DYNAMIC DEMAND CONTROL OF 3.5MW SOLAR LG PLANT USING ZERO EXPORT DEVICE

A Dissertation submitted in fulfillment of the requirements for the Degree of

MASTER OF ENGINEERING

In

Power Systems

Submitted by

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DECLARATION

I hereby certify that the work which is presented in dissertation entitled, "**DYNAMIC DEMAND CONTROL OF 3.5MW SOLAR LG PLANT USING ZERO EXPORT DEVICE**", in partial fulfillment of the requirements for the award of the degree of **Master of Engineering in Power Systems**, submitted to Electrical & Instrumentation Engineering Department of Thapar Institute of Engineering & Technology, Patiala is as authentic record of my own work carried under the supervision of **Dr. Manoj Badoni**. It refers others researcher's work which are duly listed in the reference section. The matter contained in this dissertation has not been submitted, neither in part nor in full to any other degree to any other university or institute except as reported in text and references.

Place: Patiala
Date: 07/07/2022

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It is certified that the above statement made by the student is correct to the best of my knowledge and belief.

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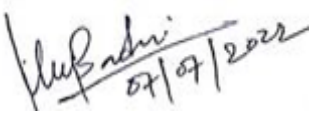

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

NOMENCLATURE

Main symbols and notations used in this study are listed below. Sometimes a symbol may have alternate meaning but in such a case; the context is sufficient to avoid confusion.

NPCL	Noida Power Corporation Limited
LGEIL	LG Electronics India Pvt. Ltd
FET	Facility Engineering Team
PV	Photo Voltaic
DG	Diesel Generator
WMO	World Metrological Organization
USB	Universal Serial Bus
SCADA	Supervisory Control and Data Acquisition
PLC	Programmable Logic Controller
GLOBE	Global Learning and Observation to Benefit the Environment
N, E, S, W	North, East, South, West
NREL	National Renewable Energy Laboratory
PC	Personal Computer
RH	Relative Humidity
SIM	Sensor Interface Module
SSE	Surface meteorology and Solar Energy
SPA	Solar position algorithm
ME	Manufacturing Engineering
MIDC	Measurement and Instrumentation Data Center
FTP	File Transfer Protocol
EPA	Environmental Protection Agency
WMO	World Meteorological Organization
ZED	Zero Export Device

LIST OF ABBREVIATIONS

Symbols	Unit	Terms
α	°	Elevation angle
σ	m/s	Standard derivation of wind speed measurement
c	m/s	Weibull scale factor
ct	-	Clearness index
fi(ct)	-	Frequency depended from clearness index
G	W/m2	Solar insolation
$G0$	W/m2	Maximum insolation without any disturbance
$H0$	W/m2	External radiation
i	-	Index
k	-	Weibull shape factor
n	-	Quantity of intervals
v	m/s	Wind speed
v	m/s	Average wind speed
Xi	-	Cumulated frequency at i
Xn	-	Total cumulated frequency
xi(ct)	-	Occasion of ct in the given interval

ABSTRACT

Recently, photovoltaic (PV) panels as part of renewable energy sources are being used in many systems. With the rapid growth of photovoltaic system connections to power networks, the development of efficient interfacing grid metals has become increasingly important for photovoltaic systems to ensure zero export. This study and work introduces the operating system, control system and flexible response of the zero export system designed for the Grid-PV system, to demonstrate the accuracy and capability of the device presented with a commercial grid-tie inverter.

Solar photovoltaic energy (PV), or solar energy capture by photovoltaic panel to generate electricity, is considered one of the most promising markets renewable energy portfolio, due to its ability to reduce global warming and convergence CO2 reduction targets set by international governments and international agreements. The PV industry has grown almost steadily in recent years, as shown by increasing production capacity and growing networks of solar suppliers and funding systems worldwide.

Chapter 1

1.1 Introduction

Based on India's National Energy Policy, the target value of renewable energy in India is 175GW. Solar energy is one of India's most significant renewable energy sources. The Indian subcontinent is the largest solar power plant in India at 4.8kWh / m2 / day. Due to the small percentage of solar energy consumption, the government intends to increase the percentage by mounting the Roof top Solar Power Plants. Roof top Solar Power Plants is a best solution for increasing solar energy use because as stated by the Minister of Energy and Minerals Resources, one of the most important users in the Manufacturing Industry.

In the roof top solar power plant installed at the manufacturing plant of LG Electronics, greater Noida is 3.5MW of capacity. In this plant by generating the solar energy we used for their own use in the various assembly line of LG products.

One of the major issues came into effect when the power supply from the grid, gets shuts downs due to which load requirement at the plant level gets decreased but the generation of solar becomes greater than the energy. So, this is the major issue find in our industry.

In this research work, I have proposed the solution to control this misbalance of the power demand. With the help of Zero Export Device we have controlled the load demand and generation of the power. In this study we will discuss each and every aspect of the Zero export device.

1.2 Literature Survey

To understand clearly about this topic I have done my literature survey which is as follows:

Prashant Malik [2021], in "**Hybrid operational approach for PV/DG micro grid without storage device":** In this paper it is found that when grid and solar radiation was available the controller with proposed hybrid approach impeccably matches the demand without any export to grid in all conditions.

Zeeshan Ali Abbas [2021], in "Intelligent Hybrid Energy Resource Connected Demand Side Load Management System-Case of Pakistan": This paper examines a continuous burden control framework coordinated with a cross breed energy framework, for example, a matrix tied photovoltaic (PV) framework, independent PV framework, wind-turbine, nearby lattice and expects to have client command over-burdening electrical hardware. It is found the projected system can also be effectively when used on huge scale in Pakistan to reduce the supply gap and demand and current power outages.

Elsayed Saad [2021], in **"Implementation of a Modified MPPT Strategy for Solar-PV Arrays Connected to Harmonic-Polluted Grids Under Partial Shading Conditions":** This is argued

that Connecting the LCL filter between the VSC and the grid removes the harmonics and minimizes their impact. It is clear that the LCL filter lowers the current THD release of VSC within an acceptable range (<5%).

Gomathi Ramalingam [2018], in **"Modeling and Analysis of a PV-based Shunt Active Filter with BESS for Power Quality Enhancement Under Dynamic Load Conditions":** It is discussed that The shunt active filter is controlled using conservative power theory which provides selective compensation through the active filter. The various disturbances in the grid currents due to the loads are alleviated using this current decomposition technique. A "Battery Energy Storage System" (BESS) is connected across the solar PV array to store energy during surplus production of power and to provide energy when the PV array output is nil or very low.

Rujaporn Sumon [2018], in **"Modelling of photovoltaic power plants and loads for dynamic simulations in power system":** It is argued that the integration of PV into an integrated system with different interference suggests that a large amount of PV in the power system leads to the stability of a high-power system and unreliability. Without a controlled system, the stability of the power system may result in an unstable and uncontrolled operating environment since the simulation was started both before and after the disruption.

Seyed M.H. Nabavi [2014], in "**Dynamic Performance Response Evaluation of Solar Gate" [2]:** discusses to control the power generated by PV inverters introduced to suit the needs of the service. Solar Gate controls the output power of the inverters to ensure that they are equal to or less than the energy consumption of the site.

F. Bourennani [2014], in **"Optimal Design Methods for Hybrid Renewable Energy Systems":** In this paper it is discussed that the design of efficient HES("Hybrid Renewable Energy Systems") is challenging because the HES models are non-linear, non-convex, and are built with flexibility of mixed type that can be solved by traditional development methods. So to solve this problem These methods require the interaction of a designer to set parameters in order to obtain a "correct" design.

K K Prajapat [2011], in "**Simulation and Testing of Photovoltaic with Grid Connected System":** In this paper Loss of power converter plays an important role in the overall efficiency of the PV system. Grid-connected systems use a photovoltaic array to generate electricity, which is then fed to the main grid via an interactive grid inverter. When the sun generates more energy than is used in construction, the excess money is sent to the grid. To solve this problem the author had to design the proposed design options to achieve 2% to 4% conversion efficiency under different conditions, which directly improves system performance. Optimum inverter sizing depends on the weather, the inclination and flexibility as per the position and the shading ignored in this analysis.

Rujaporn Sumon [2018], in **"Modelling of photovoltaic power plants and loads for dynamic simulations in power system" :** It is argued that the integration of PV into an integrated system with different disturbances suggests that a large amount of PV in the power system leads to high power system instability and unreliability. Without a controlled system, the stability of the power system may result in an unstable and uncontrolled operating environment since the simulation was initiated and before and after the disruption.

Nitin Gutte [2018], in a "**case study of Surya logix controllers"** [website: www.suryalogix.com], in this case study 1 we have observed The plant owner is pleased with the zero export control system, because Burdon's total solar eclipse by going to each (three) building to limit excess solar energy production is now resolved, and even now the plant owner receives solar production.

1.3 Problem Formulation in the Industry

As Net metering is abandoned in many provinces in India and around the world, zero transmission becomes a near-term necessity. The ZED controller vigorously controls the output of solar inverters and allows non-electrical power transmission. Zero power delivery ensures that the inverter descends quickly at the correct value which ensures that no feed dropping on the grid and solar energy is generated at the maximum / required amount per load requirement [1].

So in this problem formulation we have observed to control the power demand we require a device which can control the power input and output of the load .To perform all these we require a device which can perform all these functions and this device is a called as **Zero Export Device (ZED).**

1.4 Proposed solutions

For the above given problems we have proposed several solutions to the management. Outbound systems include power generation units and, if applicable, battery storage systems. Such systems are not designed to feed the service grid and prevent this. The zero-export system from SMA enhances purchasing power and uses 100% of the solar energy it generates itself. Our system allows customers to expand solar energy without having to invest extra on utility grids. This is necessary if the grid operator does not allow the grid supply due to weak infrastructure and possible overcrowding, e.g. SMA offers a variety of solutions especially for PV systems that are no longer allowed or intended to supply solar energy to the grid due to limitations imposed by the grid operator.

Resolution 1: Direct self-consumption with zero export

A smart PV inverter is included in the system. This converter is designed to pull the egg out and limit power if it cannot be used at home at the same time it is built. Direct use can include 30% to 40% of normal household energy use [2].

Resolution 2: Self-utilization with a battery-storage set and zero export system

The system is fitted with a storage system so that most of the energy used is covered by electrical power from the customer's PV system. It also requires a smart PV inverter that can control power. In a typical household, half of the solar energy they produce after installing such a 50% to 70% storage system [2].

Resolution 3: Reassembling a battery-storage system for the self-consumption with the zero export in prevailing PV systems

If we want to connect a PV converter from the another manufacturer is installed in the existing system or an existing converter cannot be controllable, the system can be upgraded to the zero export system by adding a storage system. Any PV inverter/set can be used in the system in conjunction with a compatible lithium-ion battery set. The percentage of energy they generate in energy consumption is 50% to 65% [2]

Table 1.1 Different types of solution to ZED scheme

SMA solution	PV inverter	Storage system	Additional components
Resolution-1	The inverter must be able to regulate the power	-	-Components for intelligent energy management -Optional upgrade by adding components for charging electric vehicles.
Resolution-2	The inverter must be able to regulate the power.	1 Sunny Island 5.1M / 7.0H /9.0H or 1 Sunny Boy Storage with a well-matched lithium-ion battery set	-Components for intelligent energy Management. Sunny Home Manager 2.0 -Optional upgrade by adding components for charging electric vehicles -Optional system upgrade by adding a battery-backup system
Resolution-3	Any inverter can be used. Do it assurance that AC power of The PV inverter is not larger than Power of the battery inverter.	. A compatible lithium- ion battery can be used for this.	-Components for intelligent energy management -Additional contactor for disconnecting the PV inverter

1.3 Aim of work

Our main of using this Zero Export device is to block the generation of solar power in the plant. When the Power from the grid (NPCL) shuts down then the generation becomes greater than the load demand. So, to control this excessive power we have to use this Zero Export Device.

