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WHITE PAPER

SOLAR PV
PERFORMANCE ANALYSIS

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SOLAR PV
PERFORMANCE ANALYSIS

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CHECKING DATA

Checking Data

Before we start a performance analysis we need to check the availability and completeness of site data. Typically any solar asset has some form of monitoring software which can be used to visualise and download data from site.

The Performance Ratio (PR) is one of the easiest ways to evaluate site performance of any capacity, the formula is as follows:

$$PR = \frac{Production}{Irradiation\ x\ Capacity}$$

To calculate a PR we need at least:

1. Production --> Meter(s) or all inverters data

Meter data is the most accurate measurement of energy delivered to the injection point. There may be several different meters on the site depending on the size of the asset. For each day or period of measurement, we need to know the total energy delivered to each injection point.

If somehow meter data is not available, we can substitute in inverter data. Sum of inverter data is typically about 1-2% higher than meter data (because there are AC cable losses to the injection point), so inverter data should never be used to bill a client but can be used to estimate site performance.

2. Irradiation --> Some form of irradiance data

The data should be complete without gaps. E.g. in the image below the pyranometer (irradiance) data has gaps, so we can't use it to calculate a performance ratio. In this case you could (1) either use pyranometer data from a nearby site as a rough estimate or (2) use satellite data.

Time	Irradiance (W/m2)
08:20	NULL
08:25	NULL
08:30	NULL
08:35	NULL
08:40	NULL
08:45	NULL
08:50	NULL
08:55	NULL
09:00	340.00
09:05	374.00
09:10	NULL
09:15	416.00

We should combine the PR calculation with a check of availability, i.e. what % of the site is available to produce energy. The availability can be calculated at the inverter and/or string level and ideally should always be 100%.

To check site availability at the string level we need in addition:

3. String current per inverter

String current data is needed to know if strings are not producing or if there is a string with a looming insulation resistance (RISO) fault which could soon cause the inverter to trip (or worse).

IN SUMMARY:

Analysis	Best Data Source	Alternative Data Source 1	Alternative Data Source 2
Inverter Availability	Inverter Power	-	-
String Availability	String Current Data	-	-
Performance Ratio	Meter Output	Inverter Output	-
Performance Ratio	Pyranometer Data	Satellite Data	Nearby Site Pyranometer Data

2.

CHECKING EQUIPMENT AVAILABILITY

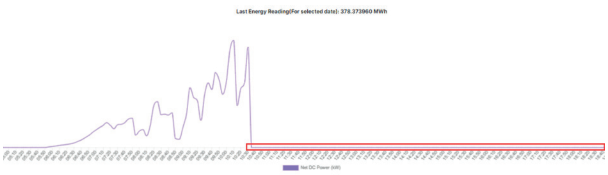
2.1 Inverter Availability

The performance of a solar PV site is based on (1) what % of equipment is available to produce energy (availability) and (2) how well that available equipment is producing energy (performance ratio). It's important to consider both in an evaluation of a power plant's performance. Today we'll look at item 1 and specifically inverter availability.

Monitoring software typically generates alerts automatically based on pre-defined parameters, for example if an inverter is in fault status then an alert is created. Or if a string current is less than 80% of the maximum current on the inverter/combiner box for 2 consecutive hours, then this generates a string alert.

Looking first of all at inverter availability, three main issues we might see are:

(1) Inverter completely down

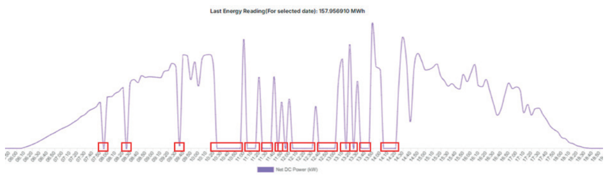


In this example we see the inverter stops producing at around 10:40.

Here we exclude issues such as a whole site trip (all inverters down) or comms issues. In this case this inverter has a critical fault and it has shut down. There can be many reasons for this fault (e.g. internal fan fault, DC insulation fault, technician forgot to restart the inverter after maintenance), but it will likely require a visit to site to assess, and/or assistance from the inverter manufacturer.

