

Sembcorp Solar Presentation Slides

Izza Natalia
DCPE/FT/3B/22

Introduction

**My Aims:
What do I want out of the
internship?**

My aims for the internship are to:

- Learn about the general workplace culture, with a focus on Sembcorp Solar as a government-linked company
- Work with different people to improve my communication skills and build confidence
- Gain and improve my technical and practical skills and tools to add to my toolbox
- Test and apply what I've learned at school in a real-world setting
- Work on projects that have, or could have, a significant impact
- Explore and determine the type of career I want to pursue by experiencing the work life at a company like Sembcorp Solar



The Company, and Industry it is in

What does the company do?

Business Model

- **Renewable Energy Solutions:** Designs, installs, and manages solar PV systems
- **Power Purchase Agreements (PPA):** Provides fixed-rate electricity to customers, often without upfront costs
- **Project Development:** Offers end-to-end services from design to maintenance, including financing options

Culture

- **Innovation and Sustainability:** Focus on creative solutions for environmental responsibility
- **Collaboration:** Emphasises teamwork and cooperation between departments
- **Work-Life Balance:** Supports a flexible, relaxed, balanced work environment
- **Continuous Learning:** Professional development and growth opportunities

Competencies

- **Technical Expertise:** Proficient in solar energy systems
- **Customer-Centric Approach:** Tailored solutions and flexible financing for clients
- **Operational Excellence:** High standards in system operation and maintenance
- **Sustainability Focus:** Commitment to renewable energy practices and support of a low-carbon economy

What are typical career paths for employees?

Technical Roles:

- **Solar Engineer:** Designs and optimizes solar PV systems
- **Project Manager:** Manages solar projects from start to finish

Operations and Maintenance:

- **Operations Engineer:** Oversees solar system operations.
- **Maintenance Technician:** Maintains and repairs solar equipment

Finance and Administration:

- **Finance Analyst:** Manages budgeting and financial planning
- **Administrative Support:** Handles project documentation and coordination

Sustainability and Innovation:

- **Sustainability Specialist:** Enhances sustainability efforts
- **R&D Engineer:** Develops new solar technologies and innovations

Business Development and Sales:

- **Business Development Manager:** Finds and develops new business opportunities
- **Sales Engineer:** Provides technical solutions and closes sales

Tasks

As an intern within the OPM (*Operational Performance Maintenance*) department, I and my fellow interns oversaw these tasks...

1. Manage data onboarding of solar sites
2. Assist in commissioning and maintaining sites
3. Pre-configure monitoring devices
4. Ensure proper organisation of routine data extraction
5. Daily tracking of offline comms for SN and/or C&I sites

1. Manage Data Onboarding of Solar Sites

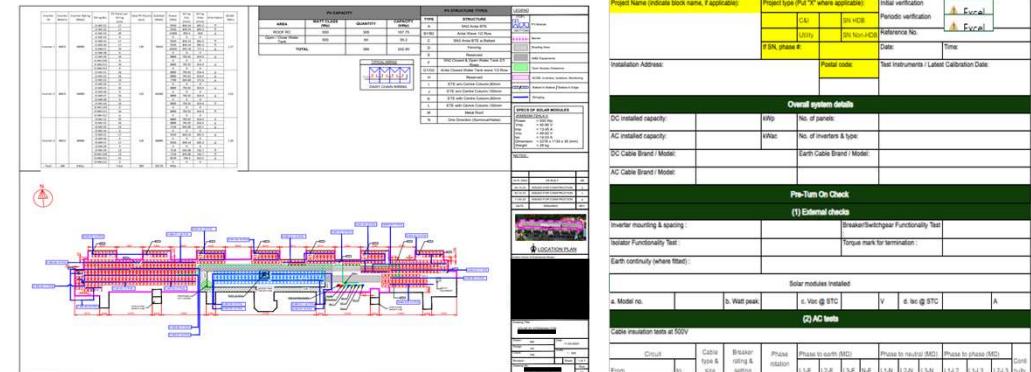
All the tabs in a pre-onboarding Excel template

Tab 20 - SiteMeta Tab 21 - SensorMeta Tab 22 - MeterMeta Tab 23 - InverterMeta Tab 24 - InverterStringMeta Tab 25 - SiteAdmin dropdown_list_info

Example pre-onboarding Excel template with filled data columns (Tab 20)

data source	site_code	site_name	farm_type	project_name	country_cc	stat	city	timezone	start_date	latitude	longitude	attitude	subsite_start	current	capacity	capacity	address	posted	esc	psos
SNS	Rooftop	SNS-NonHOB	SG	-	Singapore	Asia/Singapore				SGD										ML
SNS	Rooftop	SNS-NonHOB	SG	-	Singapore	Asia/Singapore				SGD										ML
SNS	Rooftop	SNS-NonHOB	SG	-	Singapore	Asia/Singapore				SGD										ML
SNS	Rooftop	SNS-HOB	SG	-	Singapore	Asia/Singapore				SGD										XOC
SNS	Rooftop	SNS-HOB	SG	-	Singapore	Asia/Singapore				SGD										XOC
SNS	Rooftop	SNS-HOB	SG	-	Singapore	Asia/Singapore				SGD										XOC
SNS	Rooftop	SNS-HOB	SG	-	Singapore	Asia/Singapore				SGD										XOC

This is done by filling out an Excel template with key solar site data (e.g. site meta, sensor meta, meter data, and inverter and inverter string meta).



AB (As-Built)

>> Shows the exact, completed and finalised layout of a solar site

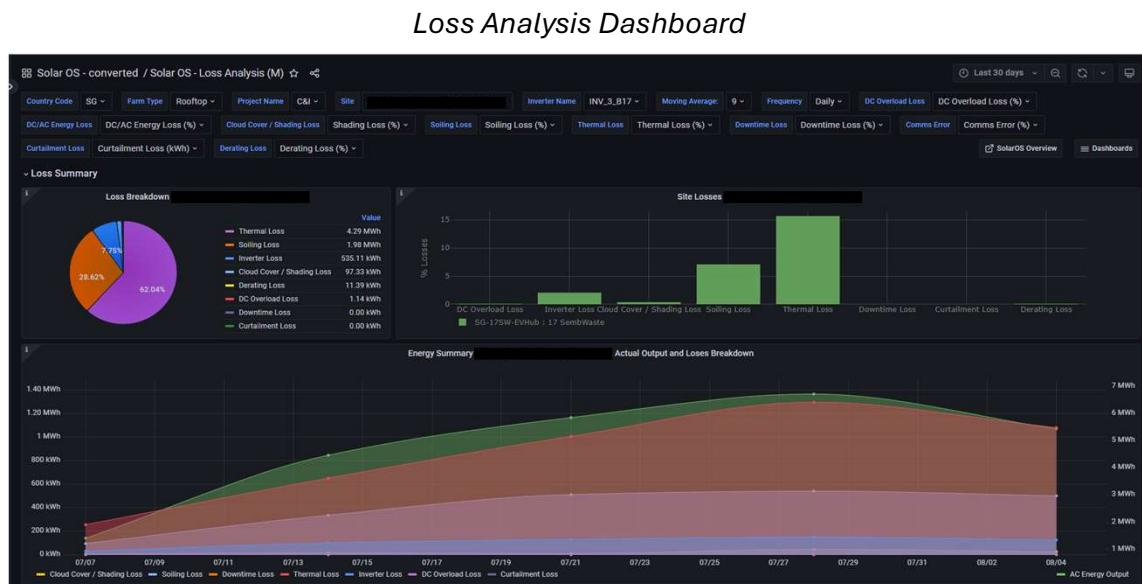
Project Name (Indicate block name, if applicable)	Project type (Put "Y" where applicable)	Initial verification					
Block	CAU	On HOB					
Utility	BN Non-HOB	Periodic verification					
Reference No.		Date					
ESN phase #:		Time					
Installation Address:		Postal code:					
Site Instruments / Label Calibration Date:							
Overall system details							
DC installed capacity:	KWp	No. of panels:					
AC installed capacity:	kVAc	No. of inverters & type:					
DC Cable Brand / Model:	Earth Cable Brand / Model:						
AC Cable Brand / Model:							
Pre-Test On Check							
(1) External checks							
Mounting & spacing:	Breaker/switchgear functionality test:						
Inverter functionality test:	Torque mark for termination:						
Earth continuity (where fitted):							
Solar modules installed							
a. Model no.	b. Watt peak	c. Voc @ STC					
d. Isc @ STC	e. Vm @ STC	f. Pmax @ STC					
(2) AC tests							
Cable insulation tests at 500V							
Circuit	Cable type & size	Breaker rating & setting	Phase rotation	Phase to earth (MΩ)	Phase to neutral (MΩ)	Phase to phase (MΩ)	Ground
From:	To:	Max. breaker size		1.0E-12.0	1.0E-12.0	1.0E-12.0	1.0E-12.0
Tie-in point:		min. breaker size		C/W / C/W	C/W / C/W	C/W / C/W	C/W / C/W
Min. breaker:	PVDB	size		C/W / C/W	C/W / C/W	C/W / C/W	C/W / C/W
	PCB			C/W / C/W	C/W / C/W	C/W / C/W	C/W / C/W

Industry Standard T&C
(Testing & Commissioning)
Template

>> Verifies all site components are tested and meet standards before system operation)

All this data is drawn from T&Cs and As-Built documents provided by EPC (Engineering, Procurement, and Construction) companies that commission said solar sites.

The data will be uploaded to SolarOS, an in-house data analytics dashboard, which simplifies accessing and analysing information for any solar site operated by Sembcorp.



Example dashboards

Recently viewed dashboards	
Solar OS - Loss Analysis (M)	Solar OS - converted
Solar OS - Site Specific Meta Tables (M)	Solar OS - converted
Solar OS - Historical Data (M)	Solar OS - converted
Solar OS - Inverter Health (M)	Solar OS - converted
Solar OS - Performance Analysis (M)	Solar OS - converted
Solar OS - Monitoring Dashboard (M)	Solar OS - converted
Solar OS - Overview (M)	Solar OS - converted

Once onboarded, employees can easily view various dashboards in SolarOS for data analysis purposes. Some of which include loss analysis, site-specific metadata, and more.

2. Assist in Commissioning and Maintaining Sites

The screenshot displays three main sections of a software interface:

- Left Panel:** Shows a list of devices with a red box highlighting a device labeled "Site is online". A red arrow points from this box to the top-left corner of the main content area.
- Middle Panel:** A table titled "(Model:EdgeLink)" showing "Tags (4)". It includes columns for Tag name, Tag type, Value, Upload time, Record time, and Quality. One row is highlighted with a red circle around the value "1547.81". A red arrow points from this circle to the bottom-right corner of the main content area.
- Bottom Panel:** A table titled "SN turn on blocks checks" with columns for various parameters like Status, Date passed, Location Code, TC, Postal Code, Turn on date, migrated date, IP address, in notifications, pyramometer, data on, T&C?, no. of meter, no. of inv, and meter/inv. A red arrow points from the right side of this table towards the bottom-right corner of the main content area.

Verify site turn-on checks (i.e. confirm that solar sites, inverters, and meters are online, and that their respective data is available).

Later, note down in Excel tracker whether the site, inverter(s), meter(s) have passed the check.