In recent times, demand for energy has been steadily rising, and we are experiencing the use of conventional and unconventional power plants. In addition, the cost of electricity is constantly rising. Therefore, owners are encouraged to install large PV systems that reduce grid use. Therefore, renewable energy sources such as photovoltaic panels (PV) are available today in many systems.

With the help of the ZED system with PV-grid interconnected power plant installed at the LG Electronics, we able to control this fluctuations of load the plant end when the grid power shut downs. We can be able to dynamic performance of the overall power demand.

1.4 Major Objectives of Work

Solar power provides local load instead of public consumption by monitoring / limiting voltage and current according to load requirement. The Zero Export device will monitor and appropriately the Inverter can produce the same unit or smaller unit than load. In this study and work we have certain major objectives which we have achieve in the stipulated time is as follows:

1) To control real-time power and will ensure that the inverter converter reduces solar output, in the event of low / no load.

2) To ensure that the converter does not crash and that at least no distorted feed is returned to the grid.

3) To analyze and evaluate the whole PV-grid connected with the zero export system design.

4) To monitor and view real-time power control functionality with a single line drawing and image.

5) To estimates the amount of power pumped due to the impact of the zero export devices every 10 minute break.

6) To creates Data Logger and provides real-time and historical data monitoring in our Solar Management Platform.

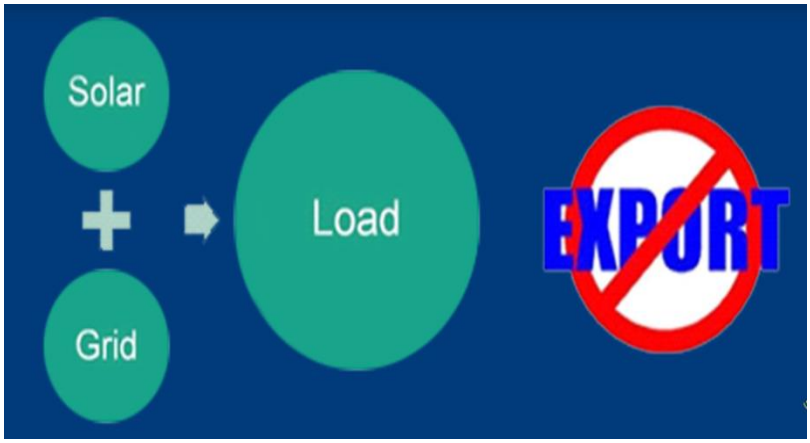


Fig. 1.1 Solar and Grid schematic diagram showing power not be exported

1.6 What is ZED (Zero Export Device)?

Zero Export means there is no transmission of electricity from the solar industry to the grid. Solar power plants send energy to bind, in the event of mass production. To stop this power transmission, solar converters need to be controlled by an external controller called ZERO EXPORT DEVICE.

Zero Export Device limits the production of solar panels according to the need for load. So that no excess power can be generated. It distorts the flow of reverse energy from a solar plant to a reference energy source [3].

Our advanced design has created remote monitoring of solar power plants as well as belt and generator. With Zero Export Owners of solar panels can use solar without the net-metering [smart meter] and can use their own solar power grid even when the electricity is off. With Zero Export Device owners can operate their generators by synchronizing their solar power grid.

Fig.1.2 ZED/ Power analyser installed at the DG area at a Transformer bus

Chapter 2

2. System Design and Methodology

As we know system design and methodology is one the important aspect to create a ZED system for the solar power plant of the LG Electronics. Design of any system requires various prerequisites such as device overview, pin description, wiring diagram etc.

2. 1 Installation

Before installing the product at the end of installation, make sure that the device is not damaged during consignment and everything looks normal.

2.1.1 Safety Instructions

. All connecting wires should not be twisted or twisted. This may result in malfunction, short circuits and malfunction of the device and / or connected sensor. Make sure that the ropes are not damaged during bolting or bolting [4].

The module can only work after it has been installed without being touched in the case. This product produces high frequency. Never use near medical equipment (eg heartbeat) and / or medical equipment (e.g. in hospitals).

2.1.2 Device overview

Before plugging in the device, make sure the voltage is off.

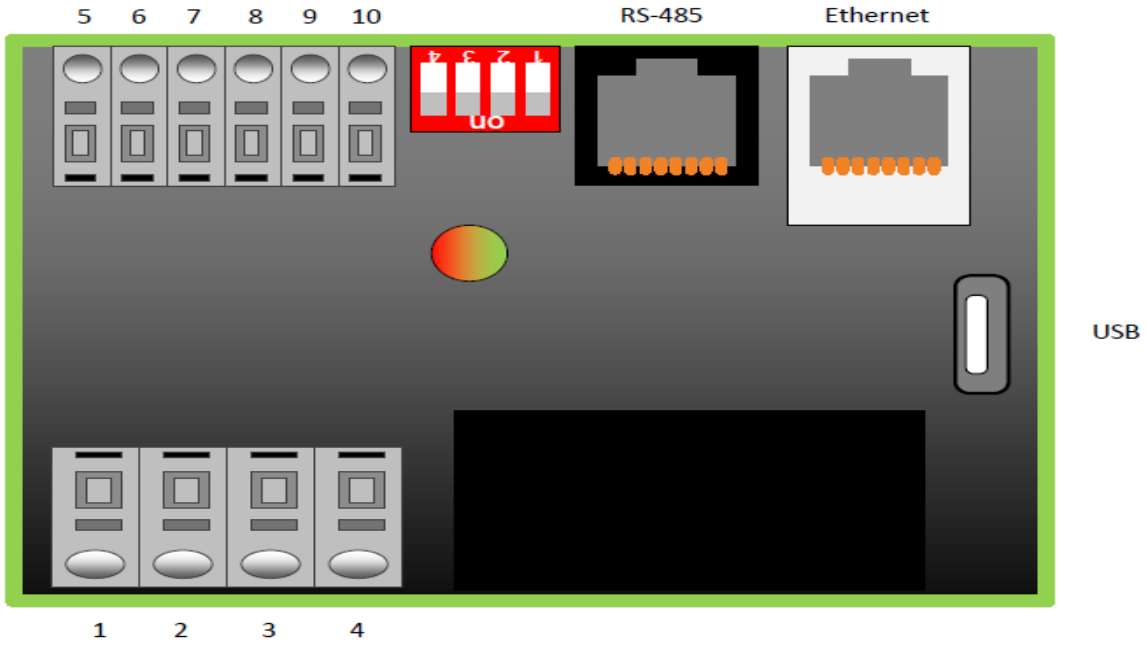


Fig. 2.1 Device schematic diagram

2.1.3 Pin Description

	Pin	Description	Minimum	Maximum
Voltage input	1	Phase 1 voltage input	85 Vac	250 Vac
	2	Phase 2 voltage input	85 Vac	250 Vac
	3	Phase 3 voltage input	85 Vac	250 Vac
	4	Neutral input of voltage		0 Vac
Power input	5	K input current transformer L1	0 Aac	5 Aac
	6	L input current transformer L1	0 Aac	5 Aac
	7	K input current transformer L2	0 Aac	5 Aac
	8	L input current transformer L2	0 Aac	5 Aac
	9	K input current transformer L3	0 Aac	5 Aac
	10	L input current transformer L3	0 Aac	5 Aac
Dipswitch	1	IP address selection	OFF = DHCP	ON = static
	2	System frequency	OFF = 50 Hz	ON = 60 Hz
	3	Single or Three phase	OFF = Three phase	ON = Single phase
	4	Internal use only	OFF = Default	

2.1.4 Wiring Diagram

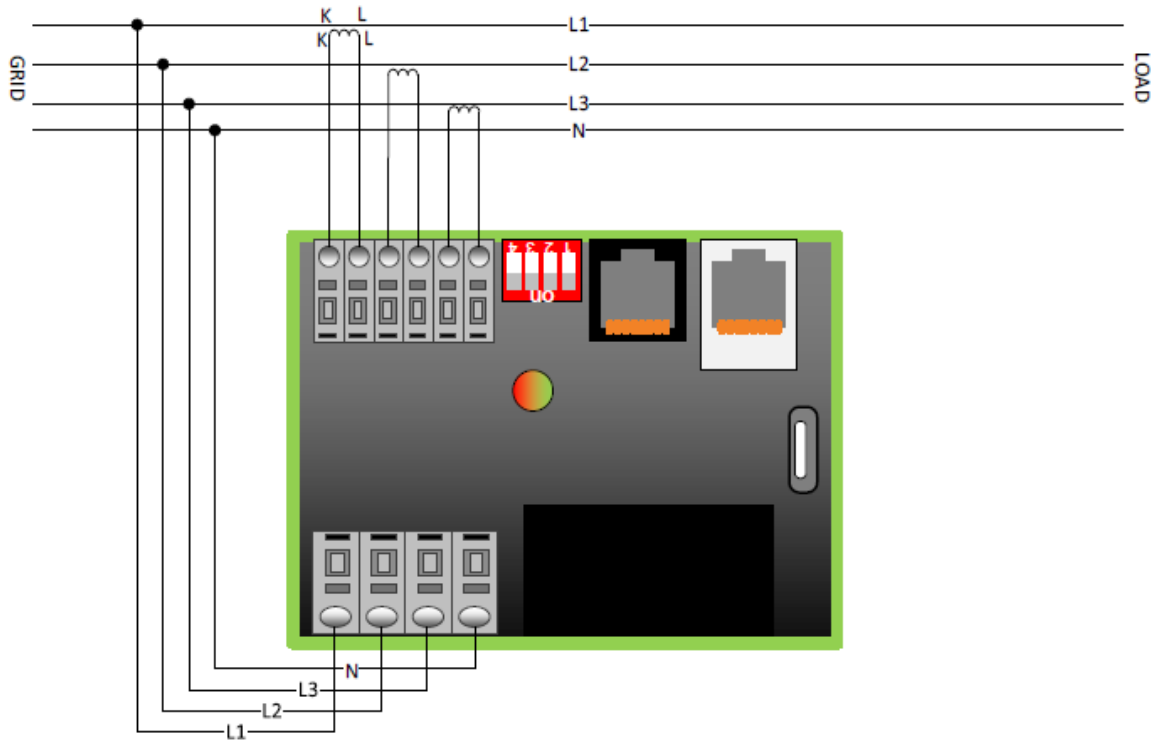


Fig. 2.2 Wiring detailed diagram of the device

2.2 What is a Zero Export Solar Inverter?

Zero Export solar converters are special purpose solar converters built within Zero Export. However, most solar inverters do not have zero emissions resources. To convert any solar inverter simply into the Zero Export Solar Inverter, we require a external controller.

2.2.1 Working of the solar Inverter System

Since we know what a solar inverter is, let's talk about its efficiency and effectiveness. Solar panels generate direct electricity with the help of electrons ranging from negative to positive. Many of the things we use at home apply to other things. This AC is caused by these back and forth electrons from negative to positive. With AC power the voltage can be adjusted depending on the device use. As solar panels only produce Direct current solar inverter is used to convert DC to AC [3].

The inverter generates a square or sine wave that can be used for utilizing the lights, t.v, lights, engines etc. Although these converters can an also generates harmonic distortions. Costly inverters use many steps to produce a sine wave and due to which we found it in the solar-powered inverters. Basically the inverters should be sufficient to deliver enough power for all the necessary things [4].

You can make photovoltaic tiles that attract energy from the sun and convert it into the original form of electrical energy that can be used for lighting, homes, industries, and companies. Photovoltaic cells consist of negative silicon bonds embedded under a piece of glass. When the Sunrays protons fall on the PV cells then they excite neutrons present in silicon. Negative neutrons now get attracted to silicon but are also trapped within the magnetic field. Cables are committed to the silicon grip on those neutrons & though connected to the electrical circuit, a current is formed in it. It then offers direct space and converts it into electrical energy using an inverter so that household appliances can work [2]. As stated previous the main household applications operate on the current which is why the inverter is used to convert DC to AC power.

