IoT Enabled Solar PV Monitoring System for Increased Efficiency – Project Helios

Acknowledgements

We would like to extend our sincere appreciation to our project supervisors, Mr. Chaminda Attanayake & Dr. Chandana Perera, for his guidance and support throughout this project. He has pushed us to achieve our absolute best and allowed us to pursue new technological advances to use and or take inspiration to improve our system.

Additionally, we would like to express our appreciation to our inter university student circle TAKG group members, our family and friends for their support and encouragement throughout this project.

Abstract

This report describes an IOT project to implement a notification to users about the current efficiency of the solar panel array and a data collection system. This system allows users to view the current output of the solar panel array, view causes to the reduction in efficiency, manage and monitor connected sensors and advise users on measures to take to resolve the issues causing the inefficiency.

The report begins by defining the background, objectives and deliverables of the project, currently available system, the factors affecting inefficiency, currently available system, the proposed system, applications used. Furthermore, a breakdown of all the hardware components used in this system and diagrams to explain the breakdown of the system at a technical level.

Table of Contents

Chapter 1: Introduction

The team is building an extension to existing solar monitoring systems for increased efficiency.

Solar Power has become a popular method of generating electricity. Be it just for home usage or entire solar farms, Solar power is the least complicated yet most reliable method to generate electricity without the pollution of the environment.

With this renewable resource accessible from almost anywhere during the daytime, an increasing number of people are adopting this method to obtain electrical power. Project Helios aims to create an updated take on the Solar PV Monitoring system. Regardless of the scale of these systems, the ability to constantly monitor the systems will aid in effective decision making on the part of the user. We aim to provide accurate and up-to-date information about the solar panels using a collection of sensors, none of which are used all together in present systems.

1.1 Problem definition

On average the maximum efficiency of a solar panel is 15% to 20% in today's market. Due to environmental factors such as elevated temperatures and dust particles collecting on top of the panels, the efficiency of a solar panel decreases by a significant percentage. Alongside this degradation, the lack of a proper way to identify the root cause of the problem makes it difficult to know whether the prior efficiency can be regained.

The main objective of this project is to get an optimum power output Increasing efficiency with in-depth telemetry from the solar panels, by informing a user about the dust accumulated on it and varied temperature changes. Furthermore, if there is any malfunctioning of the solar panels that will be displayed, we can also get information about the solar PV or battery connected for the loads. The system will also detect and alert the user when it falls below the pre-defined conditions and displays it on the GUI. Different parameters like voltage, current and temperature are displayed on the GUI. Users will be alerted in appropriate events. And this system can compatibility with existing industry level systems (Modbus enabled).

1.4 Scope

The main objective of this project is to get an optimum power output from the solar panels, by informing a user about the dust accumulated on it and varied temperature changes. Furthermore, if there is any malfunctioning of the solar panels that will be displayed, we can also get information about the solar PV or battery connected for the loads. The system will also detect and alert the user when it falls below the pre-defined conditions and displays it on the GUI. Different parameters like voltage, current and temperature are displayed on the GUI. Users will be alerted in appropriate events.

Chapter 2: Research

2.1 How Solar PV works

Solar energy is a clean renewable energy resource. Ow solar energy that is collected is using PV modules to absorb light and convert it into an energy that can be consumed as electrical current. The main method of storing the collected electrical current is using batteries to store them for when they are required to be used.

2.2 Affecting Factors

There are multiple environmental factors which affect the efficiency of Solar PV. One factor is dust particle deposits which collect on top of the solar PV. The degree of severity of dust on efficiency depends on the amount of dust collected on top and the size of the dust particles. As the mass of the dust deposit increases the power produced and efficiency drops. Furthermore, if there is a large deposit of small dust particles it will lead to much higher inefficiency of the solar panel, this is due to smaller dust particles will cause a dust layer to form thus leading to less solar radiation to bleed into the solar PV and the the rest of the solar rays end up being bounce backed.

Radiation is an important factor, due to solar PV converting Solar radiation entering the atmosphere into electrical current which can be used. This in return means that the clearer the day is the more radiation which can be converted into electricity. However, if the day tends to be cloudy the less solar radiation can be converted, due to lesser rays being able to penetrate the atmosphere.

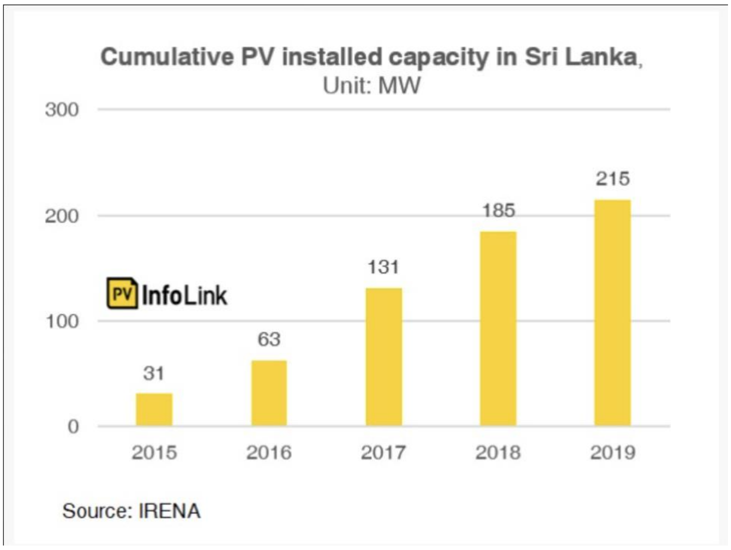
For solar PV there is a peak operating temperature, which is 25 °C. This means that the solar PV is at its peak efficiency if the temperature is at 25 °C. However, if the temperature of the panel is lesser if leads to less energy to be stored in the cells thus leading to low power generation, in the instance that there is extremely high temperatures it leads to the cell to have too much energy and leads to loss of energy because the panel is not able to absorb the radiation which it receives.

Humidity has the same effect as does Dust particles, but the major difference is that humidity may cause water to form on top of the panels, thus leads to light to be refracted away from the panel, therefore less solar rays, therefore leading to lower production of electricity, this means that efficiency has reduced compared to the panels rated efficiency

Chapter 3: Current Systems

3.1 Industry

With the current situation in Sri Lanka, many people as well as businessmen are turning to solar panels. Amongst the currently available Solar System solutions in the market, these concepts provide clear differences between their features and the environments where they can be more useful. As shown in the following, we provide the main differences. We can observe that Project Helios will be beneficial for those systems where latency and jitter are critical.



3.2 Research Studies

PV Module Monitoring System Based on Low-Cost Solutions: Wireless Raspberry Application (José Miguel Paredes-Parra, Antonio Mateo-Aroca, Guillermo Silvente-Niñirola, María C. Bueso and Ángel Molina-García/ Cartagena/2018)

"The integration of renewables into power systems has led to multiple studies and analysis in terms of grid-power quality, reliability, and/or feasibility. Among different resources to be considered as alternative energy systems, wind and solar emerge as the most mature technologies. Regarding photovoltaic (PV) installations, monitoring problems requires detailed analysis, since solar-radiation fluctuations, soiling on solar panels, or deficiency of PV-panel performance can involve unexpected power-output oscillations and, subsequently, undesirable power-generation oscillations. Under this framework, this paper describes and assesses a wireless low-cost PV-module monitoring system based on open-source solutions. Our proposal allows us to monitor installations at the PV-module level, giving detailed information regarding PV power-plant performance. The proposed monitoring system is based on the IEC-61724 standard requirements, as a flexible and ad hoc solution with relevant connectivity options. Meteorological and electrical data are collected from the developed nodes and available for subsequent analysis. Detailed information of the solution, as well as extensive results collected in Spanish PV power plants connected to the grid, are also included in the paper.”

IoT Enabled Solar Power Monitoring System – Dust particle (R.L.R. Lokesh Babu, D Rambabu,A. Rajesh Naidu, R. D.Prasad, P. Gopi Krishna /India/2018)

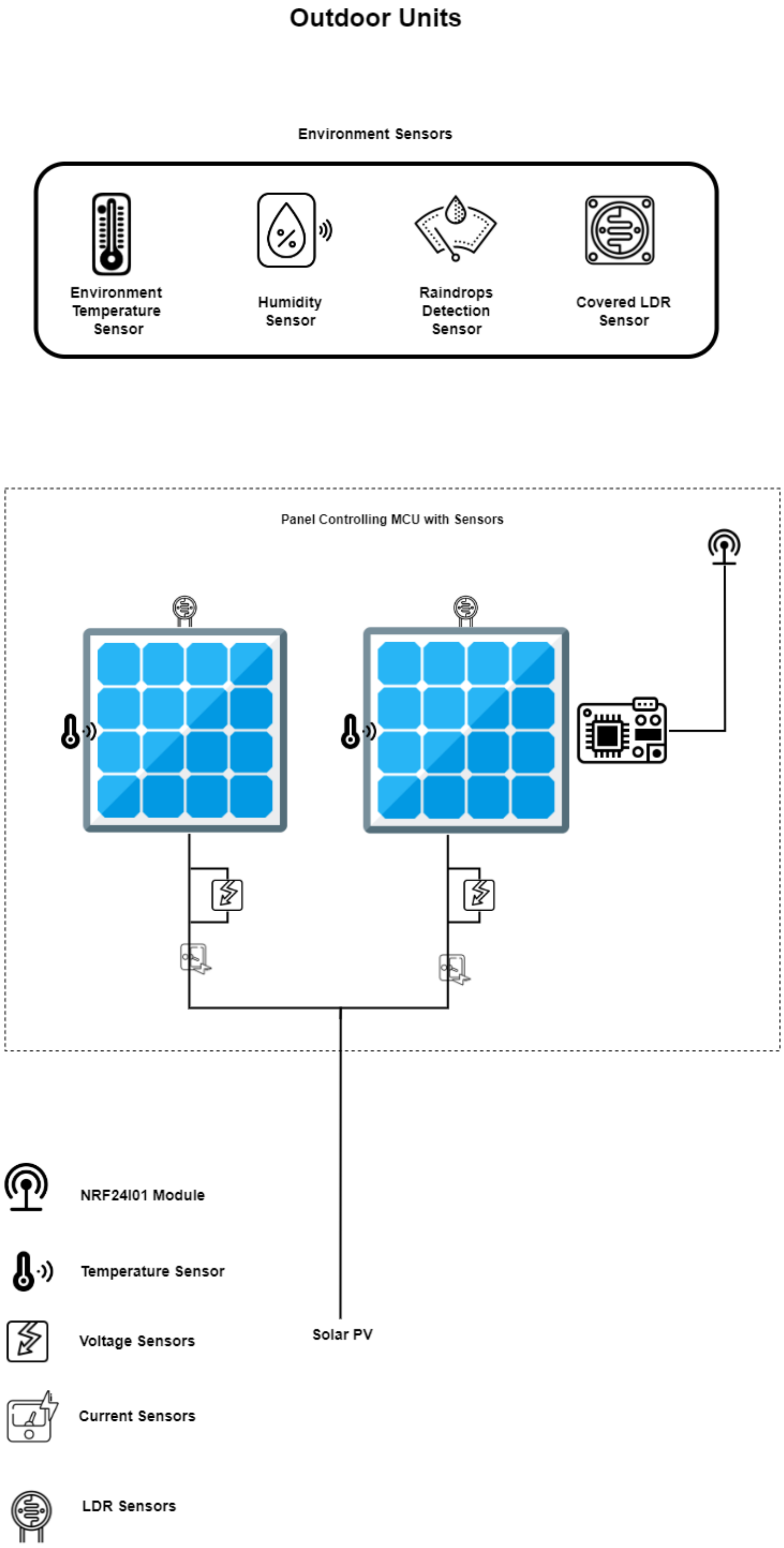
“This paper proposes a solution and method to monitor the dust accumulated on the solar panels to get the maximum power from for effective utilization. Always the output power of the solar panel depends on the radiation reached to the solar cell. The system also displays the malfunctioning solar panels lists and whether the electrical appliance is working directly on the solar panels, or the loads is on the battery. All the panels are connected, and sensors are directly connected to the central controller which monitors the panels and loads. By incorporating IoT technology the data received from the panels and appliances are sent to the cloud via the internet for future use, as well as the remote user being able to monitor the parameters of the connected devices. The user can view the current, previous, and average parameters such as voltage, current, temperature and sun light using a graphical user interface GUI. The controller is programmed with predefined conditions with user alerts when it falls below the specified conditions. Node MCU is used as a controller.”

