DEPARTRMENT OF ELECTRICAL AND INFORMATION ENGINEERING

FACULTY OF ENGINEERING
UNIVERSITY OF RUHUNA

INDUSTRIAL TRAINING REPORT SUBMITTED IN PARTIAL FULFILMENT OF THE DEGREE OF THE BACHELOR OF THE SCIENCE OF ENGINEERING

10TH OF MARCH 2025

INVO TECH HOLDINGS (PVT) LTD,
RODRIGO ROAD, DEHIWALA

(FROM 18TH NOVEMBER 2024 TO 07TH FEBRUARY 2025)
SHAHMI A.J.A (EG/2020/4333)

PREFACE

This report contains my experience throughout my second Industrial Training program for Engineering Undergraduates and my experience as Electrical and Information Engineer at Invo Tech Holdings from 18th of November, 2024 to 7th of February, 2025, where I worked in the electronics sector, energy sector specifically smart energy plug, smart meter and solar power for three months. The aim of this report is to explore what I have learned, gained, achieved and experience during my internship journey inside the organization.

I completed this 12 weeks of Industrial Training period under the guidance of Engineering Education Center of Faculty of Engineering, University of Ruhuna and National Apprentice and Training Authority (NAITA). This report brings the knowledge and experience that I got during my Industrial Training at Invo Tech Holdings.

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ACKNOWLEDGEMENT

I would like to express my heartfelt gratitude to everyone who supported me during my internship at Invo Tech Holdings. This experience has been incredibly valuable, and I am grateful for the guidance and assistance I received throughout.

First and foremost, I would like to thank Eng. Mr.Farnaz (managing director) for including me into his organization as a trainee. His guidance and encouragement throughout my internship were instrumental in my development. He provided me with insightful feedback and constructive criticism, which helped me refine my skills and grow professionally in the industry. I truly appreciate the time and effort he invested in mentoring me.

I would also like to thank my Supervisor, Mr. Assam for his collaboration and expertise. His willingness to share knowledge and involving me in various projects enriched my learning experience significantly. Working alongside him was both inspiring and enlightening.

Moreover, I am grateful to the entire team at Invo tech holdings for fostering a welcoming atmosphere. The shared commitment to innovation and excellence in the field was inspiring and motivated me to contribute my best. This internship has deepened my passion and equipped me with valuable skills that I will carry into my future endeavors. Thank you all for being a part of this transformative experience.

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1.1 Profile

Figure 1.1: Logo of Invo Tech Holdings (Pvt) Ltd

InvoTech Solar is a subsidiary of InvoTech Holdings (Pvt) Ltd, dedicated to the development and growth of renewable energy solutions. Our main goal is to provide innovative solutions to meet energy needs. Including energy monitoring Heating Air-to-air air conditioning (HVAC) systems, low voltage electrical systems (ELV) and various advanced technologies in the field of engineering. We are committed to having a positive impact on the environment and strive to be a leader in these important areas. Our team is comprised of experienced professionals who come from a variety of backgrounds and expertise. This diverse team allows us to provide a wide range of high quality products and services at competitive prices. We value customer satisfaction and work hard to ensure our customers receive exceptional support on their projects. Combining our expertise with dedication at an affordable price.

We aim to provide effective solutions that meet the needs of our customers. At the same time, it promotes a sustainable future.

1.2 Vision

“Empowering a sustainable future by harnessing the sun’s energy to provide clean, affordable, and innovative solar solutions for every community, fostering a world where renewable energy is the norm and environmental stewardship is a shared commitment.”

1.3 Mission

"To lead the transition to renewable energy by delivering high-quality solar solutions that enhance energy independence, reduce carbon footprints, and promote sustainability. We are committed to educating communities, providing exceptional customer service, and promoting innovation to create a cleaner, greener future for all."

1.4 Organization Structure

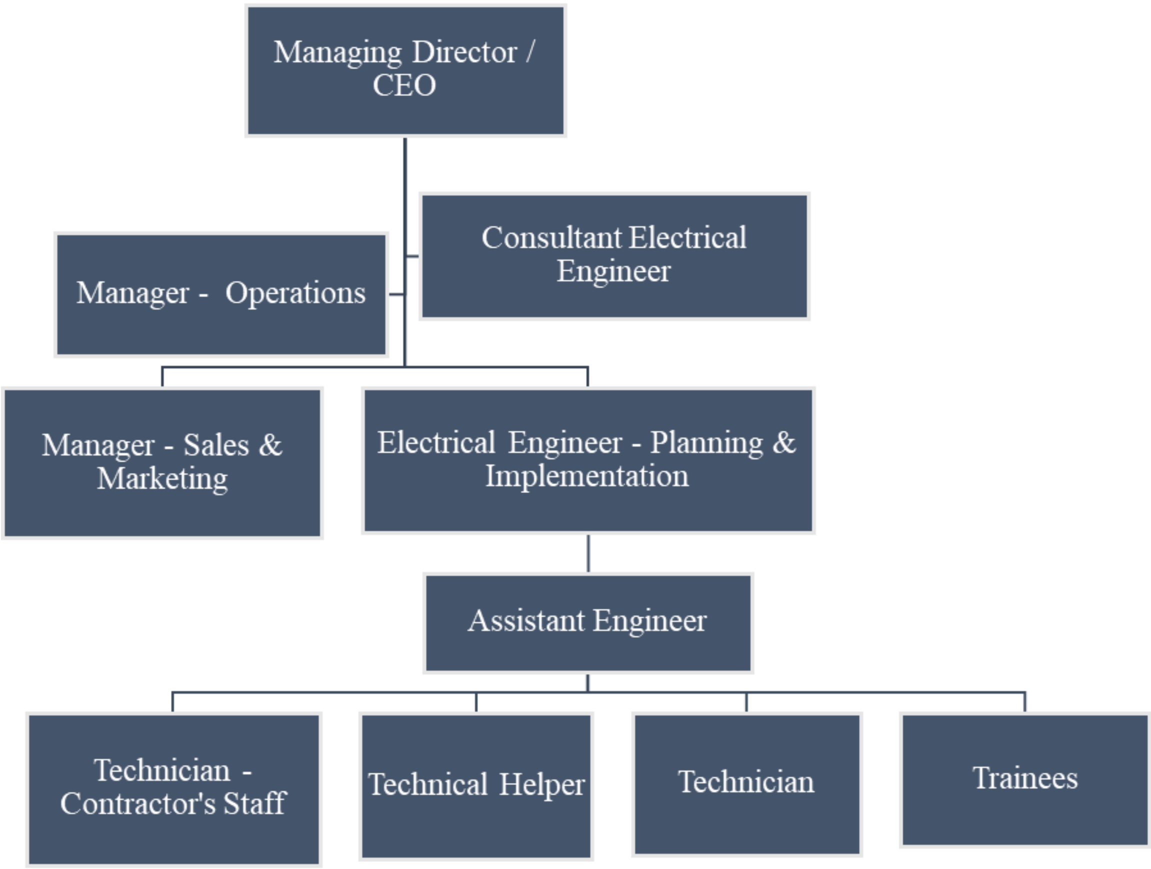


Figure 1.2: Organization Structure

1.5 Nature of Business

- ✓ Service we offer:

  - Solar PV system Installation and maintenance.
  - Electrical design and installation
  - Building Automation.
  - Extra Low Voltage (ELV) system design, supply and installation.
  - Energy Auditing and power factor correction
  - HVAC system Installation and Maintenance.

1.6 Number of Employees

- Administrative staff – 03
- Electrical engineer – 02
- Assistant engineer – 01
- Sales manager – 01
- Technicians – 02

1.7 Employee Provident Fund (EPF)

8% of the employee’s salary and 12% contributed by company will be remitted to the Central bank of Sri Lanka employee’s provident fund. Every employee contributing to the EPF will be assigned a membership number. All should fill in form A and submission same to Labor dept.” B” card will be issued by the Commissioner of Labor which should be kept with the employee to be produced at the time of withdrawal of benefit. EPF benefits could be withdrawn on resignation / retirement.

1.8 Employee Trust Fund (ETF)

Company will contribute an amount of equivalent to 4% of the employee’s salary to employee’s Trust fund. Bi annual returns are sent to all employees indicating the amount laying to their credit both by EPF and ETF.

2. Chapter 2: Training Experiences – Technical

2.1 Introduction

It was a great experience that I got in the Invo Tech Holdings (Pvt) Ltd, which mainly involved in Solar PV system installation with the training of 12 weeks durations started from 18th of November, 2024 to 7th of February, 2025 and I was able get a professional engineering experience. This program provided me with essential professional engineering experience, helping me bridge the gap between theoretical knowledge and practical applications in solar PV system installation and related technologies.

Throughout the training period, I was actively engaged in a range of activities that allowed me to gain insights into the technical and operational aspects of solar PV systems and smart technologies. During this 12 weeks of training I was engaged in several works and learnt about devices.

Here are the sections I worked.

- Smart Plug Designing
- Theoretical components and its functions of Solar PV system
- PV Syst simulation software
- Online configuration of Solar Plant with Solis Cloud app

Overall, my 12-week training at Invo Tech Holdings (Pvt) Ltd provided me with a well-rounded experience in solar PV systems and smart energy technologies. I gained a deeper understanding of design principles, simulation tools, and installation techniques, all of which will serve as a strong foundation for my future endeavors in the field of renewable energy.

2.2 Smart Plug Designing

On this section of my studies, I have learnt smart plugs and usage in industry. With growing concerns about energy consumption, there is a need for smart home devices that can monitor and control appliances efficiently. Ain to develop a smart plug that measures the voltage, current, and power usage of connected devices.

I have assigned to do the task to study about smart plug. I researched and selected components for the smart plug. Understood its block diagram and configurations. Focused on the ACS712 current sensor, analyzed its characteristic curve, and understood its noise elimination techniques. Moreover, I studied ZMPT101B voltage sensor, its characteristic curve and noise elimination method. Additionally I researched the esp32 micro controller, its pins' functionalities, and how it process input signal from sensors.

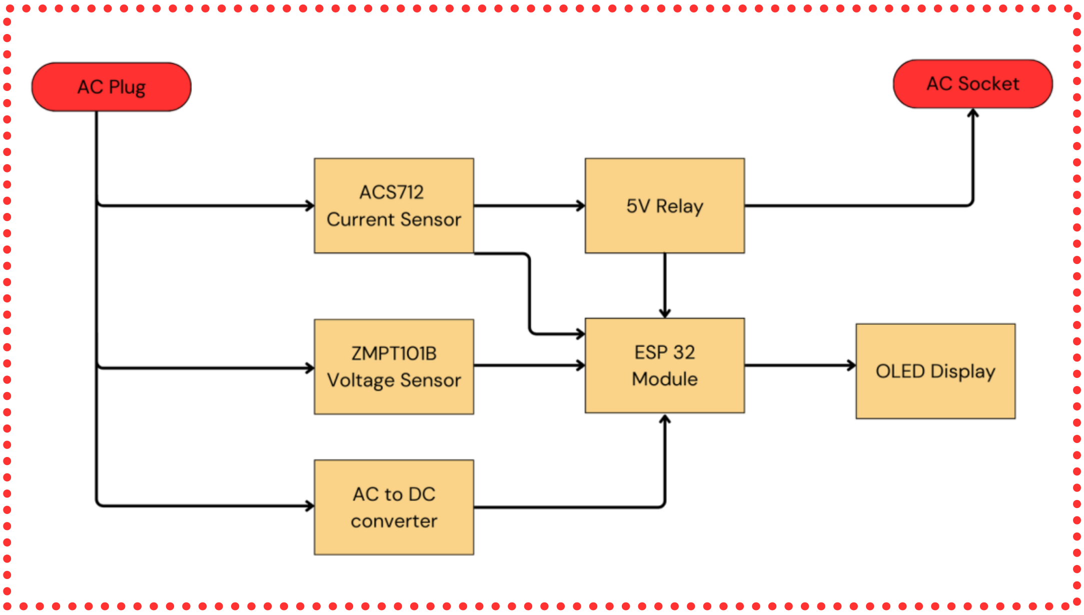


Figure 2.1: Block Diagram of Smart Plug

The smart plug implementation begins with the AC plug supplying power, which is converted to DC through an AC to DC converter to power all components. The ACS712 current sensor measures the current by being connected in series with the load, while the ZMPT101B voltage sensor measures voltage by connecting in parallel to the AC line. Both sensors send their readings to the ESP32 controller, which processes the data. The ESP32 controls a 5V relay to switch the AC socket (and the connected load) ON or OFF based on commands received. An OLED display is used to show real-time measurements of current, voltage, and power consumption.

2.2 ACS712 Current sensor

ACS712 is a current sensor and it is an analog sensor, which is used in both ac and dc current.

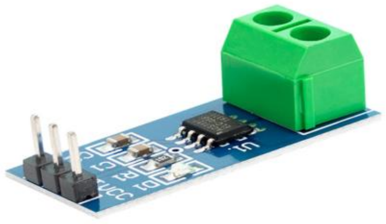


Figure 2.2: ACS712 Current sensor

Working

The ACS712 needs 5V at the VCC pin to operate. The output voltage, is just the result of current measurement and does not affect the sensor's power requirements. The Hall sensor inside the ACS712 detects the magnetic field created by the current flowing through the conductor (like a wire) placed inside the sensor's current path. The Hall Effect sensor produces a small output voltage that is proportional to the magnetic field generated by the current.

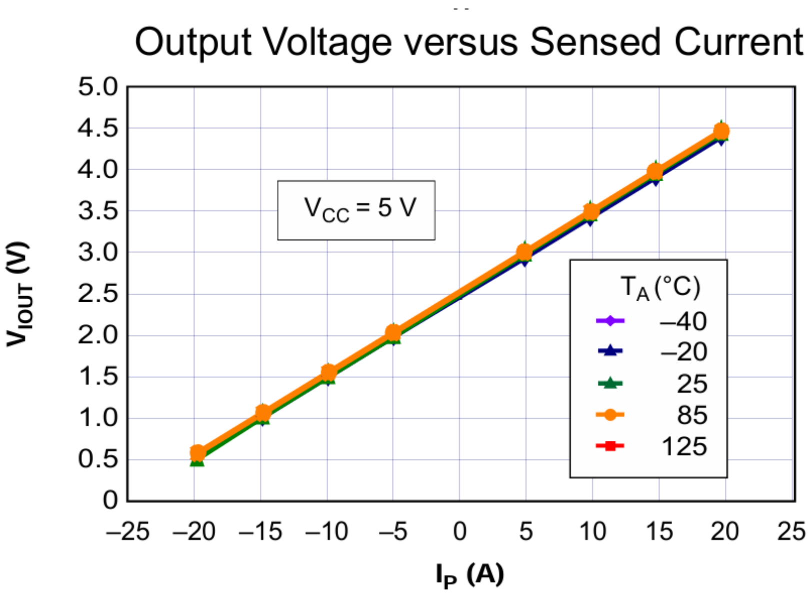


Figure 2.3: Characteristic curve

The esp32 determines the current by processing the sensors output voltage using its ADC.

$$ADC\_Value = \frac{(Measured\ Voltage)}{(Reference\ Voltage)} \times ADC\_Ref$$

Throughout the hardware filtering, which is adding a capacitor across the output pin and GND.

