JETIR.ORG ISSN: 2349-5162 | ESTD Year : 2014 | Monthly Issue
JOURNAL OF EMERGING TECHNOLOGIES AND INNOVATIVE RESEARCH (JETIR)
An International Scholarly Open Access, Peer-reviewed, Refereed Journal

IoT ENABLED SNOW MELTING SYSTEM FROM THE ROOFTOP

[1] Piyush Kumar, [2] Narayan Singh, [3] Rishav Kumar, [4] Shobhit Oraon
[5] Soumyadip Karmakar, [6] Mandeep Singh Saini
[1, 2,3,4,5] Student, [6] Professor
[1, 2, 3, 4, 5] School of Electronics & Electrical Engineering
[1, 2, 3, 4, 5, 6] Lovely Professional University, Phagwara, Punjab, India

1. Abstract: This study presents a fully autonomous roof snow removal device based on temperature sensing technology and water level sensing technology, based on a review of the existing state of roof snow removal technology. A novel type of intelligent snow removal system based on the idea of heating effect of current and temperature control is presented to avoid damage to membrane structure caused by snow load. This device is made up of electrical and electronic components. The efficient removal of snow from the roof is achieved through the collaboration of numerous systems. Snow on the roof can have a negative influence on resident's lives, thus automatic removal can help the development of the economy.

2. Introduction

Snowfall in the winter season comes with lots of fun moments but can as well present unpleasant moments. In many countries, winter is always accompanied by heavy snowfall. In snowy regions snowfall is a matter of great concern as it can block the roads, pipelines and damage the roof of a house. Roofs are construction elements that form the upper part of a building and protect it from all kinds of fall, wind, solar lights. Due to excess snow being accumulated on the rooftops, there are high chances that the housing infrastructure may collapse which will lead to property losses and could pose significant life risks to the residents in those areas. Areas prone to snowfall face death cases every year and people suffer heavy damages and have to pay the charge for it every year. Sometimes snowstorms are a big issue as they bring about strong winds in the cold weather. These winds could blow up houses and cause power lines to collapse causing people to go without power and warmth. Due to all these problems associated with snow accumulations during the winter season, the removal of snow is not only convenient but can as well enhance safety and prevent property damage.

The snow removal methods that we have been using by now are slow and gruelling and cannot be completely cleaned up. Mechanical method involves removal of snow accumulation through shovels. Shovelling requires a considerable amount of physical effort and can cause strain in body parts. In India, people are relying on traditional methods like shovelling, snow blowing and mechanical cleansing of snow as most of the snow removal devices are large and are limited to certain areas. The use of a snow-blower is sometimes very harmful because it could potentially damage your bitumen roof surface. Another way of removing snow from roofs is by a simple phenomenon that is the melting of snow. Snow on the roofs can be melted by obviously heat but different kinds of heat resources. The easiest way of getting heat is through a natural resource that is the sun. Solar heat is used to melt the snow but in the regions where there is heavy snowfall, you hardly feel any heat. So it was required to come up with an idea to provide heat to the roof internally. A heating cable is used to provide heat to the roof. A system consisting of thermocouple, Arduino, relay, amplifier, solar panel, battery and heating element is used.

Innovative snow removal technology is a need of the hour. Therefore it has become a necessity for us to come up with such an idea consisting of a model which is light-weighted, simple, automatic, environment-friendly and highly efficient. [1]

3. Literature survey

Although many types of research have been done in context with the removal of snow as Zhiyang Zhang et al in his experiment proposed the idea of removing snow by the mechanical means, he and his team use mechanical mode in the form of a slider which is completely automatic to remove snow but the analysis shows that such device leads to a mechanical blockage because of continuous contact with environment and removal of corrosion requires regular lubrication. [2]

Another research proposed by B.S Wang et al 2021 provides an idea of removal of snow by sprinklers through snow removal agents in the form of liquid, But the process here is so complex as firstly they are identifying snow by temperature and pressure and after that mixing of snow removal agents in tap water to remove the snow makes chances of failure more. [3]

In one of the research by Weijie Chen and Yingxin Wu 2021, they provided an idea of removal of snow by a moving slider which has to be operated by a man from the surface of the house which is not automatic in itself as a guider or operator is required to control such device. [4]

Another research by Howard L.Grance and Lewis T. Hendricks in 1977 in their literature title “Roof snow behaviour and ice dam Prevention in Residential Housing” suggested the idea of designing roof of the house in such a way so that sliding of ice is possible without any external agent but such designing is expensive and also is not that much effective. [5]

In one of the surveys by L.V. Zadorina, V.A. Muratova, O.M. Zverev (2019), they have provided the idea of removal of snow by vibrations. They implemented a machine kind of vibrator below the roof base which at last remove snow by vibrations but this is also not that effective as it also weakens the roof of the house. [6]

In one of the research names “Melting of snow on a roof Mathematical report by Nielsen by Anker; Claesson, Johan provides complete details about mathematical expressions of snow accumulation to its solution. Mathematical ideas have been taken from this. [7]