Integrating A Cooling System For Solar Pv Module To Maintain Energy Generation Efficiency (Karunarathna Map, Karunasena Utrk, Kumar Dgas/Sri Lanka)

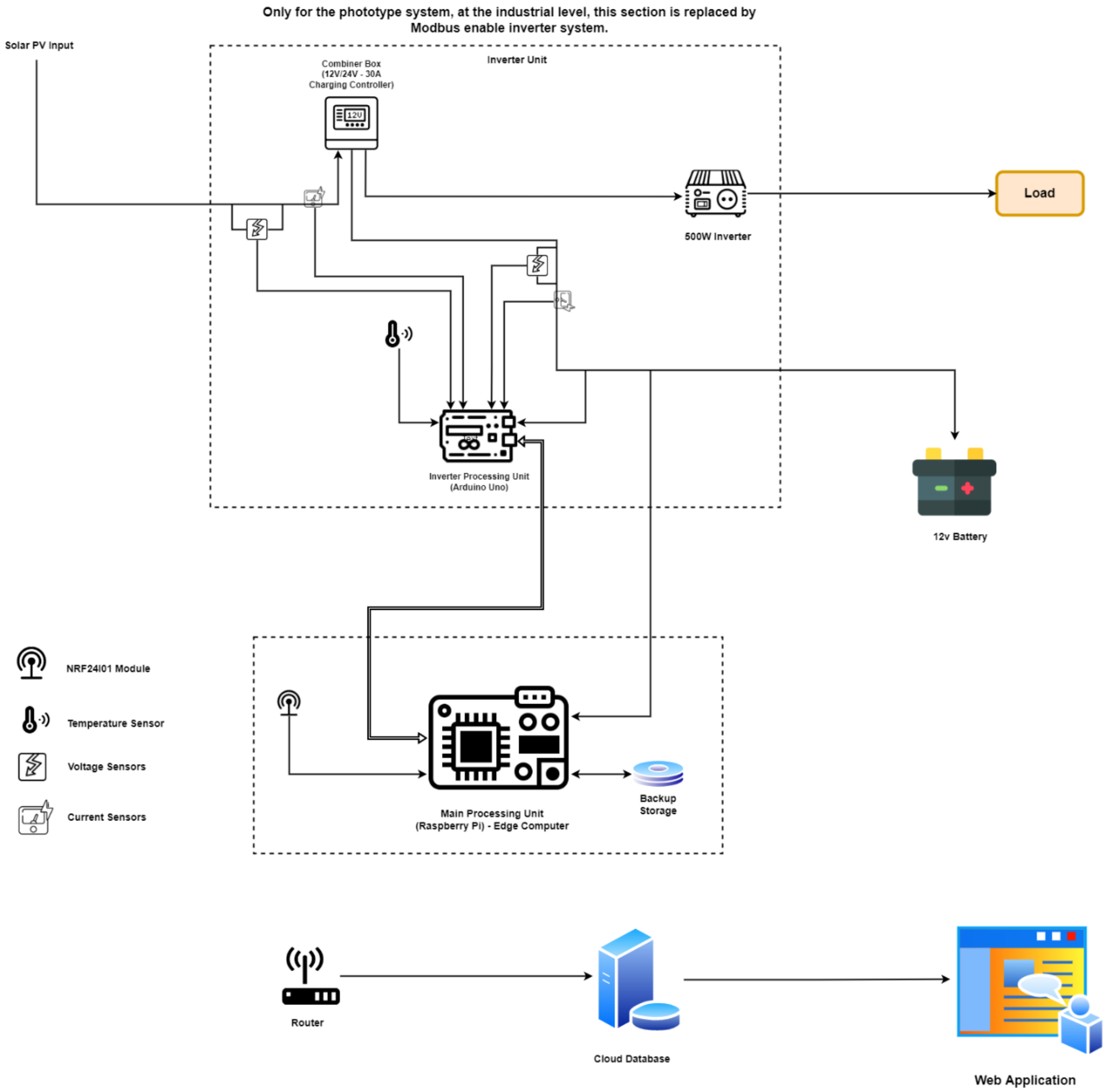
“The power output of solar panels shows an inverse relation with its operating temperature and that affects largely for countries like Sri Lanka, which are situated near the equator. The aim of this study is to increase the solar cell energy generation efficiency up to its design efficiency by using an integrated cooling system. Possible cooling techniques which are aligned with Sri Lankan context were studied by referring past research and available systems. Rear side forced water cooling with thermal collector was identified as the most feasible technique by considering economic and environmental factors. Theoretical model was developed to estimate the design parameters of the experimental setup and predict the cooling performance. Number of ten cooling channel design configurations were modelled and analysed the cooling performance using ANSYS fluent simulations. The best design configuration was identified based on heat transfer and manufacturing capability. A prototype was manufactured to investigate the cooling performance experimentally. The experimental setup was developed using two 100-Watts solar panels with the capability of solar tracking. A cooling tower was developed to remove the extracted heat. Both power and panel temperature variation were observed and efficiency improvement was estimated. Experimental results were analysed to validate the numerical analysis performed using ANSYS fluent. The research work will be further extended to identify the optimum cooling liquid flow rate. Although, the designed efficiency was not achieved, the results of the both theoretical and experimental analysis show that integrating a rear side cooling system would increase both electrical and thermal efficiency by 63%. Considering the cost benefits and the environmental conditions of the Sri Lanka, using a heat removal system for solar modules is a feasible option."

4 System Diagram

4.1 Circuit View



Indoor Units

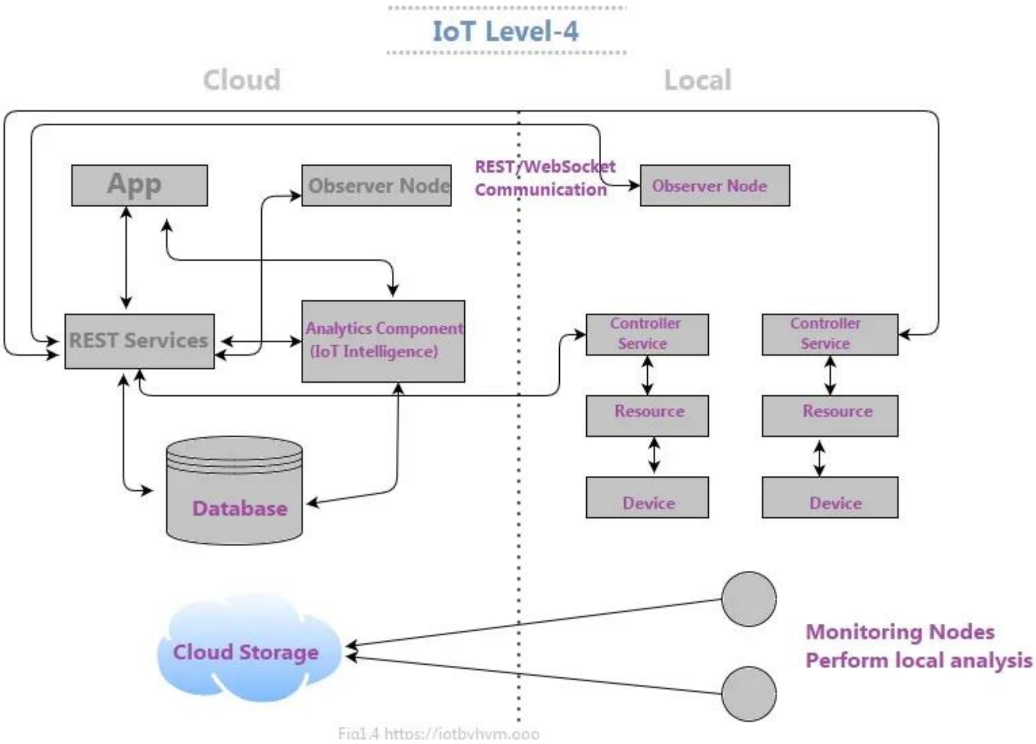


4.2 IoT Architecture: Level 4

The conceptual view of Helios IoT architecture form 3 main layers

Infrastructure Layer	Sensors, Monitoring devices
Middleware Layer	Controller Service, Modbus TCP/IP
Application and Service Layer	Cloud & Embedded IoT Application

Proposed IoT solution fall in to IoT Level 4 category.



(Mishra, 2021)

Chapter 5: Applications

5.1 Dust Detection Unit / Dispense clean solution

As mentioned before the main objective of this project is to get an optimum power output from the solar panels. Solar Panel surface dust is one of the main problems with solar power generation. If we can detect surface dust levels and clean them, it will help to get more solar power with efficiency for a long time. In this project, we come up with Dust Detection Unit to detect surface dust particles. There are two main components to doing this work.

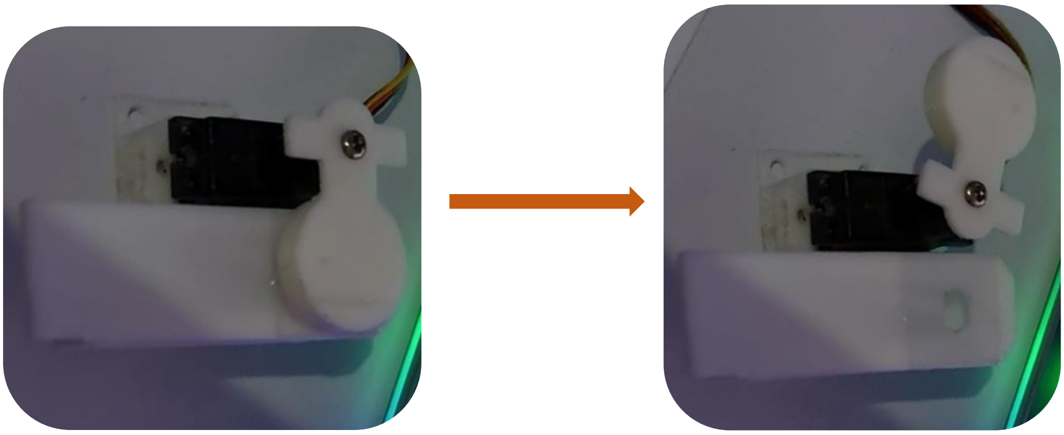
1. Uncovered LDR Sensor

Every solar panel has this sensor. This is the uncovered LDR sensor. Uncovered means this sensor opens always to the environment. This sensor faces all the environmental facts as the panel faces. If dust particles have on the solar panel, we can detect those dust particles using the help of this sensor.

2. Covered LDR Sensor with Servo Motor (Dust Detection Unit)

Every per panel array has this unit. Our system uses the Uncovered LDR sensor and the Covered LDR sensor to detect dust particles on the solar panel. This Unit has three components.

- Covered LDR Sensor – This LDR sensor is covered using a small plastic covering plate and it can move 120 degrees using a servo motor.
- Plastic Covering Plate - Plastic Plate that covers the LDR sensor
- Servo Motor – This servo motor is used to open and close the LDR sensor to the environment. And this movement surface of the servo the LDR sensor will clean automatically.



The software of our system gets LDR sensor readings of the Covered LDR sensor at a specific time. And compare those values with the Panel LDR sensors (Uncovered LDR Sensor). Using this method our system can detect dust particles on the panel surface. If a solar panel surface has dust users will inform about that. Users can check that solar panel and clean it. For future implementation, we can automate this clean process by using deploying a high-pressure watering system to the panel surface. It will clean the solar panel surface.

5.2 Temperature Sensor

Increasing the operating temperature of the PV panel reduces the efficiency and lifespan of the solar panel. The purpose of this sensor is to investigate the design of the PV module cooling system using computer fluid dynamics. A bottom temperature sensor (DHT11) is mounted on the PV panel to monitor the system temperature. Our hope is to install a sensor like this on every panel in the array.

5.2.1 Auto Cooling

An active cooling system can be installed on the front and / or back of the solar panel. This is done by allowing a small amount of air or water to flow over the surface of the solar cell.

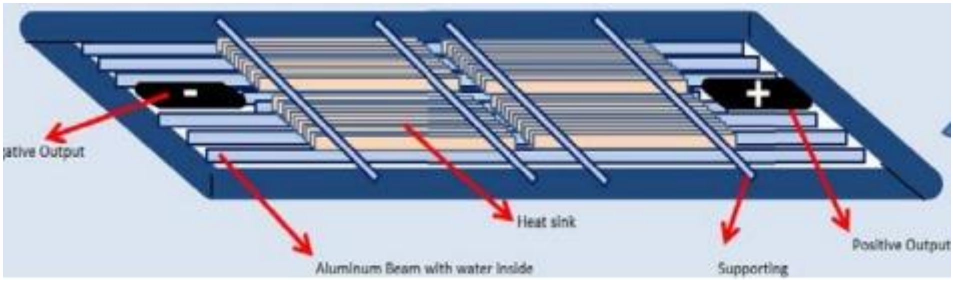
Another way is to ventilate the back of the solar panel, so we suggest mounting it slightly higher and sloping.