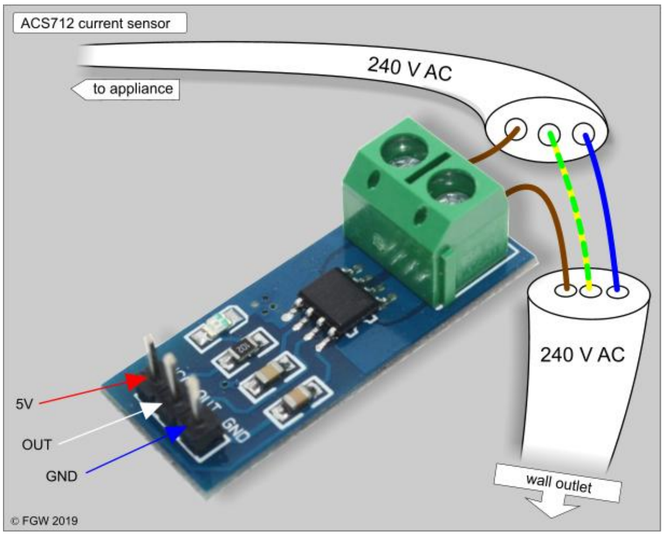


Figure 2.4: Configuration of acs712 sensor

Table 2.1: Configuration between esp32 and acs712 current sensor

ACS712 Sensor	ESP32
VCC	5V
OUT	ADC Pin (eg: GPIO34 on esp32)
GND	GND

ZMPT101B Voltage sensor

ZMPT101b voltage sensor is an analog sensor, which is used only in ac current. Output Voltage is Analog. Analog signal proportional to measured voltage.

Input voltage range

- 70V to 250V RMS
- For measure higher voltage external additional circuitry can be used. (Use voltage divider

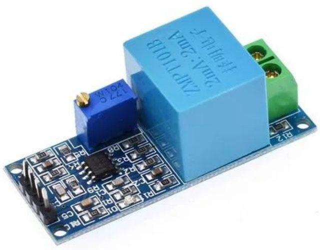


Figure 2.5: ZMPT101B voltage sensor

Working

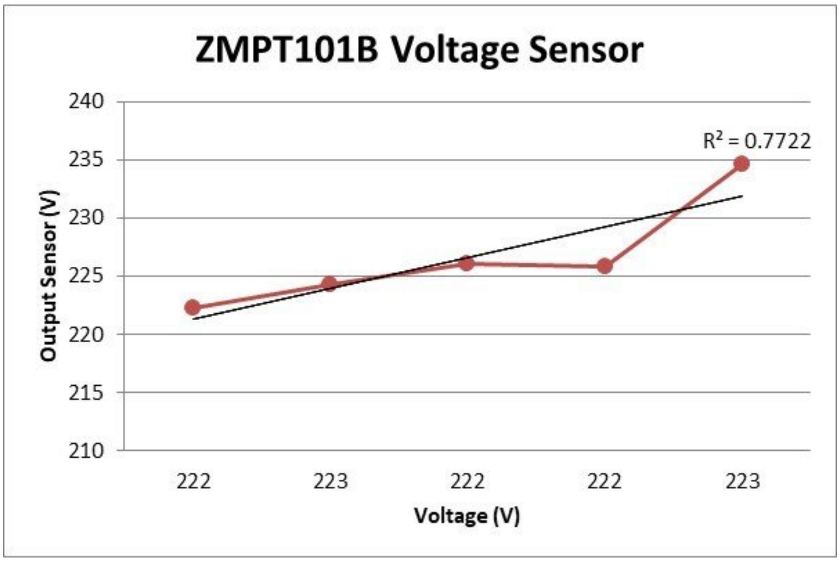


Figure 2.6: Characteristic curve

In this graph, R^2, also known as the coefficient of determination, is a statistical measure that indicates how well the regression line fits the data points.

- R^2=1: Perfect fit - all data points lie exactly on the regression line.
- R^2=0: The regression line does not explain any of the variation in the dependent variable.

Here, R^2=0.7722 suggests that approximately 77.22% of the variance in the sensor output is explained by the input voltage, indicating a moderately strong correlation between the two variables.

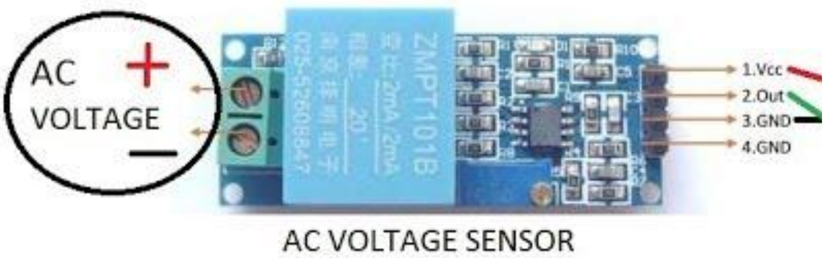


Figure 2.7: Configuration of ZMPT101B sensor

Table 2.2: Configuration between esp32 and acs712 current sensor

ZMPT101B Sensor	ESP32
VCC	5V
OUT	ADC Pin (eg: GPIO34 on esp32)
GND	GND

PZEM-004T Power sensor

Instead of using separate current and voltage sensor we can use power sensor. We can measure power directly using power sensors, which are designed to measure electrical power (active, reactive, and apparent) without requiring separate voltage and current measurements.

A highly popular module for monitoring AC voltage, current, and calculating active power, reactive power, and energy consumption.

- Range: 80V to 260V AC, up to 23kW power.
- Interface: UART (TTL or RS485).

Figure 2.8: PZEM-004T Power sensor

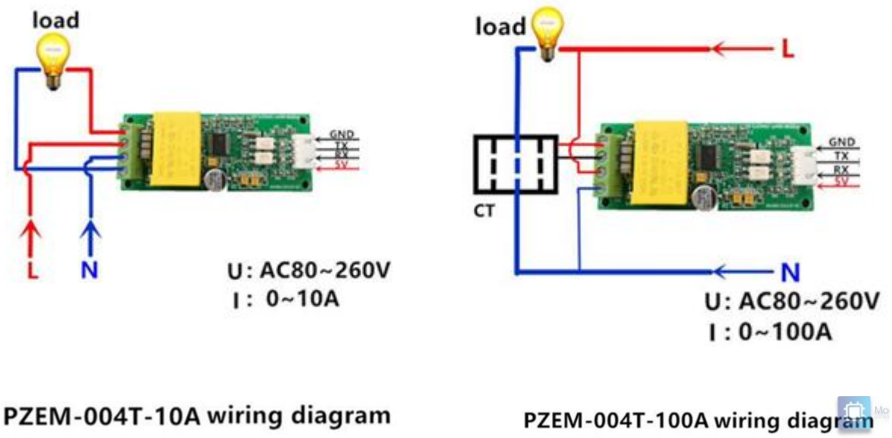


Figure 2.9: Configuration of PZEM-004T Power sensor

In the PZEM-004T power sensor, a current transformer (CT) is used to measure high currents (e.g., up to 100A) because CTs are ideal for handling high-current applications while providing electrical isolation and safety. Without isolation, the measurement circuit could be exposed to hazardous voltages, risking damage or shock.

However, when measuring lower currents (e.g., 10A), a CT is not strictly necessary because direct shunt-based current measurement is more feasible. The voltage drops across the shunt resistor is small and can be accurately measured without excessive heat or resistive losses.

Recommendation

We can use the PZEM-004T in your smart plug project instead of using separate current and voltage sensors. This module integrates the functionality to measure voltage, current, power, and energy, which simplifies the design and improves efficiency.

ESP32 Wi-Fi Module

It can interface with both analog and digital sensor. Input is dc power. Vin is input voltage for power the esp32. Typical input voltage ranges

- Via VIN Pin: 5V DC
- Via USB Port: 5V DC

Figure 2.10: ESP32 Wi-Fi Module

Signal Input for Processing

The ESP32 can work with both AC and DC input signals when connected to appropriate sensors.

Table 2.3: Signal Input of ESP32

Input	**Example Sensors/Devices**	**ESP32 Role**
DC	Potentiometer	Directly reads voltage through ADC or GPIO pins
AC	ZMPT101B, ACS712	Process AC signals via ADC after signal conditioning

Output of the ESP32

The output of the ESP32 can be both digital and analog, depending on how it is configured.

1. Digital Output

The General Purpose Input / Output (GPIO) pins of the ESP32 can be configured as digital outputs. These pins can output digital signals, which are either:

- High (1): 3.3V (logic high)
- Low (0): 0V (logic low)

Sending signals to digital sensors or other microcontrollers. Communication through protocols like SPI, I2C, or UART.

2. Analog Output

The ESP32 has two DAC (Digital-to-Analog Converter) pins, which can generate a true analog voltage output between 0V and 3.3V. These pins are:

- DAC1 (GPIO25).
- DAC2 (GPIO26).

Uses of Analog Output: Generating smooth analog waveforms (sine waves). Driving analog devices directly

PINS

3.3 V - Provide 3.3 V output voltage for peripherals.

5 V - Provide 5 V output voltage for peripherals.

Vin - Input voltage for powering the esp32.

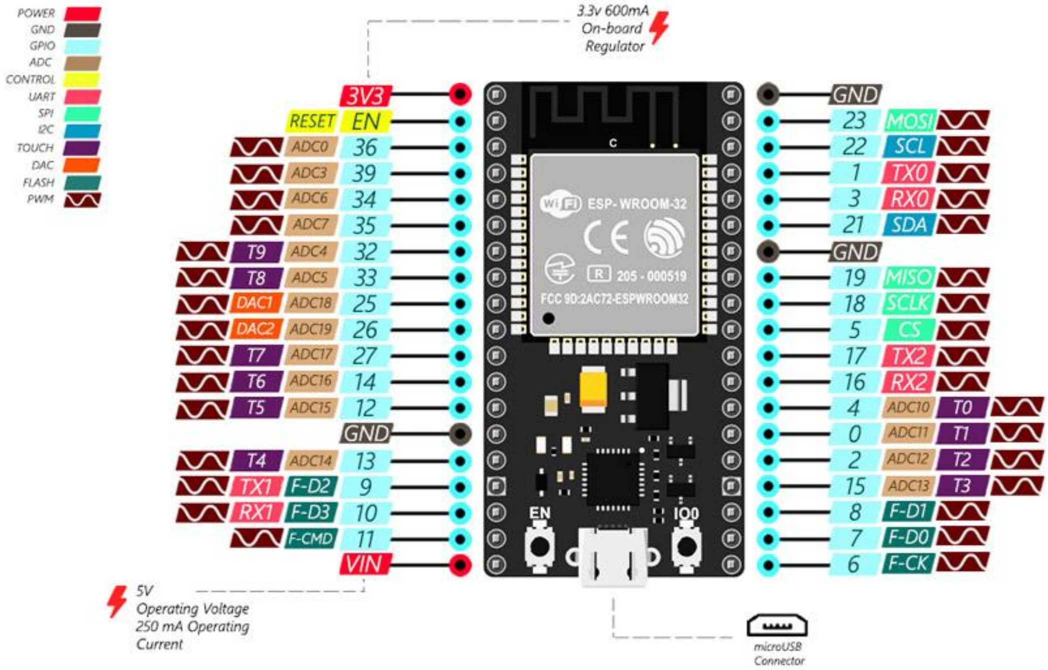


Figure 2.11: PIN Diagram of ESP32

1. SPI - Serial peripheral interface

It can send and receive data simultaneously. Full duplex and fast communication and master can communicate with multiple slaves

HSPI - High speed SPI

VSPI - Versatile SPI

Serial peripheral interface is high speed synchronous serial communication protocols used for communicating between a microcontroller and peripheral devices. Purpose is to enable high-speed communication between the eps32 and peripherals like sensors, displays, memory chips.

SPI pins

MOSI - Master Out, Slave In

MISO - Master In, Slave Out

SCLK - Serial Clock: Synchronous data transfer

It is responsible for synchronizing the transmission of data between devices in a serial communication system.

SS / CS - Slave Select, Chip Select : Select which device to communicate

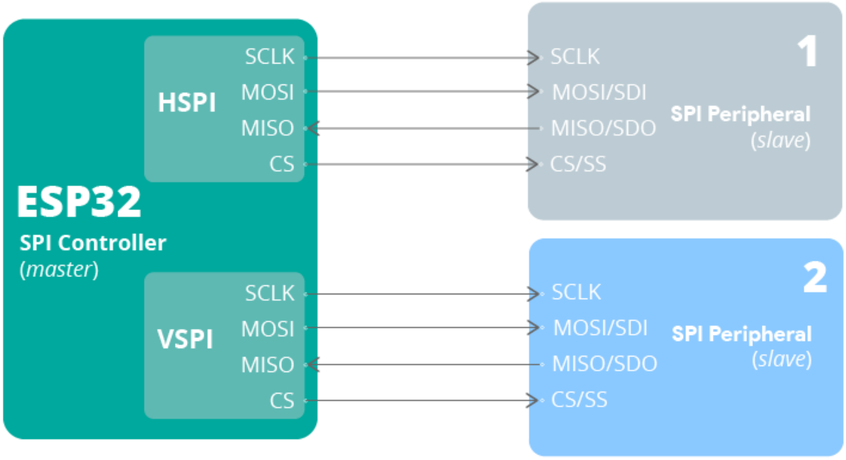


Figure 2.12: SPI Communication between ESP32 and SPI Peripheral

2. ADC pins

The ADC (Analog-to-Digital Converter) and DAC (Digital-to-Analog Converter) pins in the ESP32 are crucial for interfacing with analog signals and devices. The ADC pins convert analog signals (voltages) into digital values that the ESP32 can process.

Key Features of ESP32 ADC:

- 12-bit Resolution: Outputs digital values from 0 to 4095.
- Voltage Range: 0 to 3.3V by default (can vary with attenuation settings).
- Number of ADC Pins: 16 ADC-capable pins, divided between two ADC units (ADC1 and ADC2).

Uses of ADC Pins

1) Reading Analog Sensors:.
   - The ADC reads this voltage and converts it to a corresponding digital value.
2) Measuring Voltage:
   - Monitor battery levels or other voltage signals.

3. DAC pins

The DAC pins convert digital values into a continuous analog voltage.

Uses of DAC Pins

1) Generating Analog Signals:
   - Create sine, triangle, or other waveforms for testing or signal generation.
   - Useful in applications like audio signal output.

3) Controlling Analog Devices:

- Devices like analog actuators, audio amplifiers, or other devices that require a smooth analog voltage.

Key Features of ESP32 DAC:

- 8-bit Resolution: Outputs digital values from 0 to 255, corresponding to a voltage range of 0 to 3.3V.
- Number of DAC Pins: Two pins (GPIO25 and GPIO26)

Table.2.4: Features of ADC and DAC pins

Feature	**ADC**	**DAC**
Function	Converts analog to digital signals	Converts digital to analog signals
Primary Use	Reading sensor data	Generating analog signals
Resolution	12 bits (0–4095)	8 bits (0–255)

4. I2C pins

The I2C (Inter-Integrated Circuit) pins in the ESP32 are used for serial communication between devices. I2C is a popular protocol for connecting multiple devices to a microcontroller using only two wires.

- SDA (Data Line) : GPIO21
- SCL (Clock Line) : GPIO22

The I2C pins enable communication with various peripherals, such as Displays (e.g., OLED, LCD screens).

Key Concepts:

1) Master-Slave Communication:

- The ESP32 typically acts as the Master, controlling communication.
- Other devices (e.g., sensors) act as Slaves.