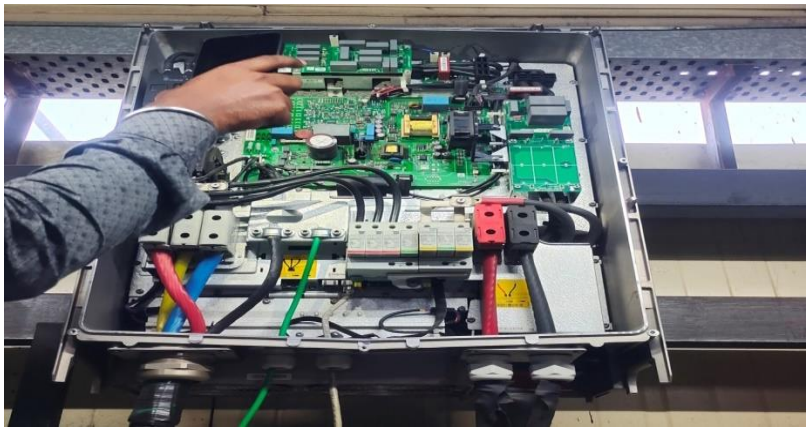


Fig. 2.3 Solar Inverter some fault detection

2.2.2 Solar Inverter Design of the system

To simply understand the construction of the solar inverter let us deliberate the following construction:

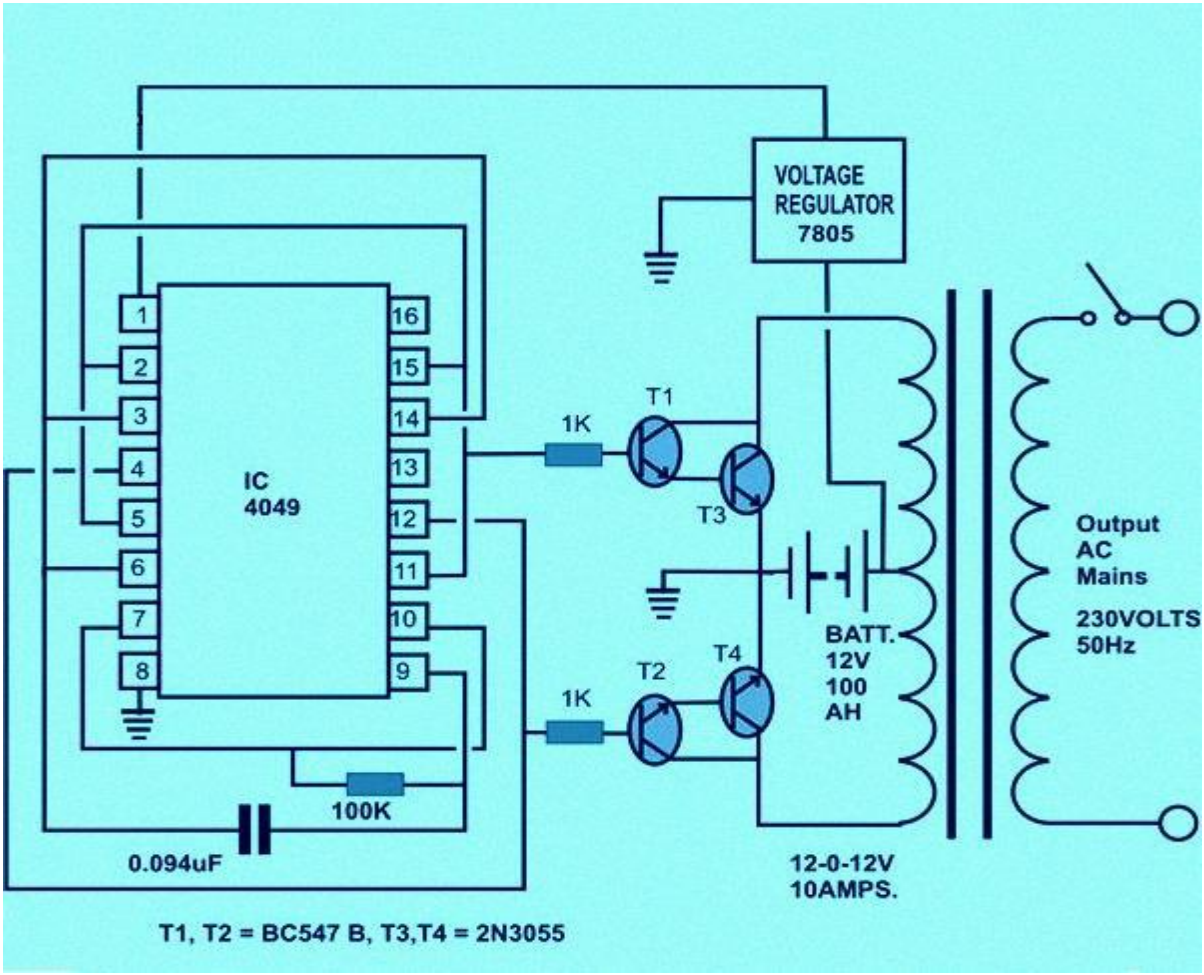


Fig. 2.4 Schematic Diagram of Solar inverter design

1. According to the circuit diagram originally finished the assembly part of the oscillator consisting of small parts. It finishes well to connecting leading part themselves and connecting all members.
2. Now connect power transistors to aluminum heat sink. It is done by cutting the aluminum sheet into fix sizes and bending their sides, so that it can grip tight.
3. Use a mica separation kit to patch-up transistors in the aluminum heat sink, to avoid all those short circuits and contact of transistors to the ground level.
4. Link the sink to the bottom of frame.
5. Also tighten the power converter near the aluminum heat sinks with the help of screws.
6. Let us connect appropriate points of the circuit board connected to the power transistors in the heat sinks.
7. Finally connect the output of the power transistor to next turn of power converter.
8. Finish by connecting external electrical appliances.
9. Intentional solar power and transformer can be added internally to control battery if require necessary. (see Fig. 2.5)

2.2.3 Solar Inverter System Design Circuit Diagram

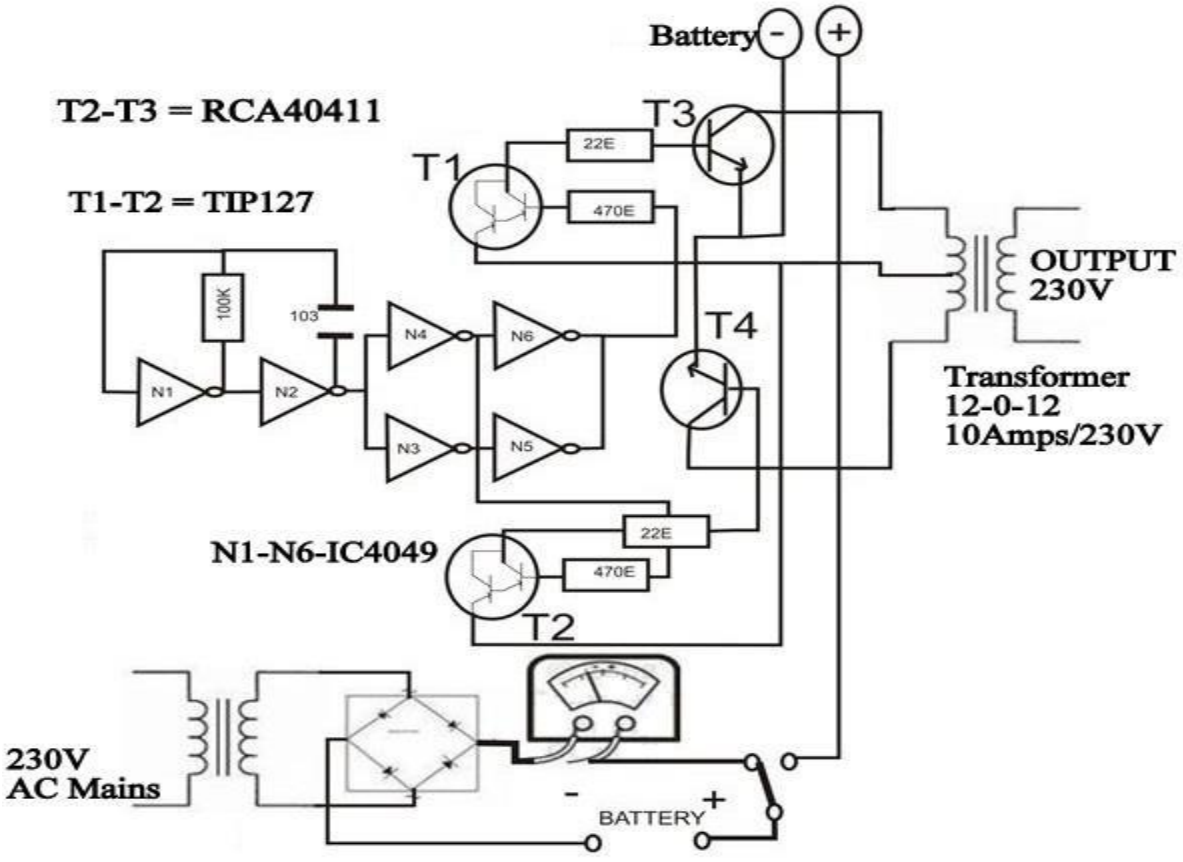


Fig. 2.5 Circuit Diagram of Solar Inverter System Design

2.2.4 Solar Inverter System Design Pros

After discussing in full detail what a solar inverter system design is and how it differs useful in making electrical applications work in housing and industrial levels, we should now elaborate the many pros of the device.

- Solar energy contributes to decreasing global warming and impacts of greenhouse effect.
- The use of renewable energy supports to save economy for lots of people who are already using solar module [4].
- Solar inverter system helps to convert DC it into batteries. It helps those people which use narrow electricity.
- This inverter have many advanced roles and very efficient.
- It is not expensive than generators.

2.2.5 Solar Inverter System Design Cons

- Initially you need to use a huge money to bought the solar inverter.
- This would operate good and generate DC, when the sunrays is good.
- Solar modules are used to get sunlight required huge area.
- The device can only work properly if the presence of the Sun is strong.

Afterward analysing the incorrectness of the inverter system say that if the device is valuable at specific areas it also requires proper storage and when it comes to solar device solar panels are a must.

Fig. 2.6 various solar inverters installed at the Bulk store of LG plant

2.3 Solar Power Trainings

In this course the we learns roughly about safety & the environment, knowledge of fire extinguishers, simulated respiration. You get an idea of trading and configuration tools, identifying different types of conductors, cords and leather extensions and shared functions. Perform tests with various Power Tools such as Wattmeter, Power Meter, etc. We comprehend the movement of the natural planet and the process of sunlight. It measures the intensity of solar radiation, analyses the effect of shadows on the sun's rays, turns the measured radiation curve and draws a solar map with respect to local time. Trainee learns about cell features and Photovoltaic modules, Batteries, Charging controls and builds Solar DC small electrical appliances.

Fig. 2.7 Solar and Energy conservation Training at the ILC, LG plant

Chapter 3

3. Working and Procedure

Avoid losing power output due to net metering delays. For sites that do not have Net Metering, power outages in inverters are reduced to improve the amount of power generation for the use of hostages and to force off-grid power transmission.

3.1 ZED Working

In the case of the Zero export controller, a double directional meter will be installed on the receiver side, which works with the maximum and minimum fixed point that can be activated by the software. Zero export solution poles connect power meters and converters to detect current load and help the user to use solar energy as per the required load. This solution will reduce the power of solar inverters as a load for each building and there will be no Export grid [5].

The load from the grid will be guaranteed to work at 4% to 8% of the approved load [6], depending on the variability / variability of the load.