SN turn on blocks checks

	D	E	F	G	H	M	N	O	P	Q	R	S	AA	AC	AE
6		412													
7	Status	Date passed	Location Code	TC	Postal Code	Turn on date	migrated date	IP address	in notifications	pyranometer	T&C?	no. of meter	No. of inv	meter/inv ratio	Date 1st check
213	pass					08-Sep-23	11-Oct-2023				Y	1	3	ok	
214	pass					08-Sep-23		12-Oct-23			Y	1	2	ok	
215	pass		26-Dec-23			15-Sep-23		13-Oct-23			AB	1	2	Ok	
216	pass		26-Dec-23			15-Sep-23		13-Oct-23			AB	1	2	Ok	
217	pass					19-Sep-23		11-Oct-23			Y	1	3	Ok	
218	pass		26-Dec-23			19-Sep-23		11-Oct-23			AB	1	2	ok	26-Dec-23

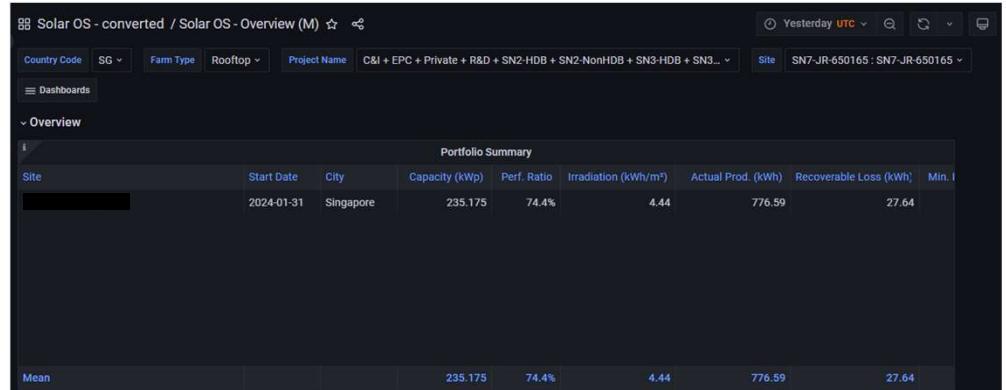
Progress Tracking file

Phase	site id	Project	SiteCode	Irradiance Sensor	Irradiance sensor if any changes?	Capacity	T&C/AB found?	PIC	onboarding	Remarks	issues
1											
1654	29-Apr		SN7							done	
1655	29-Apr		SN7							done	
1656	29-Apr		SN7							done	
1657	20-May		SN7							done	
1658	20-May		SN7							done	
1659	20-May		SN7							done	
1660	20-May		SN7							done	
1661	20-May		SN7							done	

Update Excel trackers for newly turn-on sites and onboarding progress respectively.

SN	Scenario	What to check	Pass or Fail, Remarks
1	Overview Page	<p>Go to overview page:</p> <ul style="list-style-type: none"> Check if all the sites are available in the 'Portfolio Summary' Conduct sanity check on the parameters available: <ul style="list-style-type: none"> Start Date Capacity PR Irradiation Actual Production 	<p>PR: 77.8% [incorrect data] vs 73.5% [correct]</p> <p>Actual Prod: 378.58 kWh [incorrect data] vs 357.6 kWh</p> <p>Irradiation: 6.04 kWh/m² [incorrect data] vs 5.93 kWh/m²</p> 

Example of a UAT



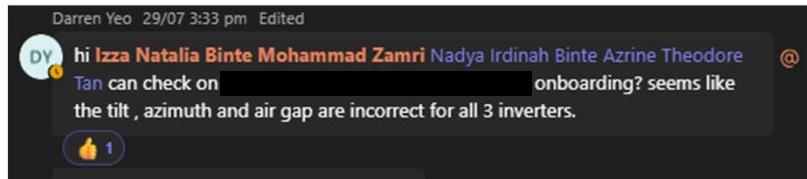
Example of a SolarOS Dashboard to check for UAT

Loss Analysis – Loss Summary	<p>Site checked:</p> <p>Go to Loss Analysis – Loss Summary Page:</p> <ul style="list-style-type: none"> Confirm that the data visualization format is correct.
Performance Analysis – Performance Ratio & Specific Yield	<p>Site checked:</p> <p>Go to Performance Analysis – Performance Ratio & Specific Yield:</p> <ul style="list-style-type: none"> Confirm that the data visualization format is correct.

Examples of Different Dashboards to Check

Conduct User Acceptance Testing (*UAT*) to confirm the accuracy of data onboarded onto SolarOS via checking certain dashboards.

Error found in SolarOS



Excel sheet created to fix the onboarding error (Fixing the inverter and/or inverter strings of a site)

site_code	inv_id	inv_input	panel_model	module_count	surface_tilt	surface_azimuth	roof_type	module_air_gap	combiner_id	combiner_input	string_name	parallel_factor
2 SN7	2	1		20	5	0	Metal	205				
3 SN7	2	2										
4 SN7	2	3		20	5	0	Metal	205				
5 SN7	2	4										

Email sent to PIC of onboarding the data to SolarOS

Onboarding error site SN7 [REDACTED]

IN Izza Natalia Binte Mohammad Zamri
To Ma Kun, Lau Ming Xuan
Cc Franco Lim, Giovani Jessica Kurniawan, Pai Wen Hong, Nadya Irdinah Binte Azrine, Theodore Tan, Darren Yeo, Yogendran Varupillay, Drew Colin Rosario Bagaoisan
SC-Restricted

44% of recipients have opened this mail.
[See more insights](#) [Feedback](#)

Hi Ma Kun/Ming Xuan,

Onboarding error site SN7 [REDACTED] is ready. Please help to find the onboarding form in the link below:

[Onboarding Errors Sites SN7](#)

Create Onboarding Error Sites Excel to fix any errors with onboarding when checking SolarOS.

3. Pre-configure Monitoring Devices

Pyranometer (Irradiance Sensor)



Smartlogger



*(Monitors and manages performance
of solar PV systems)*

*Temperature Sensors
(Module and Ambient)*



FusionSolar (Developed by Huawei) – All Plant Sites

The screenshot shows the FusionSolar interface. At the top, there are three circular dashboards: 'Plant KPIs' (16.18 MW, 64.52 GWh, 155.34 kWh), 'Plant Status' (272 total plants, 208 healthy, 56 offline), and 'Active Alarms' (16 total alarms). Below these are sections for 'Plant Name' (e.g., Singapore), 'Country/Region' (e.g., Singapore), and 'Grid Connection Date' (e.g., 2024-07-02). A detailed table lists various parameters for multiple sites, including Current Power (kW), Specific Energy (kWh/kWp), and Total Yield (kWh).

iSolarCloud (Developed by Sungrow) – All Plant Sites

The screenshot shows the iSolarCloud interface. It features a search bar and filter options for 'All Countries', 'Plant Type', 'Plant name', 'Status', 'Installed Power', 'Real-time Power', 'Yield Today', 'Monthly Yield', and 'Annual Yield'. A large table lists numerous plant entries, each with a thumbnail image, status (e.g., Normal, Commissioning), and key performance metrics.

One Site's Devices (e.g. Inverters, Meters etc.)

The screenshot shows the 'Device Management' section of the FusionSolar interface. It includes a search bar for 'Device name' and a table listing devices by 'Device type' (e.g., Inverter, Power Sensor). Columns include 'Device Name', 'Plant Name', 'Device Type', 'Software Version', 'SN', 'Warranty Expiration Date', and 'Operation'. Buttons for 'Set Parameters', 'Replace Device', 'Export Performance Data', 'Delete', 'Batch Rename', and 'Export Basic Info' are available at the top of the table.

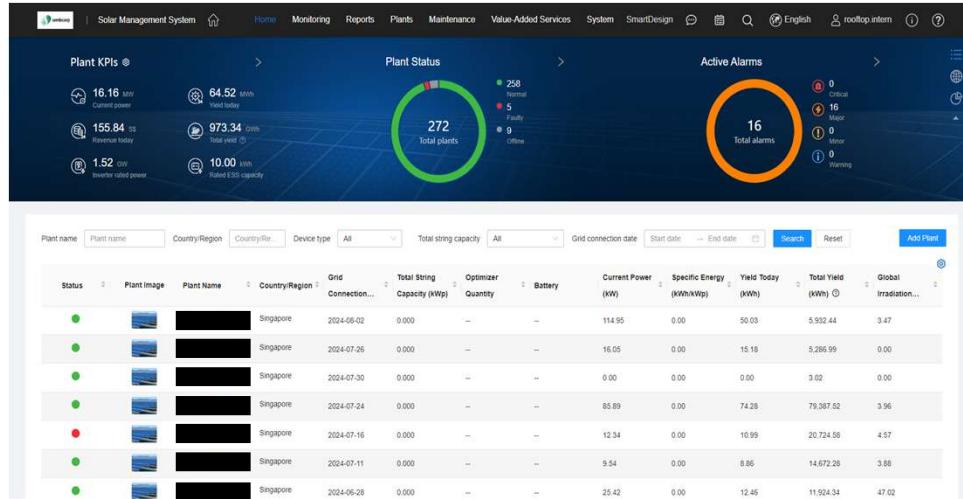
One Site's Overview

The screenshot shows the 'One Site's Overview' section of the iSolarCloud interface. It displays a schematic diagram of a solar power system with a solar panel, inverter, and grid connection. Key metrics shown include 'Real-time Power' (e.g., 12.48 kW), 'Installed Power' (e.g., 425.14 kWp), and 'Plant PR' (e.g., 96.62%). The interface also includes a timeline for 'Day', 'Week', 'Month', 'Year', 'Lifetime', and 'Custom' periods, along with 'Energy Analysis', 'Production', and 'Earnings' sections.

I connect these devices to Original Equipment Manufacturer (OEM) platforms such as FusionSolar and iSolarCloud for site asset monitoring.

4. Ensure Proper Organisation of Routine Data Extraction

FusionSolar (Developed by Huawei) – All Plant Sites



iSolarCloud (Developed by Sungrow) – All Plant Sites

The screenshot shows the iSolarCloud interface with a table of plant sites. The columns include Plant Name, Status, Plant Type, Installed Power, Real-time Power, Yield Today, Monthly Yield, Annual Yield, and Action.

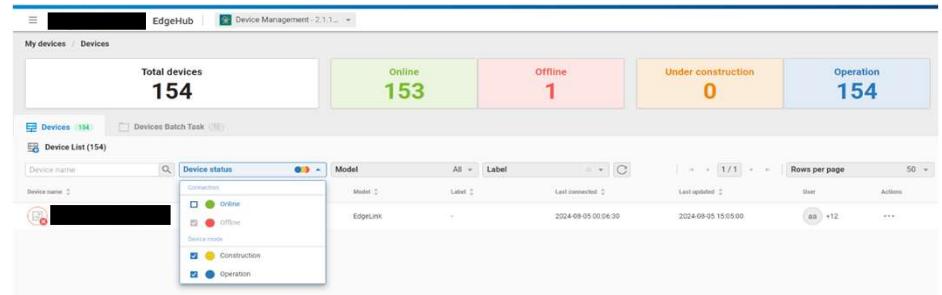
Plant Name	Status	Plant Type	Installed Power	Real-time Power	Yield Today	Monthly Yield	Annual Yield	Action
[Redacted]	Normal	Commercial PV	425.14 kWp	24.76 kW	15.10 kWh	6.64 MWh	6.64 MWh	[Star] [Edit] [Delete]
[Redacted]	Normal	Commercial PV	138 MWp	209.99 kW	101.50 kWh	2740 MWh	32.20 MWh	[Star] [Edit] [Delete]
[Redacted]	Commissioning	Commercial PV	750.00 kWp	56.90 kW	27.30 kWh	16.45 MWh	115.16 MWh	[Star] [Edit] [Delete]
[Redacted]	Normal	Commercial PV	--	--	--	0.00 kWh	0.00 kWh	[Star] [Edit] [Delete]
[Redacted]	Normal	Commercial PV	--	13.28 kW	8.40 kWh	3.95 MWh	95.56 MWh	[Star] [Edit] [Delete]
[Redacted]	Normal	Commercial PV	--	137.65 kW	54.20 kWh	26.35 MWh	599.88 MWh	[Star] [Edit] [Delete]
[Redacted]	Normal	Commercial PV	425.00 kWp	34.21 kW	17.80 kWh	9.72 MWh	371.92 MWh	[Star] [Edit] [Delete]
[Redacted]	Normal	Commercial PV	541.65 kWp	96.48 kW	30.10 kWh	8.05 MWh	388.26 MWh	[Star] [Edit] [Delete]
Offline Device6	Commercial PV	--	98.62 kW	43.40 kWh	10.20 MWh	477.54 MWh	477.54 MWh	[Star] [Edit] [Delete]

Extract/Query data from different OEM platforms or databases for monitoring, reporting and analysis.