2) Addressing:

- Each slave device has a unique 7-bit or 10-bit address, ensuring communication with the correct device.

3) Data Transfer:

- Data is sent in packets, which include the address of the device, the data itself, and control bits.

Master in ESP32

- The master is the device that initiates communication on the I2C bus.
- It generates the clock signal (via the SCL pin) to synchronize data transfer and controls the data flow.
- The ESP32 typically acts as the master in most applications, as it coordinates communication with multiple slave devices.

Slave in ESP32

- A slave is a device that responds to the master's requests.
- In some cases, the ESP32 can also function as a slave, where another master device (e.g., another microcontroller) controls it.

MASTER - SLAVE COMMUNICATION

How it Works:

Initiation: The master begins the communication by sending a signal (e.g., data, clock) to the slave(s).

Response: The slave(s) respond with data or acknowledgment when prompted by the master.

Control: The master controls the sequence of communication, and the slaves simply wait for instructions from the master.

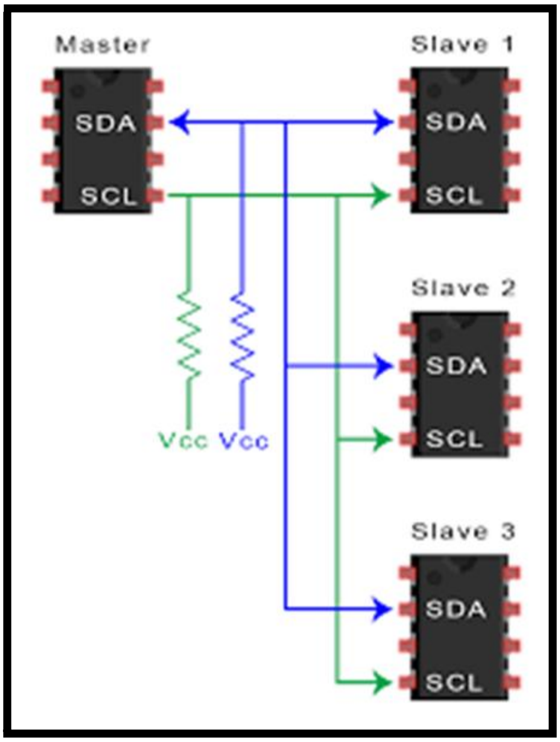


Figure 2.13: I2C Connection

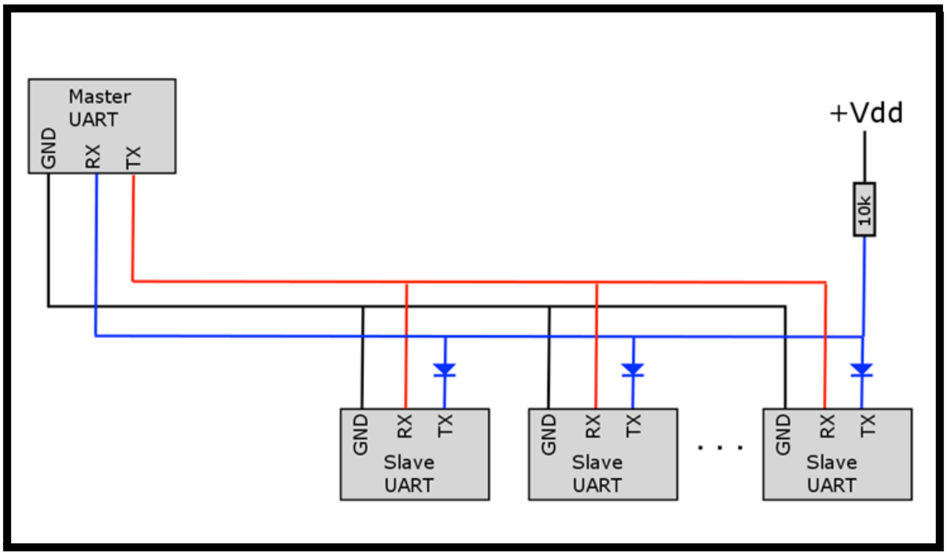


Figure 2.14: UART Connection

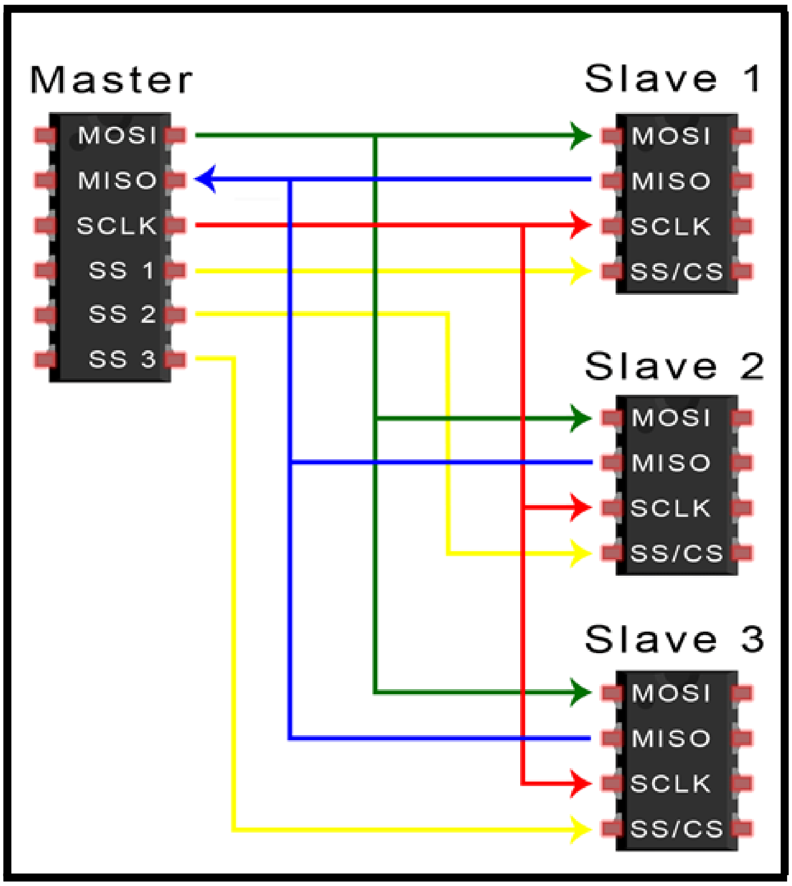


Figure 2.15: SPI Connection

5. TX and RX pins

TX - Transmitter, RX - Receiver

Used for UART communication. UART is communication protocol used for serial communication between devices. UART allows data to be transferred between a transmitter and a receiver.

Signals used in UART communication

- TX signals : Data sent in binary format (0s and 1s) at specified baud rate.
- RX signals : Data received in binary format

Data transmission will happen bit by bit over TX line. Each data framed with a start bit, data bit, parity bit, and stop bit. TX and RX pins transmit and receive a ‘digital serial data signal’. TX and RX pins are designed for digital communication and cannot be used to transfer analog data directly. If you need to transfer analog data, it must first be converted to digital using an ADC (if you're reading data) or a DAC (if you're outputting data). Once the data is digital, it can be transmitted through the TX pin using serial protocols like UART.

HLK – PM01 AC to DC Power Supply

The HLK-PM01 AC to DC Power Supply is a compact, high-efficiency module designed to convert 220V AC to a stable 5V DC output. It is commonly used in smart home devices and IoT applications due to its small size, safety, and reliability. In the smart plug project, the HLK-PM01 will be responsible for providing the necessary 5V DC to power the ESP32, sensors (ACS712 and ZMPT101B), OLED display, and the relay module.

Figure 2.16: HLK – PM01 AC to DC Power Supply

Relay

The Relay in smart plug project is a key component that acts as an electrically operated switch, controlling the connection between the AC power source and the AC socket. It allows the ESP32 to turn the connected load ON or OFF by sending a control signal.

A typical 5V relay consists of a coil and a switching mechanism. When the ESP32 sends a HIGH signal to the relay, it energizes the coil, causing the internal switch to close and complete the circuit, allowing current to flow to the load. When the signal is LOW, the relay de-energizes, opening the circuit and cutting off the power.

Figure 2.17: Relay

Connection between esp32 and relay

When we connect the relay with esp32 why we need to connect external IC between them?

1. Voltage and Current Compatibility
    - Relays need more current to work than the ESP32's pins can provide. ESP32 pins can only give about 12 mA, but relays often need 20–100 mA.
    - Solution:
        - An interfacing IC or circuit is used to amplify the current and match the voltage levels.
2. Protection from Back-EMF
    - When a relay is de-energized, it generates a back electromotive force (EMF) that can damage the ESP32's sensitive GPIO pins or its internal circuitry.
    - Solution:
        - Protection circuits or ICs with built-in protection (like diodes) are used to absorb this back-EMF.

What are the ICs will be connected?

1. Transistor Driver Circuit
   - A resistor is added at the base of the transistor, and a diode (e.g., 1N4007) is connected across the relay coil for back-EMF protection.
2. Optocoupler-Based Circuit
   - An optocoupler (e.g., PC817) is used to isolate the ESP32 from the relay circuit electrically.
   - Components:
     - Optocoupler
     - Transistor or MOSFET to drive the relay
     - Resistors and diodes

Figure 2.18: Optocoupler

ESP32 GPIO Pin → Resistor → Pin 1 (Anode) of Optocoupler

Pin 2 (Cathode) of Optocoupler → Ground (GND)

Pin 3 (Collector) of Optocoupler → Positive Side of Relay Coil

Pin 4 (Emitter) of Optocoupler → Ground (GND)

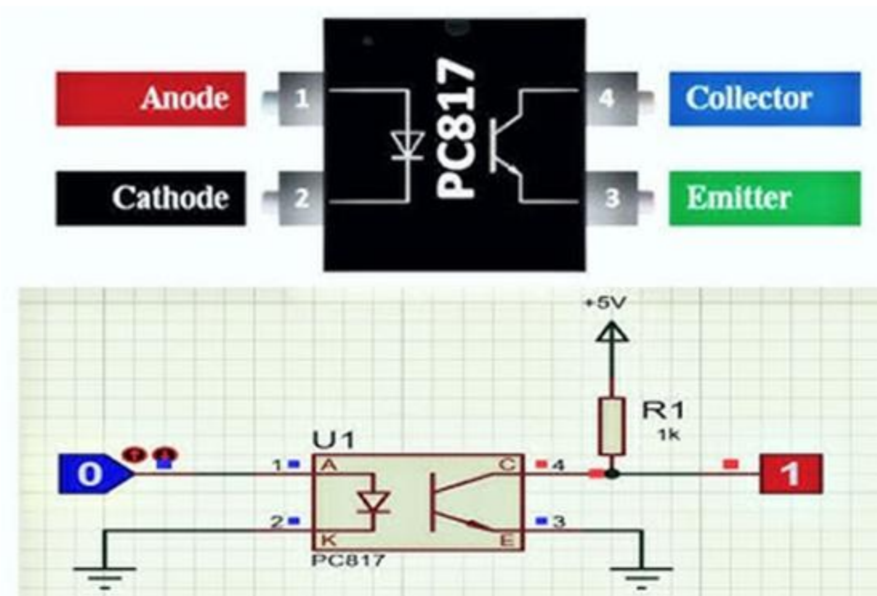


Figure 2.19: Configuration of Optocoupler

How an Optocoupler works?

- When an input voltage is applied, the LED emits light.
- The light is detected by the photosensitive component, creating an electrical signal in the output circuit.
- Since the light physically separates the input and output circuits, there is no direct electrical connection.

Protection from Back-EMF

Relays generate back-electromotive force (EMF) when switching off, which can damage low-power microcontrollers like the ESP32.

2.3 Theoretical components and its functions of Solar PV system

During this phase, I studied the theoretical concepts underlying the DC and AC sides of solar PV systems, which are crucial for understanding their operation and maintenance.

2.3.1 **About solar PV system**

A photovoltaic (PV) system is composed of one or more solar panels combined with an inverter and other electrical and mechanical hardware that use energy from the Sun to generate electricity. PV systems can vary greatly in size from small rooftop or portable systems to massive utility-scale generation plants. Although PV systems can operate by themselves as off-grid PV systems, this article focuses on systems connected to the utility grid, or grid-tied PV systems. The light from the Sun, made up of packets of energy called photons, falls onto a solar panel and creates an electric current through a process called the photovoltaic effect. Each panel produces a relatively small amount of energy, but can be linked together with other panels to produce higher amounts of energy as a solar array. The electricity produced from a solar panel (or array) is in the form of direct current (DC).

Overview of Solar PV Module

To boost the power output of PV cells, the numbers of cells are connected together in chains to form larger units known as modules or panels. Modules can be used individually, or several can be connected to form arrays. One or more arrays are then connected to the electrical grid as part of a complete PV system. Here are some of the essential components of the solar PV module that we have used.

1. **Junction Box:** The junction box is attached to the back of the solar module and contains the electrical connections for the solar cells. It houses diodes, which prevent reverse current flow, and provides the terminals for connecting the module to the rest of the solar power system.
2. **Wiring and Connectors:** These are the components that allow for electrical connections between modules in a solar array. Cables connect the junction box to the inverter and other modules. Connectors like MC4 connectors are commonly used to ensure secure and weather-resistant electrical connections.

Types of Solar PV Panels

1) Monocrystalline (Mono-Si):
- Made from a single silicon crystal.
- High efficiency (15-22%), long lifespan, and performs well in low-light conditions.
- Distinctive black or dark blue color.

2) Polycrystalline (Poly-Si):
- Made from multiple silicon crystals.
- Lower efficiency (13-18%) but more affordable than monocrystalline.
- Bluish appearance due to crystal arrangement.

3) Amorphous Silicon (Thin-Film):
- Made from non-crystalline silicon or other materials.
- Lightweight, flexible, and low-cost but lower efficiency (~10%).
- Often used in portable devices or special applications.

4) Bifacial Panels:
- Can generate power from both sides by capturing reflected sunlight.
- Higher overall energy yield.

5) N-Type and P-Type:
- Refers to the doping of the silicon material.
- N-Type: More resistant to degradation and has a longer lifespan.
- P-Type: More common and cost-effective.

Figure 2.20: PV module

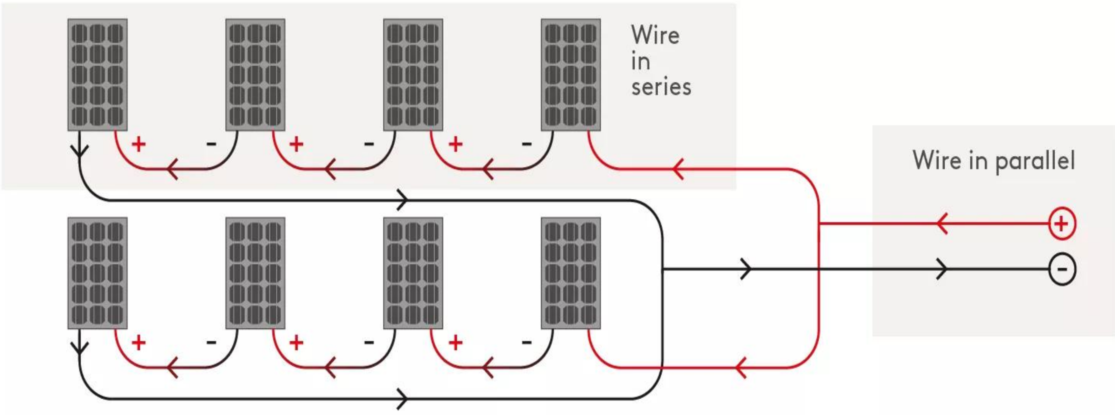


Figure 2.21: Panel Configuration

Overview of Solar PV Inverter

A solar inverter or photovoltaic (PV) inverter is a type of power inverter which converts the variable direct current (DC) output of a photovoltaic solar panel into a utility frequency alternating current (AC) that can be fed into a commercial electrical grid or used by a local, off-grid electrical network.