5.2.2 Water Heating

We use a water-cooling system. The main purpose is to cool the solar panel and thereby heat the water.

The back side of the solar panel. The diagram shows the diagram of the proposed system. An array is filled with water.

Aluminum beams are mounted on the back of the solar panel. The panel can then be cooled.



5.3 Per Panel Statistics

Panel data allows you to control variables that you cannot. We can compare the electrical differences caused by the temperature difference relative to each other.

The best option is to have a dedicated monitoring system for your solar panels to take measurements that are not affected by other electrical components. Our system is a brand-compatible monitoring system. Many types of errors can identify themselves and determine exactly what is going on. This makes troubleshooting easier.

5.3.1 Replacing Under Performing Panels

However, there are some performance issues that can affect solar panels, and if left unattended they can damage your savings. Fortunately, many of these problems arise relatively from rising panel heat.

If you suspect that your solar panels are suffering from low productivity, the first step is to identify the correct problem. You may simply be dealing with seasonal changes, or you may need to clean your solar panels. However, your solar PV system can also be a big problem.

There are some performance issues that can affect solar panels, and if left unattended they can damage your savings. Fortunately, most of these problems are relatively easy.

Many solar power problems can be solved by cleaning and checking for loose connections or broken breakers. However, some issues are a bit challenging.

Those problems can be solved by showing it to someone in the field or the panel may need to be replaced.

5.3.2 Identify Quality

Since our design is designed for remote monitoring, it usually requires the use of creative energy sources. We use solar power to power such devices. We used low energy loss sensors for energy management, and this allowed us to maintain a consistent level of system quality.

6 Helios+ Component

6.1 Overview

The solution of the proposed hardware unit is branded as “Helios+”. It contains 3 major components.

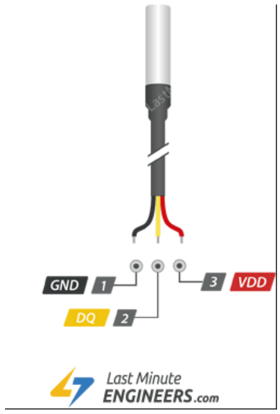
1. Edge Controller Unit – Connected to internet and inverter
2. Panel Array Node – Collect telemetry of panel and forward them to edge controller unit
3. Environment Sensor Unit – Node which collect environment telemetry

6.2 Hardware

6.2.1 Components

Sensors

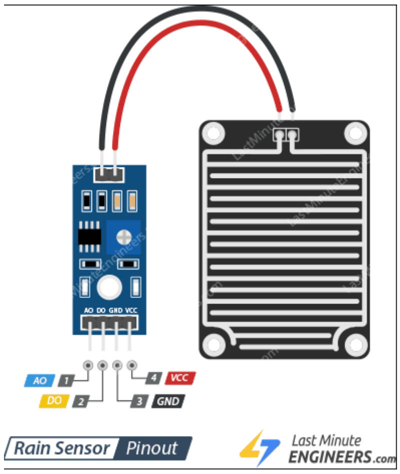
- ➢ DS18B20 Sensor Module (Waterproof Temperature Sensor)



- Check temperature of the environment.
- Signal Type – Digital
- Operating Voltage – 3V to 5.5V
- Current Consumption – 1mA
- Working Range – This sensor can measure temperatures from – 55 ° C to +125 ° C with ±0.5°C Accuracy
- Resolution – 9 to 12 bits
- Conversion Time - < 750ms

(Interfacing DS18B20 1-Wire Digital Temperature Sensor with Arduino, 2022)

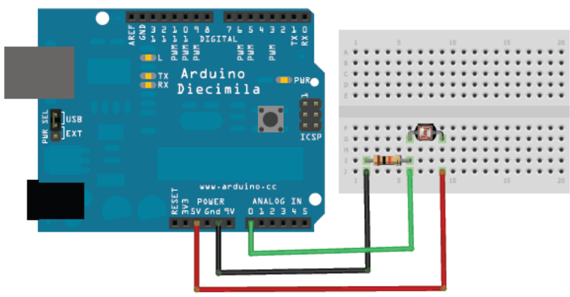
➢ Snow & Raindrops Detection Sensor Module



- For rain detection and measure rainfall intensity.
- Signal Type – Analog or Digital
- Operating Voltage – 3.3V to 5V
- The sensor produces an output voltage according to the resistance, which by measuring we can determine whether it’s raining or not.

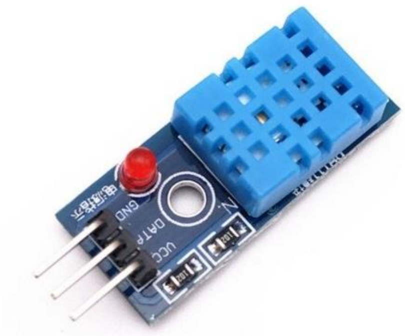
(In-Depth: How Rain Sensor Works and Interface it with Arduino, 2022)

➢ LDR Sensor



- Used for detecting light intensity and surface dust
- Signal Type – Analog
- Operating Voltage – 5V
- Value Range – 0 to 1023

➢ DHT11 Sensor Module (Temperature and Relative Humidity)



- Check per panel temperature and humidity.
- Signal Type - Digital
- Operating Voltage – 3V to 5V
- Temperature Range – 0 to 50 ° C / ± 2°C
- Humidity Range – 20 to 80% / 5%
- Sampling Rate 1 Hz (Reading every second)

(Insight Into How DHT11 DHT22 Sensor Works & Interface It With Arduino, 2022)

- Voltage Detection Module (spits out an analog signal) DC 0~25V

- Measure DC Voltage
- Signal Type - Analog
- Operating Voltage – 5V
- Input Voltage – 0V to 25V
- Voltage Detection Range – 0.02445V to 25V
- Analog Voltage Resolution – 0.00489V

- ACS712 20A Current Sensor Module (spits out an analog signal) – Measure Current

- Measure Current - Ampere
- Signal Type – Analog
- Operating Voltage – 4.5V to 5.5V
- Measure Current Range – -20A to +20A
- Sensitivity – 100mVA

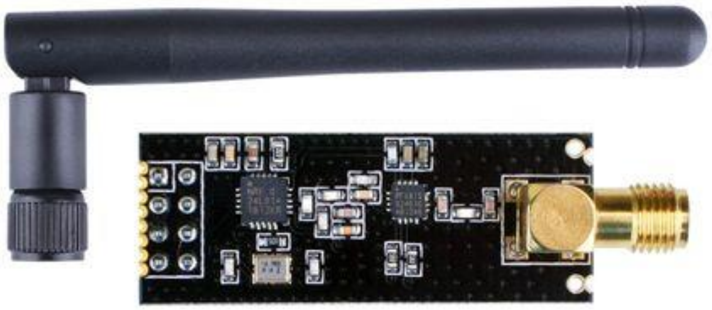
Actuator

- ➢ Servo Motor Metal Wheel MG995

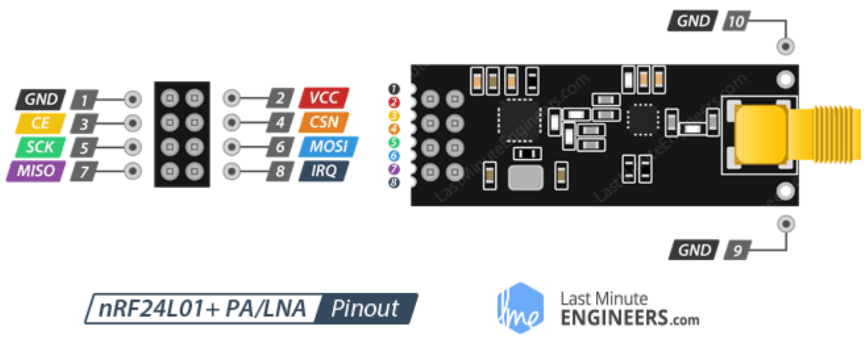
- Used to open and close the dust checking LDR sensor.
- Signal Type – Digital
- Operating Voltage – 4.8V to 7.2V (**6V recommended**)
- Operating Speed (4.8V no load): 20sec / 60 deg
- Operating Speed (6.0V no load): 16sec / 60 deg (no load)
- Operating Angle: 120degree
- Temperature range: 0 ºC - 55 ºC

Communication

➢ NRF24L01 2.4GHz Wireless Transceiver Module



- Communication between Edge computing unit and Panel control unit.
- Operating Voltage – 1.9V to 3.6V (**3.3V recommended**)
- Frequency Range – 2.4 GHz ISB Band
- Modulation Format – GFSK (Gaussin Frequency Shift Keying)
- Max Air Data Rate – 2 Mb/s
- Max Output Power – 0 dBm
- Max Operating Current – 13.5mA
- Min Current (Standby Mode) - 26µA
- Communication Range – 800+ m (line of sight)



(In-Depth: How nRF24L01 Wireless Module Works & Interface with Arduino, 2022)

Edge Computing

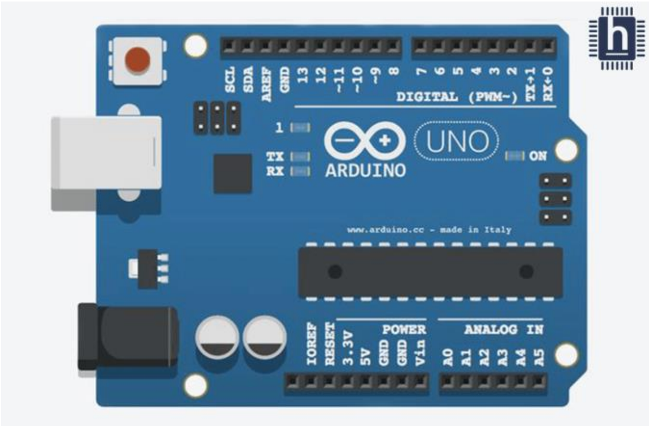
➢ Raspberry Pi 4 Model B 4GB RAM 1.5GHz 64bit CPU – Edge Computer

- Receive panel data using the NRF24L01 Module and do some required process.
- Some of those processes are convert integer values to float values (Panel Controlling Unit send some float data using integer format), Add panel id names and sensor reading names.
- Receive Inverter data from the Inverter Unit.
- And Upload data to the cloud storage.

➢ microSD UHS-I 32GB Memory Card (For Raspberry Pi)

- Store Linux OS (Ubuntu) for Raspberry pi and store panel data if network connection is down.

➢ Arduino Uno – Inverter Processing Unit



- Work as inverter controller unit and send data to Edge Computer
- We use this unit for only the prototype model.
- Show some information about the inverter using OLED Display

➢ Arduino Mega – Panel Controlling Unit

- Connect all the panel sensors and actuator
- Collect sensor data and send that data to Edge Computer using the NRF24L01 Module

Other Components

➢ LM2596 DC-DC Buck Converter Step-Down Power Modules

- Used to decrease the voltage for necessary components.

