Sun Tracking Solar Panel Array For Arctic Applications

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1. Introduction

1.1 Objective

The use of renewable energy has steadily increased over the past years as the world moves to decrease carbon emissions. The United States currently has 17.5% of its energy usage sourced by renewable sources 1.8% of the total energy consumption being solar energy [1]. For the United States to lessen its carbon emissions, the usage of renewable sources like solar needs to become more commonplace. Adding more solar energy to the grid has its complications. One such challenge is the fluctuation and accessibility of solar energy. The sun is only out for a portion of the day, but, in many cases, is obscured by clouds. These limitations make solar more accessible to locations like the Southwestern United States. For the United States to lower its carbon emissions, solar energy needs to be more accessible to places such as Alaska. Currently, Alaska gets a small fraction of its energy from solar. Most solar energy in the state is off the grid and primarily used in remote villages for heating [2]. In regions such as Alaska, where year-round sunlight is not as readily available solar panels need to extract as much energy from the sun as possible.

Our goal is to create a solar panel array that can help make solar energy more accessible to places like Alaska. We intend to do this by making a solar panel array that will autonomously track the sun throughout the day using a microcontroller, ensuring that even in the cold climate of Alaska, the system will still function by heating the components that could freeze in that climate.

1.2 Background

Solar panels that track the sun are in use in many industrial applications today; sun-tracking arrays can provide a 25-35% increase in overall efficiency [3]. Tracking solar panel systems are not as in use in residential applications, making residential systems less efficient. Tracking Systems are generally larger and heavier than a fixed panel system. Our goal here is to make it light enough that it can mount on rooftops.

1.3 High-Level Requirements

- The system must be able to withstand “Arctic” temperatures as low as -35∘C.
- The system must have power running through it. Either from the battery source or the solar panels.
- The system must be at least 15% more efficient than a fixed solar panel array in terms of energy production.

2. Design

The arctic solar panel array has four essential sections of operation: the power unit, control unit, movement unit, and temperature control unit. The power unit ensures a constant supply of power to the other components: 5V to the microcontroller or 12V to the tilt and pivot motor. The control unit houses the microcontroller and calculates the sun’s position and tells which relay should be on or off. The movement module will position the solar panel array based on the inputs from the control module. The temperature unit will maintain an optimal temperature to keep the overall system running smoothly.