4. PROPOSED METHODOLOGY

4.1 Design Ideas

The whole system consists of electrical and electronics design of a fully automatic snow removal device which includes temperature sensing technology and water level sensing technology based on literature and actual research. The electronic structure consists of a thermocouple, a water level sensor, a thermocouple-to-digital converter, Arduino UNO, connecting wires and an LCD to display the temperature output. Whereas the electrical components included in this project design are relay, heating element, a solar charge controller, battery, and a solar panel. The roof snow removal device is a combination of electrical and electronic devices that desegregate system structure and flow control technology. This system first uses electronics principles, electrical fabrication and other disciplines to design the structure, and uses properties of sensors and components to optimise the model. The thermocouple sensor is used to sense the temperature variation in the environment during snowfall. Correspondingly the water level sensor is used to perceive snow. When the thermocouple sensor detects some unanticipated fall in temperature to a threshold value, it triggers the system. In addition, the system is set off when the water level sensor observes an increase in snow accumulation on the rooftop, it initiates the Arduino system. When both the conditions are attained, the system gets underway. Afterwards, inspect and enumerate various parts to certify the comprehensibility and attainability of the device and examine the refining technology to ensure the processing precision and assembly requisite. Furthermore, owing to the design of the control system, electrical consolidation is realised and the automation level of the device is enhanced. Eventually, the system is made and amended.
The particular depiction proposals are as follow:

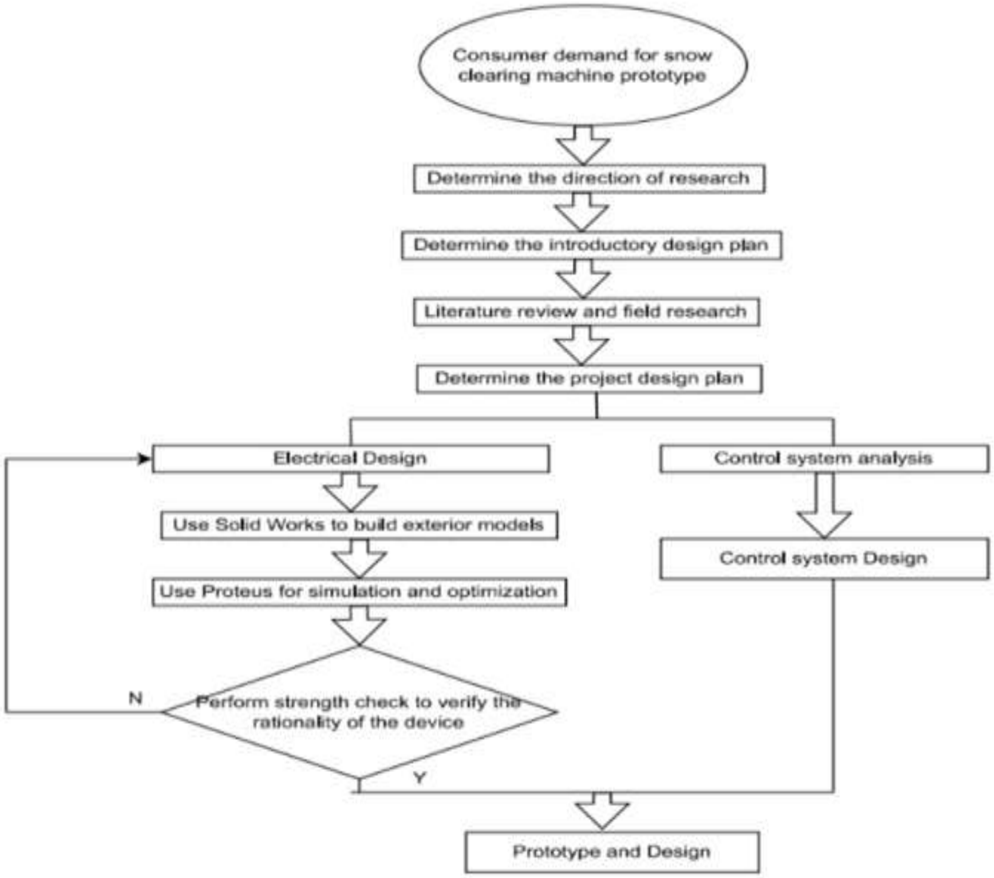

Figure 1.0 Design outline

4.2 Overall Design:

Interfacing a thermocouple with the Arduino platform is done by merging a thermocouple-to-digital sensor. This IC is a Cold-Junction Compensated Analog to Digital Converter amplifier especially designed for use with thermocouple. The converter provides 14-bit of digitalized temperature data with 0.25 °C resolution. The converter module sends serial data to Arduino by SPI protocol. The temperature reading is shown on the 16x2 LED display. In parallel, a water level sensor is interfaced with Arduino to check the snow accumulation on the rooftop. As it reaches a threshold value, the output pin goes high and sends analog signals to Arduino. Arduino is interfaced with a relay which is a programmable electric switch that can be controlled by Arduino. It is used to programmatically control on/off the heating element which uses comparatively high voltage from the DC source.