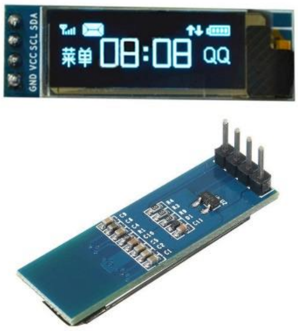
➢ 12V/24v 30A Auto Solar Panel Charge Controller

- Charge Controller for the inverter unit

➢ 12V DC 500W Inverter

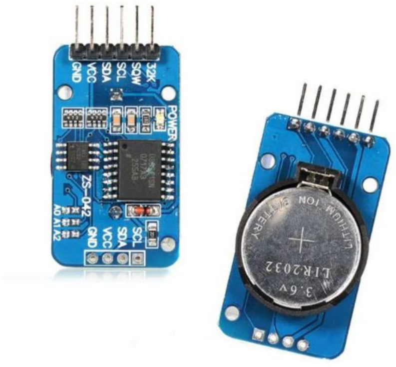
- 12V DC to 210V - 230V AC power inverter for the inverter unit

➢ 128×32 IIC I2C Blue OLED LCD Display Module SSD1306 Driver



- For display small information about inverter (Solar PV, Battery Voltage, Inverter Temperature, and Battery Level)

➢ DS3231 RTC Module



- RTC means Real Time Clock. RTC modules are simply TIME and DATE remembering systems which have battery setup which in the absence of external power keeps the module running.
- Used to remember time and date for the panel controlling unit.
- Operating Voltage – 2.3V to 5.5V
- Can operate on LOW voltages
- Consumes 500nA on battery backup
- Operating temperature: -45ºC to +80ºC
- CR2032 battery backup with two-to-three-year lifespan

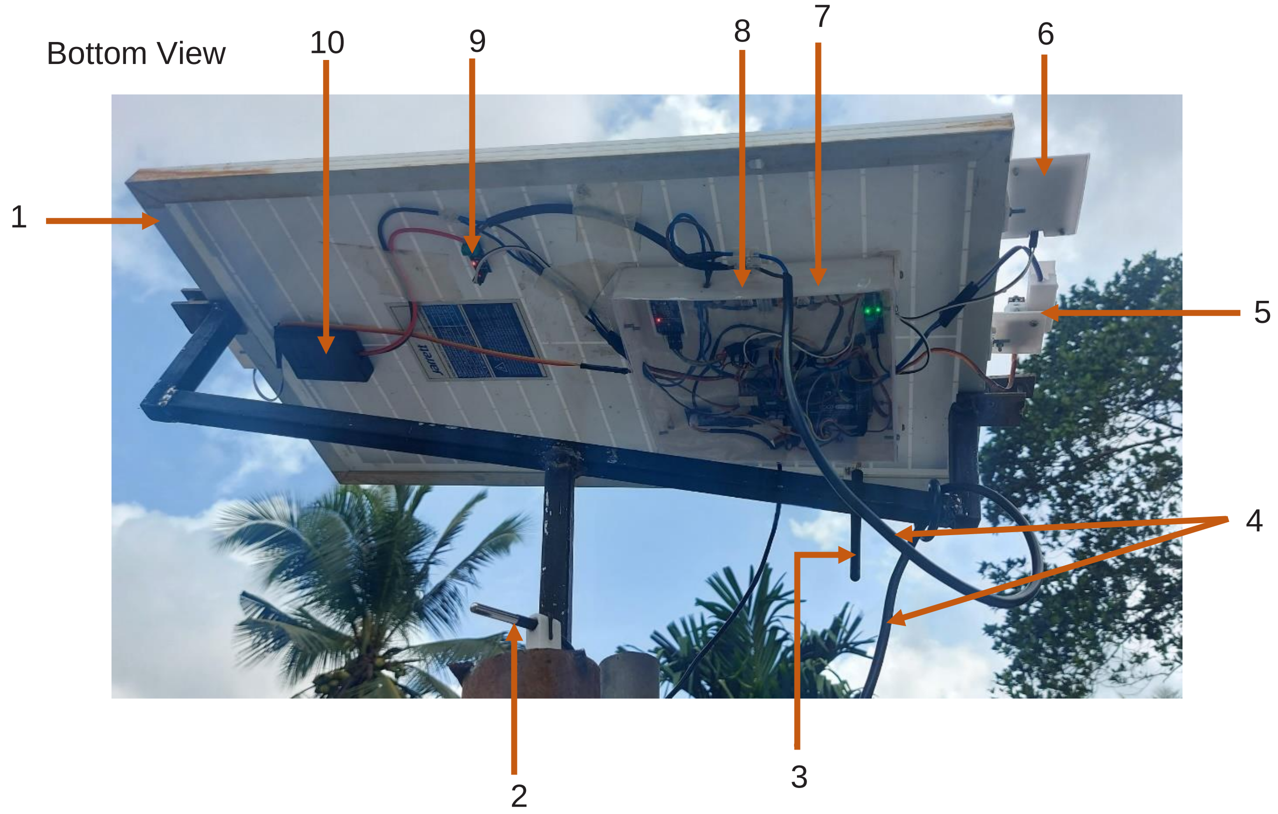
(DS3231 RTC Module, 2022)