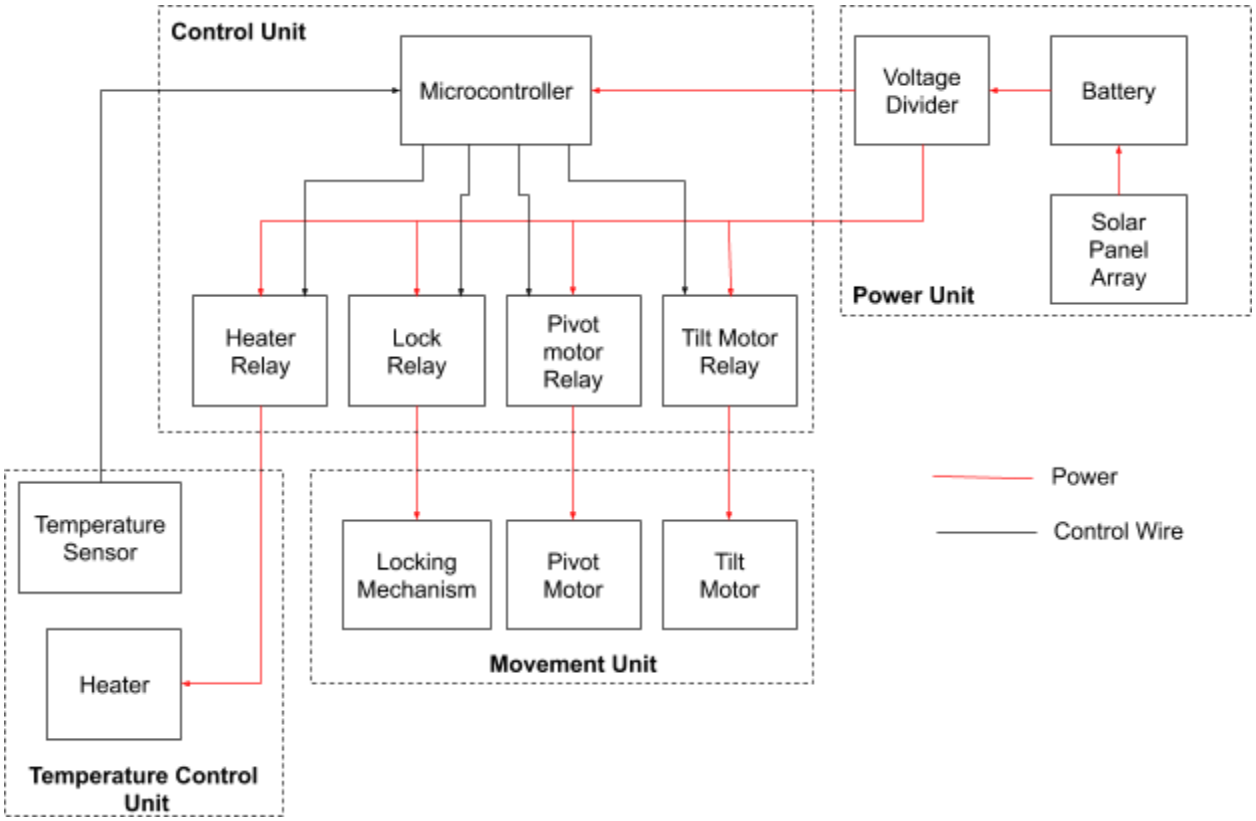

Figure 1. Block Diagram

2.1 Power Unit

The power unit is required to get energy from the solar panel array and supply power to the rest of the system.

2.1.1 Battery

The battery powers the motors, heater, and microcontroller. While the Solar Panel charges the battery, the battery maintains the power requirements of the rest of the system. It will be used during the night time to keep the heater on for the solar panel.

Requirement: The battery must supply 18V +/-5% to the system at all times.

2.1.2 Voltage Divider

The Voltage Divider will allow us to create the required voltages for our circuit to operate the microcontroller (5V), the motors (12V), and the locking mechanism. The heating coil will require a different voltage as well as adjusted based on temperature.
Requirement: Must supply 5V to the microcontroller and 12V to the motors.

2.1.3 Solar Panel Array

The array in mind will be four panels that will charge the battery with enough power so that it can power the rest of its components with excess energy going to the grid.
Requirement: At the sun's highest point, the solar panel array must provide at least 9V and 150mA.

2.2 Control Unit

The control unit houses the microcontroller as well as the relays used to control each component. The control unit receives the outside temperature as an input from the temperature sensor. The control unit outputs the correct motor positions to the movement unit as well as power to the movement unit.

2.2.1 Microcontroller

The microcontroller will calculate the position of the sun and output the signals needed to move the solar panel array to the correct degree. These control signals include the enable/disable that goes to each relay and the positioning information to the motors.

Requirement 1: The microcontroller must accurately calculate the sun’s position in the sky.

Requirement 2: The Controller must output the correct enable/disable signals when the array needs to reach a new position.
Requirement 3: When the outside temperature falls below 0°C, the controller must turn the heater on.

2.2.2 Heater Relay
The heater relay will receive an enable/disable signal from the microcontroller. When enabled, the heater will send power to the heater.

2.2.3 Lock Relay
The lock relay receives an enable/disable signal from the microcontroller. When enabled, the lock relay will send power to the locking mechanism, disengaging the lock allowing for the array to move.

2.2.4 Pivot Motor Relay
The pivot motor relay controls the power input to the pivot motor. The pivot motor relay will receive an enable/disable signal from the microcontroller. When enabled, the relay will send power to the pivot motor so the array can move.