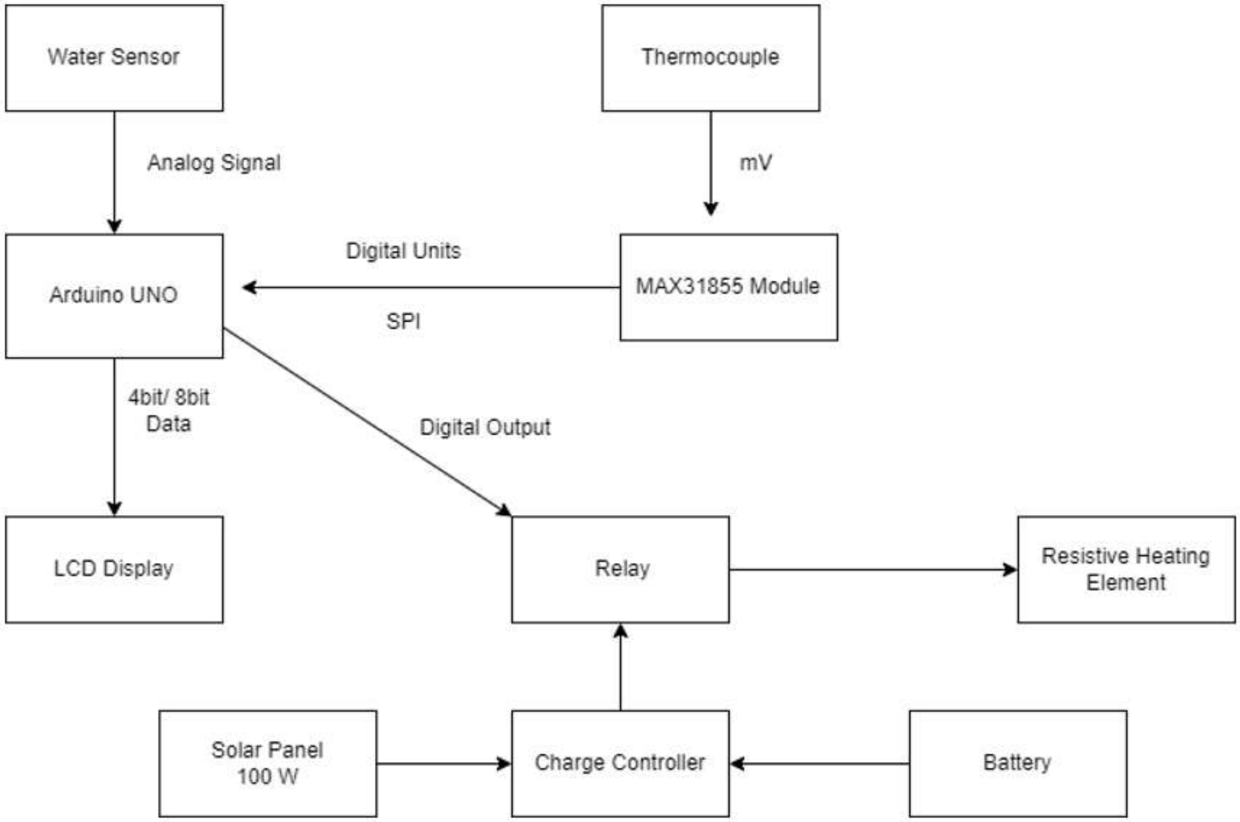

Fig 1.1 Overall design of the system

4.2.1 Device design plan for each module:

A K-type thermocouple (yellow and red conductors per ANSI/ASTM E230) initialises the circuit as it reads temperature by the two dissimilar ends and makes temperature gradient between one end and the other. Once this is achieved, a very low voltage potential is formed and current starts to flow. Because the thermocouple output voltage levels are very low, a thermocouple-to-digital converter is used to optimise the input limits of the analog-to-digital converter (ADC). The K-type thermocouple uses Seebeck effect to turn differences into small voltages which the MAX31855 can read and make available over an SPI connection as shown in Fig 1.2

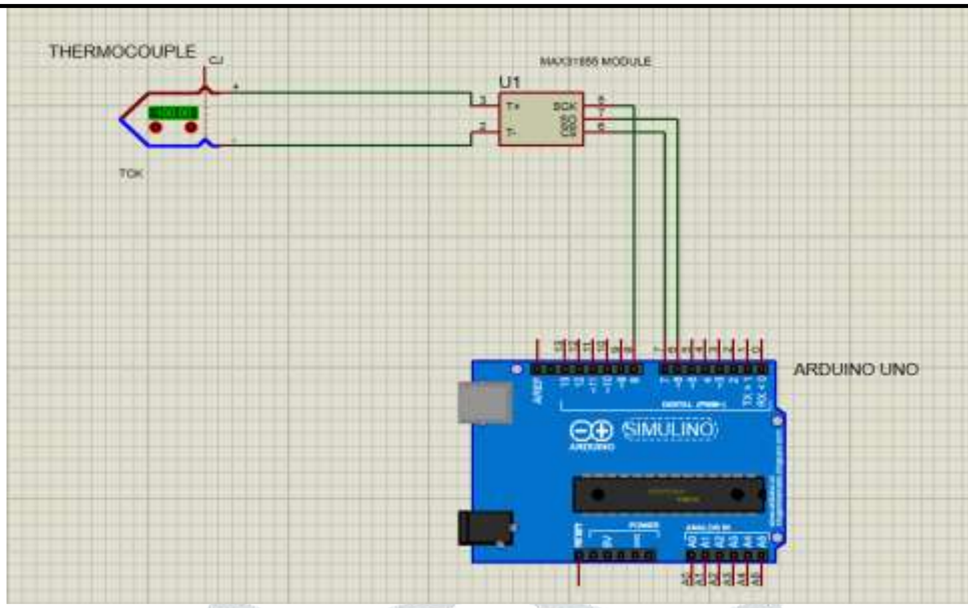

Fig 1.2 Thermocouple sensor interfacing with Arduino

The MAX31855 thermocouple amplifier is a simple 14-bit resolution, SPI- compatible, serial interface thermocouple digitizer. It takes a standard type-K thermocouple in one end, digitises the temperature measured and sends the data out the other end via a SPI interface, thereby interpreting the data and translating it. MAX31855 is used to connect K-type thermocouple to UNO board. The output voltage from MAX31855 is given to the ADC of the UNO board. In the MAX-31855 sensor, 3 data pins are connected to digital IO pins including one ground pin and one 5v input pin.