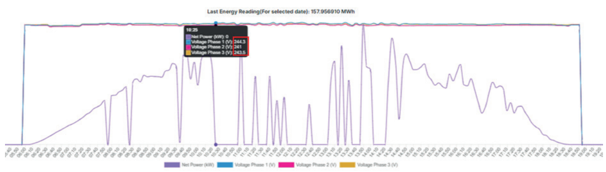
If the maintenance team assesses the fault and can't immediately find the solution, a claim should be made with the inverter manufacturer. Whilst waiting for feedback from the inverter manufacturer, it would be helpful to switch out the inverter with a spare (in the case of string inverters) to minimise downtime.

(2) Inverter tripping on and off



In this case the inverter is heavily cycling on and off which will heavily damage inverter components. There can be several causes for this cycling: grid instability, AC supply instability, internal inverter fault, DC insulation fault etc.

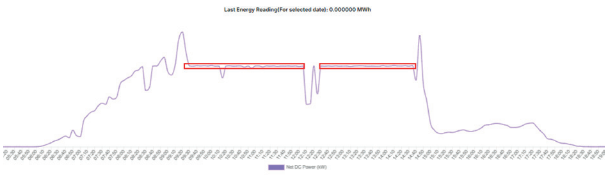
For example you can check the AC supply to check if the inverter is tripping on under or overvoltage. An inverter with 220V AC supply may be set up to accept grid voltage in a 10% range of 220V, therefore 200-242V. If the grid voltage goes below 200V or above 242V then the inverter trips.



For the above example the issue linked back to grid overvoltage, the AC supply was frequently above 242V as we can see on the image above (at 10:25 the phase 1 and 3 voltage was >242v), which caused the inverter to trip. In this case it is possible to adjust the inverter overvoltage settings to make the inverters less sensitive to grid fluctuations. Prior to making any changes, the asset owner should obtain approval from the inverter manufacturer and the grid operator.

Generally, the inverter fault log should give more indications to what is causing any inverter tripping.

(3) Inverter curtailed to a certain capacity



In this case the inverter is technically available (which is why you cannot just rely on availability alone as a metric to evaluate performance) but the curtailment still reduces the overall site capacity available to produce energy.

This curtailment might be caused by low factory load (for zero export systems), grid export limitations, internal inverter issues such as fan faults, incorrect setting of inverter active power etc. In this case the inverter had an internal fan fault which limited the inverter's output to prevent overheating. Whatever the case, the root cause should be identified and actions put in place to mitigate.

Ensuring 100% inverter availability is critical.

SUMMARY OF THIS SECTION:

Inverter Issue	Potential Cause 1	Potential Cause 2	Potential Cause 3	Potential Cause 4
Inverter Down	Inverter Fault	DC insulation fault	Technician forgot to restart after maintenance	-
Inverter Tripping On/Off	Grid instability	AC supply instability	Inverter fault	DC insulation fault
Inverter Curtailed	Low factory load	Grid export limitation	Inverter fault	Incorrect active power setting