1. **MPPT (Maximum Power Point Tracker):** This is an advanced algorithm that dynamically adjusts the operating point of the inverter to ensure the system operates at the maximum power point of the solar panels, optimizing energy harvest. MPPT is located bottom of the inverter.

2. **DC Input Terminals:** Where the DC electricity from the solar panels enters the inverter.

3. **AC Output Terminals**: The terminals where the inverter outputs the AC power, either for use in the home or for export to the grid.

Figure 2.22. PV inverter

Panel mounting process

We had to install 24 * 550w JA panels in this project. So all the panels were divided into 6 groups, each group having 4 panels. Before the panel mounting process needed DC wiring works were finished according to the string calculations. Thus we have used 2 strings for the 10 kW system each string having 12 panels. Usually the slop of the panel should be lies from north to south for the optimal production.

Figure 2.23. Panel mounting

Inverter Fixing

Fixing the solar PV inverter on the wall is a crucial setup in the whole process. When selecting the inverter location several factors must be considered. Here as follows

- Location: inverter should be installed in a ventilated, dry and away from direct sun light area to ensure its safety, longevity and performance over the years.
- Height: It’s recommended to mount the inverter at eye level for ease of access to monitoring displays and maintenance.

Figure 2.24. Inverter fixing layout

DC side Wiring

DC system of a solar PV system shall include DC cables, isolators, surge protective devices (SPD), connectors etc. All DC component ratings of the system shall be derived from the maximum voltage and current of the relevant part of the PV module adjusted in accordance with the safety factors. Maximum output of the individual modules shall be taken into account when calculating the component ratings. To minimize the risk of faults, Voltage drops PV DC cable runs should be kept as short as practicable. The DC cable type is designed to withstand the extremes of the environmental, voltage and current conditions, under which they may be expected to, operate. Here we have used 4mm DC cable for the installation. Here are the key components for DC side wiring in a solar PV system:

- 595 W Solar Panels
- DC Isolators
- DC SPD
- DC Fuse
- Inverters
- DC Cables

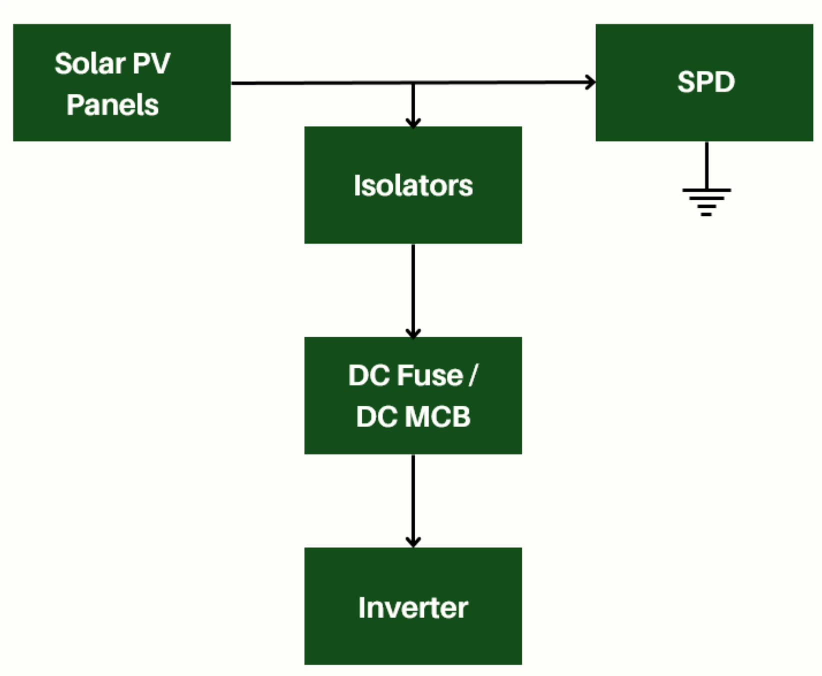


Figure 2.25: DC wiring configuration

Brief list of the components used at the DC side are as follows.

A. MC4 Connector / DC plug:

MC4 connectors are commonly fitted to module cables by the manufacturer. But still the installers needed these connectors to connect the DC cable with separate PV modules accordance with the designs.

Figure 2.26. MC4 Connector

B. DC isolators:

DC isolator is electrical safety components which can be operate manually to isolate the PV modules in case of emergencies or maintenance purposes. Generally 1000v DC isolator is recommendable for all the Solar PV systems.

Figure 2.27. DC Isolator

C. Surge protection Devices (SPD):

DC surge protection devices (SPDs) are critical components in photovoltaic (PV) systems, designed to protect against electrical surges and spikes. These devices are specifically engineered to safeguard electrical installations by diverting excessive voltage away from sensitive components. Electrical surges in PV systems can be caused by various factors. One of the most common causes is lightning strikes, which can induce high voltage surges that travel through power lines and impact connected equipment. Additionally, switching operations within the power grid can produce transient over voltages that propagate through the system.

Figure 2.28. DC SPD

D. DC fuse with holder:

DC fuses play a critical role in safeguarding the electrical components from potential damage due to over currents or short circuits. These fuses are strategically placed within the system to protect the cables, PV modules, and other sensitive equipment from electrical faults that could lead to fires or system failures. The primary function of a DC fuse is to act as a safety device that interrupts the flow of excessive current.

Figure 2.29. DC Fuse with Holder

Finished DC wiring work at the site

Outputs from the fuses are directly connected with the MPPT of the inverter using MC4 connectors according to the string calculations for the optimum generation.

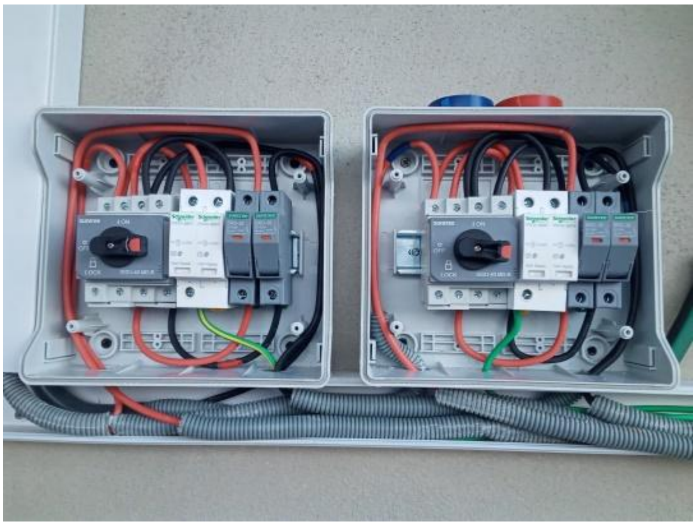


Figure 2.30. Finished DC wiring

AC system and wiring:

The ac side of the inverter is responsible for synchronizing the output voltage with the utility grid or supplying power to local loads. Inverters perform several functions, they ensure the output voltage and frequency with the grid standards, manage power flow to maximize efficiency and frequency regulation. Components used at the AC side are as follows.

A. 4P AC MCB:

Primary function of the AC MCB is to protect the circuit from overcurrents caused by overloads. MCBs also can be used to disconnects the circuit when there is any need, maintenance or troubleshooting, providing a safe way to isolate the system.

Figure 2.31. 4P AC MCB

B. 4P AC SPD:

SPDs are designed to absorb and divert excess voltage caused by lightning strikes, power surges from the grid, or other transient events, preventing damage to sensitive equipment in the solar PV system. AC SPDs contribute to the overall reliability and longevity of the solar system. This is especially important for commercial or industrial applications where system downtime can have significant consequences.

Figure 2.32. 4P AC SPD

C. 4P AC Isolator:

Isolate entire solar system from utility grid if there is any maintenance purpose. Also preventing the over current from flowing into the circuit.

Figure 2.33. 4P AC Isolator

Finished AC wiring at the site

Figure 2.34. Finished AC Wiring

Bus bar connection:

At the end of the installation a Bus bar box was fixed to supply the connection to the utility grid or consumer loads. Bus bar boxes can with stand high voltages to supply multiple loads.

Figure 2.35. Bus bar connection

Grounding Process:

Grounding is very important process for any of the electrical power system, it plays crucial role in the system by protecting against electrical shock.in the event of fault it provides a safe path for excess current to flow to the ground. Proper grounding helps safeguard solar inverters, and other equipments from surges, lightning strikes. So the lifespan of the components can be extended and ensure reliable operation.

The grounding lugs are used to connect the structure and Railing bars with earth cable from initial point to earth rod.

Figure 2.36. Finished grounding works

The above mentioned topic has outlined the essential components, its functions and installation process of a 10 KW on-grid rooftop solar PV system. The structural works might be varying depend on the roof type and number of panels.

Break down Visits:

Went for a site visit to check the breakdown work in Sainthamaruthu. Mobile application indicated that there was no grid connection for a particular time. Firstly the inverters working condition was checked manually, then the breakers were checked by removing the distribution boxes. Finally we found that AC isolator has burnt due to loose connection. As a solution the burnt isolator was replaced by new one. Finally all the voltages were checked using Multi meter.

Figure 2.37. Burnt AC Isolator

Received a complaint from an outside customer that their 5kw solar PV inverter’s production was lowering from previous month production without any reason. So we went for an inspection to check the status of the plant. Initially we have checked the DC side readings. It was indicated that one string has 0 reading and stopped the DC power supply. So finally we found that the MC4 connector of the String has burnt at several places due to improper crimping technics. As a result new MC4 connector has replaced to the string using proper crimping tool. After that the DC voltage was checked for both strings.

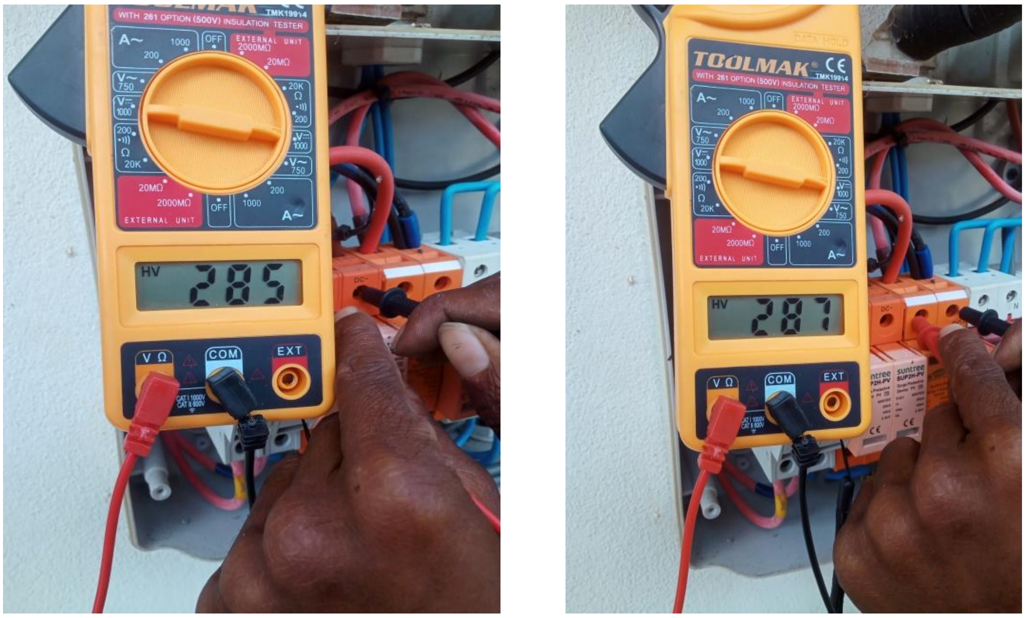


Figure 2.38. DC Voltage Checking

2.4 PVSyst Simulation Software

PVsyst is a leading software tool designed for the simulation, design, and analysis of photovoltaic (PV) systems. It enables users to optimize solar energy systems through accurate location data, system configuration, and performance simulations. During my internship, I explored the software's capabilities, including system sizing, shading analysis, loss estimation, and report generation. This report outlines the steps taken to simulate a PV system, provides an overview of PVsyst's features, and highlights how these steps were implemented to ensure accurate simulation results.

Figure 2.39: PVSyst Simulation Tool

How to Use PVSyst

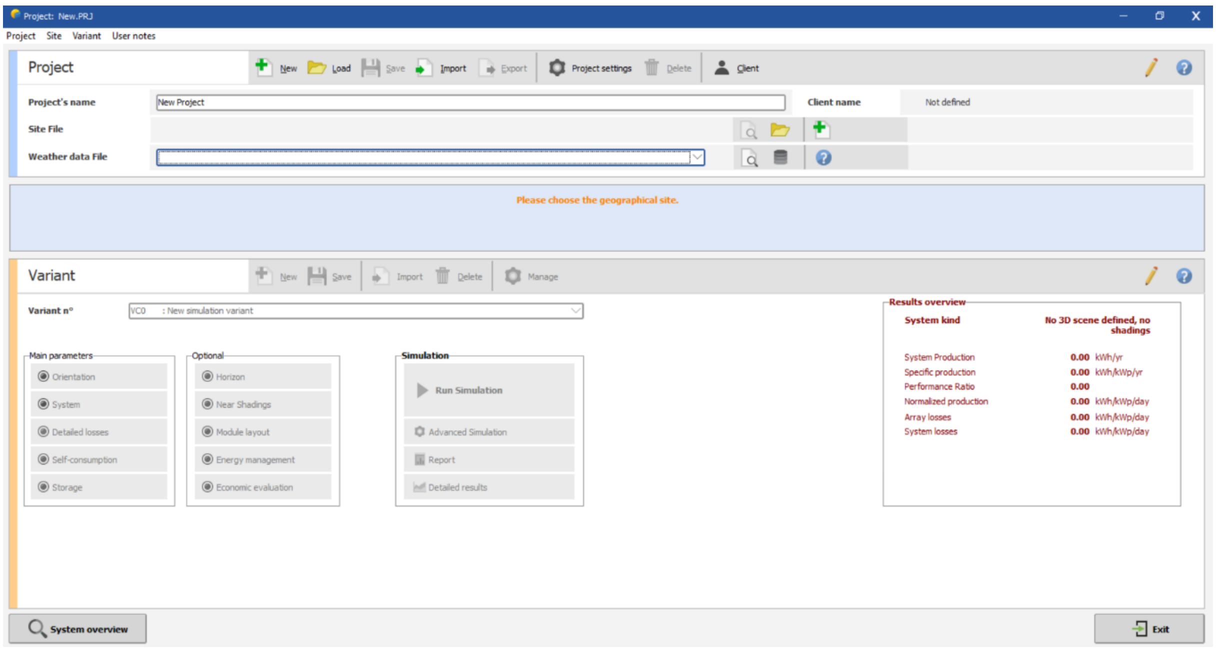


Figure 2.40: PVsyst software Interface

Steps to Use PVsyst:

1. Create a New Project:

Open PVsyst and click on "New Project." Enter project name, description, and geographical location (latitude and longitude or select from the database). Choose the system type: grid-connected, off-grid, or standalone.