The working principle is as follows:

1. Read Active Power from meter

2. Is Active power > Max Set point? If yes, increase power on inverters

3. Is Active power < Min Set point? If yes, decrease power on inverters

4. Repeat from step1

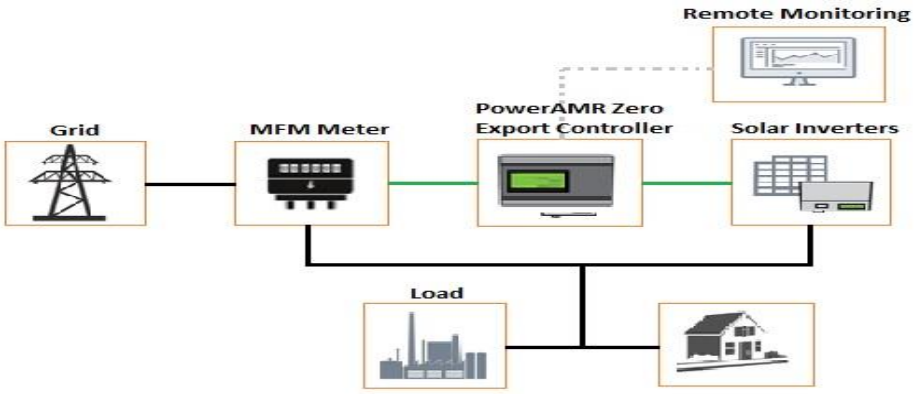


Fig. 3.1 Working and the principle of ZED

3.2 Various Resolutions Using Zero Export Device

Outbound systems include power generation units and, if applicable, battery storage systems. Such systems are not designed to feed the service grid and prevent this. The zero-export system from SMA enhances purchasing power and uses 100% of the solar energy it generates itself. Our system allows customers to expand solar energy without having to invest extra on utility grids. This is necessary if the grid operator does not allow the grid supply due to weak infrastructure and possible overcrowding, e.g. SMA offers a variety of solutions especially for PV systems that are no longer allowed or intended to supply solar energy to the grid due to limitations imposed by the grid operator.

Resolution 1: Direct self-consumption with zero export

A smart PV inverter is included in the system. This converter is designed to pull the egg out and limit power if it cannot be used at home at the same time it is built. Direct use can include 30% to 40% of normal household energy use [3].

Resolution 2: Self-utilization with a battery-storage set of system with a zero export

The system is fitted with a storage system so that most of the energy used is covered by electrical power from the customer's PV system. It also requires a smart PV inverter that can control power. In a typical household, half of the solar energy they produce after installing such a 50% to 70% storage system [3].

Resolution 3: Reassembling the battery-storage set for self-utilization with the zero export in prevailing PV systems/grid

If we want to install a PV converter from another manufacturer is installed in the existing system or an existing converter cannot be controllable, the system can be upgraded to the zero export system by adding a storage system. Any PV inverter/set can be used in the system in conjunction with a compatible lithium-ion battery set. The percentage of energy they generate in energy consumption is 50% to 65% [4].

3.3 Resolution 1: Direct Use with Zero Export

3.3.1 System Arrangement

Systems can be used as zero export systems even if grid installation is not possible or necessary, as long as 100% of the generated energy is used by itself. Now, it is more crucial that a PV inverter can monitor the power produced so that only as much as the power is produced as this is now used and no power is get to the grid.

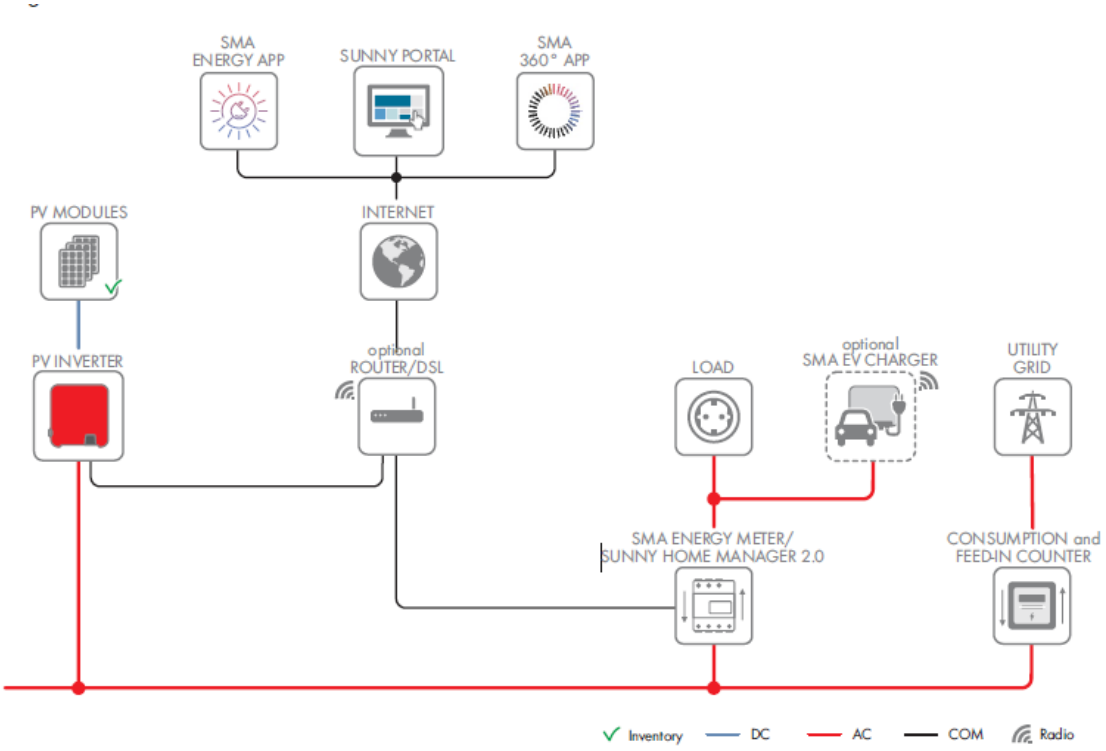


Fig. 3.2 Resolution 1: Direct Use with Zero Export

If your PV system inverter cannot control the power, it should be replaced with a new switch. Alternatively, you can upgrade your PV system by adding SMA.

The SMA inverters listed below can be used to regulate the power within the stipulated time:

3.3.2 Zero Export System Requirements

If your PV system is equipped with a power controller, you can use your system as a zero-export system without any upgrades. For zero export, the hardware components listed below should be included in the PV system:

- Controllable PV converter
- Sunny Manager

Sunny Manager should provide rated values from the communication point every 200 ms to achieve the required control power. Therefore, the setting on Sunny Portal must be changed after registering the program:

- On the Configuration page > Device Overview > Home Manager > Symbols page, select the button.

- In the Counter Configuration field, set the measurement interval to 200 ms [8].

- Additional components for enhancement for personal use, e.g., radio-controlled sockets or control rod. With this solution, you can always install the backup system over time.

3.4Resolution 2: Self-use with battery storage system and zero export

3.4.1 System Arrangement

In the case of systems where grid installation is not possible or desirable, but you want to increase the amount of self-generating power used, we recommend installing a storage system over a smart PV inverter.

This reduces the cost of purchasing the grid to a minimum. To ensure that the system does not provide grid usage, SMA Home Manager 2.0 should be installed. It measures power at the point of contact, disconnects the PV converter as soon as the battery storage system is fully charged, and prevents electrical power from flowing into the operating grid [4].

Here, it is important that the PV inverter can control the power generated so that only as much power is produced as it is currently used. The storage system, which includes a battery and a battery inverter, incorporates power generators and allows you to adjust the operating time so that your solar power can be used at night, for example. For example, the power generated can be used to charge an electric car. Additionally, installing a battery support system may provide protection in the event of a power outage[5].

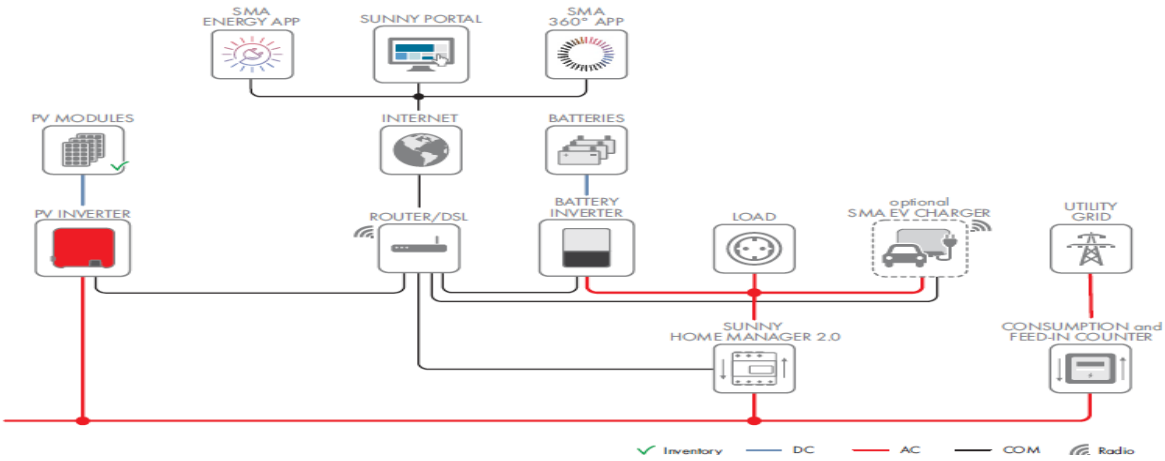


Fig. 3.3 Resolution 2: Self-use with battery storage system and zero export

The SMA inverters enumerated below meet the following requirements of Re-Solution- 2 [5] and they do not need to be exchanged:

Table 1.2 Requirements to use solution 2

PV Inverter	**Battery Inverter**
Sunny Boy (SB)	**Sunny Boy Storage (SBS)**
SB6.0 AV-50	SBS2.5-20
SB6.0 AV-50	SBS3.7-20
SB7.0 AV-50	SBS3.2-20
SB5.0 AV-50	SBS6.0-20

3.4.2 System Requirements

For zero export devices, hardware constituents enumerated below need to be installed in the PV system installed with the battery storage setup:

- Controlled PV converter
- Sunny Boy Storage 2.1/3.6/5.3
- Compatible battery storage system
- Sunny Manager

Sunny Manager should provide rated values from the communication point every 200 ms to achieve the required control power. Therefore, the setting on Sunny Portal must be changed after registering the program:

- On the Configuration page > Device Overview > Home Manager > Symbols page, select the [Process] button.
- Select Extended Configuration.
- In the Counter setting field, set the measurement interval to 200 ms.
- Additional components for enhancement for personal use, e.g., radio-controlled sockets or control rod.

3.5 Resolution 3: Retrofitting with a battery-storage setup for the self-depletion with the Zero export in fundamental PV systems

3.5.1 System Arrangement

If we want to install a PV converter from another manufacturer is installed in the existing system or an existing converter cannot be controllable, the system can be upgraded to the zero export system by adding a storage system. Any PV inverter/set can be used in the system in conjunction with a compatible lithium-ion battery set. The percentage of energy they generate in energy consumption is 50% to 65% [3].

As soon as the specified charging mode is reached on the battery, the battery converter opens the connector and this temporarily disconnects the PV converter from the system. If the battery drops to the required charging condition, the battery converter closes the battery-connected connector so that the PV converter can generate power again.

Here, it is one of the most important that charging energy of the battery set of inverter is at minimum and equal to highest AC power of the PV set used. This ensures that the power from the PV system is not fed to the service grid but is received by the battery storage system, or the PV system is disconnected from the contact [4].