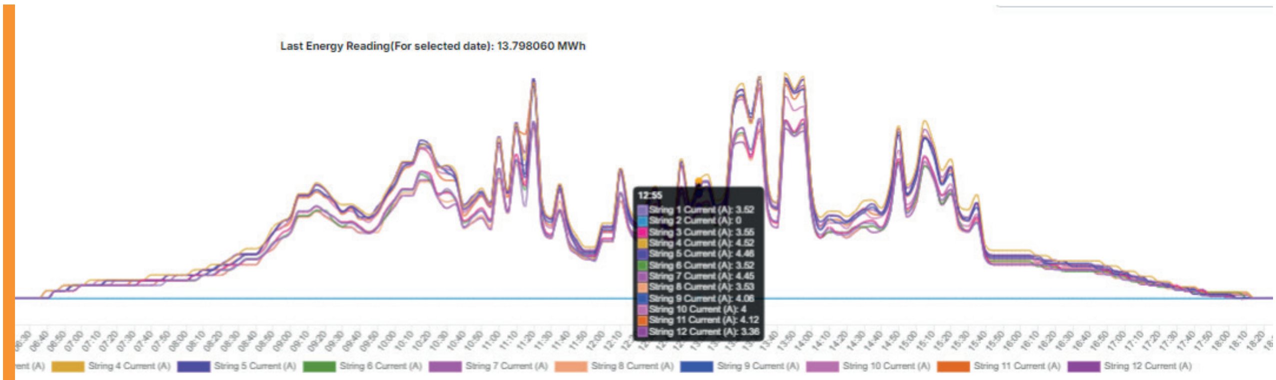
2.2 String Availability

After ensuring the inverter availability is as high as possible, it's also good practice to check string level availability.

As a reminder:

- If there are 10 inverters on a site each with the same capacity, and 1 is not producing, the available capacity drops by 10%.
- If there are 100 strings on a site each with the same capacity, and 10 are not producing, the available capacity also drops by 10%.

So non-producing strings also have a big impact on site performance, hence why it's important to not just check inverters but also string availability!



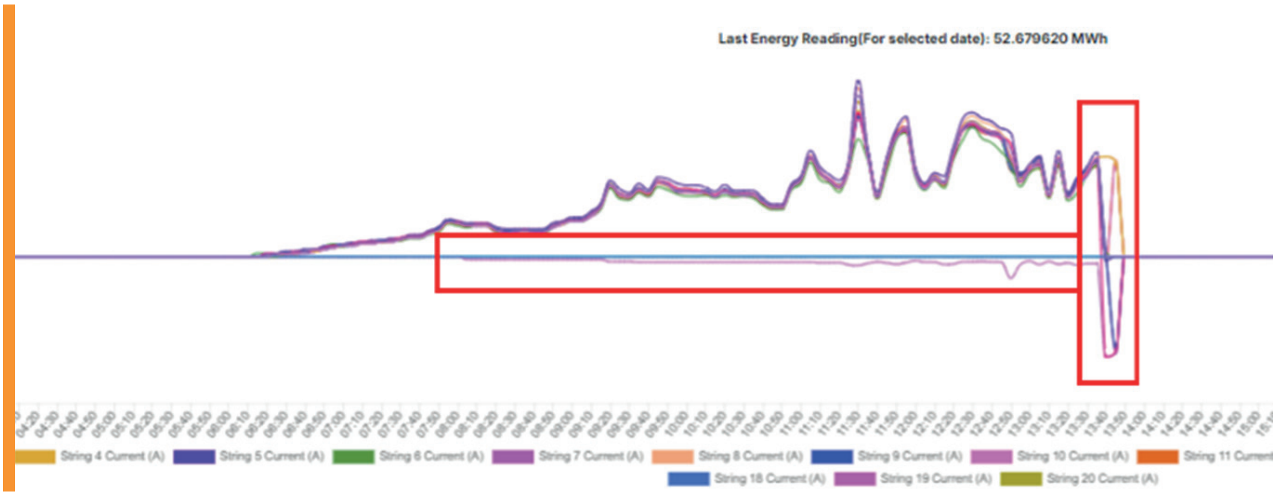
On the above example we can see that string #2 is showing 0 Amps current. This string needs to be checked on site to rectify the source of non-production (loose MC4 connector, string fault, blown fuse etc).

Standard monitoring software should generate automatic alerts based on string failures (e.g. "generate alert if any string current =0 for 2 hours"). It should also be able to differentiate between single or double strings so that you don't get false alerts based on normal plant design.

Certain inverter manufacturers such as SolarEdge or SMA don't like sharing string current data with 3rd party monitoring software platforms. If your monitoring system doesn't generate string alerts then it can be worth manually creating scripts or macros to download data from the logger and automatically flag any strings that are not generating current when irradiance is >50 W/m2.

Watch out for negative current

String level data is not just important to check for availability, it can also be critical in looking for serious issues such as insulation resistance faults or short circuits.