ADC output of this voltage is processed by a microcontroller to give temperature reading. Voltage is connected from the Arduino 5V pin (input voltage) to a circuit (using a breadboard). Then the circuit is established and the output temperature reading is displayed on LCD. LCDs have a parallel interface, meaning the Arduino Uno manipulates several interface pins at once to control the display. To get the displayed output, the following connections are done as shown in Fig 1.3

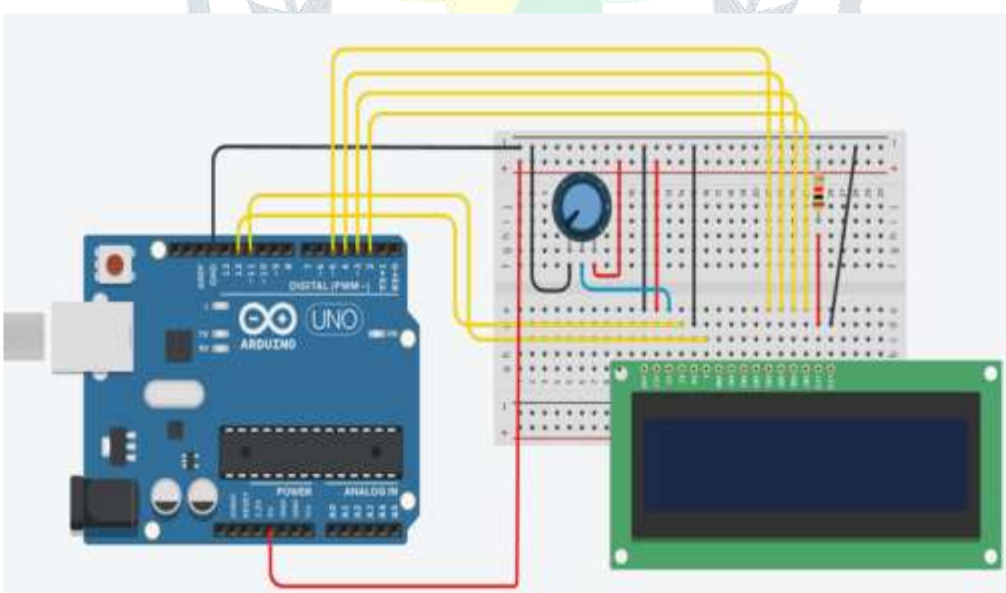

Fig 1.3 LCD interfacing with Arduino

Additionally, a 10k potentiometer is wired to +5V and GND, with its wiper (output) to LCD screens VO pin (pin 3). The temperature detected from the thermocouple sensor is displayed on the LCD screen.

The water level sensor has a series of ten exposed copper traces. There are five power traces and five sensing traces. These traces are interwoven in parallel so that per two power traces there is one sensory trace. The traces act as a variable resistor whose resistance varies according to the water level. The change in resistance corresponds to the distance from the top of the sensor to the surface of snow. The resistance is inversely proportional to the height of snow. The more snow the sensor is immersed in, the better the conductivity is, higher the resistance is. According to the resistance, the sensor generates an output voltage. To power the sensor, VCC and GND pins are connected to Arduino's 5V and GND pins, respectively.

The water sensor will output a high 5V signal as output on its A0 when the snow touches the sensor legs. The threshold also plays a vital role here. As the quantity of snow increases the threshold level, A0 pin goes high.