5. Daily Tracking of Offline Communication for SN and C&I Sites

Log in	Site	Case No.	Category	Type	Site & Scope	Inv Name	Trigger	Open Start Date	End Date
5/8/2024	[REDACTED]	S2150D20 Reliability	Site Communication D	Entire Site	All devices got missing data			23/7/2024	
5/8/2024	[REDACTED]	S2151D20 Reliability	Site Communication D	Entire Site	All devices got missing data			15/6/2024	

These are the sources where I find out the sites that have offline comms.



Tracking for OM-OPM									
C430	A	B	C	D	E	H	I	J	K
	Status	Open Date	Close Date	No. of days	Project	Location Code	Postal Code	Issues Category	Actual Issues
415	DA-Open	26-Jan-2024		193		C&I			
416	Open	15-Aug-2023		357		SN2-HOB			

In the 'Actual Issues' column for row 416, there is a red box highlighting the cell containing 'Abnormal Comm'. A red arrow points from this cell to a callout box on the right side of the slide.

Reference any previously reported issues in the 'OM-OPM Tracking' Excel sheet that might explain offline communication problems.

sites comms offline for 2 Aug and last connected & open start date:
SN2/3:

23/7/2024 ELU upgrade
15/6/2024 ELU/SR upgrade
15/6/2024 ELU/SR upgrade
6/6/2024 ELU upgrade
22/2/2024 Waterproofing
22/2/2024 Waterproofing
7/5/2024 ELU/SR upgrade
23/7/2024 ELU/SR upgrade
20/10/2023 ELU upgrade
10/6/2024 ELU upgrade

Submit a daily list of these sites, their recently connected/open start date and the reasons that might explain their offline comms to the "Tracking Offline Comms" group chat.

This is so that other employees can directly address these issues with these sites with Mirai and other relevant systems.

My CDIO Project

Inverter Loss Analysis

SYNOPSIS

This project analyzes inverter losses at solar sites to identify root causes, providing evidence and informing strategies to reduce these losses across sites.

CONCEIVE

To provide the company with analysis to identify root causes of inverter loss and offer insights for developing solutions to reduce these issues.

DESIGN

Software: Azure Data Explorer (ADX), Microsoft Excel and Powerpoint, Jupyter Notebook, SolarOS

IMPLEMENT

Research and Data Collection

Data Organization/Cleaning/Prepping etc. and Analysis

OPERATE

Analysis pending further actions taken



Inverter Loss Analysis

Izza Natalia

19 March 2024 - 8 August 2024



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Name of Student: Izza Natalia

Course and Class: DCPE/FT/3B/02

SP Liaison Officer's Name: Mr
Benjamin Lee

Company Liaison Officer Name: Ms
Pai Wen Hong

Conceive!

What are the users' needs?

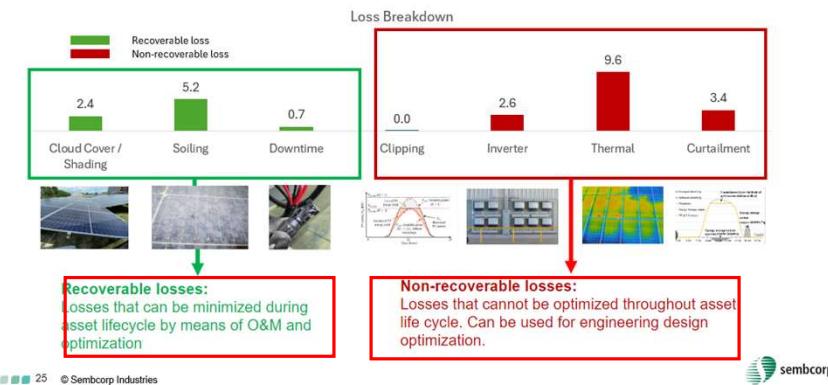
- Provide insightful analysis to understand inverter loss root causes
- Offer information on root causes to develop effective solutions/strategies to reduce inverter loss issues

What features will help meet these needs to achieve the functional goals of the project?

- Data analysis tools to detect patterns and root causes of inverter loss
- Interactive visualisations (*graphs, charts, dashboards*) for data interpretation
- Correlation of inverter loss patterns to assess their impact
- Trend analysis to identify anomalies in inverter performance
- Later sharing data, code, and raw materials used on Sembcorp's SharePoint for other employees' use

Types of losses

In Solar Operations team, we will prioritize on minimizing recoverable losses



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Found in SolarOS training powerpoint by Sembcorp

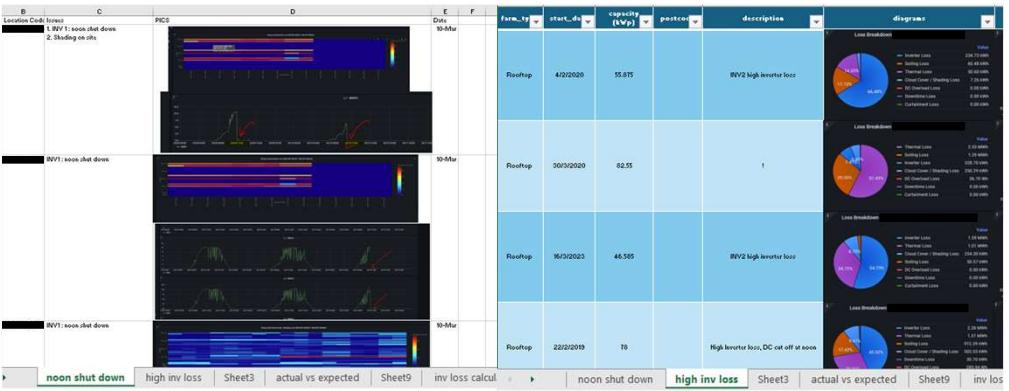
We began by analyzing various types of non-recoverable losses across our sites.

Low PR screening_Apr2024			
F1280	C	D	E
954	SN2-HDB	Performance	Inverter Issue
983	SN2-HDB	Performance	Inverter Issue
1002	SN2-HDB	Performance	Inverter Issue
1033	SN2-HDB	Performance	Inverter Issue
1035	SN2-HDB	Performance	Inverter Issue
1086	SN2-HDB	Performance	Inverter Issue
1106	SN2-HDB	Performance	Inverter Issue
1127	SN2-HDB	Performance	Inverter Issue
1132	SN2-HDB	Performance	Inverter Issue
1135	SN3-HDB	Performance	Inverter Issue
1142	SN3-HDB	Performance	Inverter Issue
1159	SN3-HDB	Performance	Inverter Issue
1183	SN3-HDB	Performance	Inverter Issue
1194	SN3-HDB	Performance	Inverter Issue
1178	SN3-HDB	Performance	Inverter Issue
1209	SN3-HDB	Performance	Inverter Issue
1233	SN3-HDB	Performance	Inverter Issue
1243	SN3-HDB	Performance	Inverter Issue
1245	SN3-HDB	Performance	Inverter Issue
1251	SN3-HDB	Performance	Inverter Issue
1257	SN3-HDB	Performance	Inverter Issue
1280	SN3-HDB	Performance	Inverter Issue
1282	SN3-HDB	Performance	Inverter Issue

INV-3 DC/AC energy loss-high, Soiling

inverter 1 not generating, resolved
inverter 1 generating, resolved
high inv loss from 1
High inverter loss for inv 1
high inv loss for inv 3

Each month, we reviewed the 'low PR screening,' identifying inverter loss as a key non-recoverable factor contributing to low Performance Ratio (PR) at the sites.



Sites that experience inv shutdown during noon

High inverter loss of certain sites (via SolarOS)

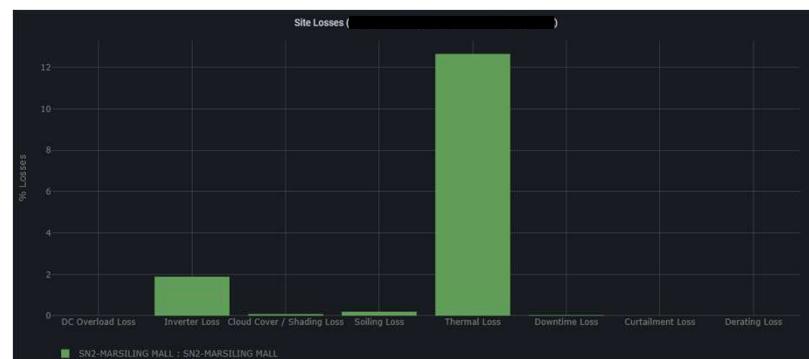
Recognizing the impact of inverter loss, we decided to focus our efforts on understanding this issue to improve the overall efficiency of our solar sites.

Excel created by RO that lists out project's layout

Project 3 : Non-recoverable inverter loss improvement		find out the reason for high non-recoverable inverter losses
Objective :		find out reason for non-high recoverable inverter losses and find measures to reduce recoverable inverter losses
<ul style="list-style-type: none"> - nature of inverters - SolarOS >> Losses 		
Scope :		solar sites

Internship p 11Mar-8Aug

Tasks/ Description	Start Date	End Date	Duration	Remarks	Actions
1. Setting Objective : 2. Scope 3. Timeline 4. R & R / Stakeholders	18-Mar	05-Apr	3 weeks	1. Objectives: find out reason for non-high recoverable inverter losses and find measures to reduce recoverable inverter losses 2. Scope: C&I, SN, Rooftype (Metal & RC) , Brand (Huawei, Sungrow) , Model () , Data (ADX) 3. Stakeholders (GD, Procure, Supplier & OM)	1. Model for different asset (PIC : Izza) 2.



Design!

Choice of hardware and/or software, including standards

- Azure Data Explorer (*ADX*)
- Microsoft Excel
- Microsoft Powerpoint
- Jupyter Notebook
- SolarOS

Systems Integration (How does the above work together?)

- **Azure Data Explorer:** Retrieves raw data from solar sites, keeping in mind relevant parameters for my project
- **Microsoft Excel:** Cleans, structure, and prepare raw data from Azure Data Explorer
- **SolarOS:** Provides real-time data visualizations from its dashboards when Azure Data Explorer data is unavailable
- **Jupyter Notebook:** Uses Excel's pre-processed data for in-depth analysis, using Python scripts to generate custom visualisations and conduct data analysis on inverter loss
- **Microsoft PowerPoint:** Consolidates all the analysis and graphs into a cohesive report presentation, incorporating data visualizations and insights from Jupyter Notebook and SolarOS



Azure Data Explorer



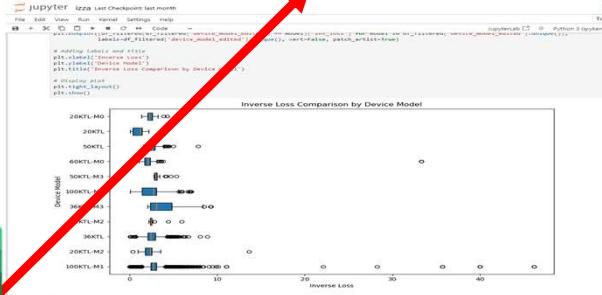
The screenshot shows the Azure Data Explorer interface with a search bar at the top containing the query: "SELECT * FROM [MyDatabase].[dbo].[MyTable]". The results pane displays 10 rows of data from the table, each with columns: id, name, value, and date. The data includes various entries such as '1, John, 25, 2023-01-01' and '10, Michael, 30, 2023-01-10'. The bottom navigation bar includes tabs for 'Logs', 'Metrics', 'Metrics (Preview)', 'Metrics (Preview) (Preview)', 'Tables', 'Tables (Preview)', 'Tables (Preview) (Preview)', 'Metrics (Preview) (Preview) (Preview)', and 'Metrics (Preview) (Preview) (Preview) (Preview)'.