In the above example we see one string gradually showing more and more negative current from 08:00 until at 13:40 when there is a big failure, after which several strings display around -10A negative current. Negative current is a serious issue which typically means there is a short circuit often leading to overheating/fire.

This advanced "warning" could only be seen by looking through string data, in this case there was no inverter warning or fault until the incident happened.

Such negative current situations should be treated with great care, as there can be life-threatening current flowing through the cable tray or module frames during the day. It's highly recommended to wait until irradiance has reduced so that string current is <0.5A before attempting to repair such issues.

3.

CHECKING SOURCES OF UNDERPERFORMANCE

3.1 Meter vs Sum of Inverters

Your solar site has all irradiance and production data accessible and all inverters and strings are available and producing normally. But you've still got a "low" performance ratio, what to do?

Performance Ratio (PR) varies from site to site based on module choice, DC/AC sizing, design, interrow shading, installation type (ground mount, rooftop, floating) etc, but generally a reasonable PR is around 80% for a new site. This figure reduces approximately 0.5% per year taking module degradation into account, so as an example, a 10-year-old site should still be achieving around 75% PR levels. A well simulated PV Syst will be a good benchmark to compare an operational site's performance too.

Throughout the year the PR of the site will vary based on seasonal change:

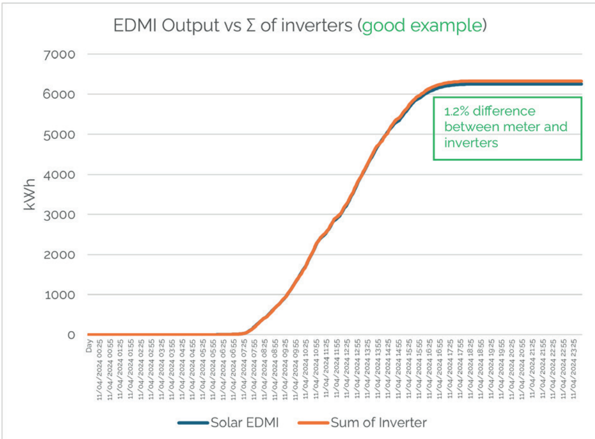
- In winter the sun is lower in the sky so there will typically be more module shading which reduces PR;
- In dry conditions, a lot of dust is created which increases module soiling and reduces PR;
- In a hot summer, the PR will generally decrease as module output reduces with increased module temperature (negative temperature coefficient);
- Inversely during low irradiation days <3kWh/m2/day (e.g. rainy season, humid winter), the PR will increase as modules perform better at lower temperatures.

So an analysis of the PR shouldn't just be done on a 1 hour or 1 day basis. It should span multiple days (at least 1 month and ideally more) to get an idea of seasonality and how the site is really performing.

CASE STUDY

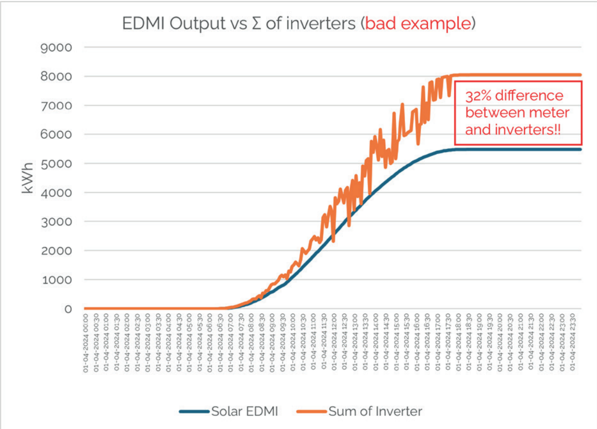
Coming back to our example (which was recently encountered) ... we have a newly installed solar site, all modules and inverters are new, all strings and inverters are 100% available and all are generating energy normally. There are no alerts indicating any issue with the DC field. But somehow the PR is 55% and causing a major headache.