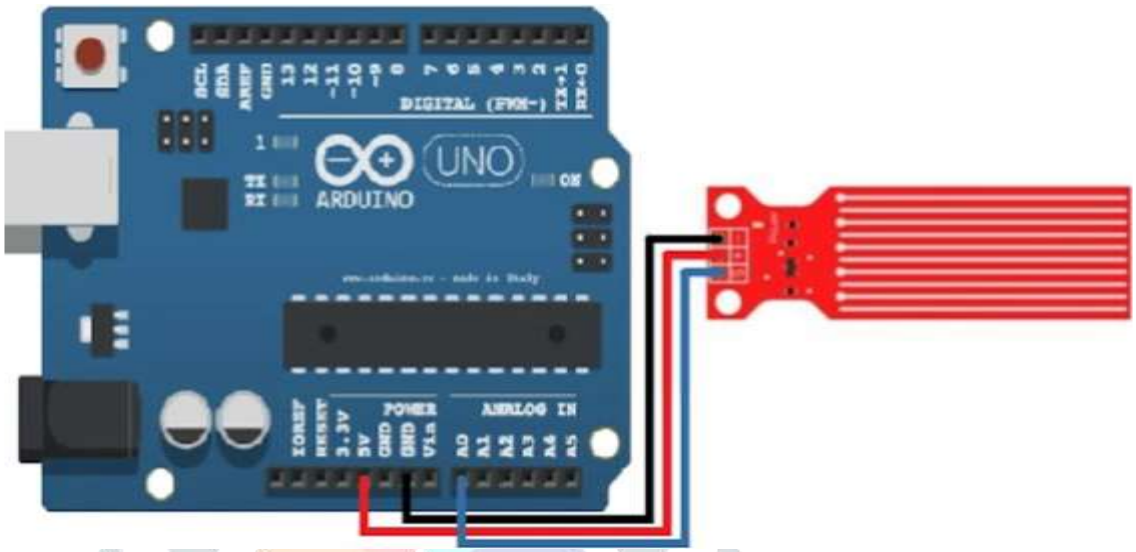

Fig 1.4 Water level sensor interfacing with Arduino

A relay is used to allow relatively low voltage output from Arduino to easily control electric circuits. The relay accomplishes this by using the 5V output from an Arduino pin to energise the electromagnet which in turn closes an internal, physical switch to turn ON and OFF an electric circuit. The switching contacts of a relay are completely isolated from the coil, and hence from the Arduino. The relay HW-307 30V DC/ 10A is used to control the heating element implanted as a load (Fig 1.5). When both the conditions of minimum water level and threshold temperature is achieved, the relay turns ON the heating element. However, if one of the above mentioned conditions is not achieved i.e, either the water level of ice falls below the contact area of the water sensor or the temperature output of K-type thermocouple sensor is above the threshold temperature value, the relay turns OFF the heating element and hence the circuit is cut.

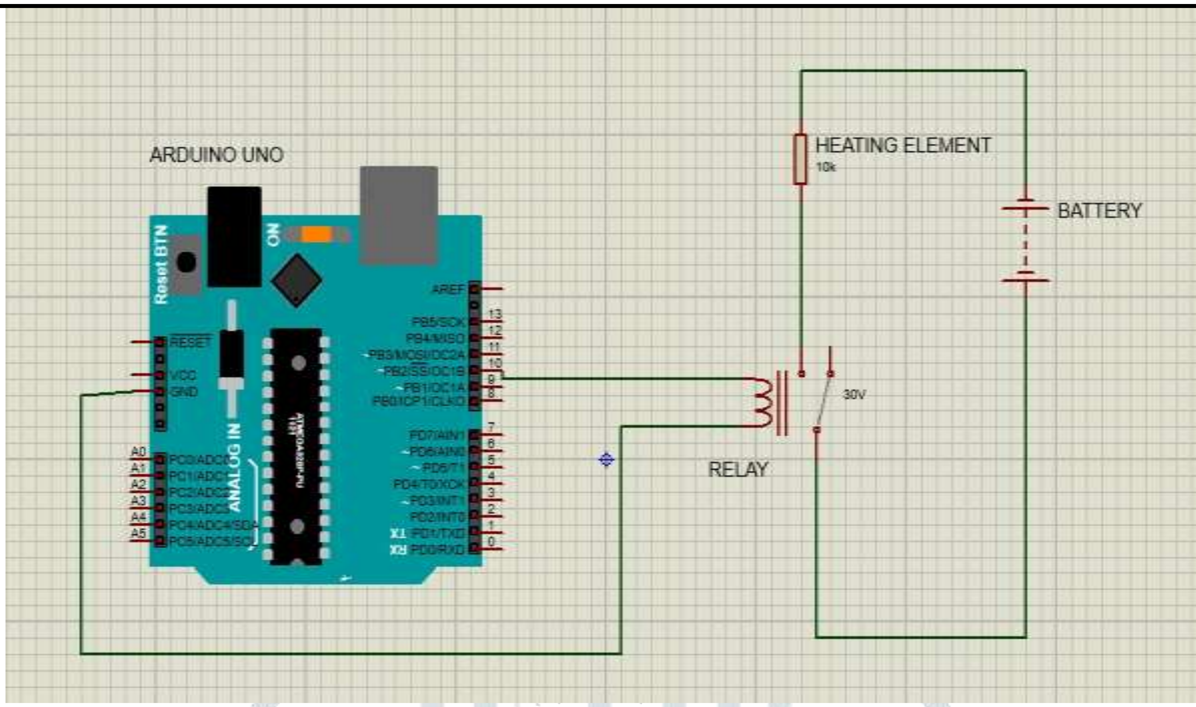

Fig 1.5 Controlling Relay with Arduino

A 100W monocrystalline solar panel is used as a source of energy for this project. When sunlight strikes the solar panels, it is transformed to DC electricity. When electricity enters the battery, it is converted to DC electricity and stored. The DC electricity then leaves the battery and is then used to operate the heating element.