2. System Configuration:

Modules Selection: Choose from the PVsyst component database or input custom modules.
Inverter Selection: Select inverters from the database or enter your own.
Tilt and Orientation: Define the tilt angle and orientation for the PV array based on site conditions.

3. Array Configuration:

Define the number of strings, number of modules per string, and array wiring. Set the tilt and orientation to optimize solar energy capture.

4. Shading Analysis:

Use the 3D Shading Tool to model shading from buildings, trees, or other obstacles.

PVsyst offers several key features that make it a comprehensive tool for designing and analyzing photovoltaic systems. It includes a comprehensive component database that provides a wide range of PV modules, inverters, and other system components, which can be selected based on real-world specifications. The software also has a powerful shading analysis tool, using a 3D model to simulate shading effects from surrounding objects like buildings and trees, helping to optimize panel placement.

Steps for PV System Simulation and Implementation

For an example take 20kW System Implementation

1. Location Selection

The first step in PV system simulation is selecting the project location. PVsyst provides an integrated map interface where you can choose the exact location for your system. This ensures accurate irradiation and weather data specific to the selected site.

The choice of location is crucial for optimizing the system's energy production, as solar irradiation varies depending on geographic position. For optimal performance, ensure that the location you choose aligns with local weather patterns and the solar resource potential.

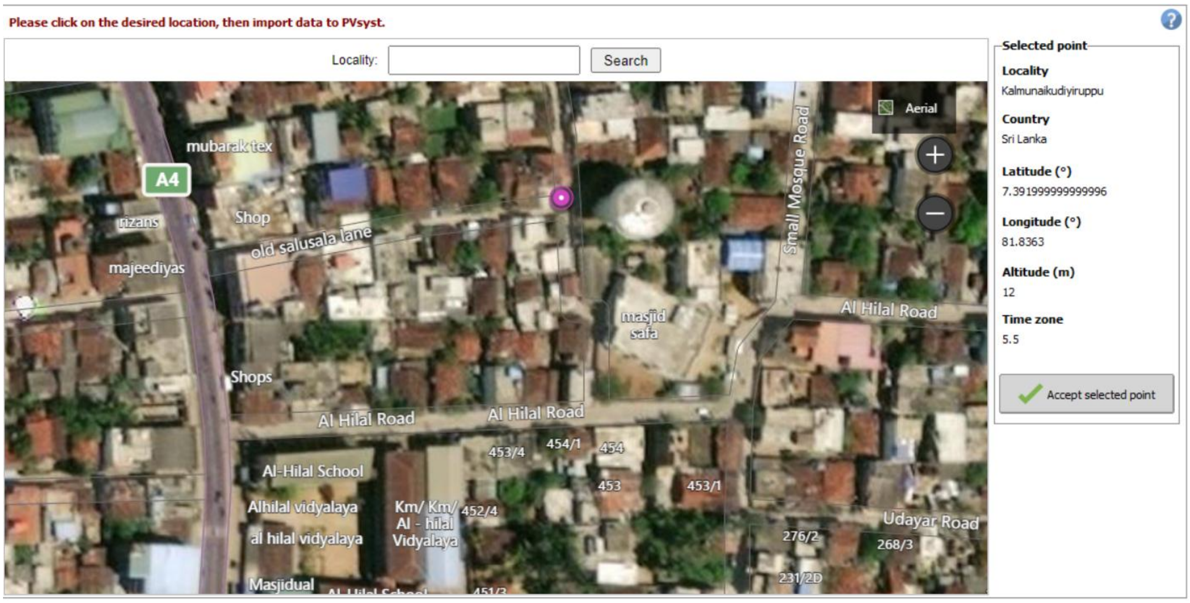


Figure 2.41: Select location on map

2. Geographical Coordinates

Once the location is selected, precise geographical coordinates (latitude and longitude) are entered. These coordinates help PVsyst to pull accurate solar radiation data and weather patterns for that location. In many cases, PVsyst can automatically extract the coordinates from its built-in map database.

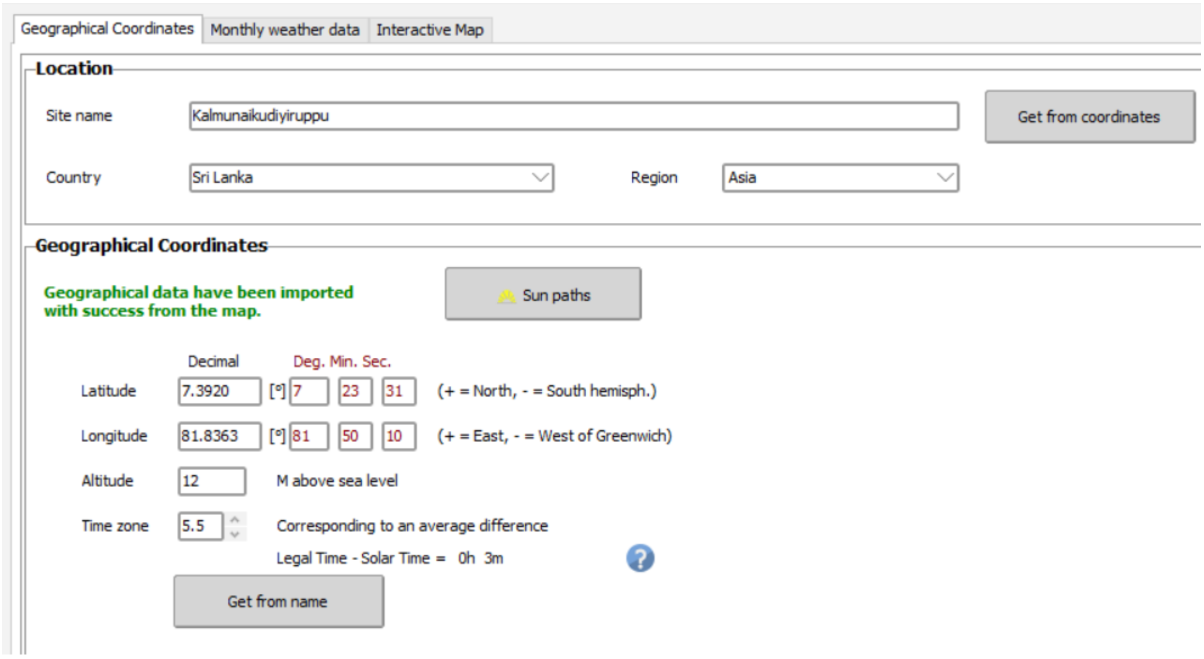
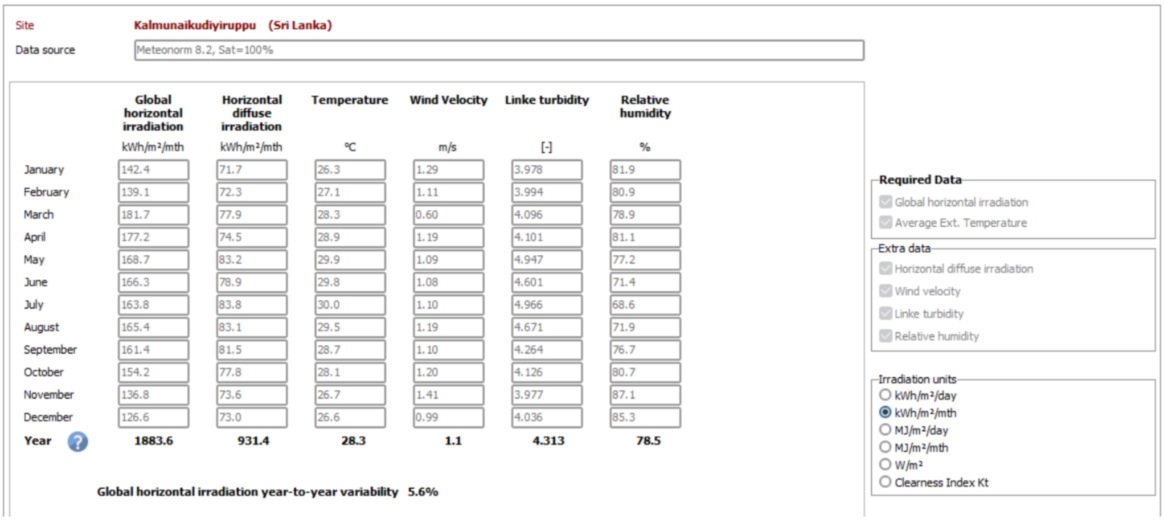


Figure 2.42: Geographical Coordinates

3. Weather Data

Weather data is essential for simulating solar energy production. In PVsyst, you can import climate data, including solar irradiation levels and ambient temperature, which directly impact the efficiency of the PV system. PVsyst offers internal databases for a wide variety of locations, but if needed, you can also integrate external weather data sources for site-specific simulations.



	Global horizontal irradiation kWh/m²/mth	Horizontal diffuse irradiation kWh/m²/mth	Temperature °C	Wind Velocity m/s	Linke turbidity [-]	Relative humidity %
January	142.4	71.7	26.3	1.29	3.978	81.9
February	139.1	72.3	27.1	1.11	3.994	80.9
March	181.7	77.9	28.3	0.60	4.096	78.9
April	177.2	74.5	28.9	1.19	4.101	81.1
May	168.7	83.2	29.9	1.09	4.947	77.2
June	166.3	78.9	29.8	1.08	4.601	71.4
July	163.8	83.8	30.0	1.10	4.966	68.6
August	165.4	83.1	29.5	1.19	4.671	71.9
September	161.4	81.5	28.7	1.10	4.264	76.7
October	154.2	77.8	28.1	1.20	4.126	80.7
November	136.8	73.6	26.7	1.41	3.977	87.1
December	126.6	73.0	26.6	0.99	4.036	85.3
Year	1883.6	931.4	28.3	1.1	4.313	78.5

Global horizontal irradiation year-to-year variability 5.6%

Figure 2.43: Weather Data

4. Orientation

Optimizing the orientation of the solar panels is key to maximizing energy production. In this step, you can adjust the tilt and azimuth angles to match the geographical location of the project. PVsyst uses the site's latitude to calculate optimal tilt angles, which can be adjusted further based on the local climate and terrain.

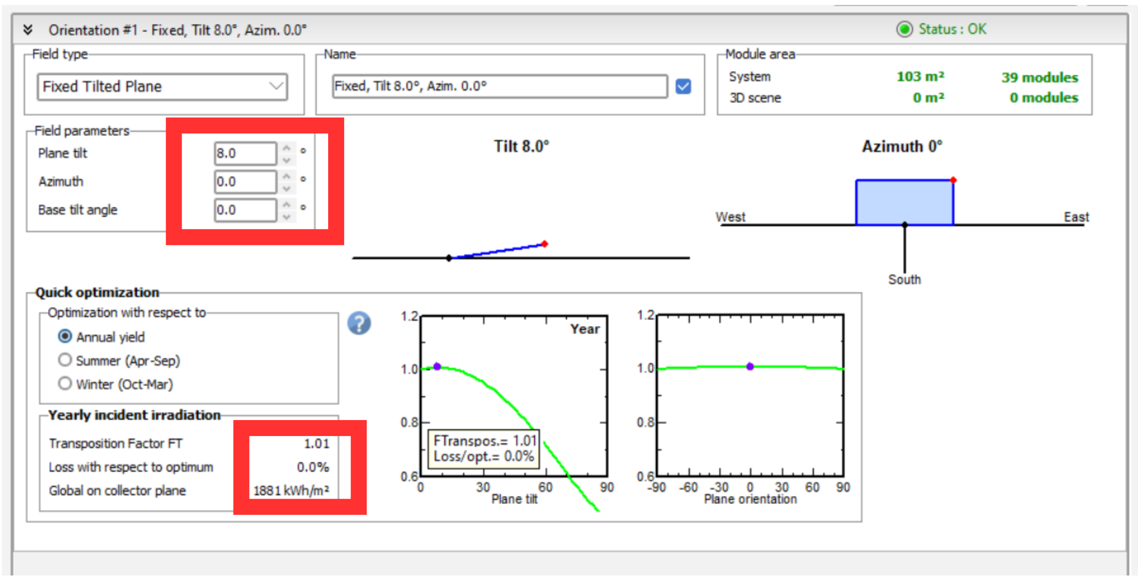


Figure 2.44: Orientation

5. System Information

At this stage, you select the components of the PV system, such as solar modules and inverters. PVsyst provides an extensive database of module and inverter models from various manufacturers. The selected components should be carefully configured based on the project's specifications, ensuring that they match the energy demands of the site. You can fine-tune parameters like module power, efficiency, and inverter capacity to optimize the overall system performance.

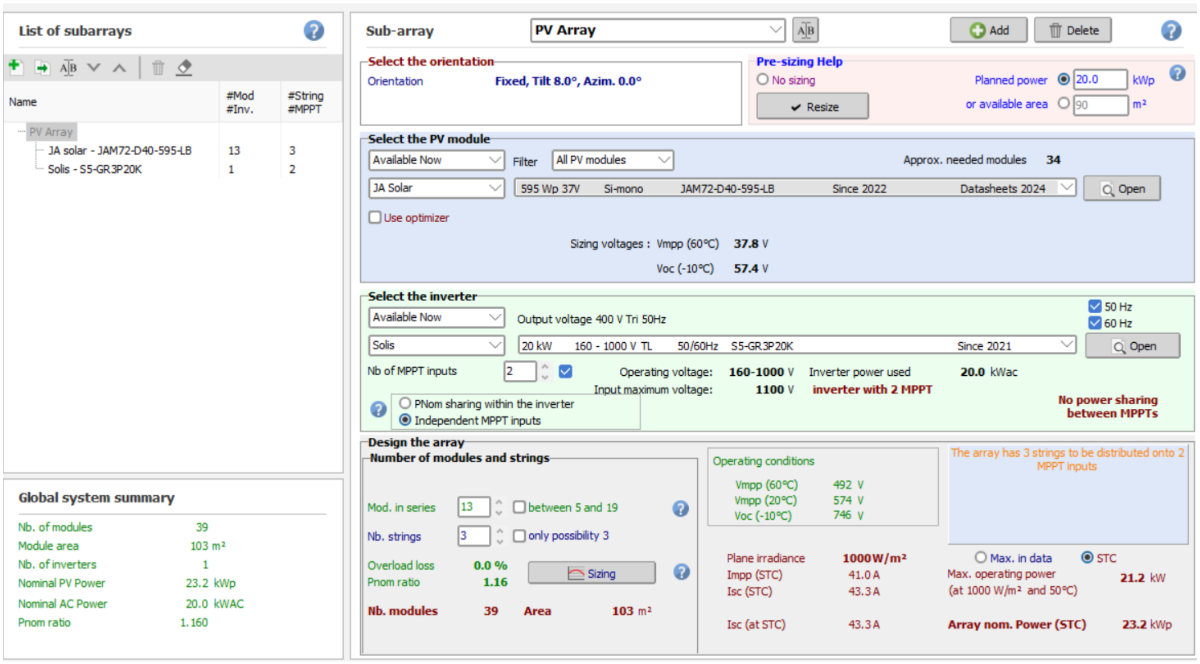


Figure 2.45: Information PV module, Inverter

6. 3D shading scene

In PVsyst, creating a 3D shading scene involves defining the layout of your photovoltaic system, including panel orientation, tilt, and surrounding obstacles like trees and buildings, which can affect panel performance due to shading. You start by creating a new project and entering the shading calculation module, where you can define terrain type, panel angles, and add 3D objects to represent obstacles. The software allows you to simulate how shadows from these objects will affect the panels at different times of the day or year.