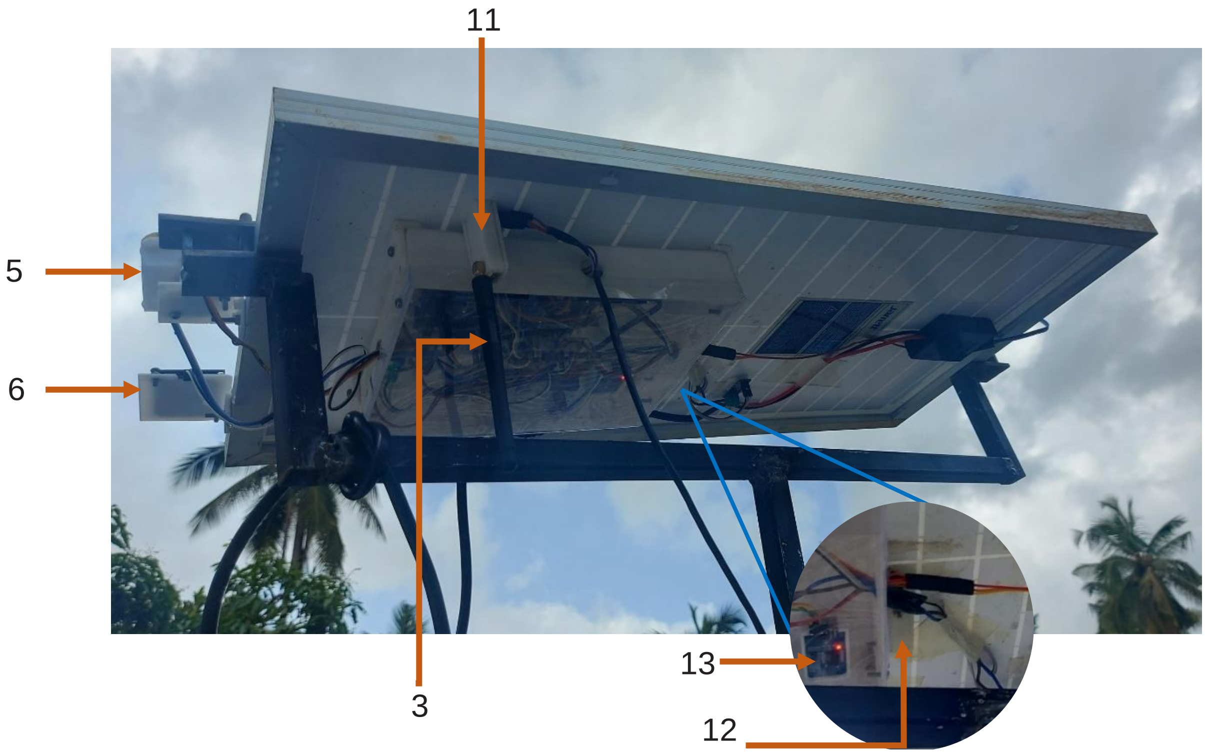
6.2.2 Working Product

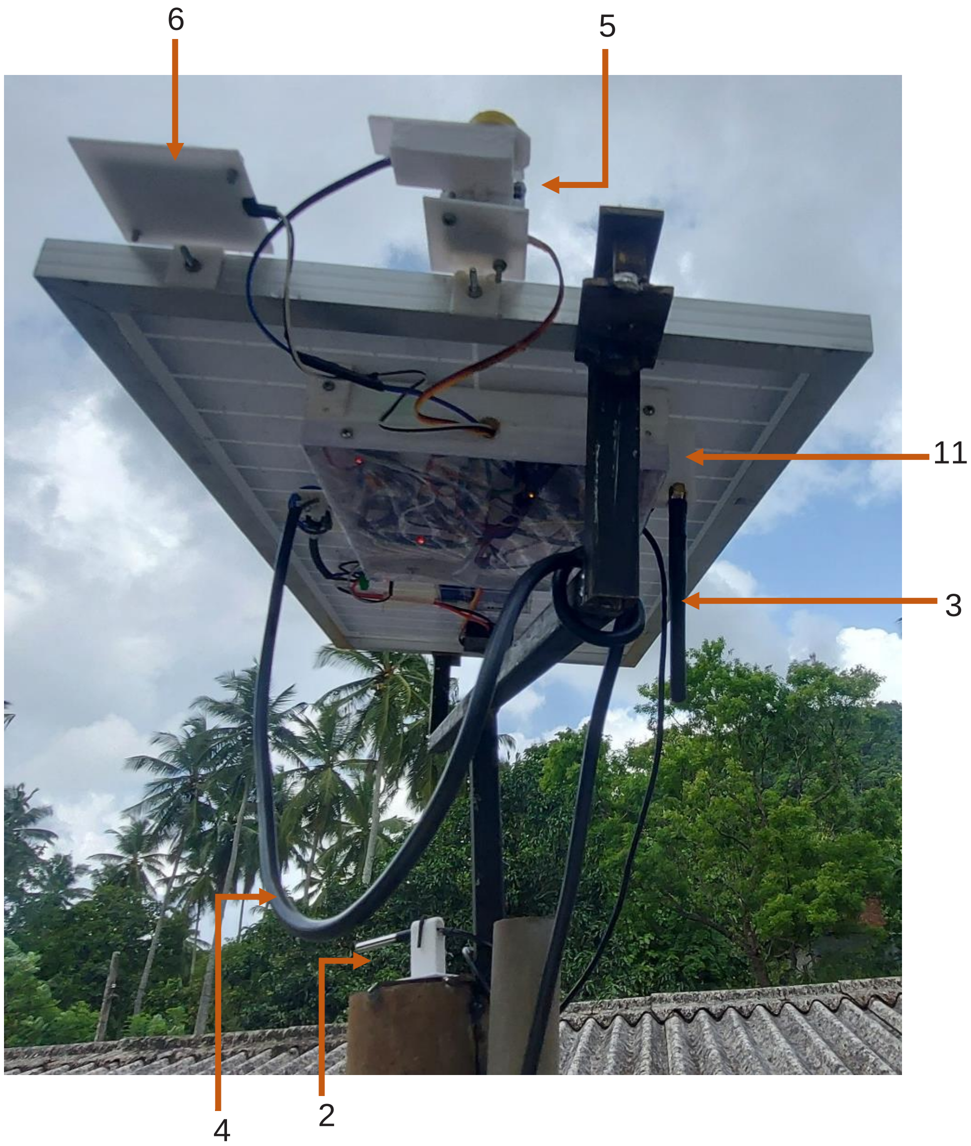
6.2.2.1 Outdoor Unit

Solar Panel Array Node

Bottom View



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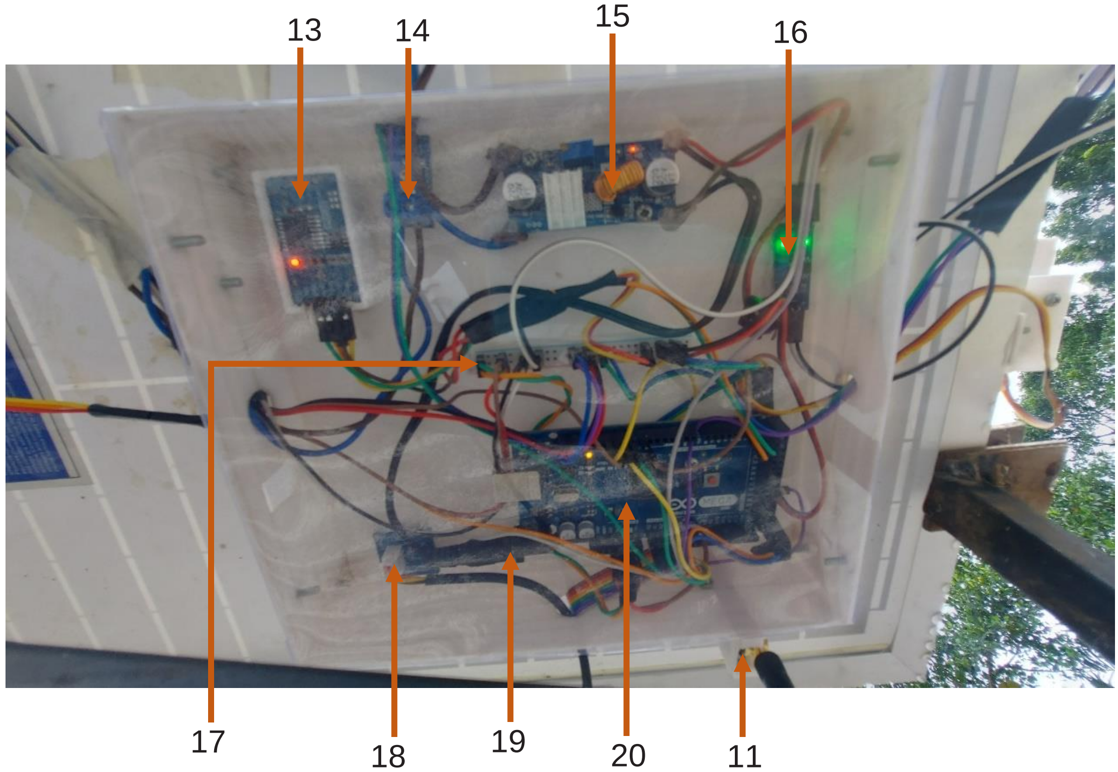
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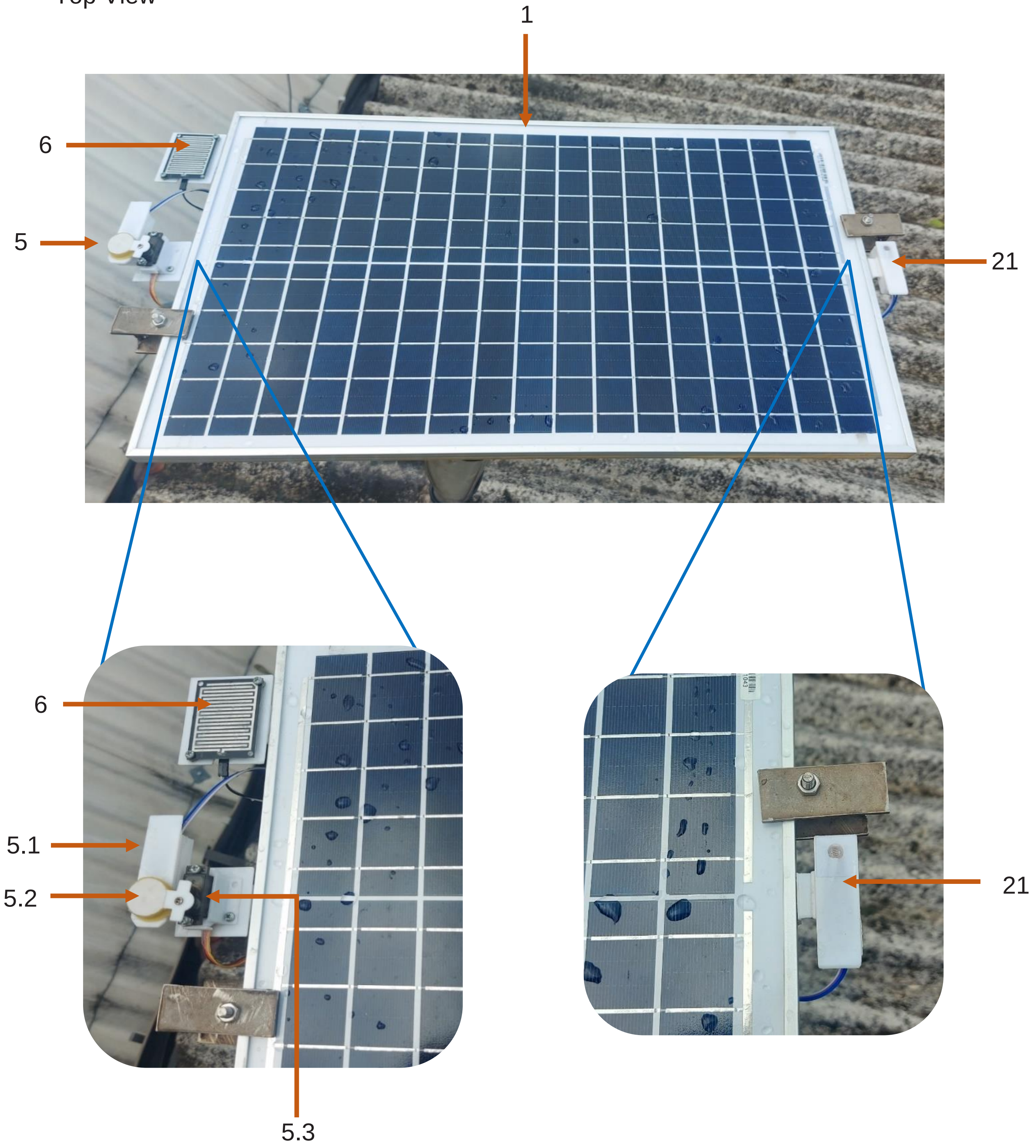
Top View



1. Solar Panel – In this prototype design, we use only one solar panel. This is the main solar panel of the panel array. In a real implementation, every per panel array has a panel with the Solar Panel Controlling Unit.

2. DS18B20 Sensor (Waterproof Temperature Sensor) – Only one sensor uses for an entire solar farm. This sensor is used to collect data about environmental temperature.

3. Extremal Antenna for NRF24L01 Module

4. Solar PV Output – This power line connects with the Solar PV Input in the Inverter Unit. This power line curries power generation of the solar panels to the Inverter Unit.

5. Dust Detection Unit – Every per panel array has this unit.

5.1. Covered LDR Sensor
5.2. Plastic Covering Plate
5.3. Servo Motor

6. Snow & Raindrops Detection Sensor (Sensing Pad) – Only one sensor uses for an entire solar farm. Used to detect rainfall or snowfall.

7. Panel Controlling Unit Box – Number 13 to 20 components are included in this box.

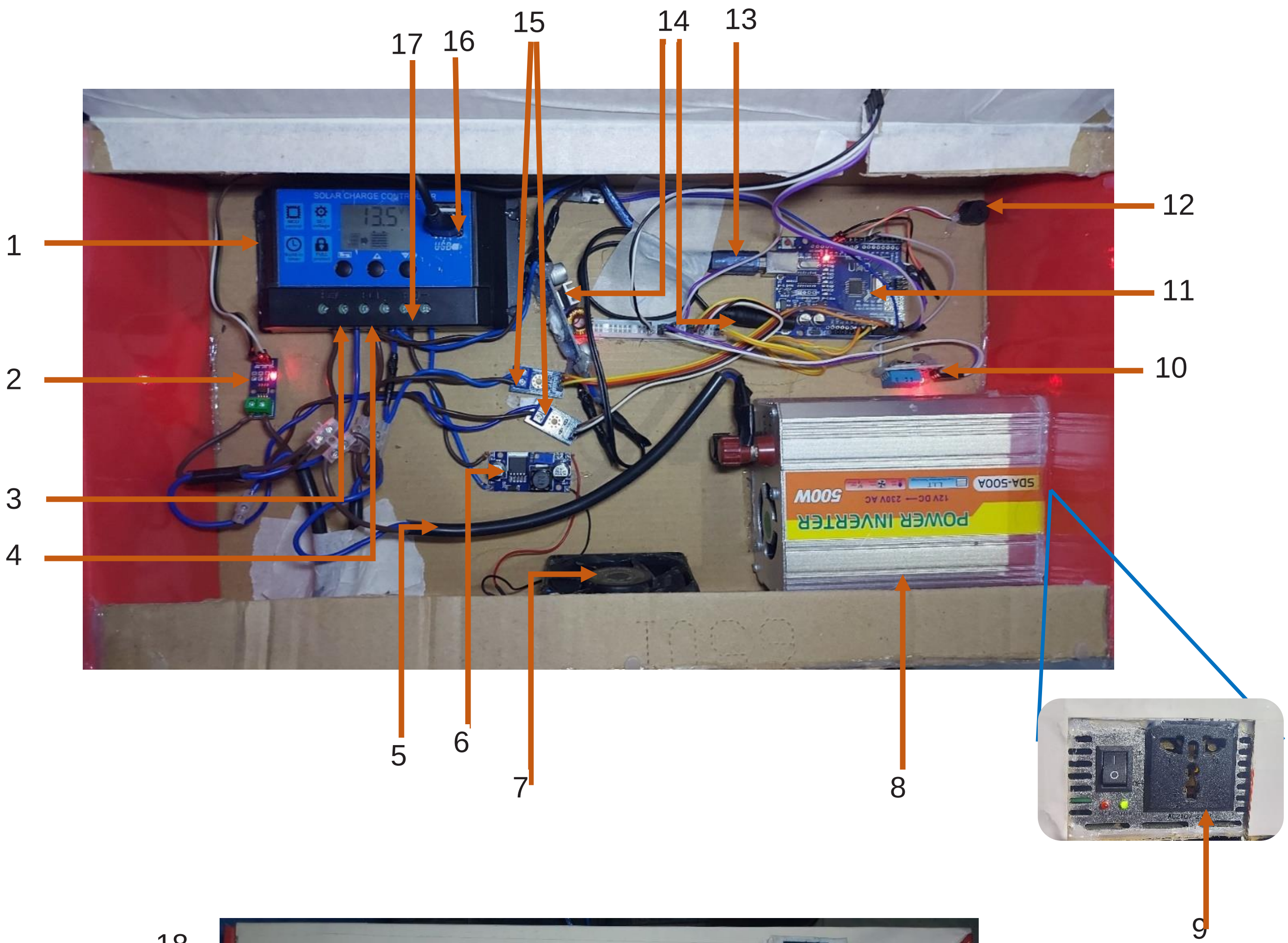
8. Wire Connector – Panel power wires and Main Power line connection

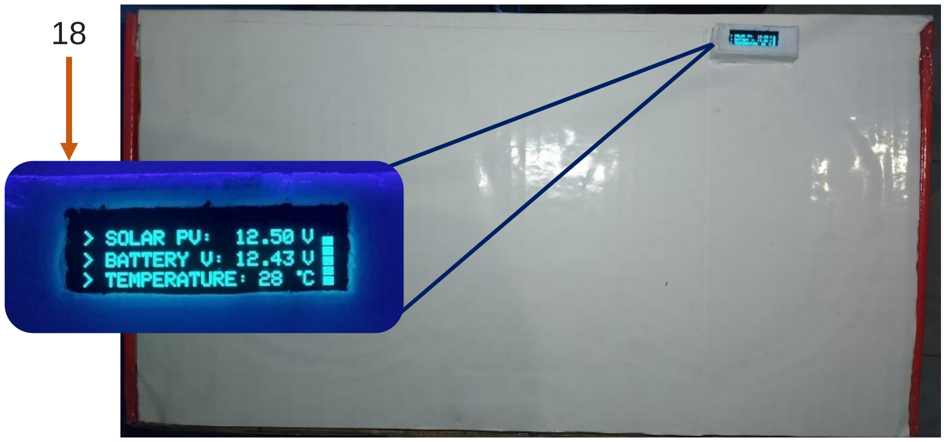
9. Current Sensor – Every solar panel has this sensor to measure per panel ampere.
10. Panel Power Wire Connection Box
11. NRF24L01 2.4GHz Wireless Transceiver Module
12. DHT11 Sensor Module (Temperature and Relative Humidity)
13. DS3231 RTC Module
14. Voltage Sensor - Every solar panel has this sensor to measure per panel voltage.
15. Buck Converter (Step-Down) – Power supply for Arduino Mega
16. Snow & Raindrops Detection Sensor (Module)
17. 5V Power Supply – For sensors and actuator
18. DS18B20 Sensor (Module)
19. Arduino Mega Power Supply Input
20. Arduino Mega Board

21. Uncovered LDR Sensor –Our system uses this LDR sensor and the Covered LDR sensor to detect dust particles on the solar panel.

