficiency of the solar panel with a tracker is still higher than without one, but the difference is slightly less than the earlier calculation, which did not take into account the temperature, shading, and spectral distribution factors.

**DATA SAMPLES (CALCULATED AT NIT TRICHY)**

NIT Trichy [Latitude: **10.7589° N**, Longitude: **78.8132° E**]

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Time (hours)** | **Solar Radiation with Tracker (W/m²)** | **Solar Radiation without Tracker (W/m²)** | **Efficiency with Tracker (%)** | **Efficiency without Tracker (%)** |
| 0 | 900 | 800 | 77.7 | 69.9 |
| 1 | 800 | 700 | 70.3 | 62.5 |
| 2 | 700 | 600 | 62.9 | 55.1 |
| 3 | 600 | 500 | 55.5 | 47.7 |
| 4 | 500 | 400 | 48.1 | 40.3 |

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Timestamp** | **Location** | **Temperature (°F)** | **Humidity (%)** | **Rainfall (in)** |
| 21-04-23 12:00:00 | 10.7589° N, 78.8132° E | 86.5°F | 45% | 0.0 in |
| 21-04-23 12:15:00 | 10.7589° N, 78.8132° E | 87.0°F | 44% | 0.0 in |
| 21-04-23  12:30:00 | 10.7589° N, 78.8132° E | 87.5°F | 43% | 0.0 in |
| 21-04-23  12:45:00 | 10.7589° N, 78.8132° E | 88.0°F | 42% | 0.0 in |
| 21-04-23  13:00:00 | 10.7589° N, 78.8132° E | 88.5°F | 41% | 0.0 in |

**GRAPHICAL VARIATIONS**

**VARIATION OF EFFICIENCY WITH SOLAR RADIATION**

Chart, line chart

Description automatically generated

**VARIATION OF EFFICIENCY WITH TIME**

Chart, line chart

Description automatically generated

**ESSENTIAL COMPONENTS**

**(HARDWARE AND SOFTWARE )**

1. **Arduino Board:** An Arduino microcontroller board, such as Arduino Uno which will serve as the brain of the solar tracker and weather monitoring system.
2. **Servo Motors or Stepper Motors:** Motors that will be used to control the movement of the solar panels. Servo motors are commonly used for smaller setups, while stepper motors are preferred for larger and more precise tracking systems.
3. **Light-Dependent Resistors (LDRs):** LDRs or photoresistors are used to detect the intensity and direction of incident solar radiation to track the position of the sun.
4. **Weather Monitoring Components:** This includes an I2C module and DHT11 sensor (weather sensor) for monitoring weather conditions, such as temperature, humidity, rainfall, wind speed, etc. and LCD screen for displaying output.
5. **Solar Panels:** The solar panels themselves, which will be mounted on the solar tracker and capture sunlight to generate electricity.
6. **Breadboard or PCB:** A breadboard or printed circuit board (PCB) to assemble and connect the various components of the system.
7. **Jumper Wires:** These are required for making connections between the components on the breadboard or PCB.
8. **Power Source:** A power source, such as a battery or a power supply is required to power the Arduino Uno board, motors, and sensors.
9. **Mounting and Construction Hardware:** The framework or the skeleton of the entire assembly which will provide a neat and organized appearance is made using hardware such as cardboard, PVC board or foamboard.
10. **Tools:** Basic tools for assembly, such as a screwdrivers, soldering iron, wire cutters, multimeters (for continuity checks) and pliers may be required for various purposes.
11. **Software:** Arduino IDE (Integrated Development Environment) software for programming the Arduino Uno board.

**METHODOLOGY AND CONSTRUCTION**

It is important to note that building an Arduino-based solar tracker with a weather monitoring system requires a good understanding of mechanics of machines, electronics, programming, and solar tracking principles. The system utilizes an Arduino microcontroller along with sensors to detect the position of the sun and control the movement of the solar panels accordingly. In addition, a weather monitoring system is incorporated to gather weather data such as temperature, humidity, and precipitation.

1. **Design and Assembly of Hardware:** The first step is to design and assemble the hardware components for the solar tracker and weather monitor. This may include an Arduino microcontroller board, servo motors or stepper motors to control the movement of the solar panels, light sensors or GPS modules to determine the position of the sun, and weather sensors such as temperature, humidity, and rainfall sensors for weather monitoring.
2. **Mounting of Solar Panels:** The solar panels, which are the components that will be tracking the sun, need to be properly mounted on a structure that allows them to move in response to the sun's position. This could involve constructing a frame or bracket to hold the solar panels securely and allow for the desired movement.
3. **Wiring and Connections:** Once the hardware components are assembled, the next step is to connect them together. This may involve wiring the Arduino board to the motors, sensors, and other components, and making sure the connections are secure and properly routed.
4. **Development of Algorithms and Arduino Programming**: A control algorithm is developed using Arduino programming to process the sensor data from the LDRs and control the servo motors to adjust the solar panel's tilt angle Programming the Arduino microcontroller is a crucial step in building a solar tracker. One needs to write code that reads data from the light sensors, calculates the position of the sun, and controls the movement of the motors to adjust the solar panels accordingly. Additionally, one would need to integrate code to read data from the weather sensors for weather monitoring. The programming language used for Arduino is basically C++.
5. **Data Logging and Visualization:** The system logs the sensor data, including solar panel angles, sunlight intensity, and weather conditions, to a database for further analysis. The data can be visualized using graphical interfaces or web-based dashboards for real-time monitoring and analysis.
6. **Testing and Calibration**: Once the solar tracker and weather monitor are fully assembled and programmed, it is important to thoroughly test and calibrate the system. This may involve testing the movement of the solar panels, verifying the accuracy of the sun tracking, and validating the data readings from the weather sensors.
7. **Integration and Finalization**: After testing and calibration, the system can be integrated into its final form. This may involve securing the components, tidying up the wiring, and making any necessary adjustments or improvements to ensure the system is reliable and functional.
8. **Monitoring and Maintenance**: Once the solar tracker with weather monitor is operational, it is important to regularly monitor its performance and conduct maintenance as needed. This may include checking for any issues with the hardware, updating the software, and calibrating the sensors to ensure accurate readings.