One critical aspect to check is the comparison between the output at the meter and the sum of the inverter output. As previously mentioned in episode 1, inverter output is normally around 1-2% higher than the meter output, this is because from the inverter to the meter there are AC cable losses so the meter output will be slightly lower. The delta between inverter and meter output should look something like this:



Here we see that the meter and inverter curves follow each other well during the day and the sum of inverter output is 1.2% higher than the meter (EDMI). This is as expected.

However when comparing the sum of inverter output and the meter output on this site, the meter output was 32% lower than the sum of inverter output!

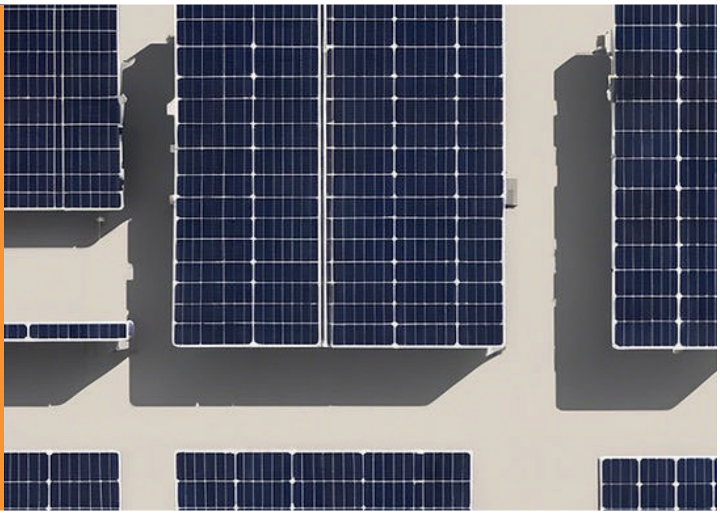


Clearly something was wrong at the meter. A team was immediately sent to site and it was found that one of the phases at the EDMI meter had blown. So all the inverter production on that phase was just being lost!

The fault was repaired and the site PR jumped instantly from 55% to 80%.. the client was happy! It was a simple solution which had a massive impact on site performance. Also such a fault isn't necessarily picked up by monitoring alerts, so it's a good check to do.

3.2 Shading

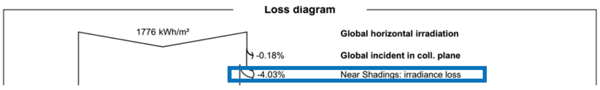
At some stage during the year all solar projects will have shading, either from nearby objects (e.g. buildings, antenna, trees), or from far objects (e.g. mountains) or from interrow shadings (e.g. one module shades another nearby module).



In the northern hemisphere, the sun is lowest in the sky (winter solstice) around the 21st December and in the southern hemisphere around the 21st June. When the sun is lowest in the sky this will lead to the highest shading losses as there are typically more horizontal obstacles than vertical ones.

When designing the site, the engineering team should of course plan to minimise shading losses by doing a full survey of the site, noting down any obstacles (chimneys, guard rails, walkways, buildings) and leaving a buffer area around them to minimise shading impact. Also string wiring should be considered to limit any shading losses and optimisers can be used to further mitigate losses. A PV Syst simulation including shading scene analysis should then be done as a reference for site performance.

So when we talk about underperformance from shading, we're specifically referring to the losses above the budgeted financial model losses. E.g. in the below example if the financial model has 4% shading losses and we work out that actually there are 5% shading losses, then we have 1% underperformance from shading.



Working out the exact shading losses is not easy because they vary throughout the day and the year, but we can estimate shading losses by simply comparing the output of non-shaded inverters vs the output of shaded inverters. So the losses are the difference in output between the non-shaded "reference" inverter(s) and those that are shaded. Taking a reasonable sample of days over the year and performing the same calculation allows for a good general estimation of shading losses.

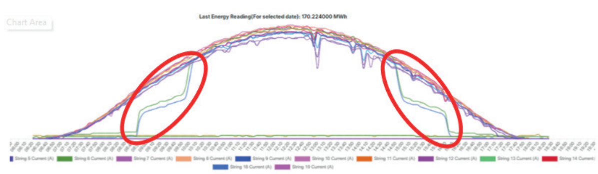
Some shading such as trees are quite easy to fix by pruning or removing the tree. This is the same for ground mounted sites, where the vegetation needs to be well managed to never shade the bottom row of modules.