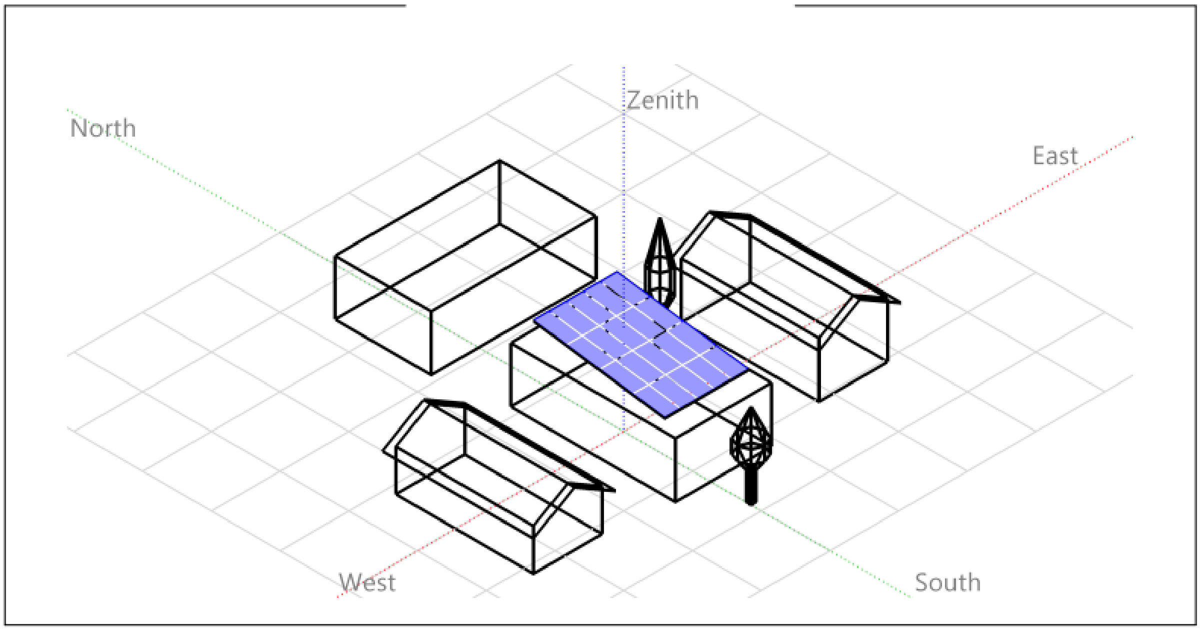


Figure 2.46: 3D scene of PV system

Throughout the above simulation the report will be generated. On that report the predefined graphs will be included.

Predefined Graphs

PVsyst offers predefined graphs to help analyze system performance over time. Key visualizations include:

1. **Normalized Productions (per installed kWp):** This graph shows the system's production normalized to the installed capacity (kWp), allowing for a comparison of performance across different installations or configurations.

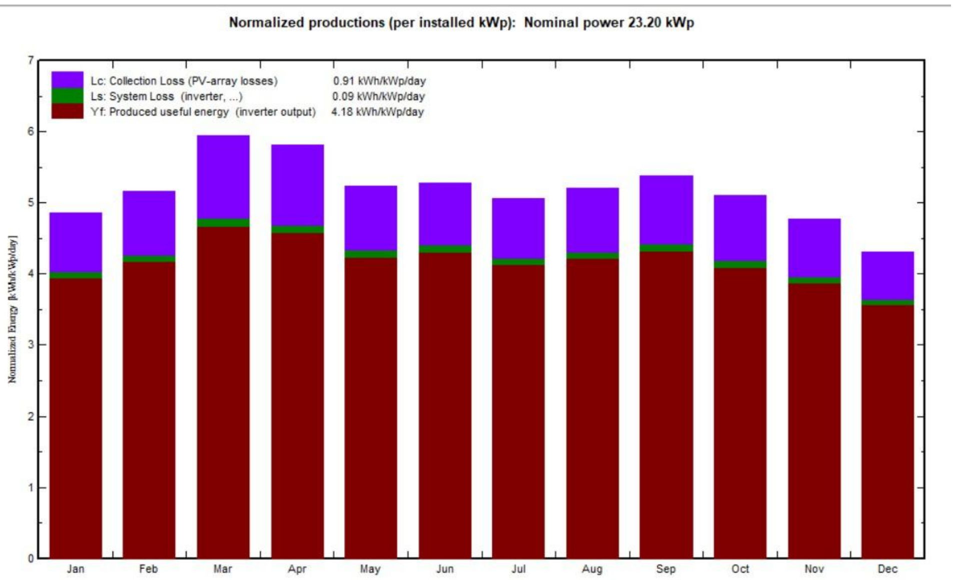


Figure 2.47: Normalized Productions (per installed kWp)

2. **Daily System Output Energy**: This graph displays the daily energy output of the system, providing insights into the total amount of energy produced each day over a specific period.

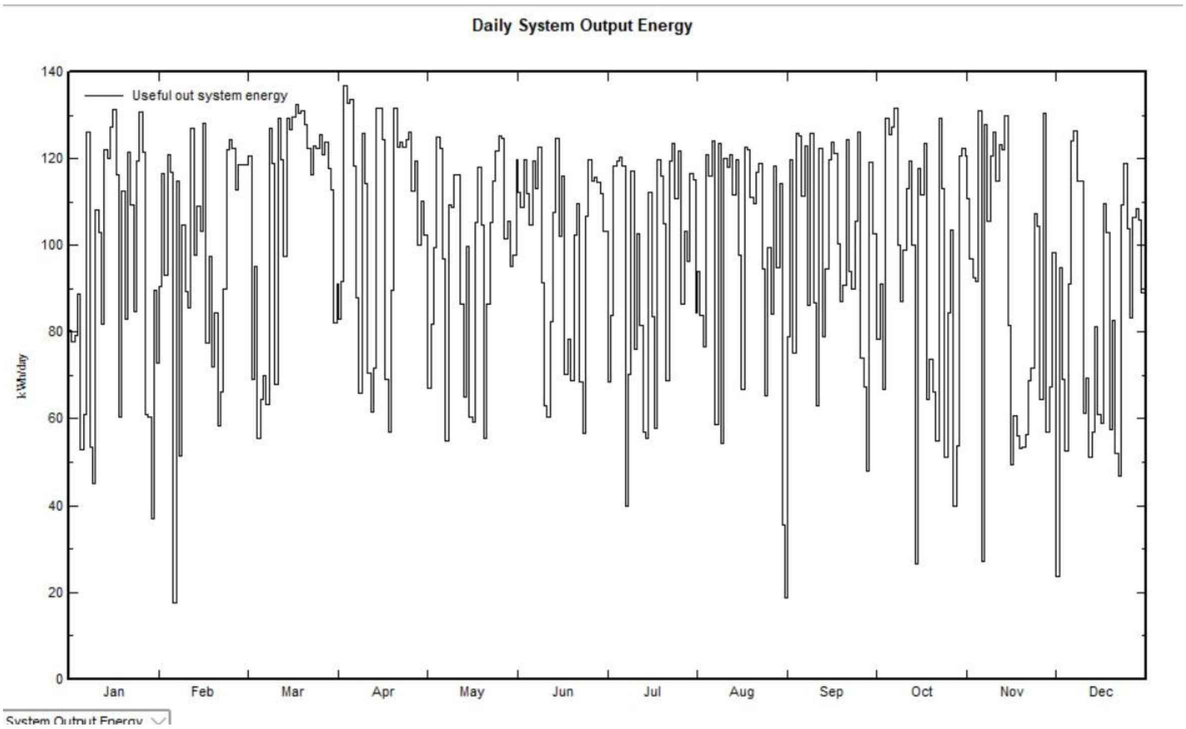


Figure 2.48: Daily System Output Energy

3. **Daily Input / Output Diagram:** This diagram compares the system's energy input (from solar radiation) with its energy output (electrical energy produced), helping to visualize energy conversion efficiency.

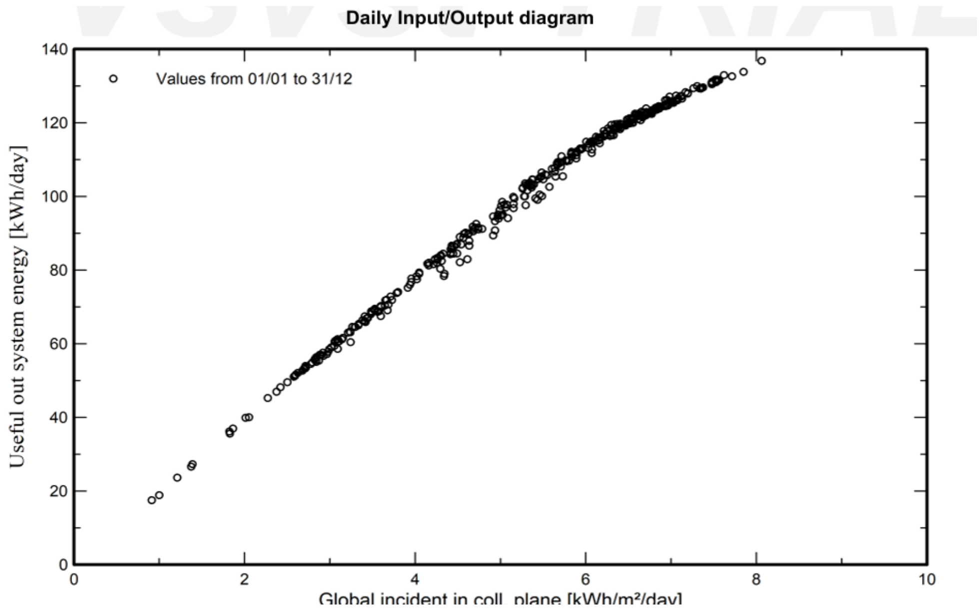


Figure 2.49: Daily Input / Output Diagram

4. **System Output Power Distribution**: This graph shows the distribution of the system's output power throughout the day, highlighting peak production times and overall system efficiency at various points.

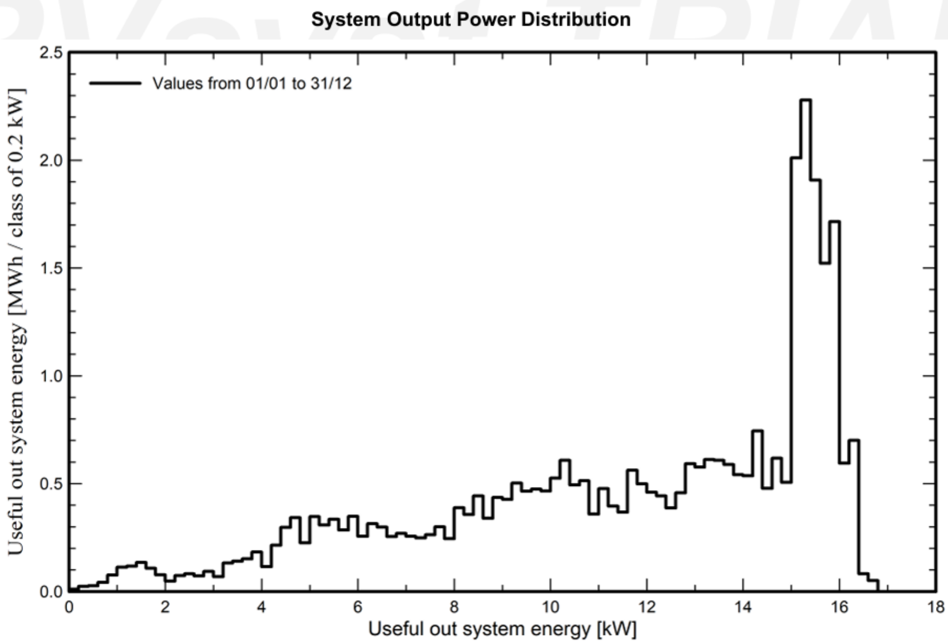


Figure 2.50: System Output Power Distribution

5. **Loss Diagram:** This diagram breaks down and visualizes various losses in the system, such as shading, temperature, and conversion losses, allowing you to identify and address factors reducing system efficiency.

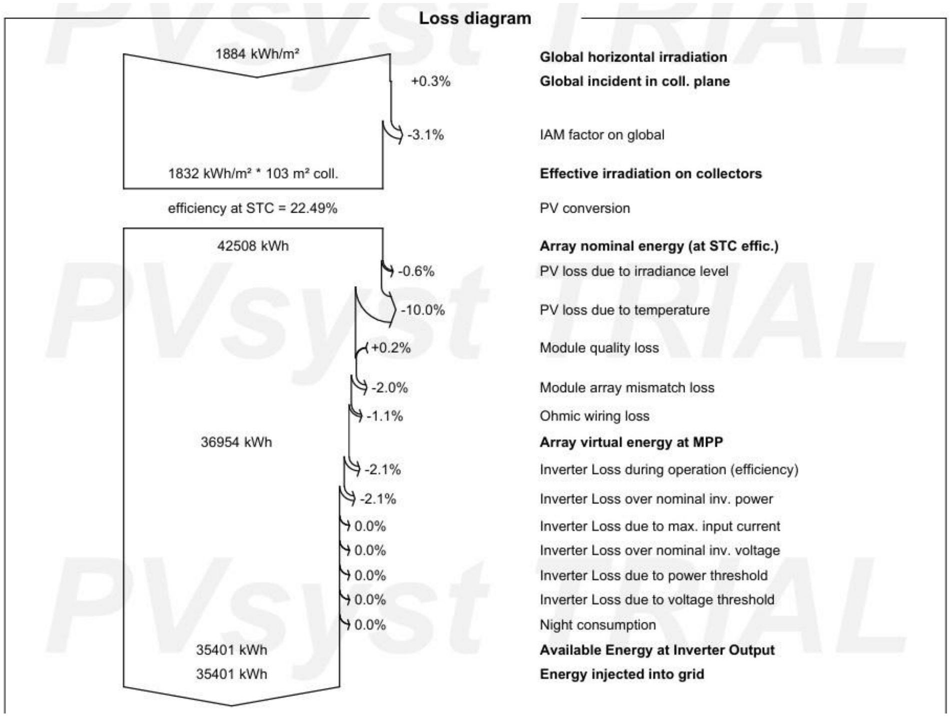


Figure 2.51: Loss Diagram

2.5 Online configuration of Solar Plant with Solis Cloud app

The integration of Wi-Fi connectivity in solar power systems has revolutionized the way these systems are monitored and configured. With the advancement of smart technology, solar power systems now offer users the ability to manage and optimize energy production remotely via online platforms. Wi-Fi-enabled solar power systems allow for seamless integration with mobile apps like Solis cloud, enabling real-time monitoring of system performance, troubleshooting, and configuration adjustments from anywhere with internet access. We have used **Solis cloud** mobile application to connect the Wi-Fi data logger

Data Logger

Figure 2.52: Data Logger is connected with Inverter

Let's dive into Solis cloud with the example project of 20Kw.