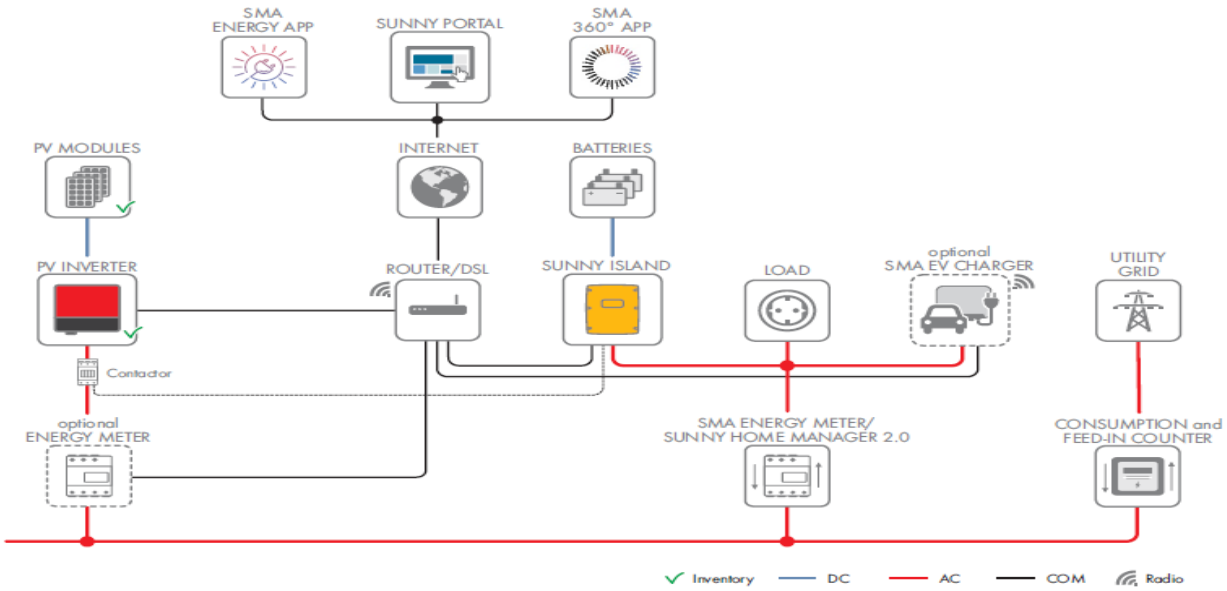


Fig. 3.4 retrofitting a battery-storage system for the self-consumption with the Zero export in prevailing PV systems

3.5.2 System Need for Zero Export

For zero export, the computer components listed below must be installed in an existing PV system installed with a battery storage system:

- An existing PV inverter is used. Any PV inverter can be used for this.
- Additional connector to control closed loop PV inverter
- Compatible lithium-ion battery
- Sunny Manager

Sunny Manager should provide rated values from the communication point every 200 ms to achieve the required control power [8]. Therefore, the setting on Sunny Portal must be changed after registering the program:

- On the Configuration page> Device Overview> Home Manager> Symbols page, select the [Process] button.
- Select Extended Arrangement.
- In the Counter Configuration field, set the measurement interval to 200 ms.

Additional extensions for personal use, e.g., radio-monitored sockets or the control rods to use e-mobility again, you need to upgrade the system by adding a SMA EV Charger.

Chapter 4

4.1 Solar Roof Top Plant Maintenance

4.1.1Maintenance Classification

Maintenance can be broadly divided into two main categories namely Scheduled Maintenance and Random Retention. The description of each section has many details in this section.

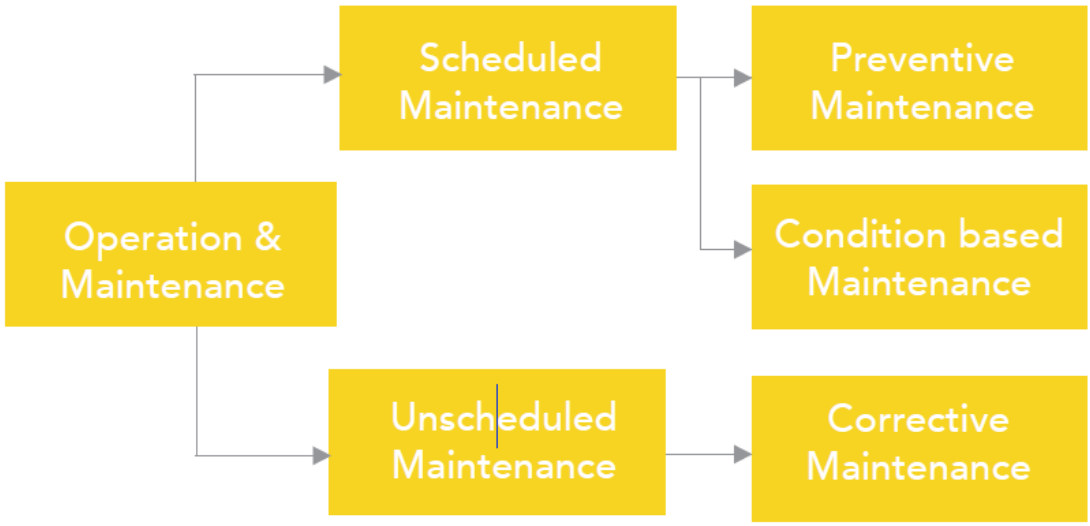


Fig. 4.1 Different Types of Maintenance

4.1.2SCHEDULED MAINTENANCE

Fixed maintenance (SM), as the name suggests it is pre-planned and based on the standard care, correcting and preventing errors from occurring. SM is done from very time to time. When repairing, it is very important to refer to the temporary data provided by the supplier so that one is familiar with the part and the safety measures, which must be followed while retaining the part. Under SM there are two common ways to manage nutritious foods [6].

a) Preventive Maintenance

b) Condition based Maintenance

- **Key features of Scheduled Maintenance**
  - Frequent intervals according to manufacturer's authorisation
  - Significant balance between SM costs and yield increases which is required throughout the life of the system.
  - SM is performed at the non-peak and best hours during the night.

a) Preventive Maintenance

Preventive Maintenance (PM) includes routine testing, servicing and cleaning modules on a regular basis. It is done to reduce downtime and unnecessary production losses. Improves performance, increases availability and reduces the chances of equipment malfunction. In preventive care, a general care strategy is followed to test the plants and perform at very low hours so that the generation is not affected. But it can also include unnecessary site visits and high repair costs.

The planning and frequency of a PM is determined by a number of factors such as environmental conditions, selected technologies and warranty conditions. A perfect balance should be desired between the cost of planned repairs and the growing yield during the life of the system.

The main events under PM include:

Mounting structure integrity	Cabling connections
Module cleaning	Balance of plant
Hotspots detection	Inverter Servicing
Junction box servicing	Earthing protection
Inverter servicing	Vegetation control

Recommendations:

- Cleaning time before 11 A.M. and after 5 P.M.
- Plant maintenance in night hours

Fig. 4.2 Solar module cleaning at the LG plant, Noida

B) Condition-based Maintenance

Condition-based care involves monitoring of the equipment and operation of the equipment in real time and addressing a potential problem early to prevent malfunction. This method uses timelines to obtain evidence that equipment is deteriorating, with the intention of prolonging service life by avoiding future problems. Improves system performance and efficiency in anticipation of failures and early detection.This type of care requires special diagnostic equipment and a strong plant performance monitoring system that can extend and improve system health.

4.1.3UNSCHEDULED MAINTENANCE

Random adjustment addresses system and partial failure after occurrence. Important parameters are diagnostic, correction time and response speed. Depending on the type of error the reference response time may be within 48 hours. Under random adjustment there is one common method of maintenance management:

Corrective Maintenance

Corrective repairs include repairing broken equipment and reusable. In short, this saves labour time and labour but over time, it can be very costly in terms of the downtime of equipment, repairs and the life of short equipment. It includes

- Establishment loose connections
- Replacing damaged modules
- Replacing fossil fuels
- Fixed air conditioning
- Fixing inverter errors
- Repair equipment damaged by attackers
- Replacing spray connectors
- Correcting SCADA errors
- Correction of mounting structural faults

4.2 Operation & Maintenance Management

Following aspect is considered in the operations and their maintenance management as follows:

4.2.1 Measuring the Quality of Your O&M Program

O&M management is an integral part of any program. The management of the organization must quandary the different components of that organization into a business. From their exposure, the full program should contain of five different organizational functions: Performance, Care, Engineering, Training, and Management - OMETA.

Fig. 4.3 Operation and Maintenance Working principle

Operations:

- **Management**- Ensuring the effective implementation and management of operations.
- **Occupational Behavior**- Ensuring process efficiency, safety, and reliability.
- **Resource Usage Management**- Monitoring of all the equipment's.
- **Technician Knowledge & Performance**- Every technicians work according to their experience.

Maintenance:

- **Management** - Improving the effective management resources of India.
- **Performance Management** - Effective and safe care management of the practices to promote cost-effective, safe, and reliable plant performance.
- **Preservation Protection** - Contributing to the efficiency and reliability of the plant systems.

Engineering Services:

- **Organization and Management of Engineering** - Improves the overall application and management according the tech background.
- **Apparatus Repair** – proper repair of all the equipment should be done.

- **Apparatus Performance controlling** - Monitoring activities that improve the overall efficiency of equipment.
- **Engineering and Documentation Provision Processes** - Ensuring that engineering and documentation support systems provide appropriate guidance [6].

Admin:

- **Admin Management** - creating effective implementation of rules and regulations, management of operational equipment.
- **Admin objectives** - Develop and implement legitimate administrative objectives to improve apparatus performance.
- **Supervisor Monitoring** - Monitoring and evaluating channel operations.
- **Staffing and Qualifications** - Ensuring that vacancies are filled by good qualified and trained people.
- **Safety Campaign**- Achieving a great level of workforce and public safety.

4.2.2 Improvement Campaigns of the Facility Engineering (Electrical Part)

A) FI-11 Campaign:

Basically this is improvement philosophy used in various countries such as Koreans. In this philosophy we have focuses on several points such as:

- Clean up 3 steps
- Autonomous management
- SMT
- Press shop
- 6 Tool
- ESD(Electro static discharge)
- Process Loss
- Logistics Loss
- Equipment Loss
- Memo Suggestion

In this campaign we have to improve our electrical utilities area which is DG Area and their electrical and mechanical stores. Also, we have some improvement work or activity for that particular month.

In the last 4 month we have secured 2 times position in this category. Electrical manager Mr. Deepak sirs have made me in-charge for this campaign.

B) 5S Campaign

This is also a improvement campaign to increase the productivity of the Resources which is our DG area and store area. Basically 5S is a five step organisation technique to create and maintain an intuitive workspace. Originally this concept comes from Japanese [7] i.e.

- Seiri
- Seiton
- Seiso
- Seiketsu
- Shitsuke

The meaning of these terms in English is as follows:

- Sort
- Set in Order
- Shine
- Standardize
- Sustain

Fig. 4.4 a 5S hoarding at the factory premises

4.2.3 Electrical Utility

We have sanctioned load of 10MW from the NPCL (Noida power corporation limited), we have also installed the 3.5MW roof top solar power plant and for the backup power we have 4 LTDG having rating (4x1250KVA) and 4 HTDG rated (4x2000KVA) and also have 2 rental gas generator setup also.

Fig. 4.5 Image of 1250KVA LTDG installed at the electrical facility of LG plant of Noida

Fig. 4.6 Image of 2000KVA HTDG installed at the electrical facility of LG plant of Noida

For the operation whole generators sets, we have installed a SCADA ("Supervisory control and data acquisition"), with the help all the system and operation is automated.