Microsoft Excel



Jupyter Notebook



Microsoft
Powerpoint

A screenshot of a Microsoft Word document. The ribbon menu at the top includes Home, Insert, Draw, Design, Transitions, Animations, Slides Show, Review, View, Help, Comments, Catch up, and Present. A red arrow points diagonally upwards from the bottom right of the slide content area towards the ribbon menu. The slide itself has a title 'Findings' and a subtitle 'Click to edit title styles'. It contains several tables and a chart. One table shows 'Vs DC/IAC Ratio' and 'Vs L-Opt% (No. of panels)'. Another table lists 'SG12CK-P2 > SG-GE-BL2W' with rows for INV1, INV2, and INV3. A third table lists 'SKTL > SN3-JUR-736' with rows for INV2, INV3, and INV4. A fourth table lists '100KTL-M2 > 3G-WINGSTUCK-3SL' with rows for INV1, INV2, and INV3. A chart titled 'Comparison of Panel Area and Thickness (mm²)' is also present.



Implement!

List of activities carried out in implement stage

1. Research:

- Conducted detailed research on inverter specifications and performance by reviewing datasheets
- Retrieved raw data from Azure Data Explorer and began data extraction

2. Data Collection:

- Collected solar site data for the entire month of April (1 April to 30 April)
- Focusing on parameters such as AC energy, DC energy, inverter loss, efficiency, site code, and device model for initial investigation
- Began data extraction of specified raw data from Azure Data Explorer

3. Data Preparation:

- Organised and cleaned data in Microsoft Excel, including creating new parameters and equations for analysis
- Generated initial graphs to validate data accuracy and filter out anomalies

4. Data Filtering and Processing:

- Wrote Python scripts to exclude abnormal inverter loss peaks and refine the dataset
- Set lower and upper boundaries to identify outliers (*i.e., inverters with significantly higher or lower losses compared to their usual/mean*)
- Identified the top 4 inverter models with the highest percentage of outliers, focusing on models with the most inconsistent and extreme inverter loss values
- Investigated potential inverter issues based on the outlier data
- Identified sites where these top 4 inverter models showed the highest percentage of outliers

5. Data Analysis

- Applied research-based analysis techniques and visualization methods to these chosen inverter models and their respective sites

6. Integration of Additional Data:

- Used SolarOS to supplement data with real-time performance insights and granular details not available in Azure Data Explorer

7. Visualization Creation:

- Developed custom visualizations, charts, and graphs in Jupyter Notebook to analyze inverter performance

8. Reporting and Presentation Preparation:

- Created a PowerPoint presentation consolidating analysis findings and visualizations
- Reviewed and refined the presentation based on feedback from Reporting Officer and OPM employees

8. Feedback and Iteration:

- Incorporated feedback to improve clarity, effectiveness, and detail in both analysis and PowerPoint presentation

Research

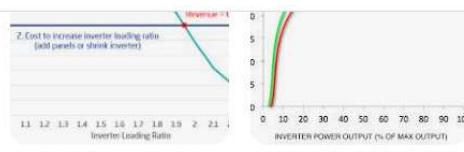
Filtered In | localhost | Inverter L | Solar OS | Google load perc | Solar OS | Inverter.l...

google.com/search?q=load+percentage+inverters+graph&safe=active&sca_esv=3b07b09e3325ea...

inv loss.xlsx onboarding readings imp folders uat Solar Dept Master ... Solar Dept Master ... Solar Dept Master ...

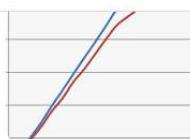
Google

load percentage inverters graph



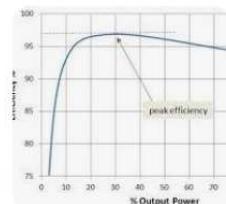
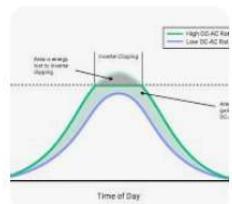
How to optimize your inverter lo...

Fluence blog



Two Reasons You Must Look At Effi...

SolarQuotes



Solar inverter sizing: Choose the ri...

Aurora Solar

Efficiency of Inverter: Calculation ...

Linquip

Trends in Inverter Loading Ratio b...

ResearchGate

6 more images ▾

HIGH YIELD

- DC 15A current input, compatible with over 500W+ PV module
- Dynamic shading optimization mode
- Built-in PID recovery function

SMART O&M

- Key component diagnosis and protection
- Smart IV Curve Diagnosis
- Grid fault record function, easy for remote O&M

LOWER INVESTMENT

- Easy to handle thanks to 34% weight reduced
- Plug and Play with Buckle Design

PROVEN SAFETY

- IP66 protection and C5 Anti-corrosion
- DC Type I+II SPD, AC Type II SPD
- Support AFCI 2.0 function

CIRCUIT DIAGRAM

DC Input, DC Switch, DC Filter, MPPT Inverter, MPPT Boost, DC Bus, Inverter Circuit (SGIC), AC Filter, AC Relay, AC Output.

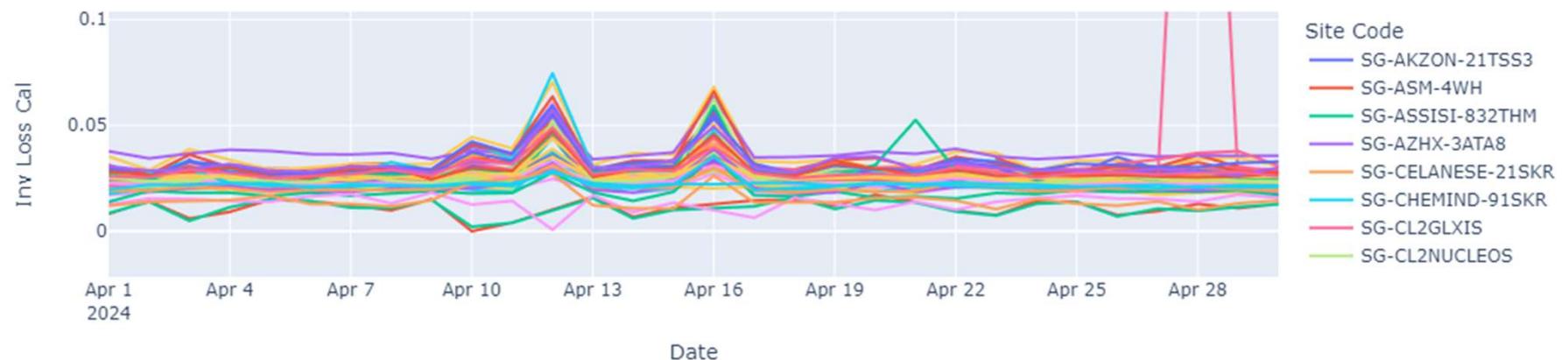
EFFICIENCY CURVE (SG50CX-P2)

Normalized Output Power (%)	500V (%)	600V (%)	800V (%)
5%	99.5	99.5	99.5
10%	99.8	99.8	99.8
20%	99.9	99.9	99.9
30%	99.95	99.95	99.95
50%	99.98	99.98	99.98
100%	99.99	99.99	99.99

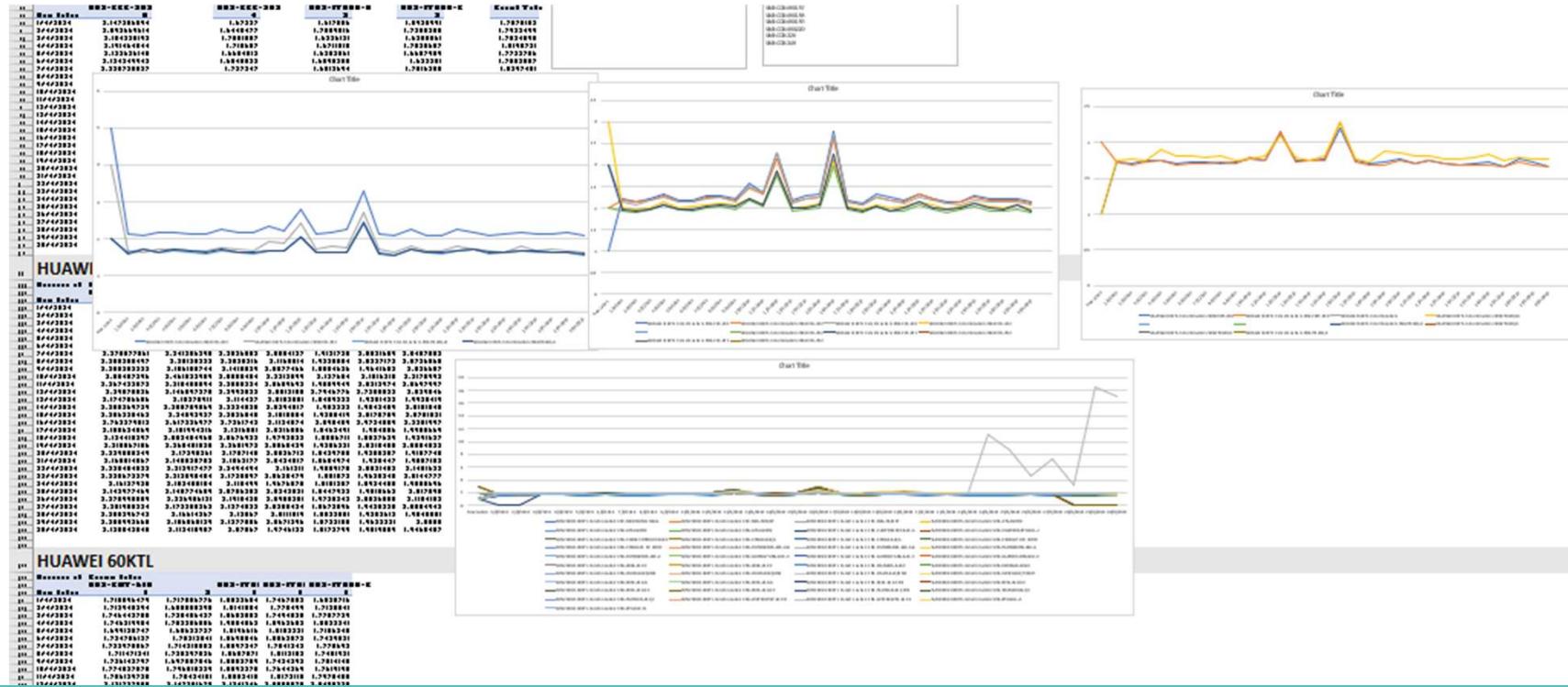
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Data Collection

Interactive Line Graph of Inv Loss Cal Over Time



Data Preparation



To ensure the accuracy of raw data, I generated initial graphs to test and validate it, checking for any anomalies before moving on to more in-depth analysis in Jupyter Notebook.

Creating Load%
parameter from
act_pwr parameter



A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	U	V	AB
site_id	subsite_id	inv_id	ts_local	date	ts_utc	site_code	freq	act_pwr	load %	react_pwr	pwr_factor	ac_engy_daily	ac_engy_total	I_A	I_B	I_C	V_AB				
336 336_1		1	1.712E+09	1/4/2024	1.71E+09		50.03	0.652	100	-0.006	1	501.01	46111.29	0.948	0.929	0.93					
336 336_1		1	1.712E+09	2/4/2024	1.71E+09		50.01	89.485		-0.076	1	316	46441.95	124.817	125.809	125.248					

Creating equations in Excel to calculate new parameters from raw data for data analysis.

J3	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	U	V	AB
	site_id	subsite_id	inv_id	ts_local	date	ts_utc	site_code	freq	act_pwr	load %	react_pwr	pwr_factor	ac_engy_daily	ac_engy_total	I_A	I_B	I_C	V_AB				
=([@act_pwr] / 110)*100	290 290_1	1	1.712E+09	1/4/2024	1.71E+09			0	0	0	0	0	35555.8	0	0	0	0					
	290 290_1	1	1.712E+09	1/4/2024	1.71E+09			0	0	0	0	0	220.8	35776.6	0	0	0					
	290 290_1	1	1.712E+09	1/4/2024	1.71E+09		50.01	22.585	57.022727	0.434	0.999	171.1	35726.9	30.5	30.6	30.7						

Parameter calculated.