6.2.2.2 Indoor Unit

Inverter Unit





1. 12V/24V Auto Solar Panel Charge Controller
2. Ampere Sensor – Used to measure Solar PV Input Ampere
3. Solar PV Input
4. Battery Connection – Connected a 12V battery
5. Inverter Power Input (12V DC)
6. Buck Converter (Step-Down) – Power supply for cooling fan
7. Cooling Fan – To manage temperature inside the inverter unit
8. 12V DC 500W Inverter
9. Inverter Power Output (210V – 230V AC)
10. Temperature Sensor – Used to measure temperature inside the inverter unit
11. Arduino Uno Board
12. Buzzer – Give warning signals and startup sound

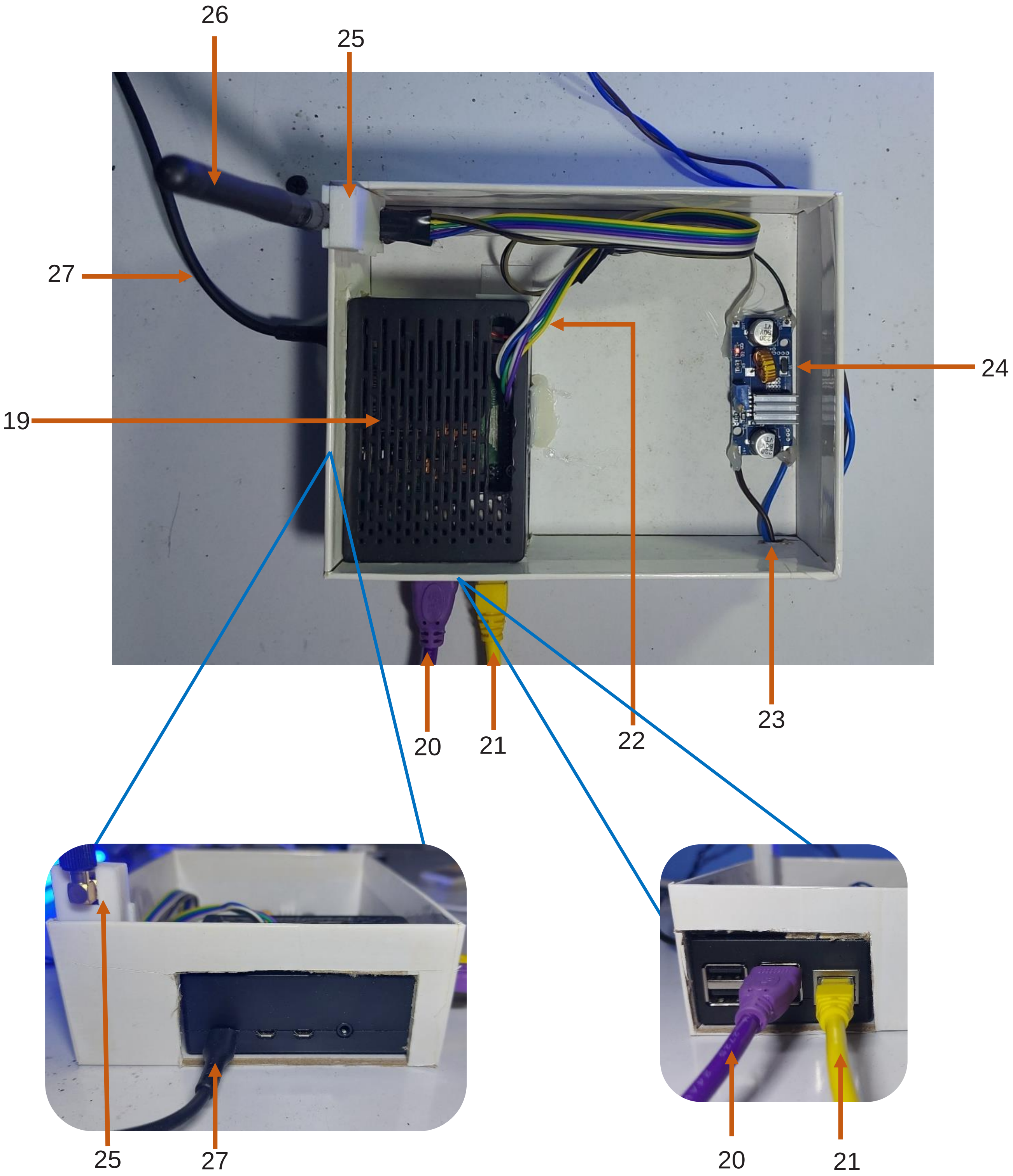
13. USB Cable – This cable connects with the Raspberry PI and sends inverter data using serial communication. In a real implementation, we can use other communication protocols enabled in an industry-level inverter (like Modbus protocol).

14. Buck Converter (Step-Down) and Power supply for Arduino Uno
15. Voltage Sensors – Used to measure Solar PV Input Voltage and Battery Voltage

16. USB Power Output – Raspberry PI power supply cable connect with this USB Port.
17. 12V Power Output – This power output connects to a buck converter and converts that power to below 10V and it connects to the cooling fan.

18. OLED Display – This display is used for only the prototype model.

Edge Controller Unit



19. Raspberry Pi – Edge Computer

20. USB Cable – Connected to the Arduino Uno

21. Ethernet Cable – Connected to the router to send data to the cloud storage, or user can use Wi-Fi to connect with the router.

22. Jumper Wires Connection – Used for connecting NRF24L01 Module

23. 12V Power Input – Give power to the Buck Converter (24)

24. Buck Converter (Step-Down) – Power supply for NRF24L01 module (Convert 12V Input power to 3.3V)

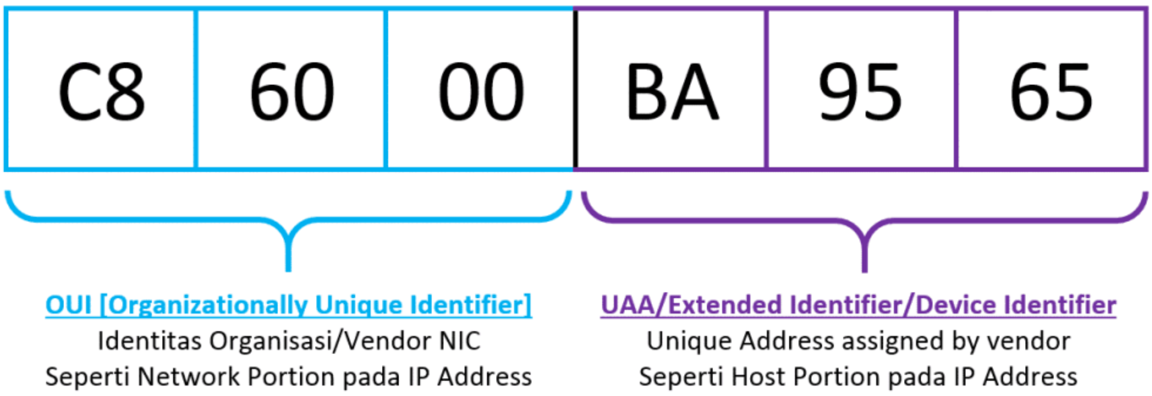
25. NRF24L01 2.4GHz Wireless Transceiver Module

26. Extremal Antenna for NRF24L01 Module

27. USB Type-C Power Supply

6.2.3 Network: Device Identification

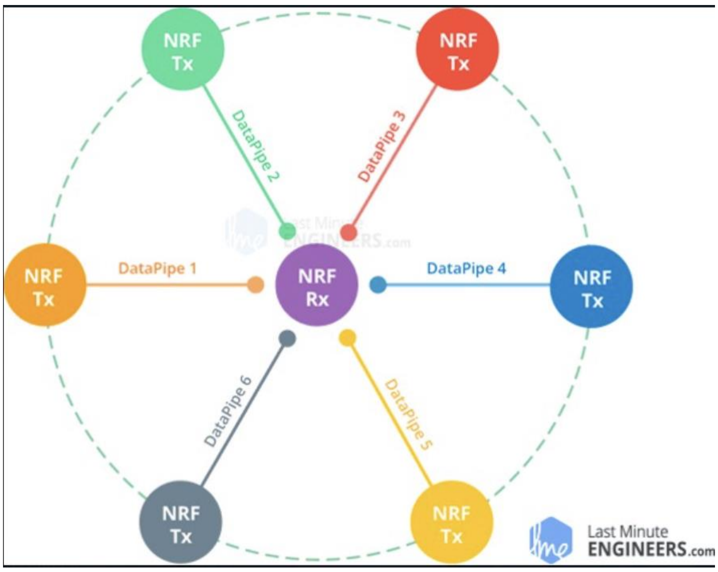
A media access control address (MAC address) is a unique identifier assigned to a network interface controller (NIC) for use as a network address in communications within a network segment. (Lawrence Technological University, n.d.)



(Huawei Enterprise Support Community, n.d.)

Each device component in this project is assigned a unique MAC address. It allows the edge controller to identify each panel array separately. Controller nodes' mac address is used to identify Azure Hub devices.

6.2.3 Network: NRF24L01

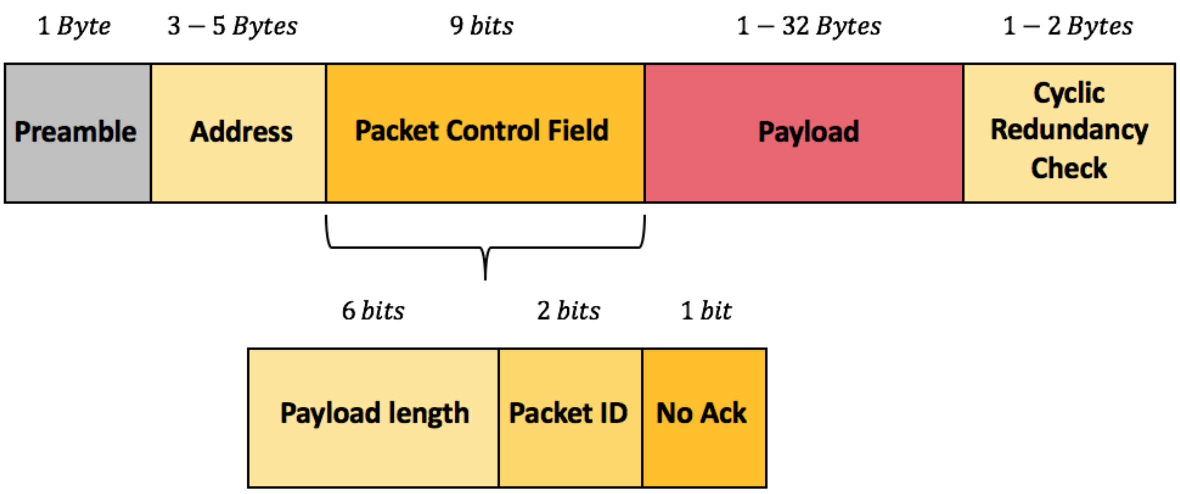


(Lastminuteengineers.com, 2021)

Panel array node communicates with the edge controller through the nRF24L01+ transceiver module.

Multiple nodes send telemetry data to a single edge controller.

The transceivers will be using a packet structure known as Enhanced ShockBurst. This simple packet structure is broken down into 5 different fields, which is illustrated below.



(Fraser, 2017)

A cyclic redundancy check (CRC) is an error-detecting code which validates where the data frame is damaged during radio transmission. While prototype of this project uses only one panel, a panel array with more panel requires custom protocol on top. CRC available in NRF24L01 module firmware can only validate payload up to 32 bits.

6.3 Software

Modbus is a serial communication protocol developed by Modicon published by Modicon® in 1979 for use with its programmable logic controllers (PLCs). (www.se.com, n.d.) It has become an industry standard for device communications. Newer integrations of Modbus protocol support communication via TCP/IP.

The edge controller has designed with Modbus TCP/IP built in. It allows the controller to connect with Modbus enabled inverters.

7 Helios Cloud

7.1 Telemetry

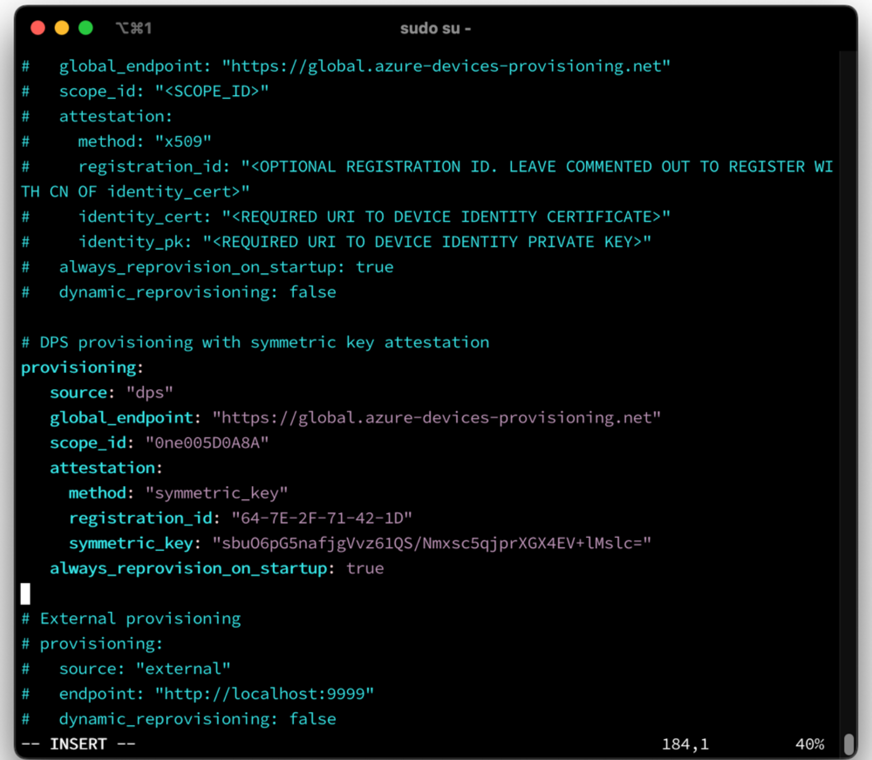
Telemetry is the automatic recording and transmission of data from remote or inaccessible sources to an IT system in a different location for monitoring and analysis. (Stackify, 2017)

Voltage, Amperage, Temperature, Humidity (Rain drop) and LDR reading of sensors are telemetry data of this project.