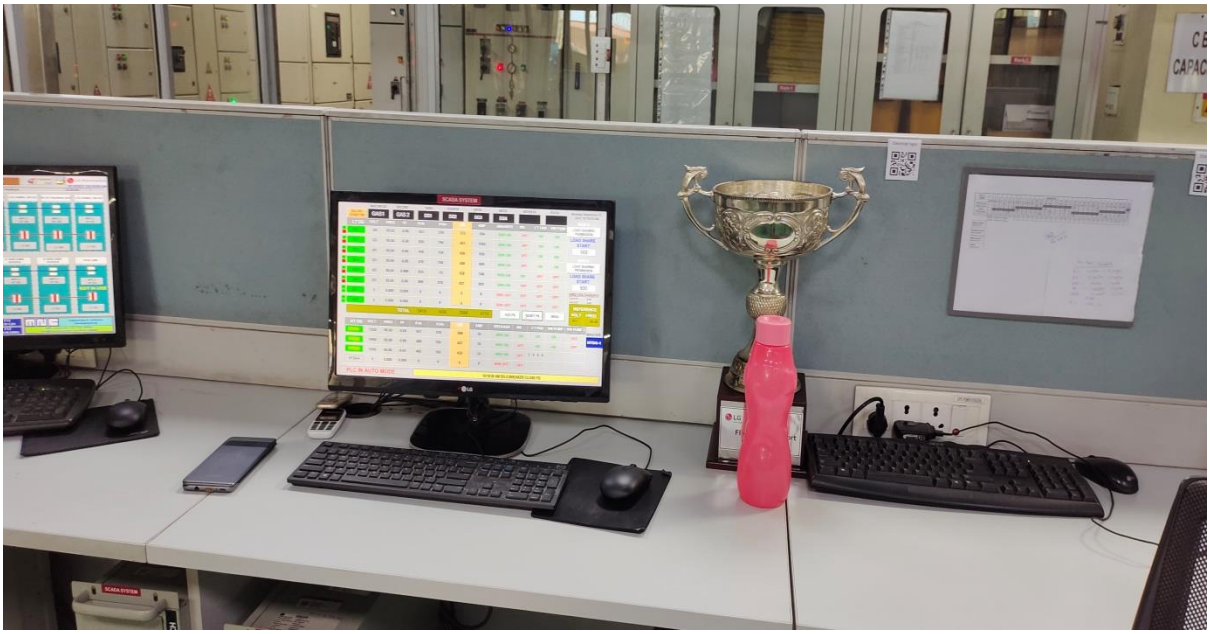


Fig. 4.7 SCADA Room of Electrical facility at LG plant

1) Electrical safety Trainings

While operating in a industries and manufacturing plants, electrical safety is one the important factor for any organisation. So to improve safety we have given proper trainings to all the workforce includes workers, vendor, apprentice and staff technicians [6].

2) Electrical Protection

Introducing your staff technicians to the electrical safety rules and principles help to clear the works of what you should and should not do when working with electrical units, PDBs, and systems. Train your new joinee, or update your team's existing information about working conditions.

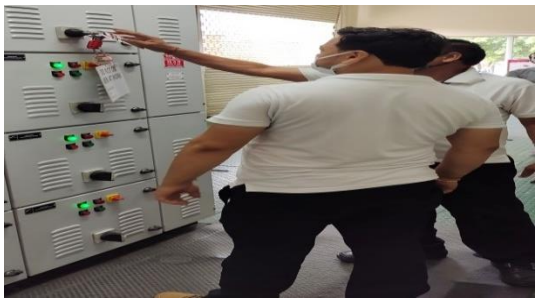


Fig. 4.8 Safety Instructions by senior technicians

3) OSHA Safety Guidelines

As a business or boss, it is your lawful obligation to teach your workers about the rise and grouping of electrical wellbeing rules set by the “Occupational Safety and Health Administration” (OSHA). These OSHA principles are set to "guarantee protected and solid working circumstances for representatives" [6], to forestall hazardous and risky electrical circumstances. Integrating this subject of electrical security preparing into your electrical wellbeing preparing won't just save your organization from costly punishments and legitimate punishments however will likewise shield your representatives from wounds and accidents at work.

Fig. 4.10 working of manpower for some electrical works

4) Qualified and Not qualified Workforce

To accomplish total electrical security in the work environment, it is likewise really smart to examine among your group the distinctions among qualified and inadequate individuals. You can utilize this valuable chance to explain their jobs and obligations, see who is endlessly approved to work in the live and evolving conditions, and help them to remember a restricted admittance limit or a significant region where there are developing power potential open doors.

Fig. 4.11 Manpower working on a specific site

5) Personal Protective Equipment (PPE) Kit

In spite of the fact that it isn't in fact imaginable to kill all risks during electrical activity, the utilization of individual defensive gear (PPE), and legitimate wear, can limit leftover dangers and wounds in an enormous region. They should know precisely why they are wearing it, how to store and discard it, and their limits in safeguarding themselves from electrical contentions.

6) Protected Tools and Equipment

These apparatuses act as the principal line of guard in an unusual circumstance, for example, contacting electrical machines that are inappropriately marked areas of strength for as. Assist your group with figuring out the significance of these instruments, and how they contrast from standard devices that are effortlessly planned with additional elastic.

Fig. 4.11 Technicians and manpower working on the 5S & cleaning works at LG Plant

7) Electrical energy risks

Prior to taking up their electrical administrations, it is likewise vital that your electrical specialists are furnished with adequate data about the dangers related with blackouts. Pass on the most well-known energy perils like shock and consumes blasts and flames, and electric shock, how they can happen, and how they can be really kept away from.

Fig. 4.12 Electrical safety training given to all the manpower of the vendors by Electrical manager Mr. Deepak Singh

8) Electrical emergency response

In spite of the utilization of exceptionally strong electrical security frameworks, electrical-related risks are as yet conceivable. Nonetheless, having thoroughly prepared staff individuals who comprehend what they endlessly shouldn't do in such outrageous cases can go far in saving lives and downplaying wounds and wounds.

Chapter 5

5.1 Common Tools & Equipments Used

The person in charge of O&M for solar systems should know and be equipped with tools and equipment. RTPV systems usually require special equipment and these devices must be stored in a safe place and well maintained. Therefore, it is important that all essential tools, backup parts and equipment are kept in place and ready for use. The measurement tool should be regularly inspected for its effectiveness and accuracy [8].

Table 1.3 a list of such tools & equipment is enlisted below

Safety	**First aid kit**	**PPE**
Documentation	O&M Manual	Datasheets
	System Service register	Paper & Pen/Pencil
Equipment	Digital Multimeter	Clamp Meter
	Hydrometer	Sun pathfinder
	Thermography Camera	Sun pathfinder
	Pyranometer	IV – Tester
	Battery maintenance kit	Battery water filler
Tools	Screw drivers	Nut drivers 1/4in & 5/16in
	Crimping tool set	Angle Finder
	Measuring Tape	Compass
	Cleaning Brush	Flashlight
	Hammer	Cutting Pliers

Equipment

Fig. 5.1 Equipment used in the maintenance for solar plant

Tools

Fig. 5.2 Tools required for the solar plant maintenance

Safety Tools

Fig. 5.3 Safety tools for electrical facility

5.2 TESTING METHODS & TECHNIQUES

5.2.1 Testing by using Multimeter

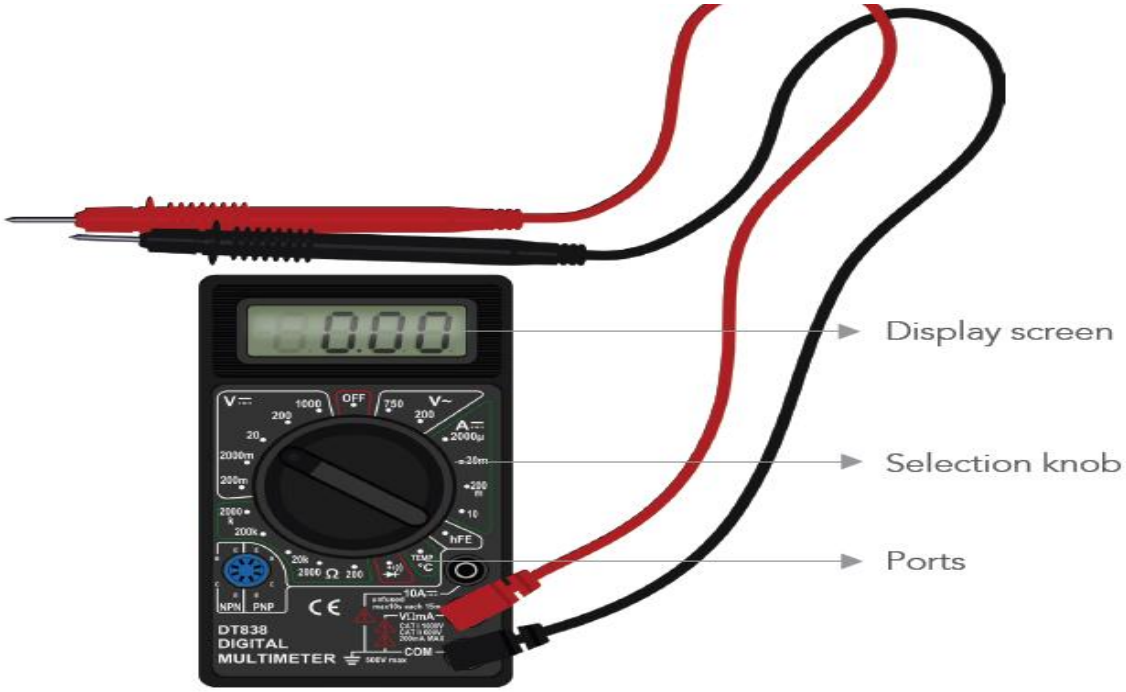


Fig. 5.4 a Digital Multi-meter

The person in charge of O&M for solar systems should know and be equipped with tools and equipment. RTPV systems usually require special equipment and these devices must be stored in a safe place and well maintained. Therefore, it is important that all essential tools, backup parts and equipment are kept in place and ready for use. The measurement tool should be regularly inspected for its effectiveness and accuracy [9].

The parts of the multimeter include:

- **Display screen**: The screen shows the value of the measured parameter number.
- **Selection knob**: Multimeter performs many functions such as reading voltage, current and resistance. Select button permits the client to choose the necessary capability.
- **Pins**: Different types of digital multimeter are commonly used to output PV module and bulk unit and to test AC equipment such as inverters and other circuits.

5.2.2 Testing by using Clamp Meter

Fig. 5.5 an electrical clamp meter

The clamp meter is an electronic test tool that combines current sensor with a basic digital multimeter. Clamps measure current and probes measure voltage. Having a dangling active jaw connected to a power meter allows consumers to simply hold close to ropes, cords and other conductors anywhere in the electrical system and measure its current strength, without interrupting it. It measures AC & DC voltage, AC current, continuity, resistance, and has other models, DC current, temperature, power, frequency and more [9]. Typically, they measure about one-tenth of the unit making them perfect for electrical work.

5.2.3 Testing by using Infrared (IR) Camera

Fig. 5.6 Infrared camera used for various testing in the electrical facility

IR imaging is performed to detect the causes of power loss in a few parts of a PV plant. O&M staff can use a number of diagnostic procedures [9]. Heat recording of all parts of the PV plant such as PV modules, various connecting boxes, inverters, and cables are used to identify system defects that may not be noticeable [10].

- Before starting the IR scan, make sure the PV array is active and that the temperature difference in the modules is not visible when the system is not working.
- Before testing is performed make sure the inverter is working.

Chapter 6

6. Test and Results

After the installation and commissioning of ZED system with whole PV system grid we have observed good results and can also be tracked with our real time tracking website.

6.1Technical Backgrounds

The construction and type of weather station is determined by PSET. One of the reasons for this unit is the benefit of good costs. The sensory suspension works much better compared to other semiprofessional channels.

6.1.1Weather Stations Data

The main device used in this thesis is the weather channel from "Davis Instruments" [11]. The Integrated Sensor Suite (ISS) combines different sensors to measure the actual weather.

- Rain collection meter
- Temp. sensor instrument
- Barometer
- Humidity sensor instrument
- Radiation sensor
- Wind sensor & anemometer

The biggest advantage is the large wireless range, which influences the purchase decision. The channel sends information via free radio band. It can travel up to 300 m in line of view. The distance over the walls is estimated at 60 to 120 m per construction [11].

Fig. 6.1 Weather Station mounted

The channel is able to sample at seven different times from one minute to 120 minutes. When the PC is turned on the recipient will save the data. The recipient can keep up to 2,560 records. Each record contains 30 values (day / time, temperature, wind speed,) [12]. For a period of 1 minute the recipient can store data for 42 hours. Older data will be reduced and lost if it is not transferred over time to the PC [12].

6.1.2 Solar radiation sensor

The solar radiation sensor (Figure 6.2) is one of the primary interest sensors. It is placed next to a rain collector. The level of construction ensures that the sensor is installed horizontally. In addition the sensor has double shell housing to prevent interference.