More examples of parameters being created from raw data's original parameters:

Creating inv_loss
parameter from
effcy_daily parameter



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	Q
1	site	subsite	inv	date	temp_min	temp_max	temp_mean	dc_engy_total_m	ac_engy_daily_ma	ac_engy_total_ma	dc_engy_dail	ac_engy_dail	inv_loss_cal	effcy_dail	inv loss	site_code
6556	336	336_1	2	22/4/2024	31.8	56.2	45.75714286	56309.45	374.1	54372.47	387.65	374.1	3%	96.5045789	3.49542113	SG-WINGTUCK-
6557	336	336_1	2	22/4/2024	31.8	56.2	45.75714286	56309.45	374.1	54372.47	387.65	374.1	3%	96.5045789	3.49542113	SG-WINGTUCK-

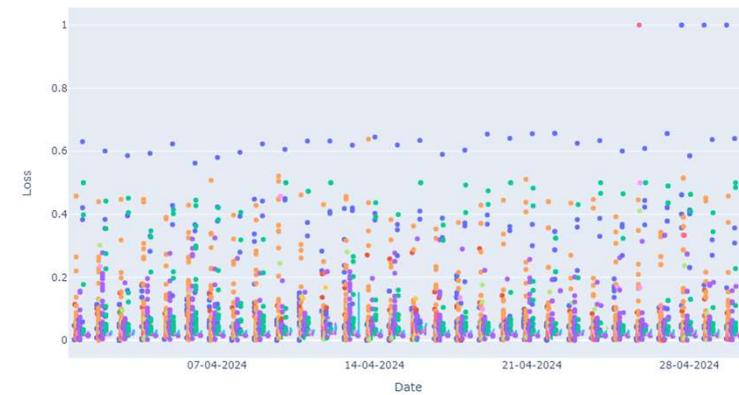
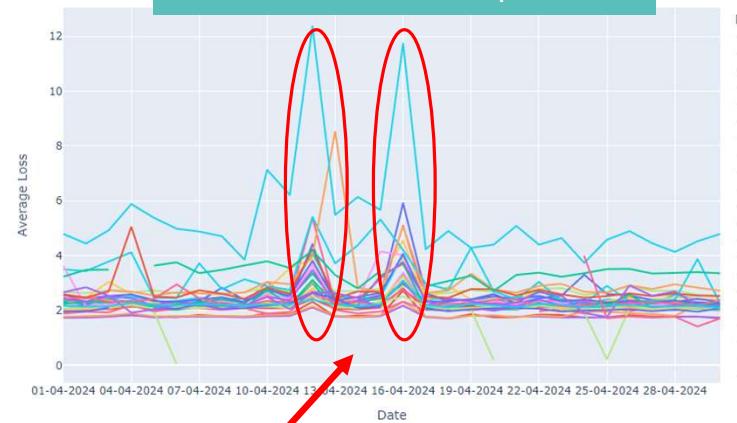


	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	site	subsite	inv	date	temp_min	temp_max	temp_mean	dc_engy_total_m	ac_engy_daily_ma	ac_engy_total_ma	dc_engy_dail	ac_engy_dail	inv_loss_cal	effcy_dail	inv loss	deletion_flag
6556	336	336_1	2	22/4/2024	31.8	56.2	45.75714286	56309.45	374.1	54372.47	387.65	374.1	3%	96.5045789	3.495421127	FALSE
6557	336	336_1	2	22/4/2024	31.8	56.2	45.75714286	56309.45	374.1	54372.47	387.65	374.1	3%	96.5045789	3.495421127	FALSE

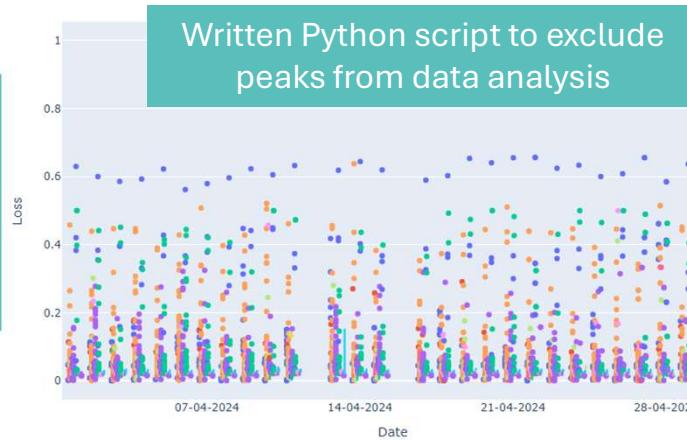
Creating inv_loss_cal parameter
from dc_engy_daily and
ac_engy_daily parameters

Data Filtering and Processing

Abnormal inv loss peaks



Written Python script to exclude peaks from data analysis



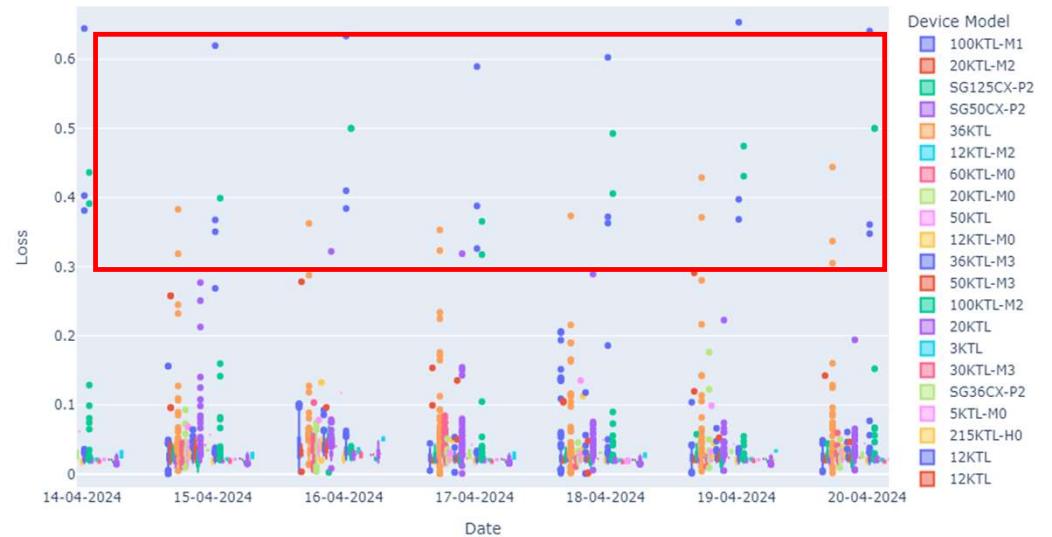
In this project, I have chosen to ignore inverter losses on April 12th and April 16th, where these abnormal peaks of inverter losses occur.

Set lower and upper boundaries to identify outliers:

- **Upper boundary:** $Q3 + 1.5 * IQR$
- **Lower boundary:** $Q1 - 1.5 * IQR$

- Identified the top 4 inverter models with the highest percentage of outliers, focusing on models with the most inconsistent and extreme inverter loss values
 - **Outlier percentage** = $(\text{Outlier count} / \text{Total inverter models count}) * 100$
 - >> Suspected inverter model issues

Interactive Time-Series Boxplot of inv_loss by device_model_edited



Outliers Count Table Apr:

device_model_edited	outlier_count	total_device_count	outlier_percentage
Inv Model A	50	62	80.645161
Inv Model B	38	76	50.000000
Inv Model C	20	62	32.258065
Inv Model D	432	2025	21.333333
	166	869	19.102417
	32	187	17.112299
	2	14	14.285714
	47	396	11.868687
	57	483	11.801242

I identified sites with the top 4 inverter models that have the highest percentage of outliers.

Outliers Count Table for Specific Models:

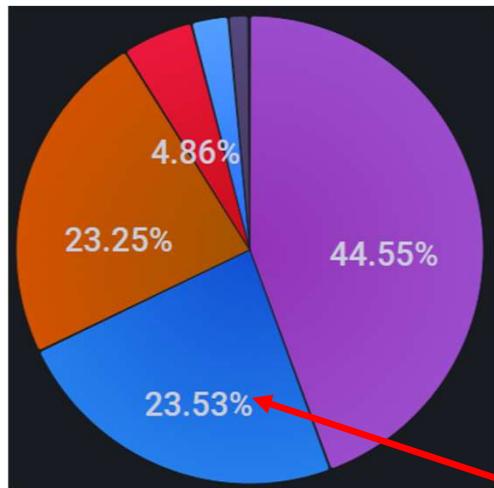
	device_model_edited	site_code	outlier_count	total_device_count	outlier_percentage
2			5	5	100.000000
18	Inv Model A	Site A	27	31	87.096774
17					
8	Inv Model B	Site B	60	93	64.516129
11					
6					
15					
3	Inv Model D	Site D	33	76	43.421053
12					
5	Inv Model C	Site C	20	62	32.258065
0					
1					
16					
7					
4					

Did not choose this inverter model or its respective site because of its unusual outlier percentage