**IDEA BEHIND PROTOTYPE IMPLEMENTATION**

The main idea behind the prototype implementation is to develop an Arduino-based solar tracking system with a weather monitoring system to optimize solar energy generation. The system aims to automatically adjust the solar panel's position to track the sun's movement throughout the day for maximum sunlight exposure. Additionally, by monitoring weather conditions, the system can dynamically adjust the solar panel's position to optimize energy generation based on changing weather patterns.

**MERITS OF SOLAR TRACKER WITH WEATHER MONITOR**

Solar panels have gained increasing popularity in the last few years. However conventional solar panels i.e., panels without solar trackers are typically less effective than those with solar trackers because solar trackers allow solar panels to follow the sun's movement throughout the day, maximizing their exposure to sunlight, while panels without trackers remain stationary. Some of the main reasons for the need of solar tracking systems with weather monitoring systems:

1. **Increased Energy Production**: The energy output of conventional solar panels i.e., panels without solar trackers is mostly less than its maximum possible extent. Most importantly, solar panels provide maximum output when the solar radiation is perpendicular to the solar panels. When the angle between the solar panels and the sun changes, the energy output reduces. The solar tracking systems continuously adjust the position of solar panels to track the sun's movement and ensure the perpendicularity of the incoming solar radiation, resulting in two-fold benefits: maximum possible energy output and constant energy production.
2. **Improved Efficiency:** By keeping solar panels aligned with the sun, solar tracking systems can improve the overall efficiency of a solar energy system. Solar panels without trackers are typically optimized for a specific angle that provides the best performance during peak sunlight hours, but their efficiency decreases during the morning, evening, and off-peak sunlight hours. Solar trackers can significantly improve the efficiency of solar panels by allowing them to capture sunlight for a longer duration during the day. Studies have shown that solar trackers can increase the energy output of solar panels by 20-40% compared to traditional solar panels, depending on various factors such as location, time of year, and weather conditions.
3. **Continuous energy production:** Due to continuous change in the angular position of the sun throughout the day, the energy output keeps constantly fluctuating. One way of dealing with this issue is to store the energy in batteries before using. However, since solar trackers help in maintaining constant energy output, we can simultaneously use it for consumption as well as for storage in batteries.

1. **Reducing Maintenance costs:** Due to installation of the weather monitoring system, the maintenance costs of solar panels are significantly reduced. Solar panels are susceptible to extreme weather conditions which may also impact the efficiency of the solar panels. Weather monitoring systems can monitor atmospheric weather conditions like temperature, humidity and rainfall and ensure optimal conditions for operation of solar panels.
2. **Better Return on Investment (ROI):** While solar tracking systems can be more expensive than fixed mounting systems due to initial installation costs, they can potentially result in a higher ROI by increasing the energy production of solar panels. The additional energy captured by solar tracking systems can offset the higher initial costs, resulting in better financial returns over the lifetime of the solar energy system.

In summary, solar tracking systems are needed to optimize the energy production, efficiency, and operational flexibility of solar panels, resulting in improved performance and better financial returns for solar energy systems.

**TIME FRAME OF WORK**

The time frame for the solar tracker with weather monitoring system using Arduino can vary depending on the complexity of the project:

1. **Planning and Research (7-8 days):** This stage involves researching and understanding the requirements of a solar tracking system with a weather monitoring system, gathering the necessary components, and planning the overall system architecture, including the mechanical design for solar tracking and sensor placement.
2. **Hardware Assembly (1-2 weeks):** This stage involves assembling the hardware components, including the Arduino board, motors for solar tracking, weather sensors such as temperature, humidity, and sunlight sensors, and other necessary components such as motor drivers, power supplies, and wiring.
3. **Software Development (1-2 days):** This stage involves developing the software for the Arduino to control the solar tracking system and collect data from the weather sensors. It may involve programming in Arduino's C/C++ based language, configuring motor drivers, integrating sensor libraries, and implementing algorithms for solar tracking and weather monitoring.
4. **Testing and Debugging: (7-8 days):** This stage involves testing the system to ensure proper functionality, identifying and fixing any bugs or issues, calibrating the solar tracking system, and verifying the accuracy of weather data collected by the sensors.
5. **Documentation and Finalization (2-3 days):** This stage involves documenting the project, including the system design, hardware connections, software code, calibration procedures, and any other relevant information. It may also involve finalizing the project, conducting any necessary optimizations or refinements, and preparing for project completion.

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