Fig. 6.2 Solar Radiation Sensor

In thermal rays . The air between the shells cools the body with convection. The cutoff ring in the shell enhances the cosine response [12]. It is a pyranometer based on cells with a silicon photodiode. The internal amplifier turns the current into a voltage range from 0 to + 2.5 V ("DAVIS INSTRUMENTS"). Table 3.5 shows the technical data for radiation sensors.

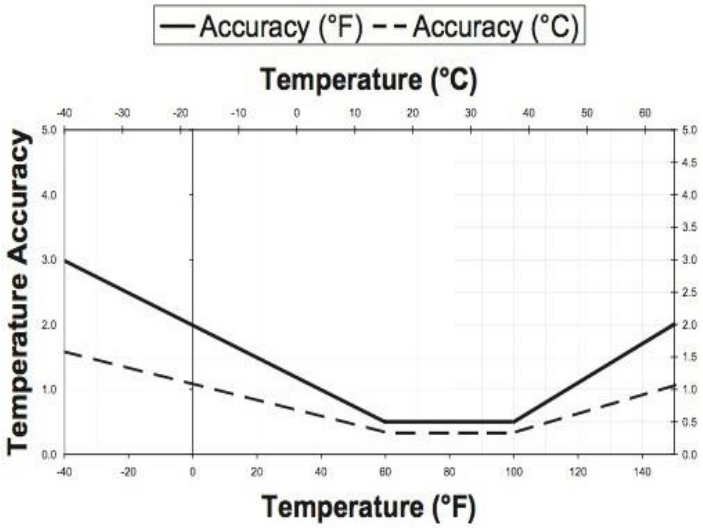
Table 1.4 Data sheet of the solar radiation sensor [11]

Data sheet for solar radiation sensor	
Units	1 W/m2
Range of sensor	0 to 1,600 W/m2
Precision	5 % of full scale
Implication	up to ±3% per year
Cosine Curve	±3 % for the angle of incidence from 0° to 75°
Temp. Coefficient	-0.15 % per °C (-0.077 % per °F)
Change Interval	45 seconds to 1 minute (5 minutes dark)
Current Data	Immediate Reading
History Graph Data	Hourly Average, Daily, Monthly Highs
Indicator	In height Threshold for Immediate Reading

6.1.3 Temperature sensor

The temperature sensor is mounted on a radiation shield under the rainwater harvesting cone. The PN junction silicon diode, which has a temperature dependent on forward voltage, converts the temperature into an electrical signal. It is taken every 10 to 12 seconds [11]. The sensor has a range of range from 40 ° to + 60 ° C. Above 7 ° C its accuracy is ± 0.5 ° C. In Figure 3.4 the process of accuracy over temperature is displayed. This radiation defect can be reduced by radiation exposure by fans to + 0.3 ° C. It can only order a different part [12].

Fig. 6.3 Accuracy over temperature trend for Davis temperature sensor



6.1.4 Moisture sensor

The film capacitor element measures the relative humidity. The principle of operation of a thin sub-film between electrodes changes its dielectric consistency and humidity. This change can be measured by the volume of the element.

The sensor measures from 1 to 100% RH with an accuracy of ± 3% between 0 and 90% RH and ± 4% between 90 and 100% RH. Each year the sensor can drift ± 0.5% with accuracy. Update time is between 50 seconds and 1 minute [13].

6.1.5 Pressure sensor

Unspecified sensor type measures barometric pressure at a range of 540 to 1,200 mbar. The accuracy is ± 2.0 mbar and the update time is up to the 1 min. or can be forced with the receiver support [14].

6.1.6 Wind direction sensor

The air space is measured by an air valve. The potentiometer turns the direction into a resistance. Adjustment is 1 ° with an accuracy of ± 3 ° in the range of 0 to 360 °. With an interval of between 2.5 seconds and 3 seconds this is one of the fastest sensors in the ISS [15].

6.1.7 Wind speed sensor

Wind speed measurements are made with air cups and magnetic switches. Each pulse from the switch is equal to one shaft rotation. Speed is measured in mph and is converted to other units such as m / s. The update time of 2.5 seconds and 3 seconds is equal to the wind direction sensor [13].

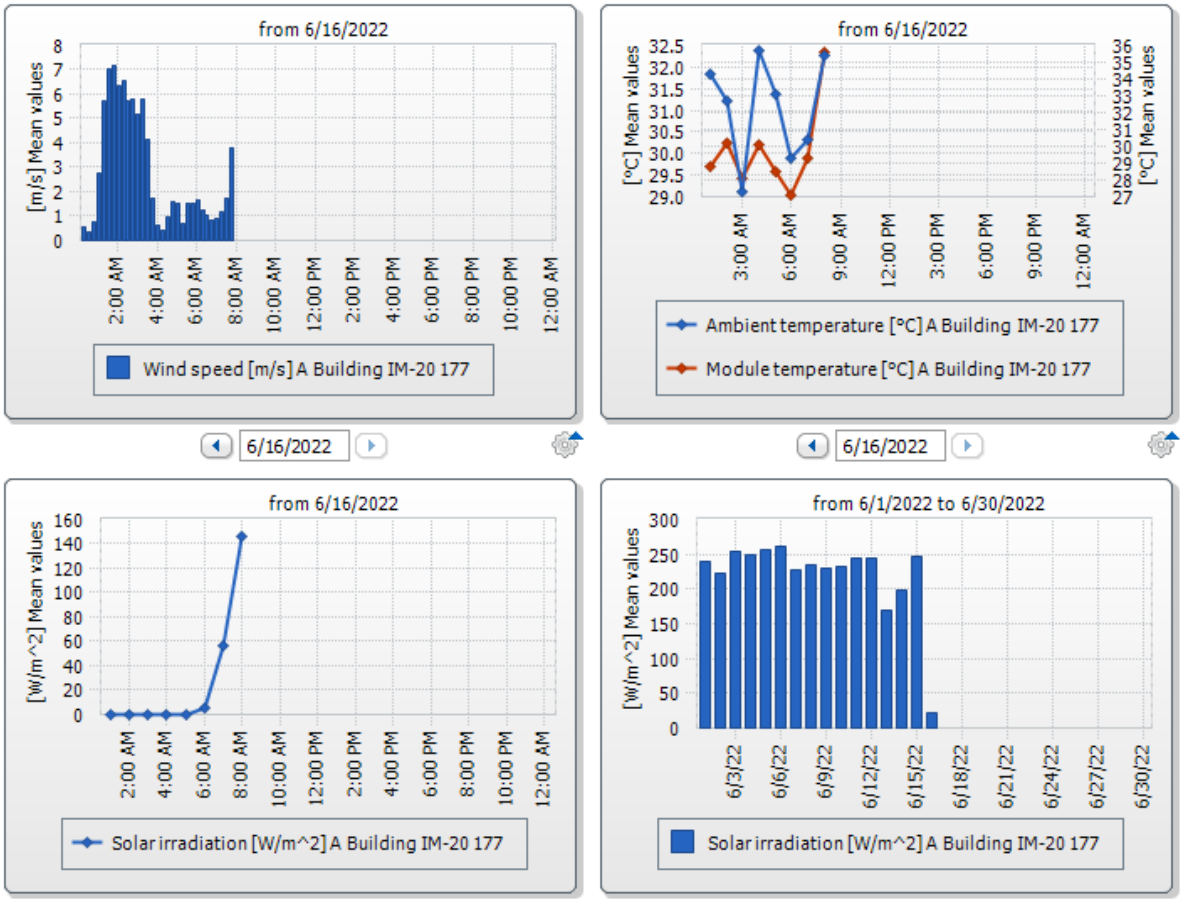


Fig. 6.4 Weather stations all data of the LG Plant including wind speed, module temperature, and solar irradiation [16].

6.2Solar Generation/ Assessment Data

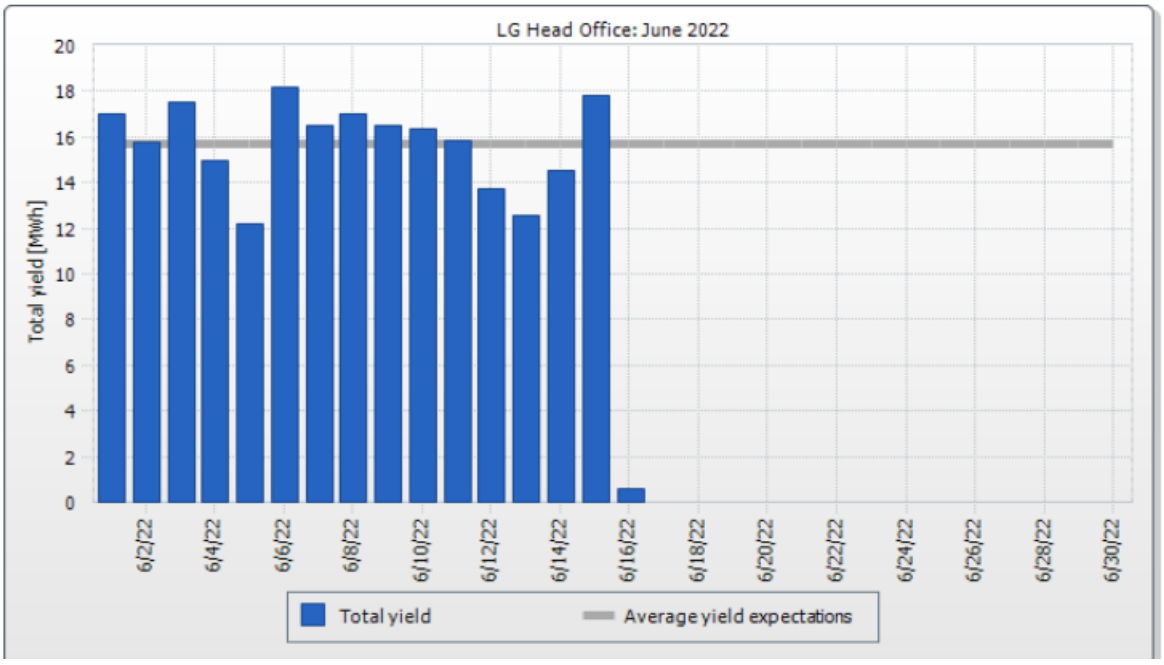


Fig. 6.5 Solar generation report on the monthly basis of the plant [16]

As seen very clearly that last year generation i.e. 2021 was the highest after the installation of the solar power plant [16] .The overall generation as compared to previous 2022 it is also performing very well up to the May 2022 and the predictions for year 2022 says that it will lead to the year 2021 due to high operation and maintenance activities.