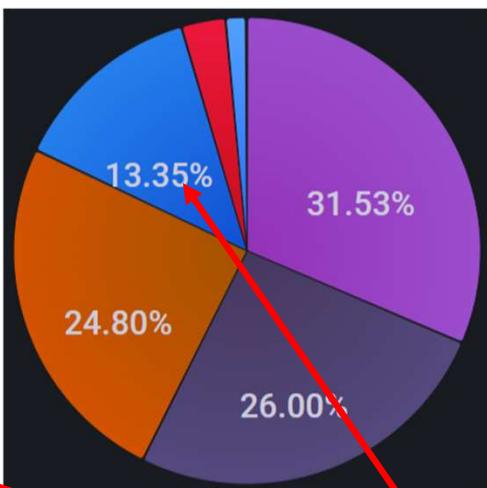
>> Too high, doesn't seem reliable

4 Solar Sites Chosen with Inverter Issues

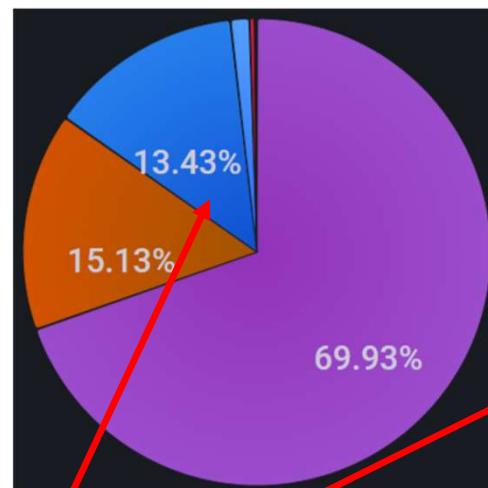
Site A



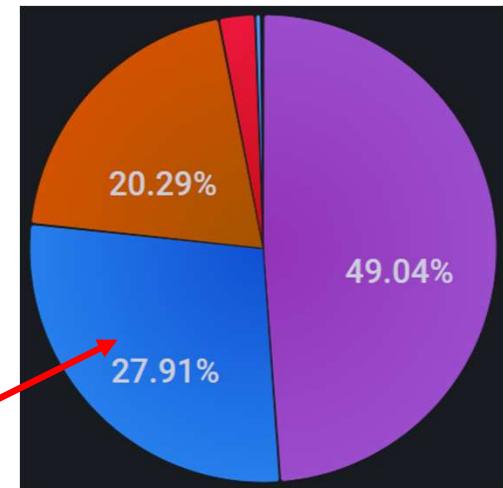
Site B



Site C



Site D



*Inverter loss% of out of all the losses of a
solar site*

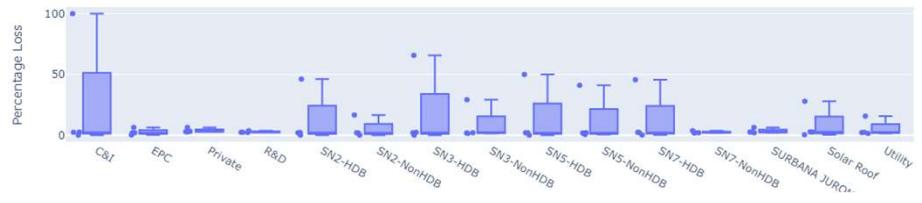
Data Analysis

Line graph

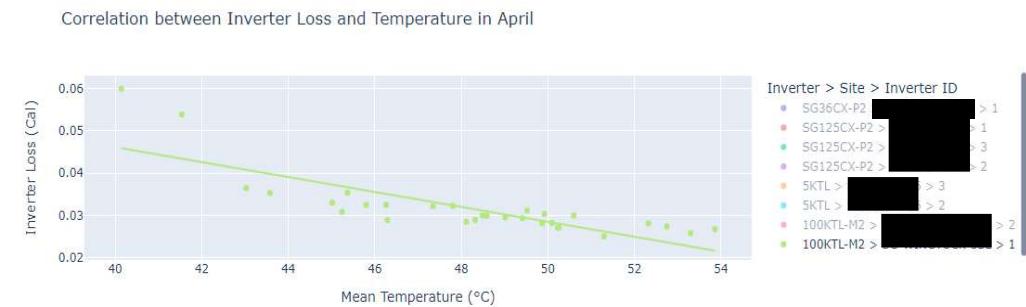


Box and whiskers plot

Distribution of Loss Statistics by Site Types



Scatterplot with correlation line



Integration of Additional Data

The screenshot displays the Solar OS interface with two main components:

- Inverter Info Table:** A data grid titled "Inverter Info Table for [REDACTED]" showing details for four inverters. The columns include Inv Name, Brand, Model Name, Inv SN, API Dev ID, DC capacity (kWp), Inverter AC rating (kV), and DC/AC Ratio.

Inv Name	Brand	Model Name	Inv SN	API Dev ID	DC capacity (kWp)	Inverter AC rating (kV)	DC/AC Ratio
DB1_INV-A	Sungrow	SG36CX-P2	[REDACTED]		47.9	36	1.33
DB1_INV-B	Sungrow	SG125CX-P2	[REDACTED]		164	125	1.31
DB1_INV-C	Sungrow	SG125CX-P2	[REDACTED]		164	125	1.31
DB1_INV-D	Sungrow	SG125CX-P2	[REDACTED]		164	125	1.31

- Inverter Efficiency Daily Metric (Mean) Trend:** A horizontal bar chart showing efficiency values over time. The chart includes a legend for "slope" and data points at 0.220, -0.33, and -3.3.

**Operate and
Impact/Benefits!**

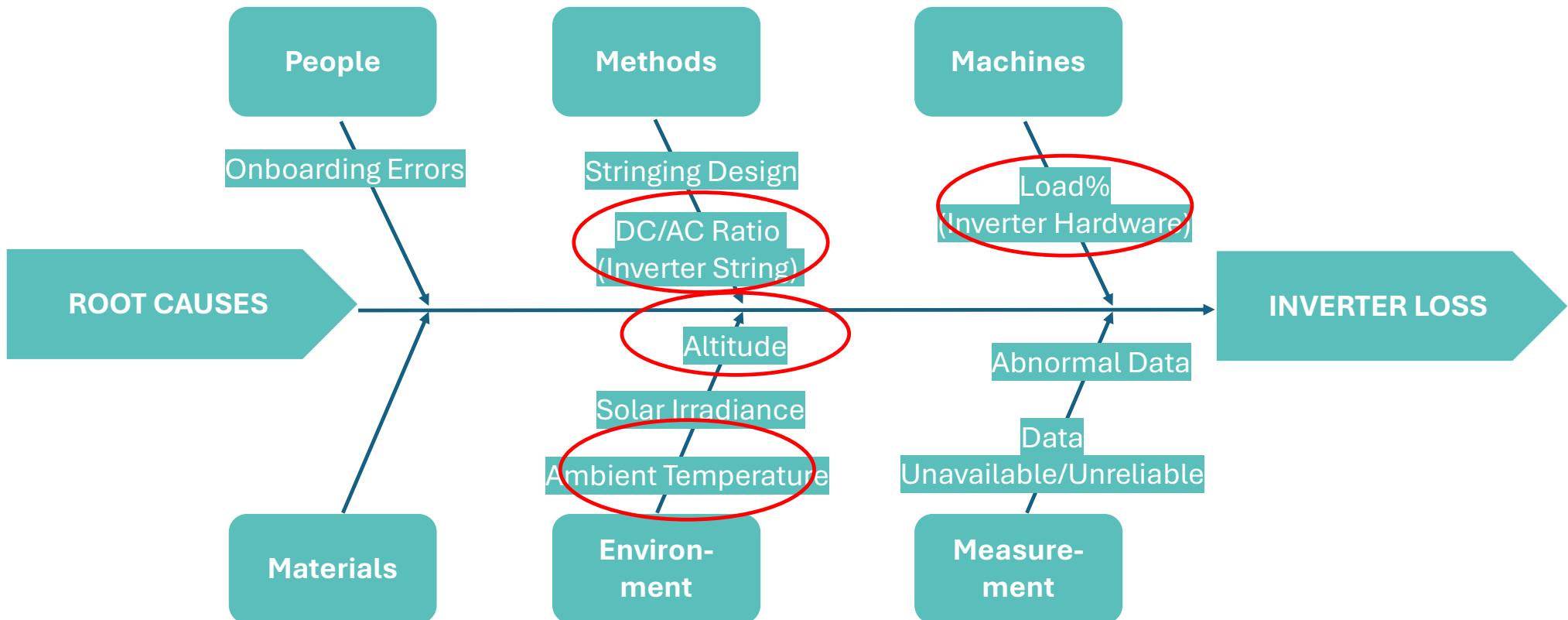
List of activities carried out in operate stage

- Had a final presentation showcasing all my findings, data and solutions to most OPM employees
- Received valuable feedback on both the presentation and analysis
- Identified areas for improvement and future actions, and ensured the project was ready for the Reporting Officer (RO) to continue post-handover

How has the project benefit the users?

- Pinpointed the root causes of inverter loss and their correlations
- Proposed simple solutions to reduce inverter losses and enhance solar site performance
- The data contributed significantly to the study and analysis of inverter loss across solar sites
- Guided further, more specific, actions to be taken on my project such as...
 - Further analysis on how solar irradiance affects inverter temperatures
 - Investigating Load% issues at specific sites
 - Proposed an optimal DC/AC ratio to minimize inverter loss
 - Reviewing SolarOS methodology on Load%
 - Identifying the necessity for more detailed temperature data (specific 5-minute intervals vs general daily) for improved analysis

Root Cause Analysis



Conclusion - Findings

Model (Site)	Correlation between Inv Loss		
	Vs Temperature/Altitude	Vs DC/AC Ratio	Vs Load%
Inverter Model A (Site A)	<ul style="list-style-type: none"> Temperature range is very low Inverter loss is within the expected range according to the datasheet Inverter loss increases as temperature increases 		<ul style="list-style-type: none"> As Load% increases, efficiency improves, and inverter loss remains within the expected range At a certain point, as Load% continues to increase, efficiency becomes stagnant
Inverter Model B (Site B)	<ul style="list-style-type: none"> Inverter Model B: Temperature range is very low Inverter Model C: Temperature range varies from very low to very high Inverter Model D: Temperature range is very high 	<ul style="list-style-type: none"> As DC/AC ratio increases, inverter loss increases This happens when... <ul style="list-style-type: none"> DC input power increases while AC output power remains constant, or DC input power remains constant while AC output power decreases 	<ul style="list-style-type: none"> The lowest efficiency% is below datasheet expectations, but the highest efficiency% aligns with the datasheet
Inverter Model C (Site C)			
Inverter Model D (Site D)	<ul style="list-style-type: none"> Abnormal Findings: <ul style="list-style-type: none"> Inverter loss decreases as temperature increases Efficiency improves as the inverter heats up 		<ul style="list-style-type: none"> Same conclusion as for Inverter Model A and Inverter Model B

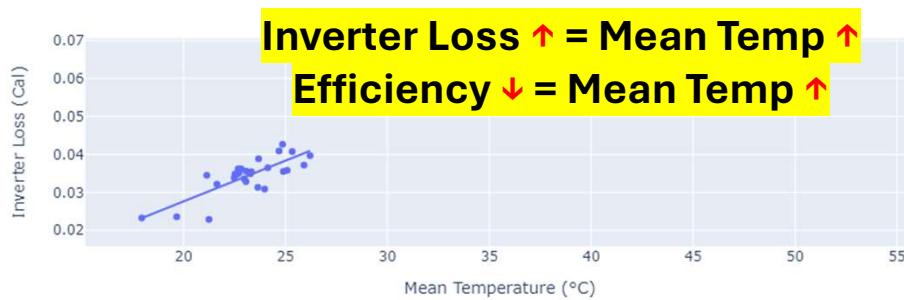
Conclusion - Solutions

Model (Site)	Correlation between Inv Loss			
	Vs Temperature	Vs Altitude	Vs DC/AC Ratio	Vs Load%
Inverter Model A (Site A)	<ul style="list-style-type: none"> Since temperatures are low and inverter loss is normal, keep monitoring 			<ul style="list-style-type: none"> Optimize the system load to stay within efficient operating ranges (? Load%) Avoid extreme loads where efficiency might stagnate
Inverter Model B (Site B)	<ul style="list-style-type: none"> If inverter loss increases with temperature, make sure inverter has good ventilation and cooling 		<ul style="list-style-type: none"> To propose an optimal DC/AC ratio (? Ratio) 	
Inverter Model C (Site C)	<ul style="list-style-type: none"> Improve cooling or ventilation to manage the wide temperature range Regular maintenance can help keep performance stable across different temperatures 	<ul style="list-style-type: none"> Make sure the inverter is well-ventilated and maintained 	<ul style="list-style-type: none"> Ensure the DC input and AC output are balanced to minimize loss 	<ul style="list-style-type: none"> Investigate factors causing lower efficiency at higher loads (More than 25% Load)
Inverter Model D (Site D)	<ul style="list-style-type: none"> Enhance cooling systems to handle high temperatures Ensure the inverter is in a well-ventilated area to maintain optimal performance 			<ul style="list-style-type: none"> Same conclusion as Inverter Model A and Inverter Model B