Specifications of Solar Panel:

- Maximum power at STC : 100 W
- Rated Operating Voltage (Vmax): 17 V
- Open-Circuit Voltage (Voc): 21.5 V
- Short-Circuit Current (Isc): 6.2 A

A solar charge controller is used for charging the battery in this project as shown in fig 1.6. In the absence of a solar charge controller, battery life is reduced due to overcharging, deep discharging of the battery. There is a high risk that the connected heating element may be disrupted due to high power flow from solar panels. [8]

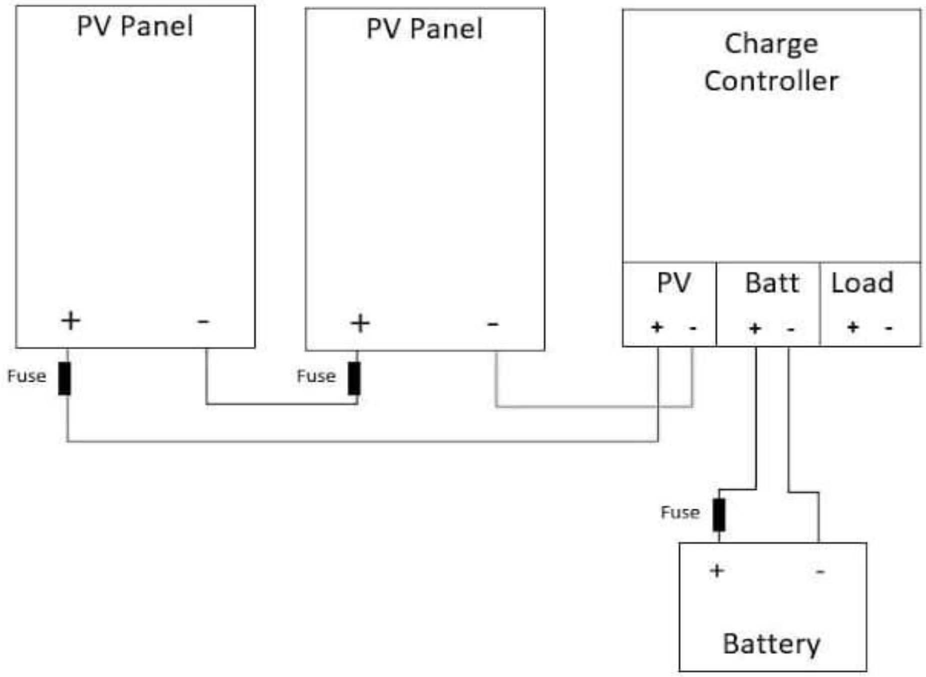

Fig 1.6 Solar Panel Charge Controller configuration

4.2.2 Interfacing ESP32 BLUETOOTH Module with Thermocouple Sensor

ESP32 is capable of functioning reliably in industrial environments, with an operating temperature ranging from –40°C to +125°C. ESP32 can dynamically erase exterior circuit defects and respond to changes in external conditions thanks to improved calibration circuitries. ESP32 is a low-power processor designed for mobile devices, wearable electronics, and IoT applications. It uses a combination of proprietary software to achieve ultra-low power consumption. In addition, ESP32 has cutting-edge capabilities including fine-grained clock gating, several power modes, and dynamic power scaling. The ESP32 can work as a stand-alone system or as a slave device to a host MCU, lowering the communication stack overhead on the primary application CPU. Through its SPI / SDIO or I2C / UART interfaces, the ESP32 can communicate with other systems to provide Wi-Fi and Bluetooth capability. [9]

The required components for the interface in this project are

- ESP development board
- MAX31855 module with thermocouple
- Connecting wires

The 5 MAX31855 module pins are connected to ESP32. These include VCC, GND, SO, SCK and CS pins present on the same side. The VCC will be connected to the ESP32's 3.3V pin. Both devices' GND will be the same. The default SPI GPIO pins of ESP32 are being used to connect with each of the remaining SPI terminals of the MAX31855 module.
After uploading the code to ESP32, the serial monitor of Arduino IDE is opened. Some information about Bluetooth is printed on the serial monitor by ESP32. Also, a 'ready' message is displayed. Bluetooth is turned on in the smartphone and is scanned for Bluetooth Devices. A list of 'Paired Devices' and 'Available Devices' is visible from the available devices, select 'ESP32'
There is no password. A smartphone application named 'Serial Bluetooth Terminal' is opened and several options are explored on the horizontal bar on the top left corner of the screen. In the device tab, ESP32 is selected. The 'link' icon on the top to connect to ESP32 Bluetooth Device is clicked. The app will display the status as 'Connecting to ESP32' while making a connection and if the connection is successful, it will display 'Connected'. The data from MAX31855 module (temperature reading) is transferred to ESP32 over Bluetooth and is received by Bluetooth Serial read function and is displayed onto the Bluetooth Terminal application in the smartphone device.