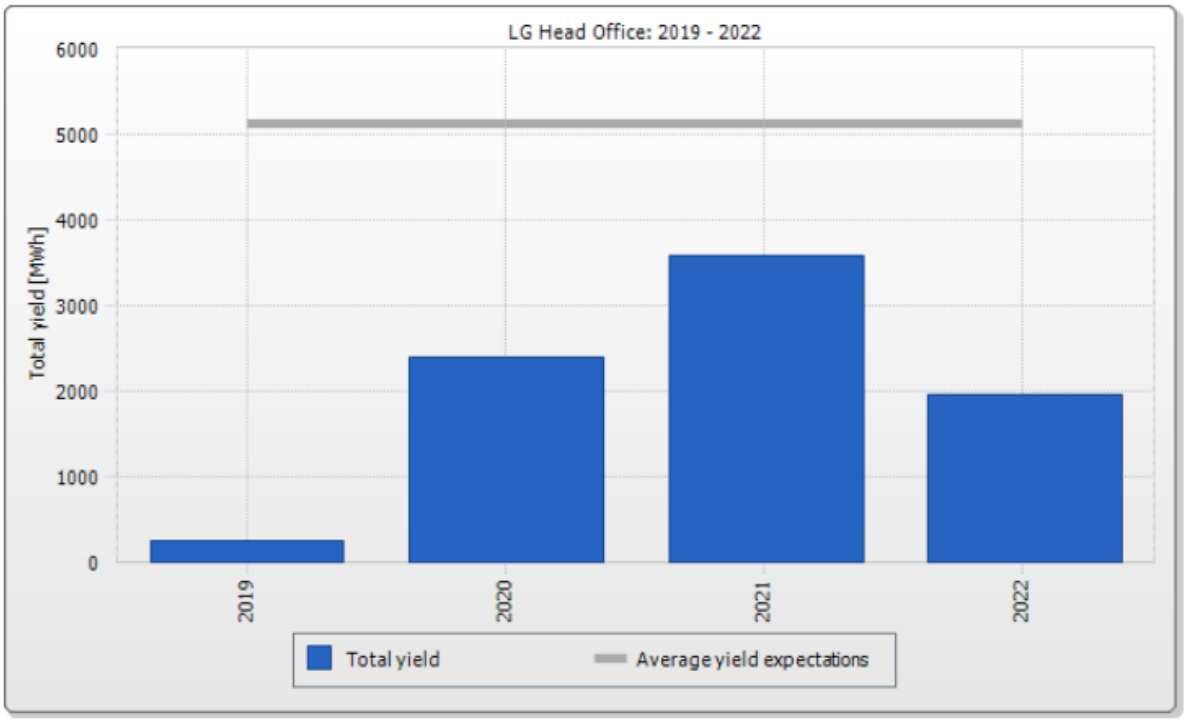


Fig. 6.6 Solar generation report on the yearly basis [16].

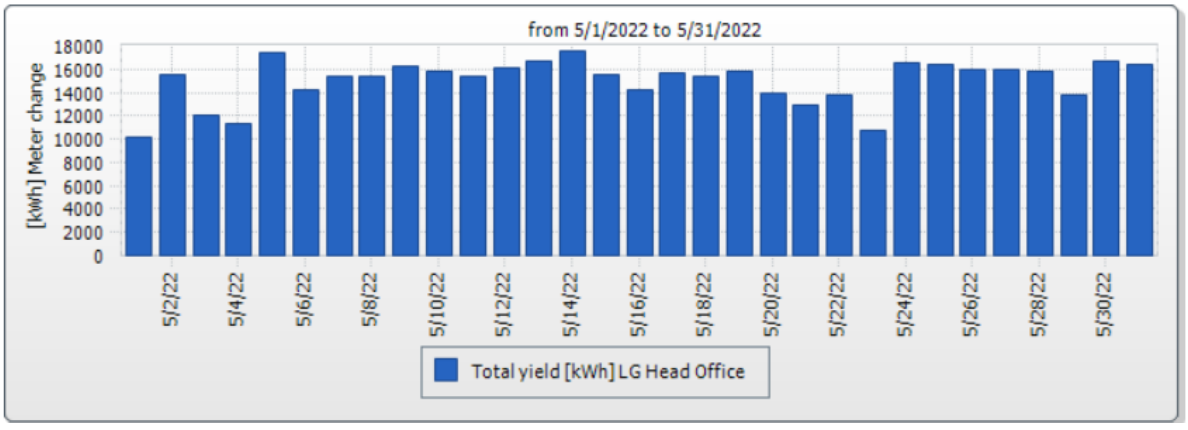


Fig. 6.7 Solar generation report from 1st May 2022 to 31st May 2022 [16]

Fig. show the overall view of the solar management system of the LG plant of 3.5MW through which we can easily monitor the various parameter of the solar plant such current PV power , communication , PV energy , wind speed , etc. [16].

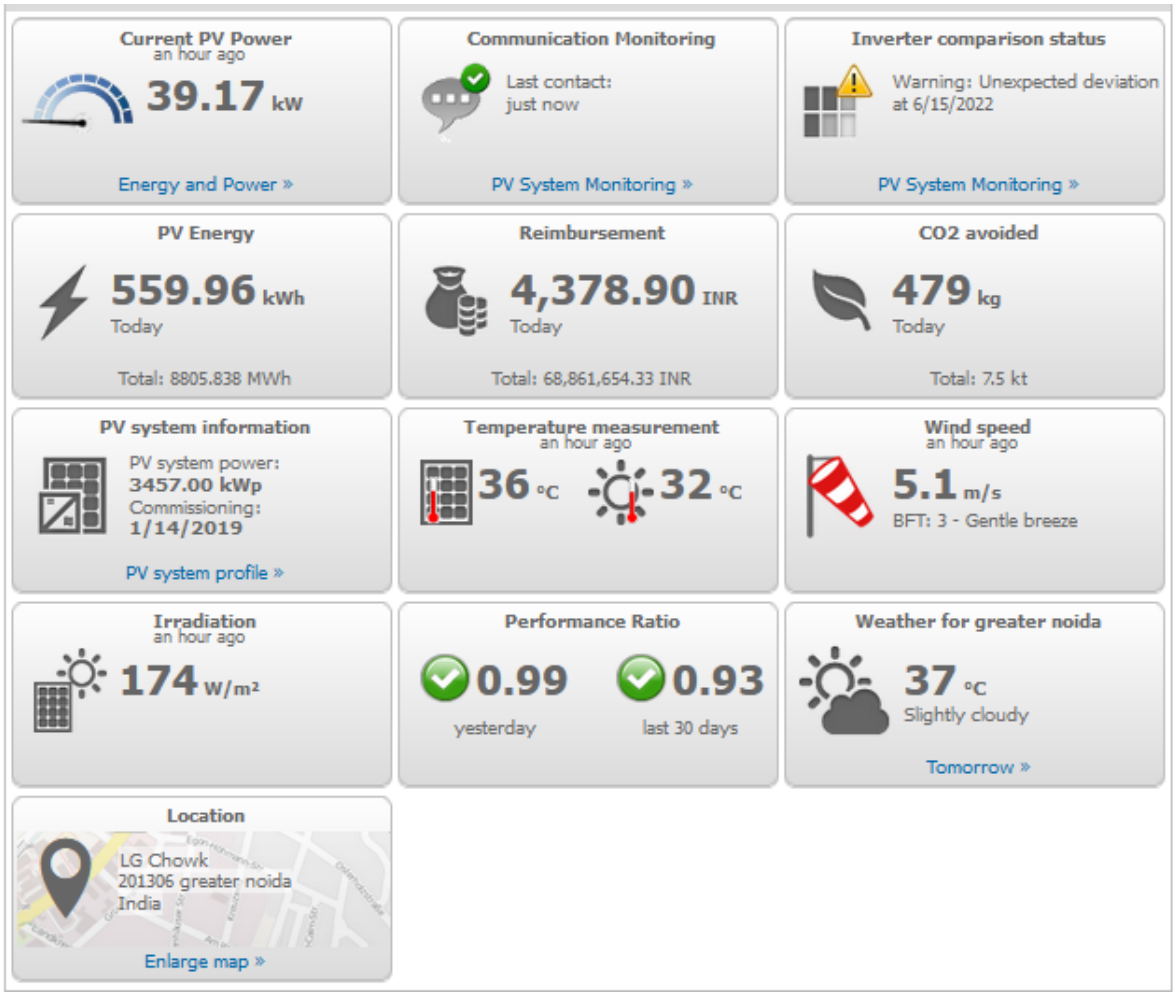


Fig. 6.8 PV system overall management system of the LG 3.5 solar plant [16]

Conclusion

In this study of installation of ZED (zero export devices) to control the demand and load evaluation of 3.5MW solar plant, we have successfully controlled and monitored the use of the ZED. By the use of the devices at all the buses we have properly controlled the generation and demand ratio of the solar generation. Following the installation of the Zero Export device, the LG Plant eliminated the risk of shipping any additional units produced by the panels. So to make sure that the system provides only the power required by his responsibilities. Eventually, the plant switched to solar energy without adding much cost to the existing system.

Finally, in India, many users of Solar PV systems have encountered problems as the provision of bi-directional meters has been slow and inefficient, plagued by bureaucracy and red-tape. So to make the whole process longer and more unsatisfying.

With the Zero Export device, we at Off-Carbon were able to eliminate this slow and difficult process of obtaining a bi-directional meter. By using a zero-emitting export device this process can be stepped aside to speed up project lead time and help the buyer use the installed solar PV system as quickly as possible.

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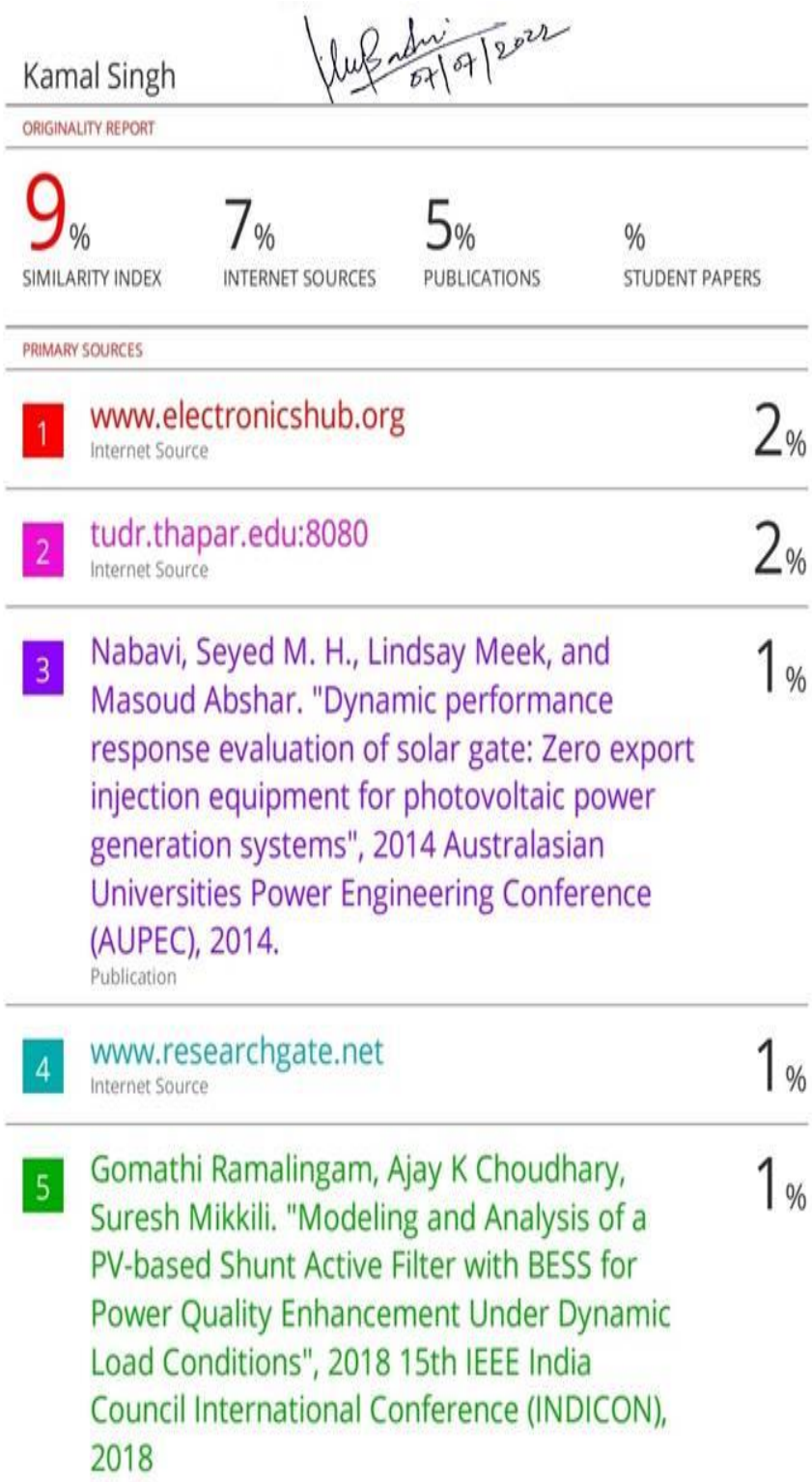

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