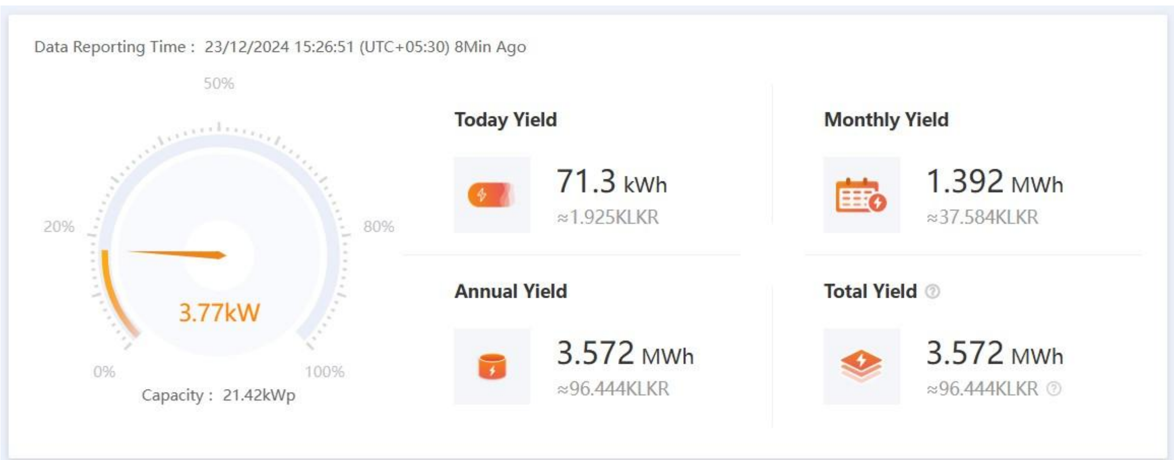


Figure 2.53: Production of 20kW of Project

Throughout the app, we can monitor energy production of a day, a month, and a year, DC voltage and DC current in MPPT, DC power, ac current, ac voltage, and reactive power.

Real time Information

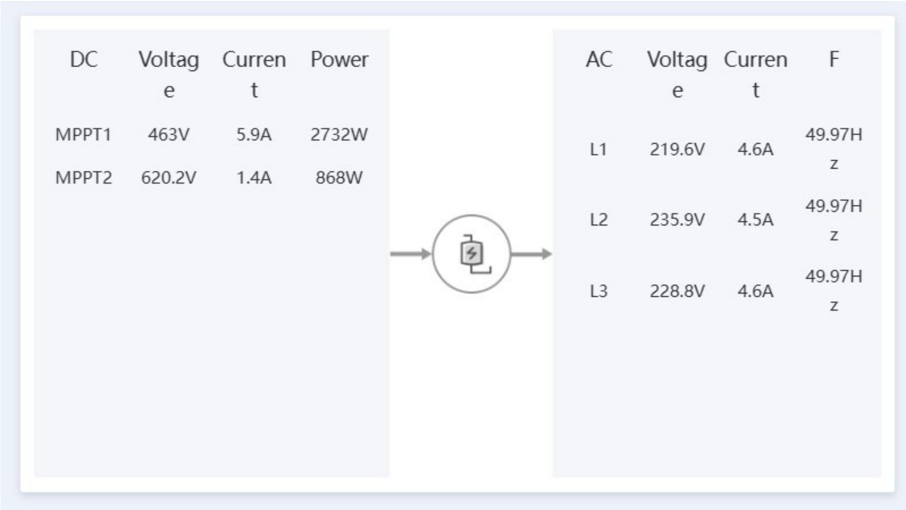


Figure 2.54: Real time information of dc and ac side

On this information MPPT is mentioned. Now let's look that term. MPPT stands for Maximum Power Point Tracking, a key feature in solar systems to optimize the power output from solar panels. It is implemented in inverters to ensure the solar panels operate at their maximum power point (MPP).

Each solar panel has a specific voltage and current combination where it delivers the maximum power. This is the MPP. MPPT devices continuously track the MPP by adjusting the electrical operating point of the solar panel. The goal is to draw the maximum possible power from the solar panel.

Power graph

This graph shows the energy production of a solar power system on December 23, 2024, measured in kilowatts (kW) throughout the day. 3.5 hours, showing the time the system operated at maximum efficiency.

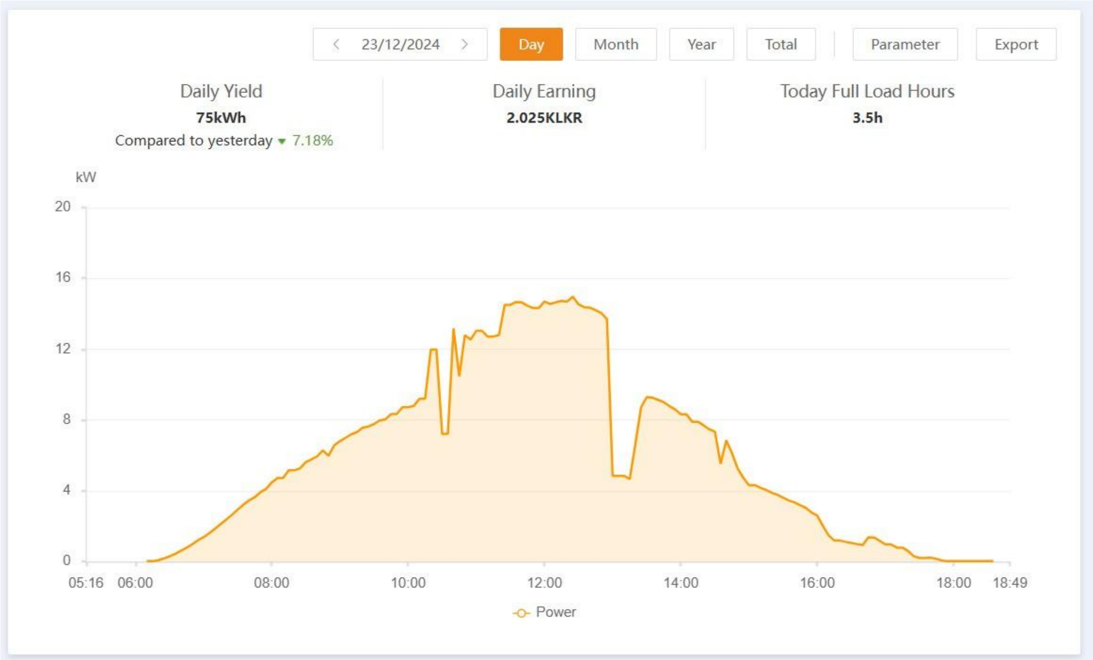


Figure 2.55: Energy production on a day

Analyzing of graph

1. Energy Production Pattern:
    - Energy generation begins at sunrise.
    - Production steadily increases as sunlight intensifies, peaking between late morning and early afternoon (around 12:00).
    - After the peak, energy production decreases gradually as sunlight diminishes toward sunset.

2. Sudden Increase and Decrease:
    - The sudden increase in power generation could be due to:
        - The sun breaking through clouds after a period of shade.
        - A temporary shift in solar intensity or clearing of dust/shadows on the panels.
    - The sudden fall in power could be caused by:
        - Clouds obstructing sunlight temporarily.
        - Shadows from nearby objects like trees or buildings.

DC voltage in MPPT

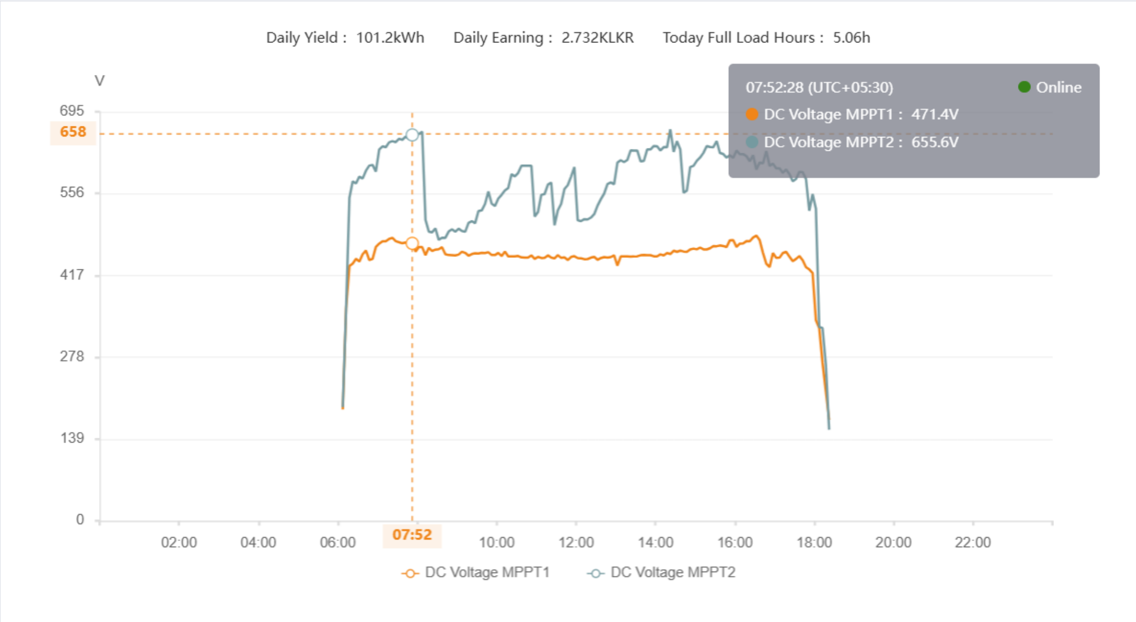


Figure 2.56: DC voltage in MPPT

1. DC Voltage MPPT1 (Orange Line):

The voltage remains relatively stable throughout the day, with minimal fluctuations. This indicates consistent performance, possibly due to a steady input from the solar panels connected to MPPT1.

2. MPPT Adjustment:

- Cause: The MPPT adjusts the voltage-current ratio to find the maximum power point during dynamic conditions (e.g., changes in irradiance or load).
- Impact: This optimization process can cause momentary dips in current as the system recalibrates.

3. Temperature-Related Effects

- Cause: Sudden cooling (e.g., from rain or wind) or heating of solar panels.
- Impact: Causes a shift in the panel's efficiency, which can affect the current output temporarily.

DC Power

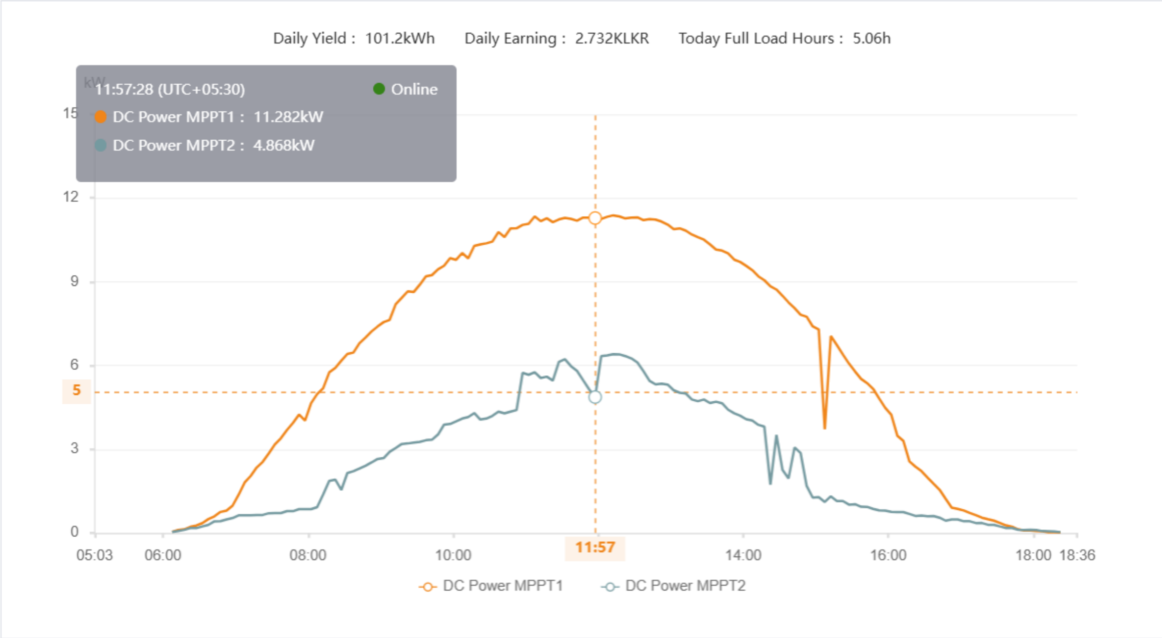


Figure 2.57: DC Power

Observation:

- Since voltage is relatively stable throughout the day, current fluctuations are the primary driver of power curve variations.
- Any sudden increase or decrease in current (caused by shading, environmental changes, or system adjustments) directly translates to a corresponding rise or fall in power.

Conclusion:

- The power curve mimics the current curve because power output depends on current when voltage is steady.
- Sharp changes in the power curve indicate the same environmental or system factors causing fluctuations in the current.

AC voltage

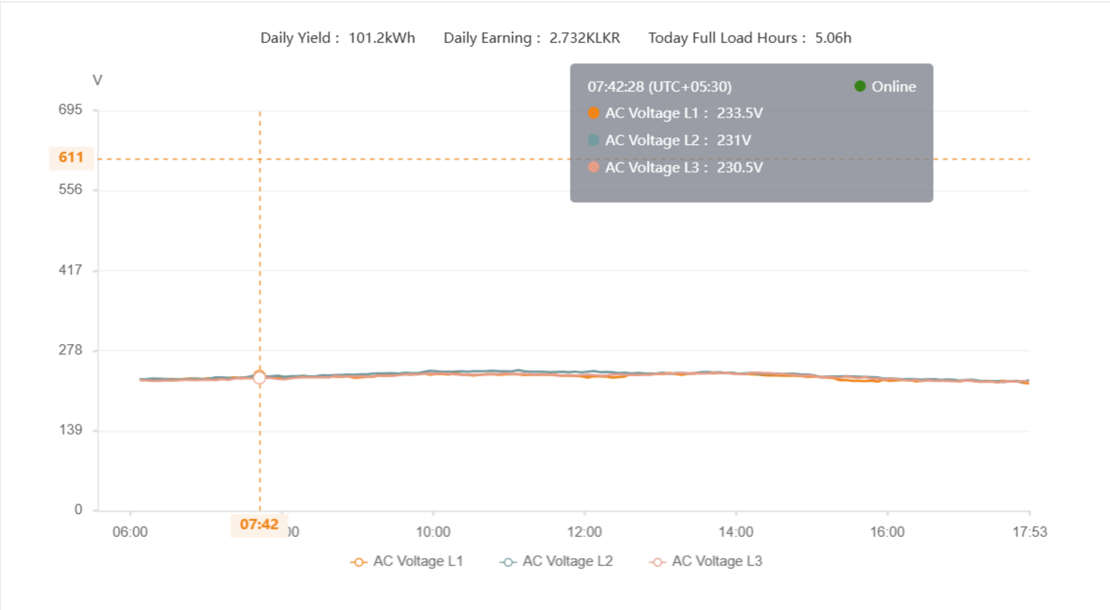


Figure 2.58: AC Voltage

1. Stability in AC Voltage

The inverter is designed to convert DC voltage from the solar panels into a steady AC voltage for grid or load supply. It actively regulates the voltage to match grid requirements or local standards.