Inv Loss vs Temperature

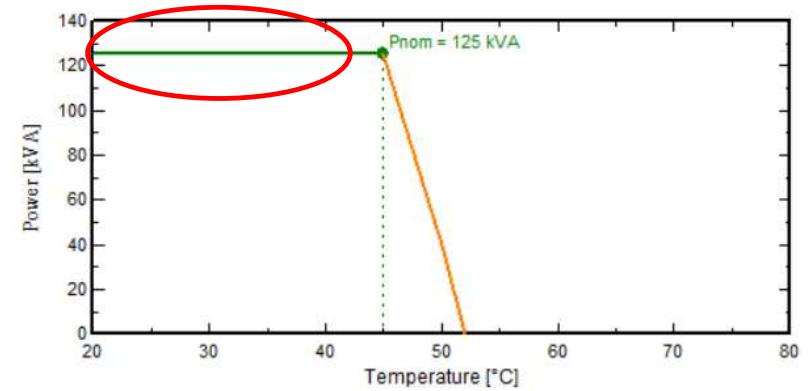
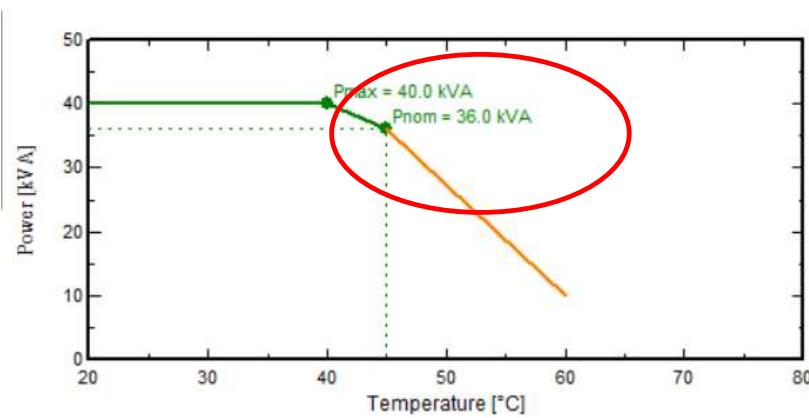
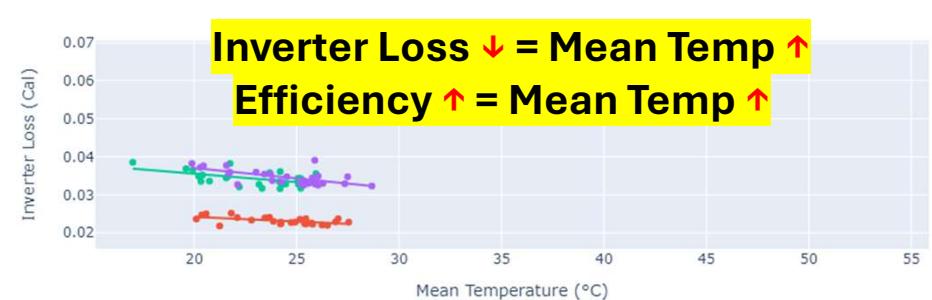
Inv Model A

Correlation between Inverter Loss and Temperature in April



Inv Model B

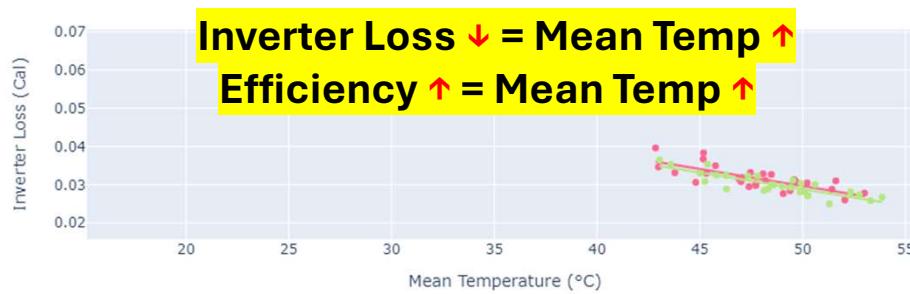
Correlation between Inverter Loss and Temperature in April



Inv Loss vs Temperature

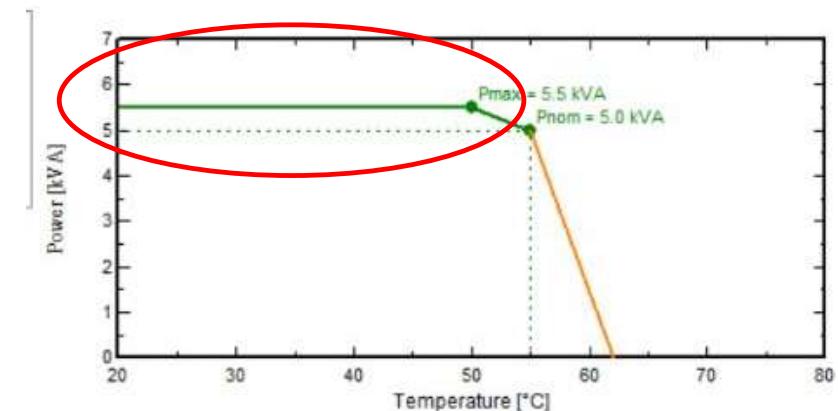
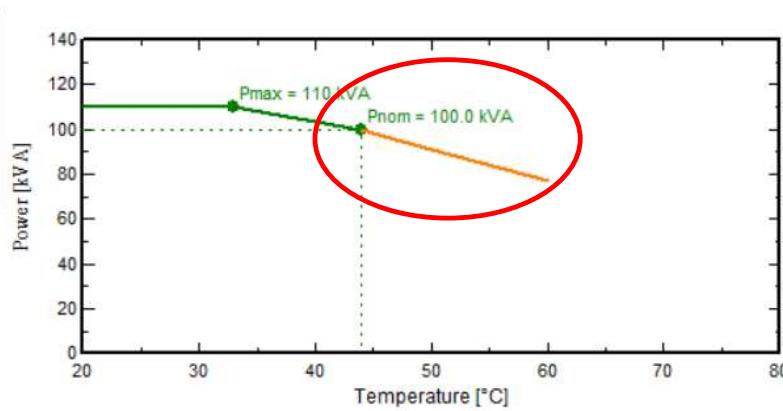
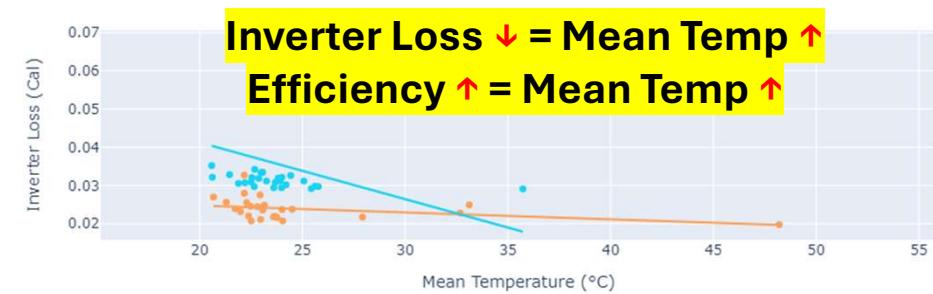
Inv Model D

Correlation between Inverter Loss and Temperature in April



Inv Model C

Correlation between Inverter Loss and Temperature in April



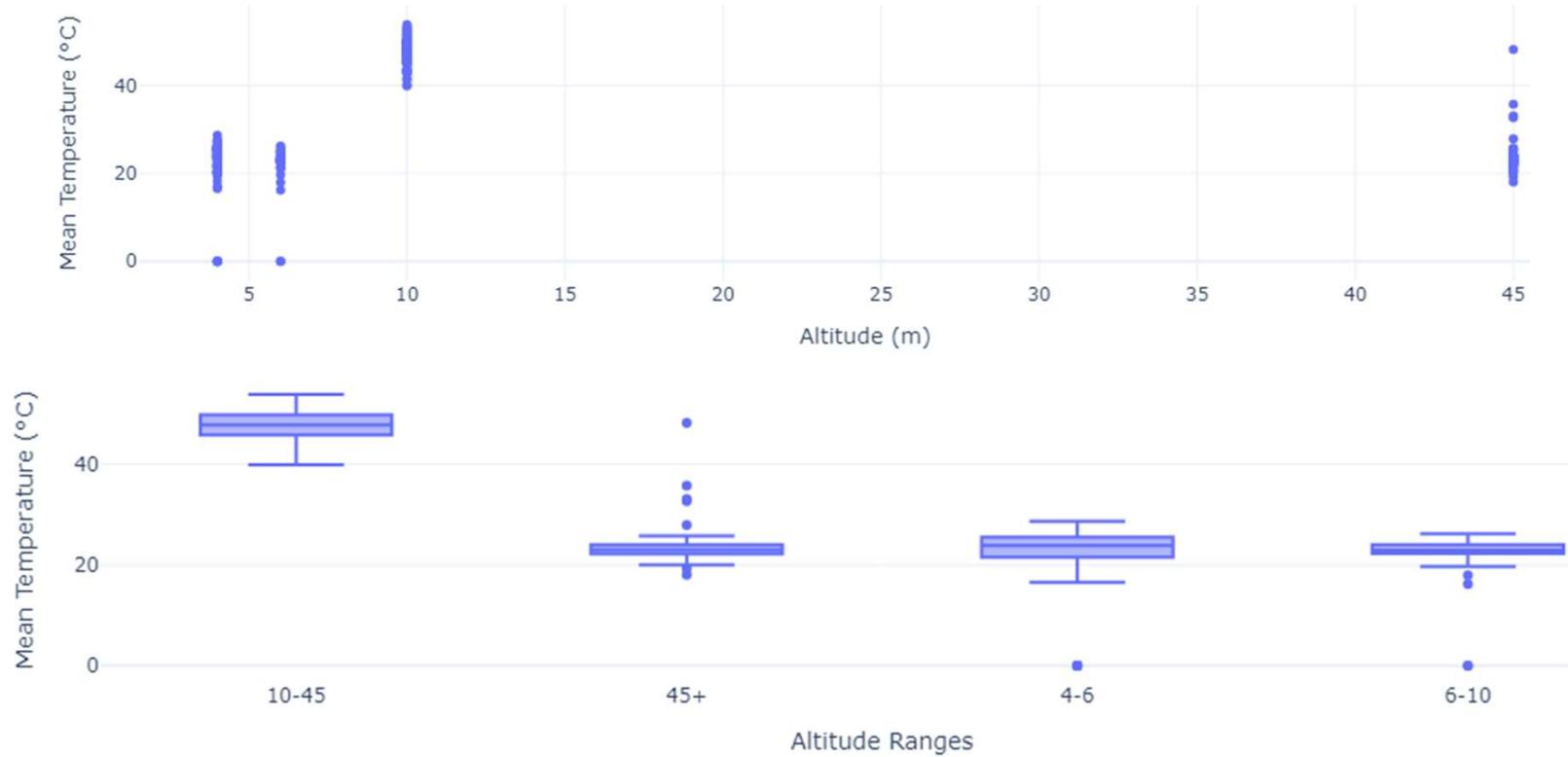
Inv Loss vs Altitude



Correlation between altitude and inverter loss: -0.05

Altitude ↑ = Inverter Loss ↓
Altitude ↑ = Efficiency ↑

Temperature vs Altitude

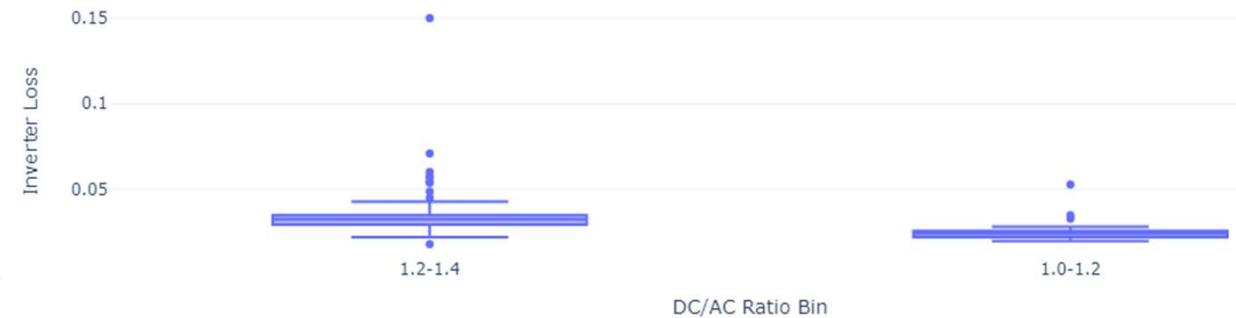


Correlation between altitude and temperature: -0.14

Altitude \uparrow = Temperature \downarrow

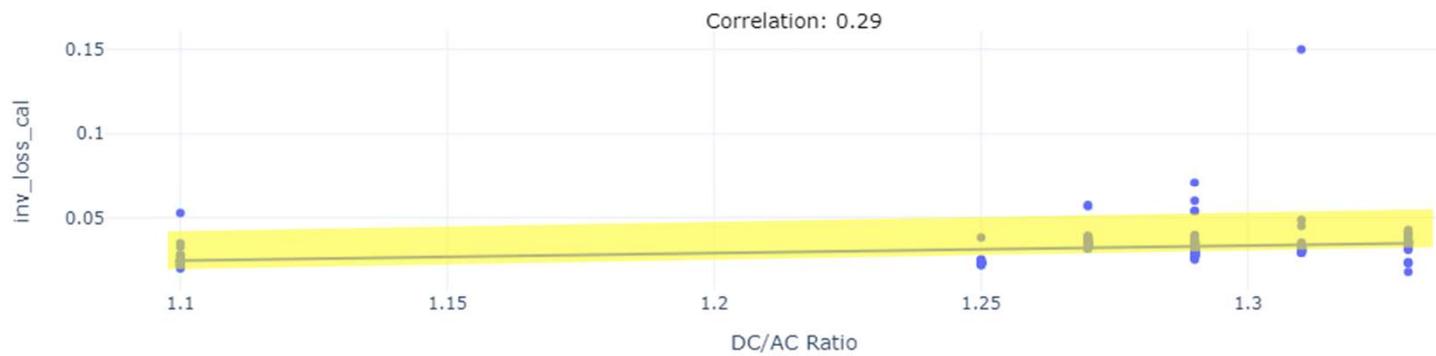
Inv Loss vs DC/AC Ratio

dc/ac ratio bin	count	mean	median	std_dev	min_val	max_val
<=1.0	0	NaN	NaN	NaN	NaN	NaN
1.0-1.2	32	0.03	0.02	0.01	0.02	0.05
1.2-1.4	236	0.03	0.03	0.01	0.02	0.15
1.4-1.6	0	NaN	NaN	NaN	NaN	NaN
1.6-1.8	0	NaN	NaN	NaN	NaN	NaN
>1.8	0	NaN	NaN	NaN	NaN	NaN