5. Simulation and Result

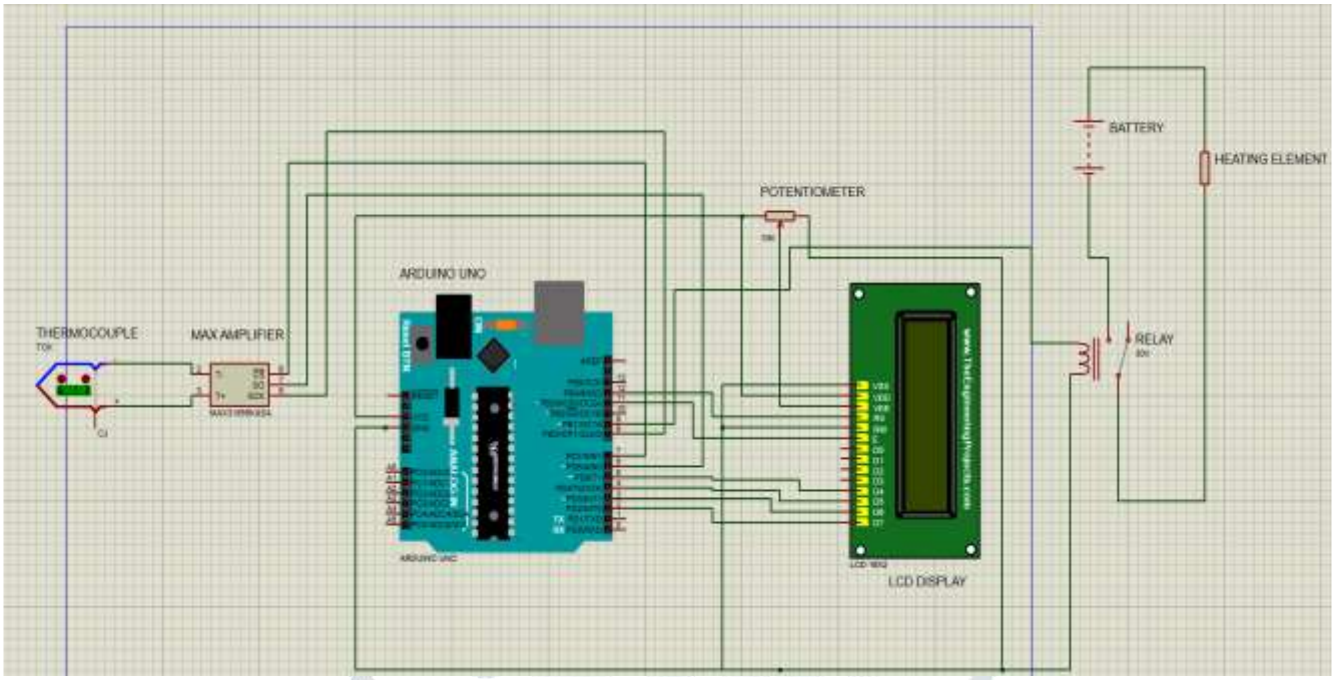

Fig 1.7 Overall Circuit Design

The MAX31855 amplifies any K-type thermocouple to measure temperature. The sensor utilises the SPI connection to transform voltage readings into temperature. Meanwhile a water sensor is used to register the change in resistance which corresponds to the distance from the top of the sensor to the surface of snow. The height of snow is inversely proportional to the resistance. The temperature output from Arduino Uno is displayed on the LCD display .A relay is used to allow relatively low voltage output from Arduino to easily control the heating element. Solar Panel and battery along with a charge controller is used as a source of electricity in this circuit.

5.1 Result

The final result of this project revolves around the melting of snow that is accumulated on the roof-tops. As soon as the circuit is triggered, the heating element is turned ON by the relay. The heating element that is used here converts electricity heat through the process of Joule heating. When electric current passes through the element, it encounters resistance, causing the element to heat up.

Shown below is the temperature vs time graph for the heating element when it is turned ON to melt down the snow accumulation.