2. Grid Compliance

Most solar inverters are programmed to comply with grid voltage standards, which ensures:

- A stable output voltage across all phases (e.g., 220 - 250 V for single-phase).
- Minimal variation regardless of solar input fluctuations.

Even if DC power fluctuates due to shading or other factors, the AC voltage remains constant, with the current adjusting instead.

AC current

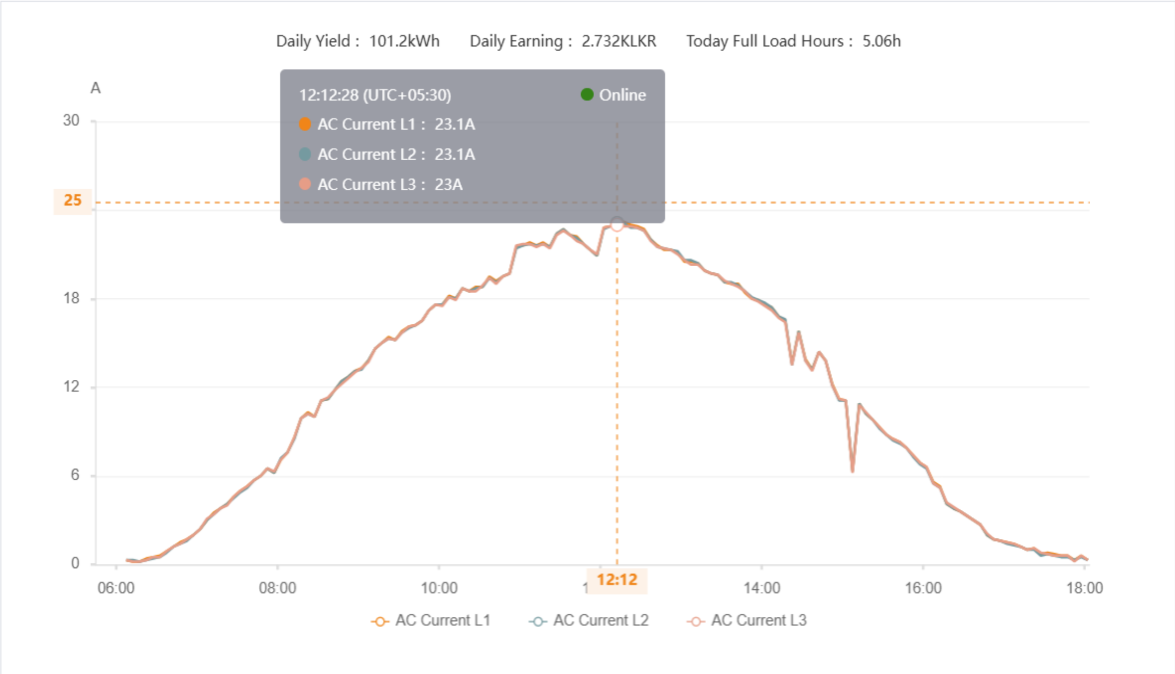


Figure 2.59: AC Current

This pattern is directly related to the DC power generated by the solar panels. As sunlight intensity increases, more DC power is generated, and the inverter converts this to higher AC power, resulting in higher AC current. The AC current reaches its highest point around midday when solar irradiance is at its peak.

These fluctuations could be caused by transient changes in solar irradiance, such as cloud cover, shading.

The current values for L1, L2, and L3 are nearly identical and follow the same pattern throughout the day. This indicates that the inverter is functioning correctly and ensuring a balanced load distribution across the three phases.

Reactive Power

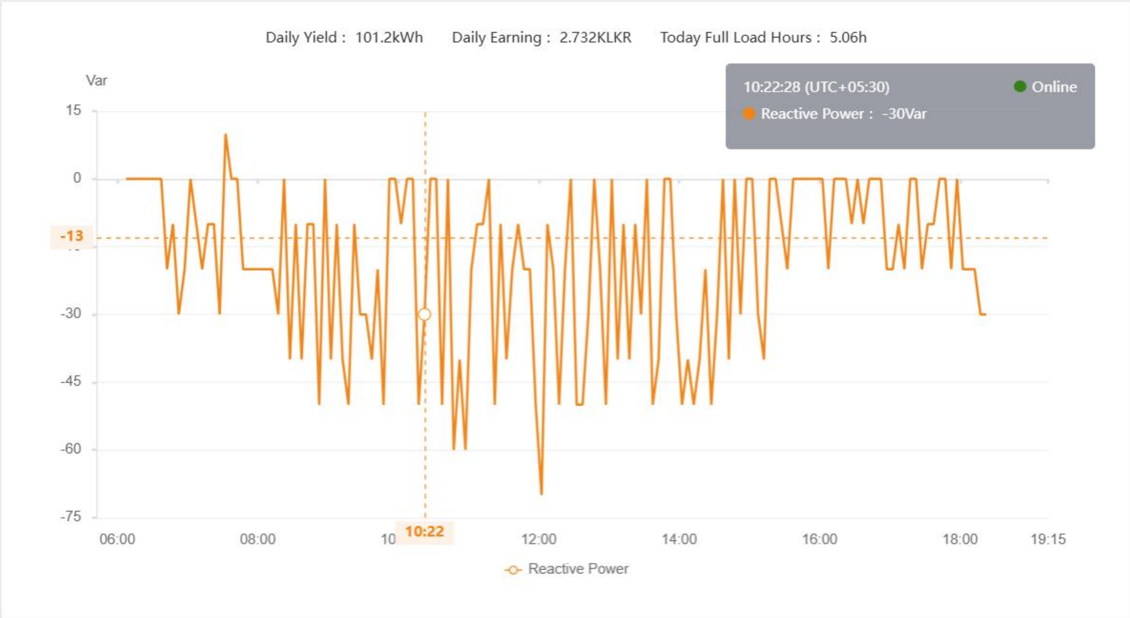


Figure 2.60: Reactive Power

Reactive Power is the power that oscillates between the source and load, essential for creating and maintaining electric and magnetic fields in AC systems.

1. Fluctuations:

The curve shows rapid changes in reactive power, which is expected in systems responding dynamically to load changes or grid requirements. Negative reactive power indicates capacitive behavior, while positive reactive power indicates inductive behavior.

2. Cause of Variations:

Rapid changes in connected inductive or capacitive loads can lead to fluctuations. The inverter adjusts reactive power to maintain a desired power factor or support voltage stability.

3. Chapter 3: Training Experiences – Management

During my 12-week internship at Invo Tech Holdings Pvt Ltd, I gained valuable management experience through various aspects of my work.

A key management skill I observed and practiced was time management and task prioritization. In various projects, it was crucial to manage time effectively, ensuring that work was completed within the allocated timelines and that all tasks, such as research, simulations, and analysis, were performed properly. Additionally, equipment maintenance was essential, and I learned how to ensure that tools and systems were properly maintained and ready for use when needed.

I also witnessed the importance of task delegation. Tasks were assigned based on team members' expertise, which ensured that each individual worked on projects suited to their skills. When it came to site visits, there were also management tasks such as ensuring that the work was properly planned and coordinated with the on-site team. For example, during visits to solar panel construction sites, proper planning was required to ensure all components were ready for installation. Logistics such as equipment transport, team coordination, and ensuring safety measures were in place were essential to successful site operations.

Moreover, I was involved in monitoring and analyzing the data from solar PV systems. This involved coordinating with team members to gather the necessary data, ensuring it was properly analyzed, and preparing reports on system performance. The management of these tasks required careful planning, monitoring progress, and adjusting based on emerging challenges.

The management experience I gained during my internship at Invo Tech Holdings Pvt Ltd has been highly valuable. It helped me develop essential organizational skills, such as task prioritization, resource allocation, and communication, which are fundamental for any engineer working in a professional setting.

4. Chapter 4: Practice of Professional Standards And Engineering Ethics

It is very important to follow the professional standards and engineering ethics in a company. At the Invo Tech Holdings (Pvt) Ltd where I had my internship consist of 12 weeks of period and I saw the sincerity of workers on follow the professional standards and engineering ethics.

a. Safety Management

Safety of human

The main things that all the company should follow and I saw at the Invo Tech Holdings (Pvt) Ltd is safety of workers. In the panel installation process, several risks were managed effectively.

- Electrical Hazards :

  Insulated gloves were mandatory when handling live electrical connections to prevent shocks or burns. Safety signs were displayed near high-voltage areas to raise awareness

- Working at Heights :

  Installation of rooftop solar panels required the use of harnesses to prevent falls. Workers were trained in height safety practices to ensure accidents were minimized.

- Protective Measures against sharp objects :

  Workers wore safety shoes to avoid injuries from sharp objects and debris on construction sites.

Personal Protective Equipment that are widely used in the solar industry.

A. **Hard Hats**: Protect against head injuries from falling objects.

Figure 4.1: Hard Hats

B. **Safety Goggles**: Shield eyes from dust and debris.

Figure 4.2: Safety Goggles

C. **Gloves**: Insulated gloves protect against electrical hazards and cuts.

Figure 4.3: Gloves

D. **High-Visibility Clothing**: Ensures workers are seen on-site.

Figure 4.4: High visibility clothing

E. **Over all kit**: Prevents body from injuries and infections.

Figure 4.5: Over all kit

F. **Harnesses**: Used when working at heights to prevent falls.

Figure 4.6: Harnesses

G. **Safety Shoe**: Preventing the feet from injuries and unwanted sharp particles.

Figure 4.7: Safety Shoe

Usages of Personal Protective Equipment at the site.

Figure 4.8: Usage of Personal Protective Equipment

Safety of equipment

As well as safety of human, safety of equipment are being considered. The cost of the devices and machines are used there are very high and repairing cost are also high. For the safety of the equipment regular maintenance are done.

- Proper Maintenance :

  Regular inspections were conducted to identify any faults in the solar panels, inverters, and mounting structures.

- Grounding :

  Equipment was properly grounded to protect it from lightning strikes or electrical surges

- Panel Orientation and Cleaning :

  Panels were properly mounted and cleaned to prevent shading and maximize efficiency without causing structural damage

b. Ethical Activities Maintenance

- Environmental Responsibility :

  InvoTech Holdings was committed to reducing the environmental impact of its solar energy systems. The company followed sustainable practices, ensuring waste materials like damaged panels and wiring were properly disposed of or recycled.

- Social Responsibility :

  The company ensured transparency with customers by providing accurate performance data of the installed solar systems. They maintained clear communication with clients about warranties, maintenance schedules, and energy efficiency expectations.

- Documentation and Transparency :

  Block diagrams of solar energy systems, connection plans, and safety protocols were prominently displayed on-site for all employees to understand and follow. This encouraged transparency and accountability at all levels.

- Professional Conduct :

  Engineers and technicians at InvoTech Holdings were required to maintain professional integrity and ethical conduct when interacting with clients, colleagues, and stakeholders.

5. Chapter 5: Environment and Sustainability

Sustainability is a significant element in addressing present and future worldwide difficulties, not limited to environmental issues. The environment, social responsibility, and the economic aspect are the three main pillars of sustainability. As an Engineer considering about the sustainability is must. InvoTech Holdings Pvt Ltd, as a solar company, places a strong emphasis on sustainability in its operations.

Environment

InvoTech Holdings demonstrated a commitment to environmental sustainability in the following ways:

- Promoting Renewable Energy: As a company in the solar industry, InvoTech Holdings actively promotes the use of renewable energy by educating customers and installing solar systems that reduce carbon footprints.
- Energy Conservation**:** Energy-efficient lighting and appliances were utilized throughout the company's premises. Air conditioners were used sparingly and set to eco-friendly modes to reduce unnecessary energy consumption.
- Use of Eco-Friendly Materials: Environmentally friendly cleaning products and solar panel maintenance solutions were used to reduce chemical contamination.

Economy

Strong focus on economic sustainability by optimizing costs and ensuring financial stability:

- Resource Optimization: The company prioritized using high-quality but cost-effective materials for solar installations to ensure longevity while managing expenses..
- Financial Efficiency in Product Offerings: The company offered solar packages tailored to different customer needs, ensuring affordability without compromising quality.

Society

- Team-Building Activities: The Company held events to celebrate employee milestones, such as promotions, birthdays, and retirements, creating a sense of camaraderie and shared happiness within the workplace.
- Community Engagement: InvoTech Holdings promoted solar awareness campaigns in local communities, educating people about the benefits of renewable energy and sustainable living.

Chapter 6: Summary and Conclusion

Invo Tech Holdings Pvt Ltd served as the training establishment for my industrial training, which spanned over a period of 12 weeks. This experience provided me with invaluable practical knowledge and exposure to real-world industry practices. The training helped bridge the gap between theoretical learning and practical applications, especially in the fields of electronics, IoT technologies, and solar PV systems. I also had the opportunity to enhance my technical and soft skills essential for a professional engineer's career.

During my time at Invo Tech Holdings Pvt Ltd, I managed to gain knowledge and hands-on experience in the following areas:

- ESP32 Development: Understanding its applications in IoT-based projects.
- Smart Plug Technology: Studied the concepts, connections, and components used in smart plug systems.
- Smart Meter Technology: Gained knowledge of the structure, connections, and components involved in smart meter systems.
- Solar PV Systems:
    - PVsyst Simulation: Conducted simulations for system performance, shading analysis, loss evaluation, and report generation.
    - AC and DC Side Configurations: Gained knowledge of solar system connections and the role of AC and DC components in overall system performance.
    - Ground-mounted Solar PV Systems: Learned about construction techniques, panel arrangement, and performance analysis using the Solis Cloud app for real-time monitoring.

Invo Tech Holdings Pvt Ltd is a well-structured organization with a talented team and a supportive work environment. I gained significant insights into electronics project development, IoT system design, solar energy systems, and real-time data monitoring and control.

Overall, my internship experience at Invo Tech Holdings Pvt Ltd was highly educational and rewarding. It provided me with an in-depth understanding of industry processes, strengthened my problem-solving abilities, and helped me develop a professional attitude essential for a career in the engineering field.

Abreviation

ADC	Analog-to-Digital Converter
DAC	Digital-to-Analog Converter
ESP	Extra Sensory Perception
PWM	Pulse Width Modulation
I2C	Inter-Integrated Circuit
SPI	Serial Peripheral Interface
UART	Universal Asynchronous Receiver-Transmitter
MPPT	Maximum Power Point Tracker
MCB	Miniature Circuit Breaker
SPD	Surge Protective Device
CT	Current Transformer
PZEM	Power Meter Module (PZEM-004T)
PVsyst	Photovoltaic System Simulation Software
HV	High Voltage
LV	Low Voltage
GND	Ground
EPF	Employee Provident Fund
ETF	Employee Trust Fund
R&D	Research and Development
AC-DC	Alternating Current to Direct Current
ELV	Extra Low Voltage
RS485	Recommended Standard 485 (serial communication protocol)
DC-DC	Direct Current to Direct Current
OLED	Organic Light-Emitting Diode
EEPROM	Electrically Erasable Programmable Read-Only Memory

PCB	Printed Circuit Board
RF	Radio Frequency
MCU	Microcontroller Unit
GPIO	General-Purpose Input/Output
VPN	Virtual Private Network

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