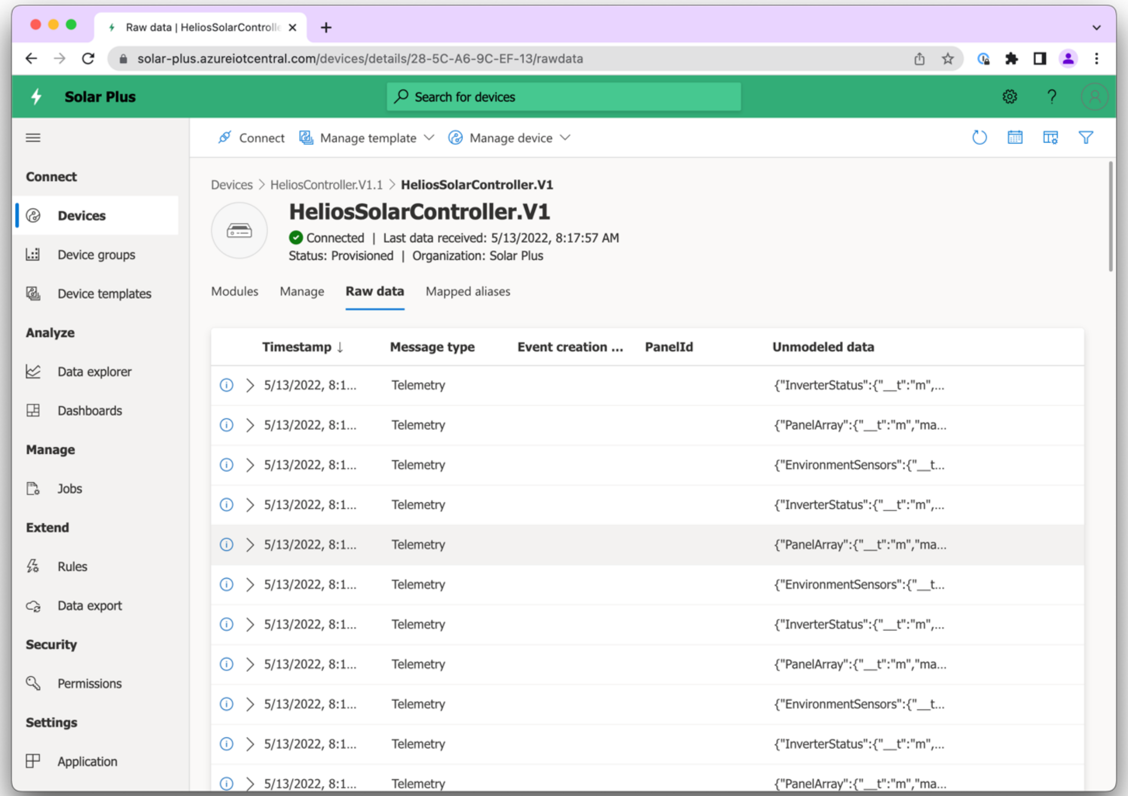
7.2 Azure IOT Hub

Azure IoT Hub is a managed service hosted in the cloud that acts as a central message hub for communication between an IoT application and its attached devices. (kgremban, n.d.)

Each edge controller is registered as a IOT Hub device.

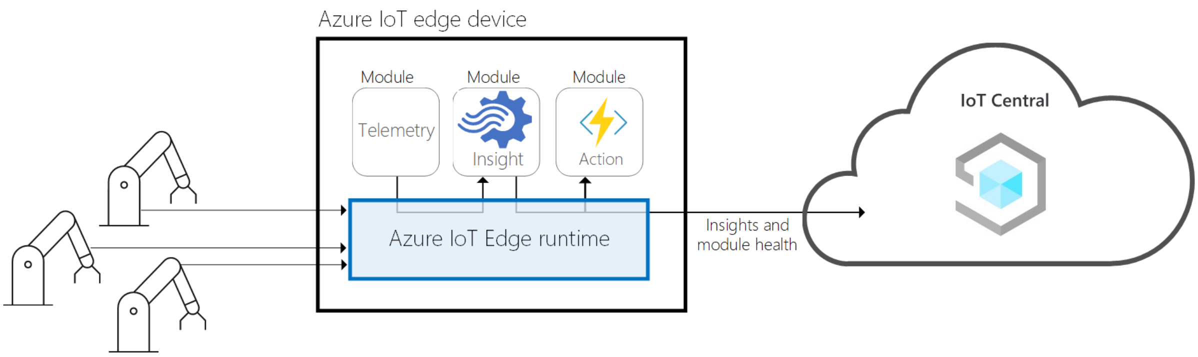


Controller send collected telemetry to azure cloud using MQTT protocol.



Once a device is connected to the Hub its telemetry data is collected and stored in azure storage.

8.3 Automatic Device Update



(dominicbetts, n.d.)

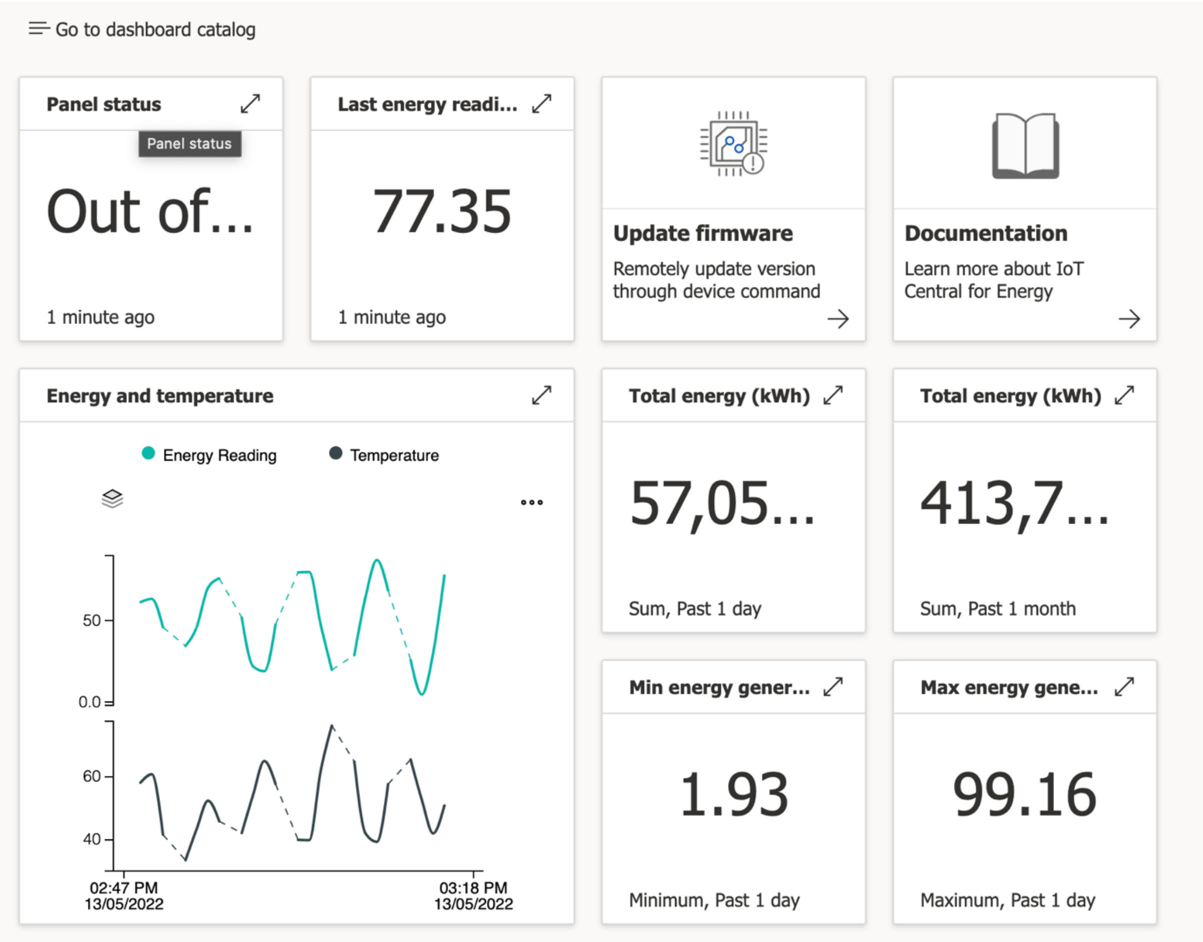
Another featured of incorporating Azure IOT stack to this project is the ability to update device software via Azure device panel. This project includes 2 python-based modules which are installed on edge controller.

1. Panel Array Telemetry collector
2. Inverter Telemetry collector

Raspberry Pi with Ubuntu 20.04 LTS is used in this project in order to fulfil this requirement.

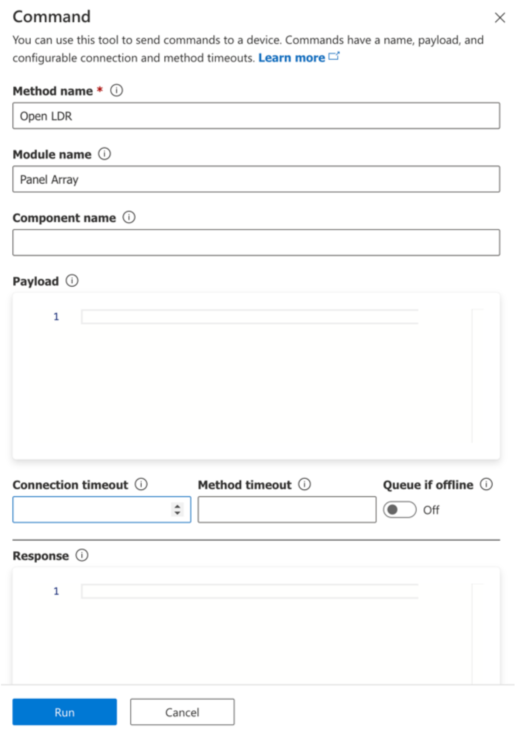
7.4 Visualization

IoT Central is an IoT application platform as a service (aPaaS) that reduces the burden and cost of developing, managing, and maintaining enterprise-grade IoT solutions. It also allows the creation of white label IOT solutions with data visualization built in.



7.5 Commands

The control LDR sensor is in closed state. Using Azure Device UI a message can be send back to a running device instance to get current readings.



8 Device Information (Sensor List & Module List with Pin Connectivity)

Arduino Mega – nRF24L01 +

- GND – Ground
- VCC – 3.3 v
- CE – D9 (Yellow)
- CSN – D8 (Green)
- SCK – D52 (Gray)
- MOSI – D51 (Blue)
- MISO – D50 (Orange)

Arduino Mega – Sensors

- Panel Voltage Sensor Signal – A0 (Green)
- Covered LDR Sensor Signal – A1 (Purple)
- Raindrop Sensor Signal – A2 (Gray)
- Panel Ampere Sensor Signal – A3 (Gray)
- Opened LDR Sensor Signal – A4 (Orange)
- DHT11 Sensor Signal (Panel Temperature) – D10 (Brown)
- DS18B20 Sensor Signal (Environment Temperature)– D11 (Yellow)

Arduino Mega – Actuator

- Servo Motor – D7 (Brown)

Arduino Mega - RTC Module

- SCL – D21 (Green)
- SDA – D20 (Orange)
- GND – Yellow
- VCC - Red

For Each Solar Panel

- Panel Voltage Sensor – Analog
- Panel Ampere Sensor – Analog
- DHT11 Sensor Signal (Panel Temperature) – Digital
- Opened LDR Sensor – Analog

Arduino Uno – Inverter Processing Unit

- Solar Voltage Sensor Signal – A1 (Brown)
- Battery Voltage Sensor Signal – A0 (Orange)
- Solar Ampere Sensor Signal – A2 (Blue)
- DHT11 Sensor Signal (Inverter Temperature) – D7 (Gray)
- OLED Display SCL – A5 (Gray)
- OLED Display SDA – A4 (Purple)

Raspberry Pi

- CE – GPIO23 (White)
- CSN – GPIO8 (Yellow)
- SCK – GPIO11 (Gray)
- MOSI – GPIO10 (Green)
- MISO – GPIO9 (Purple)
- IRQ – GPIO6 (Blue)

Conclusion

In conclusion we plan on making a monitoring system that acts as an upgrade over existing systems. With more sensors and better communication and information exchange between the Solar panel and the user, with the goal of streamlining and improving the decision making that can be done by the information received from our monitoring system. Project Helios will incorporate techniques and standards already present to make this system familiar and user friendly to new or experienced users alike. In the current situations we face globally and domestically, the creation of such a system would allow for more people to change to a better, less polluting method of generating the power needed for their day to day lives.