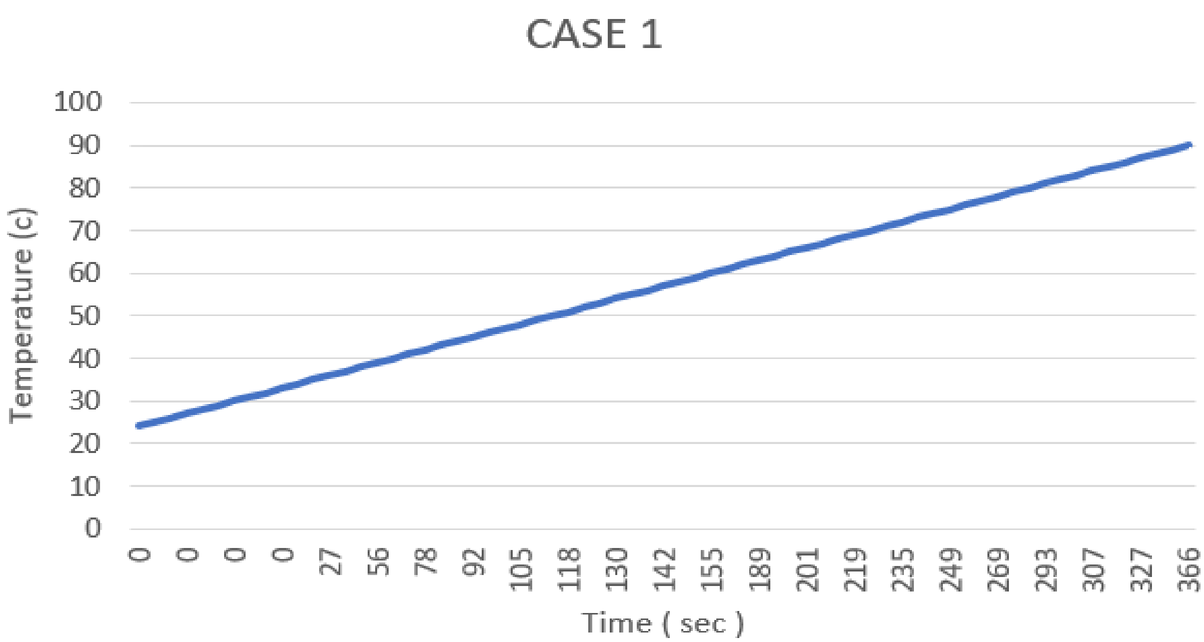

Fig 1.8 Variation in Temperature of Heating Element

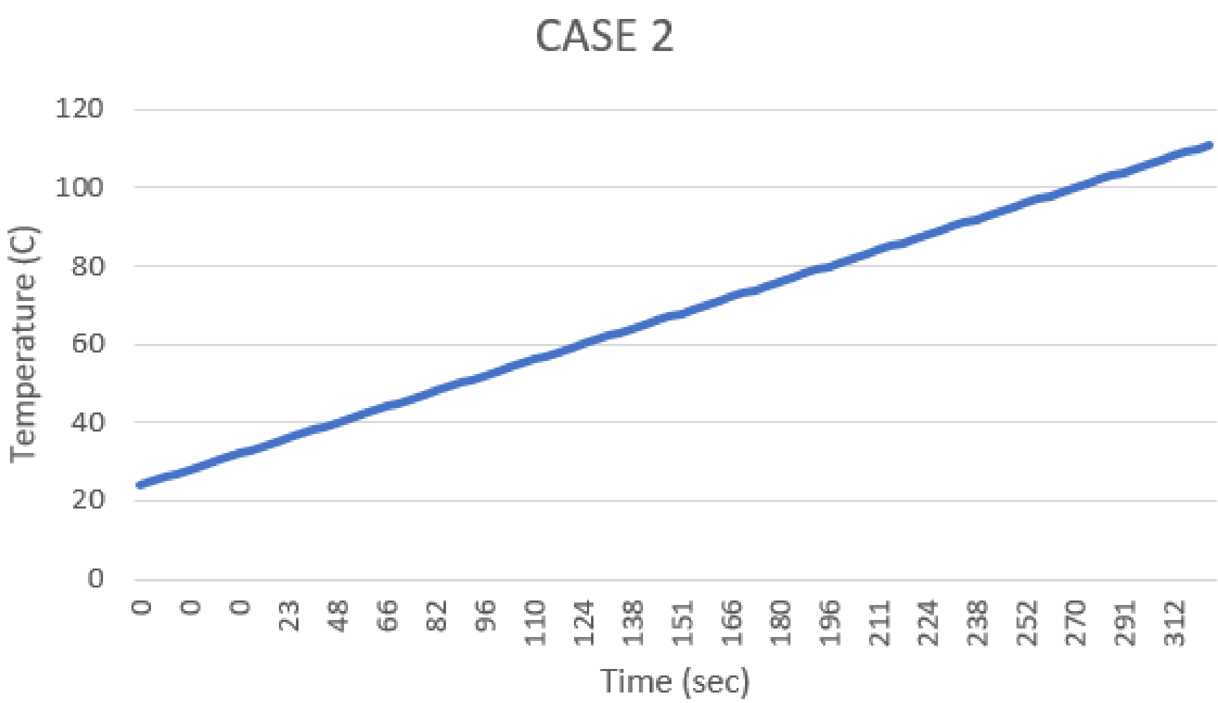

Fig 1.9 Variation in Temperature of Heating Element (Case 2)

6. Conclusion

With the advancement of technology and equipment around us, the future roof snow removal devices will gradually evolve towards computerization and intelligence to meet people's needs finer. This project model "IoT based snow removal device" based on temperature and water level sensing technology, is a fusion of electrical and electronic devices integrating electrical circuit structure and circuit control technology. It has the advantage of advanced structure, strong feasibility and elevated level of sensing technology. It is of the opinion that with the progression of society and the expansion in market demand, there will be a comprehensive space for this device to develop in the future.

7. References

1. Zhiyang Zhang, Roof Snow Removal Device Based on Visual Sensing Technology , Department of Mechanical Engineering and Automation, Wuhan University of Technology, Wuhan, Hubei, 430070, China
2. Roof Snow Removal Device Based on Visual Sensing Technology by Zhiyang Zhang
https://www.e3s-conferences.org/articles/e3sconf/pdf/2021/09/e3sconf_iaecst20_04010.pdf
3. A new snow removal device and determination of for membrane structures by BS Wang
https://iopscience.iop.org/article/10.1088/1755-1315/787/1/012014/pdf
4. A new snow removal device and determination of for membrane structures by B S Wang1, Y K Zhang1, L Meng1, S Li1, H Zhang1, and Q H Song1
https://iopscience.iop.org/article/10.1088/1755-1315/787/1/012014/meta
5. Roof snow behaviour and ice dam Prevention in Residential Housing by Howard L grace and Lewis T, Hendricks
https://conservancy.umn.edu/bitstream/handle/11299/168996/mn_2000_eb_399.pdf
6. About the possibility of using vibrations to remove snow from a sloping roof by L.V. Zadorina, V.A. Muratova, O.M. Zverev
https://ered.pstu.ru/index.php/CG/article/view/693
7. Melting of snow on a roof Mathematical report by Nielsen, Anker; Claesson, Johan
https://vbn.aau.dk/ws/files/45993057/Snow_on_roof_Math_rep.pdf
8. Solar Panel Specifications
https://www.centsys.com.au/
9. Overview of ESP 32 BLUETOOTH AND WIFI Module
https://www.espressif.com/en/products/socs/esp32