2.2.5 Tilt Motor Relay
The tilt motor relay controls the power input to the tilt motor. The microcontroller sends an enable/disable signal to the relay. When enabled, the relay will send power to the tilt motor allowing the array to move to the correct position.

2.3 Movement Unit
The movement unit contains the motors needed to move the array to the correct position. This position is given to the movement unit by the microcontroller. Once in the proper position, the locking mechanism engages, and the unit shuts down while it waits for another signal.

2.3.1 Locking Mechanism
Once the Motors have achieved an optimal placement, it is beneficial to have a locking unit to be able to turn the motors off with their respective relays rather than having them maintain their position in place and using more energy.
R*equirement: The Locking mechanism should lock within two seconds of the motors moving.*

2.3.2 Pivot Motor

This motor will control the pivot of the actual array to maintain the optimal angle between itself and the sun during the day.
Requirement 1: The motor will move the array to within +/-5% of the position given to it by the microcontroller
Requirement 2: The pivot motor must be able to move to all possible positions to track the sun

2.3.3 Tilt Motor
This motor will control the tilt of the actual array to ensure the optimal angle between itself and the sun during the day.
Requirement: The tilt motor will move to be within +/-5% of the tilt angle given by the microcontroller.

2.4 Temperature Control Unit
The temperature control unit monitors the outside air temperature and will keep the system at the necessary temperature to operate in the arctic climate.

2.4.1 Temperature Sensor
The temperature sensor reads the outside air temperature and sends it to the microcontroller.
Requirement: There is a continuous feedback loop between the temperature sensor and the microcontroller that looks for a change in temperature and adjusts the heater accordingly

2.4.2 Heater
When the outside air temperature is below 0°C the heater will turn on, allowing it to keep the system warm so it can operate in the sub-zero temperatures.
Requirement: When the outside air temperature is below 0°C, the heater must keep essential components at or above 0°C.

2.5 Risk Analysis
The component that appears to pose the greatest threat to the successful completion of this project would have to be the tilt/pivot motor array. While we are supplementing our design with a heater to prevent freezing, we need to balance the cost-durability ratio. This is to ensure that, while we do not go over the budget, we have motors powerful enough to prevent ice from forming inside the component, and in the case that ice forms, the force is strong enough to break free of it. Finding a motor that can do so is a troublesome task that we need to ensure is compatible with the rest of the design.

3. Safety and Ethics

While there are not many safety and ethical hazards that come along with our project, there are certainly some notable ones. Firstly, our design utilizes 9V lithium-ion batteries, which are usually safe but can result in potentially dangerous behavior. A larger issue is battery failure or even an explosion as our design is for use in significantly colder temperatures. To avoid this possibility, we have a heater that regulates the temperature of the entire product.

A similar issue regarding the rechargeable battery is the potential for overcharge, resulting in an exothermic reaction. For this reason, we ensure that the battery does not charge beyond 8.5 V, to allow for a comfortable buffer in an emergency.

While our design is relatively small, we are going to attempt to make it as sturdy as possible by maintaining the majority of the weight at the bottom of the product. In practice, however, our design is going to be used in a much colder environment with high-speed winds, which may result in the structure falling over and injuring people and potentially animals. To remedy this, we are going to have the assembly embedded in the ground, anchoring itself deep to prevent falling over while also using some of that underground heat to regulate temperatures.

While we are investing all resources to avoid accidents, the IEEE code of ethics category that best applies to our design would be II.9: “to avoid injuring others, their property, reputation, or employment by false or malicious actions, rumors or any other verbal or physical abuses” [4], which is ensuring that our design prevents infliction of any form of harm on any other individual through a lack of structural integrity, which we believe that our prevention practices align with I: “To uphold the highest standards of integrity, responsible behavior, and ethical conduct in professional activities” [4]. There are, without a doubt, risks undertaken in the process of designing such technology, but with the benefits far outweighing the risks, we find it to be worthwhile.

References

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