DC/AC Ratio \uparrow = Inverter Loss \uparrow

Correlation: +0.29



How to Calculate Total Voltage Range & Load Percentage

Total Voltage (V_{mp}) = V_{mp} STC (per panel) × Smallest Number of Panels

Total Voltage (V_{mp}) = V_{mp} STC (per panel) × Largest Number of Panels

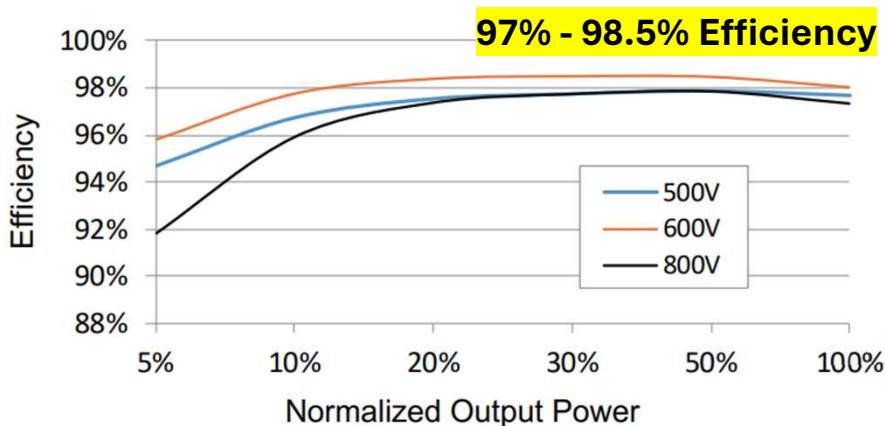
Module Meta Table for SG-UPS-31ALPS : UPS 31 Alps Avenue									
Module Brand	Model Name		Module Power		Pmax Temp Coeff	Voc Temp Coeff	LSC Temp Coeff	VMP STC	IMP STC
[REDACTED]	570	-0.30	-0.26	0.0460	42.7	14.4			
Subsite ID Inv ID MPPT Input Inv Input Brand Panel Model Name Model Power Module Count Surface Tilt Surface Azimuth									
290_1	1	1	1	[REDACTED]	570	20	5	243	
290_1	1	2	3	[REDACTED]	570	16	5	243	
290_1	1	2	4	[REDACTED]	570	16	5	243	
290_1	1	3	5	[REDACTED]	570	16	5	243	
290_1	1	4	7	[REDACTED]	570	16	5	243	

$LOAD \% = ACT_PWR / 110\% OF INVERTER'S RATING$

E.G. 100KTL INVERTER -> $100\text{KTL} \times 110\% = 110\text{KW}$

Inv Loss vs Load Percentage

Inv Model A

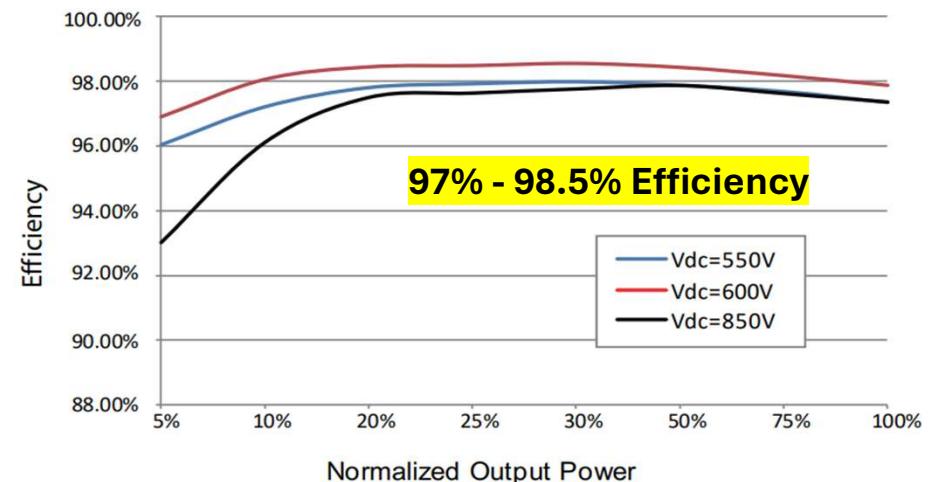


Voltage Range: 683.2 V --- 854 V

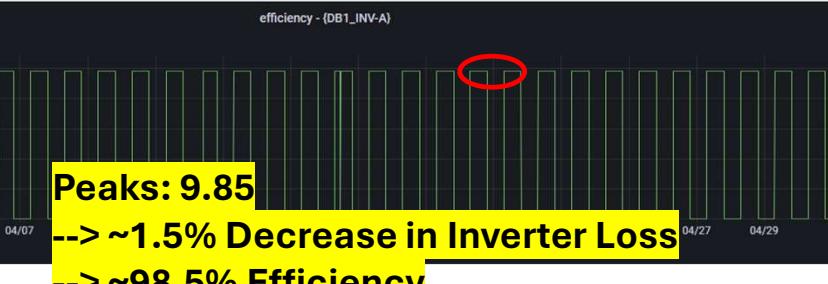


5
7

Inv Model B



Voltage Range: 643.5 V --- 815.1 V



5
7

Further Actions

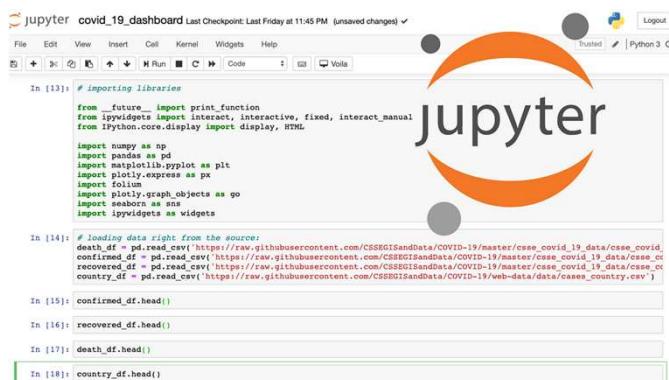
- Propose more in-depth solutions to the specific root causes
- Check the correlation between solar irradiance and temperature for inverters:
 - High irradiance leads to higher temperatures due to increased energy absorption
 - However, high temperatures can negatively impact the performance of both solar panels and inverters, reducing overall efficiency
- Examine the causes of Load% issues for the Inverter Model C at Site C:
 - Review EIOT 5-minute data and inverter logs
 - Issues could be related to SN data problems or hardware issues
- Determine and propose optimal DC/AC ratio range to minimize inverter loss
- Find out the SolarOS methodology on Load%
- Define the project scope clearly at the start
- Temperature range of the sites is based on 25 degrees Celsius (*using data from 25-100% load%*): This approach may overlook crucial data, as it relies on daily temperature averages rather than more detailed 5-minute interval temperature data

Conclusion: Skills Learnt or Practiced

- **Data Analytics and Tools:** Improved Excel skills, learned Jupyter Notebook for data analysis skills, as well Azure Data Explorer for data extraction skills

- **Understanding Solar Energy and Engineering:** Gained new knowledge of solar energy systems and engineering concepts

- **Monitoring Device Configuration:** Gained hands-on experience with monitoring device configuration and saw results on Sembcorp Solar's analytic platforms



The screenshot shows a Jupyter Notebook interface with several code cells. The first cell (In [13]) imports various Python libraries including future, print_function, ipywidgets, interact, fixed, interact_manual, display, numpy, pandas, pd, matplotlib.pyplot as plt, plotly.express as px, fortran, graphviz, go, and seaborn. The second cell (In [14]) loads data from GitHub URLs for death, confirmed, recovered, and country. The third cell (In [15]) prints the head of the confirmed DataFrame. The fourth cell (In [16]) prints the head of the recovered DataFrame. The fifth cell (In [17]) prints the head of the death DataFrame. The sixth cell (In [18]) prints the head of the country DataFrame.

```

jupyter covid_19_dashboard Last Checkpoint: Last Friday at 11:45 PM (unsaved changes) ✓
File Edit View Insert Cell Kernel Widgets Help Logout Trusted Python 3 0
+ ↻ ⌂ Run C Code Volta

In [13]: # importing libraries
# future_
import print_function
from ipywidgets import interact, interactive, fixed, interact_manual
from IPython.core.display import display, HTML
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import plotly.express as px
import fortran
import graphviz
import go
import seaborn as sns
import ipywidgets as widgets

In [14]: # Loading data right from the sources:
death_df = pd.read_csv('https://raw.githubusercontent.com/CSEGIISandData/COVID-19/master/csse_covid_19_data/csse_covid_19_time_series/death.csv')
confirmed_df = pd.read_csv('https://raw.githubusercontent.com/CSEGIISandData/COVID-19/master/csse_covid_19_data/csse_covid_19_time_series/confirmed.csv')
recovered_df = pd.read_csv('https://raw.githubusercontent.com/CSEGIISandData/COVID-19/master/csse_covid_19_data/csse_covid_19_time_series/recovered.csv')
country_df = pd.read_csv('https://raw.githubusercontent.com/CSEGIISandData/COVID-19/web-data/cases/cases_country.csv')

In [15]: confirmed_df.head()

In [16]: recovered_df.head()

In [17]: death_df.head()

In [18]: country_df.head()

```

- **Time and Task Management:** Improved skills in organizing meetings and balancing internship responsibilities

- **Professional Communication:** Improved email and messaging skills for effective communication with colleagues and supervisors etc.

- **Problem-Solving and Adaptability:** Tackled task-related challenges using work instructions and seeking help from colleagues



Conclusion

My Reflection on SDL

- Learned to ask for help and used coworkers' expertise when facing challenges—I wasn't afraid to feel "stupid" to seek assistance

- Used various sources (*work instruction documents/videos, guidance from senior colleagues, and fellow senior temps/interns*) for supplementary learning to improve my understanding and resolve any confusion regarding regular tasks and issues encountered during the internship
- This, as well as the theory and practical aspects of solar energy and solar sites >> This was immensely helpful in understanding and adding value to my internship project

- Able to manage my time between regular tasks and my own internship project by seeking my colleagues' help when under tight deadlines >> enabled me to accomplish more within the available time

Thank you! 😊