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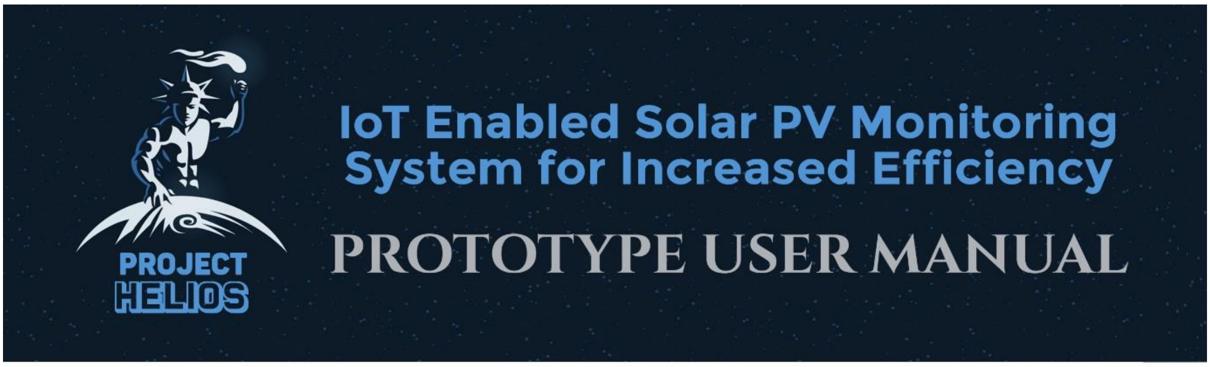
Group Contribution

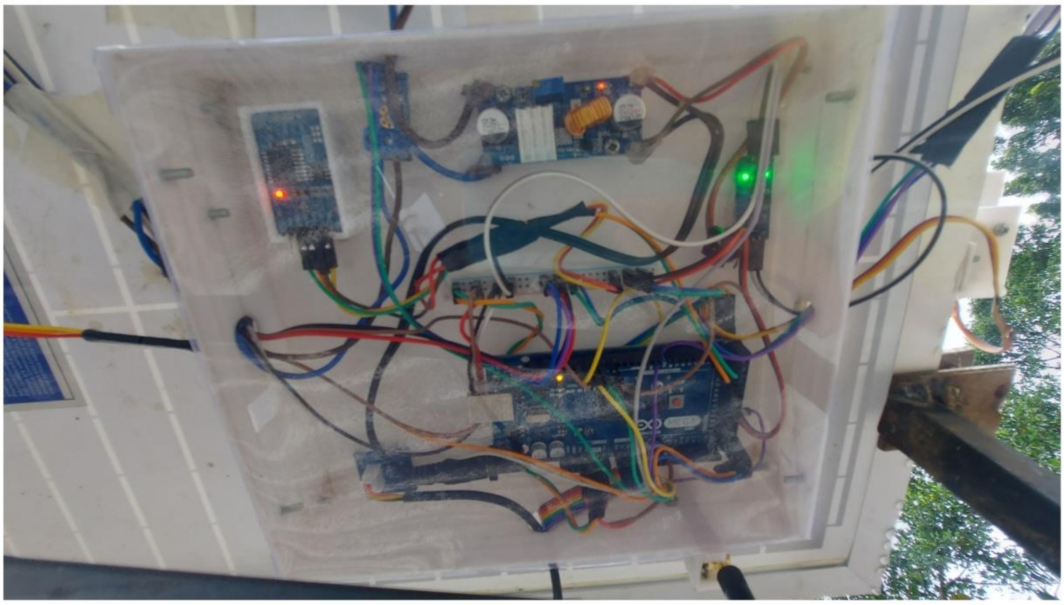
Index No	Name	Project Responsibility	Paperwork
	Galpola Galpola	Hardware Integration 3D Printing Components Arduino Programming	Application Product Description System Diagram
	Appukutti Munasinghe	Protocols	Document Research
	Warnakulasooriya Peiris	Python Edge programming Arduino Programming	Sensor device information Applications User Manual
	Hettiarachchige Hettiarachchi	IOT architecture	Document Research
	Dedugala Bandara	Azure IOT Integration Python / Arduino Programming	Helios Cloud Networking Components
	Edirisinghe Edirisinghe	User Manual Designing	User Manual

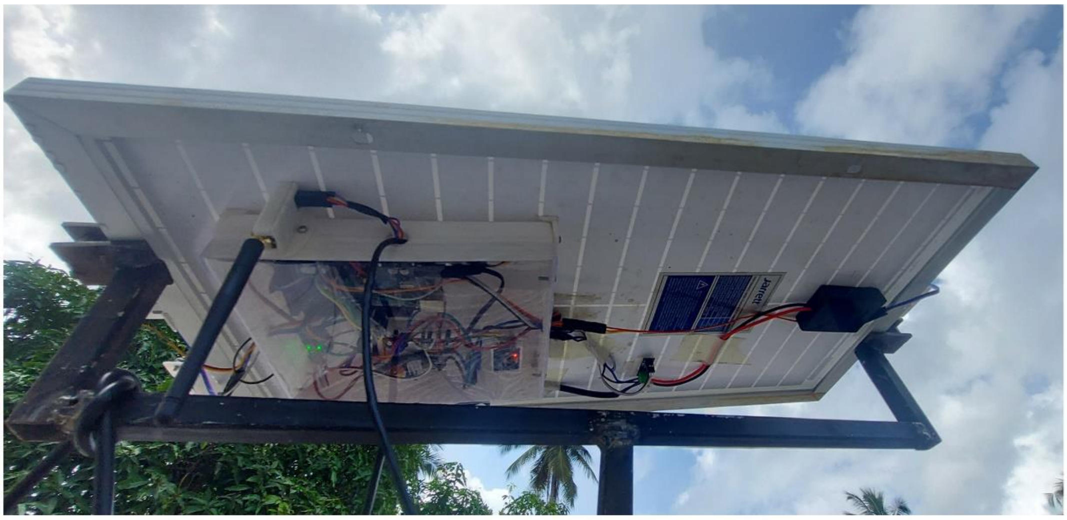
Appendices

User Manual



Project Helios aims to create an updated take on the Solar PV Monitoring system. Regardless of the scale of these systems, the ability to constantly monitor the systems will aid in effective decision making on the part of the user. We aim to provide accurate and up-to-date information about the solar panels using a collection of sensors, none of which are used all together in present systems.





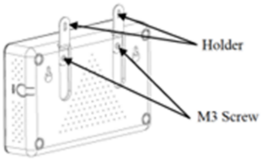
PROJECT HELIOS

Parameter Table

Model	Helios+ V1.0
Maximum input power	600W
Peak power tracking voltage	12V System < 25V
Min / max starting voltage	12V System < 25V
Maximum DC short-circuit	30A
Maximum input operating current	30A
Output Data	12V System
Peak power output	500W
Rated output power	500W
Rated output current	5A
Rated voltage range	210V – 220V AC
Rated frequency range	45Hz – 50Hz
Power Factor	> 99%
Max unit per branch circuit	2pcs (Single Phase)
Output Efficiency	12V System
Static MPPT efficiency	99.5%
Maximum output efficiency	95%
Nighttime power consumption	< 2W
THD	< 5%
Exterior & Feature	
Ambient temperature range	-35°C to +60°C
Dimensions (L × W × H)	402mm x 202mm x 101mm
Weight	1.2kg
Waterproof rating	- (This Inverter is Only for Indoor use)
Cooling	Self-cooling (Cooling Fan Included)
Communication Mode	Serial Communication with Edge Computer
Power transmission mode	Reverse transfer, load priority
Monitoring System	Web Browser / 128 x 32 OLED Display
Electromagnetic Compatibility	--
Grid disturbance	Off Grid System
Grid detection	Off Grid System

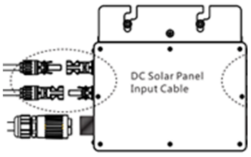
Step 1

Installation for fixed the inverter on the M3 holder with the screws attached is as following



Step 2

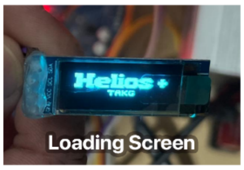
Connect the DC terminal of the solar to the inverter positive to positive, negative to negative. Shown below:

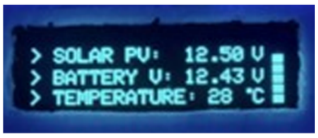


Notes

- Please connect the inverter following the operation instruction shown above. If have any question, please contact with relative persons.
- Non-professionals do not disassemble. Only qualified personnel may repair this product.
- Please install inverter in the low humidity and well- ventilated place to avoid the inverter over-heating, and clear around the inflammable and explosive materials.
- When using this product, avoid children touching, playing, to avoid electric shock.
- Connected solar panels, battery, or wind generators DC input DC power supply cable.

LED Display



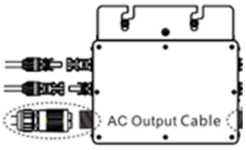


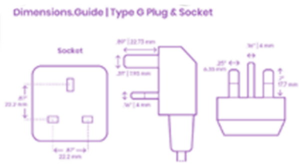
Buffer

3 second--- "Beep" sound, 3 second while device

Step 3

Plug to AC power line. Show below:





Step 4

Plug the AC output line to main AC cable;

Step 5

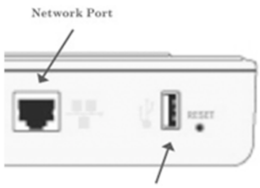
Repeat the first step to the third step to complete the installation of micro inverters;

Step 6

Finally, please connect the AC main cable to the utility grid.

Step 7

Connect to inverter to internet



PROJECT HELIOS

Internet Connction

There are two different approaches to connecting the ECU to the Internet:
• Direct CAT5 network connection to a broadband router.
• Wireless connection to a wireless broadband router

Direct CAT5 Connection

1. Make sure the CAT5 cable is connected to the network port on the bottom of the inverter.
2. Connect the CAT5 cable into a spare port on the broadband router.

Wireless Connection

Wireless Connection Using the internal Wi-Fi capabilities of the inverter:
Join the Wi-Fi to the site's LAN via the inverter's wireless functionality

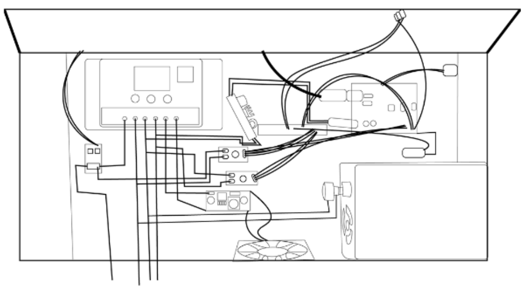
Power Up Inverter

1. Make sure the power cable is correctly connected to the power connection port on the bottom of the inverter
2. Plug the power cable into a dedicated standard AC electrical outlet.

WARNING: Make sure to use a dedicated outlet for the inverter. Do NOT plug any other devices into the same outlet as the inverter.

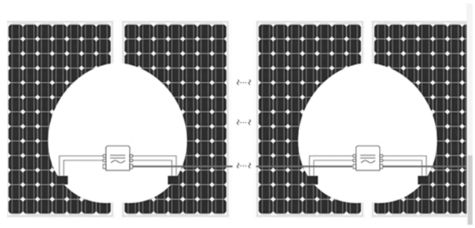
WARNING: Do NOT plug the inverter into a power strip, surge protector, or uninterruptable power supply (UPS). The surge suppression and/ or filtering on these sorts of devices will substantially diminish PLC performance

Inverter Unit



Add Up For Per Array

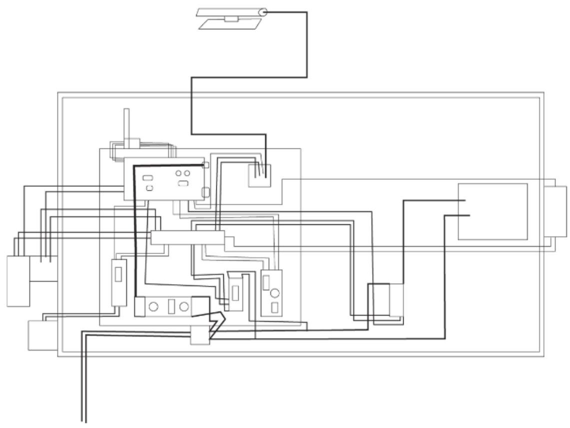
1. Turn off the System and remove Ac power cable
2. Add new panel and set sensors on Grid



Monitoring System Operating Instructions

1. The first time the inverter is powered up it is going to "192.168.1.31" and display the available Wi-Fi network IP, as well as the internal LAN IP Address.
2. Please enter the password of your network
3. After entering the wi-fi password, the inverter will remain in the normal working and "beep" sound

Per Array Controlling Unit



Edge Computer