Above we have shading caused by a crane. The crane should be moved when not in use to avoid more shading than necessary.

Here we have shading from a nearby building, this is more difficult to solve permanently but the effects can be minimised by rewiring the strings linearly to limit the losses to the string closest to the building.

In this case the modules could have been installed further up the roof slope to increase the buffer zone from the surrounding building.

Typically in the monitoring system we can see shading based on production curves that start late or finish early. In the below example we see two strings have shading both in the morning and in the afternoon. We can check the string layout to see where these strings are physically installed and whether or not we can remove the shading object.



To work out the % impact of shading on those strings, we can compare the output of non-shaded strings (nice bell curve) with the shaded strings (output dips in the morning and afternoon) As a side note we also need to be aware of shading on the pyranometer. If the pyranometer is shaded then this will artificially inflate the PR and lead to wrong assumptions!

During the design stage:

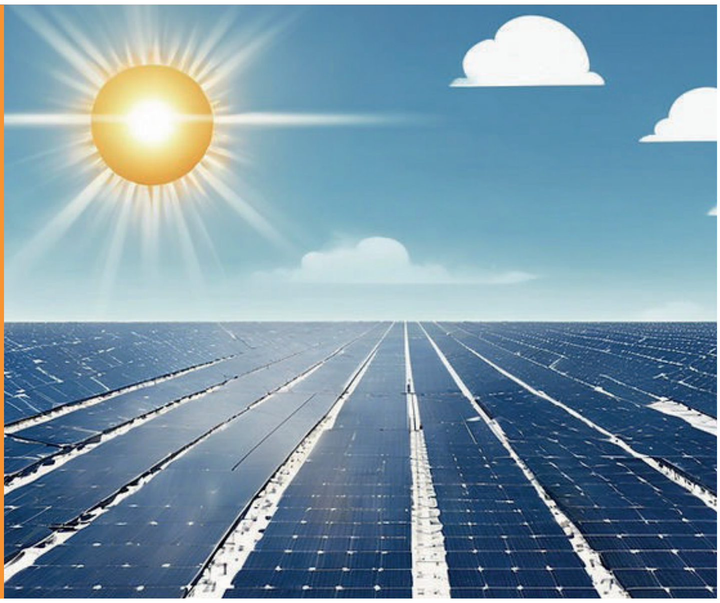
- A full site assessment needs to be done to ensure any obstacles are noted and that modules are placed where possible to avoid these obstacles (particularly for rooftop projects).
- The string layout should be designed to minimise shading of any objects noted during the site assessment. For example if there is unavoidable shading, putting linear string wiring can help to minimise that shading.

During the operational phase:

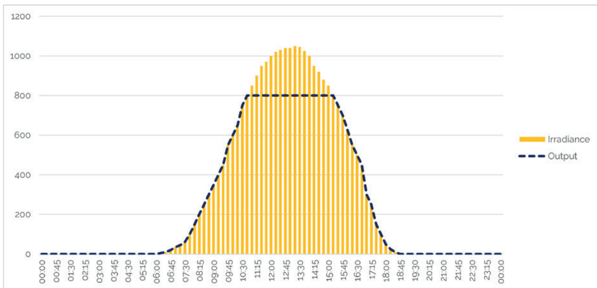
- Any temporary sources of shading (e.g. trees, cranes) need to be minimised.
- The budgeted shading in the financial model should be compared to actual shading losses as a feedback loop to improve on designing for future projects.

3.3 Clipping

Clipping refers to the scenario where inverter output is maxed out and flatlines even though irradiance continues to increase. This causes «losses» as the DC field can generate more electricity but the inverters cannot as they have reached maximum capacity.



Think of a chart like the one below as a prime example of clipping, we see the irradiance continues to climb whilst the inverter output flatlines (is "clipped"):

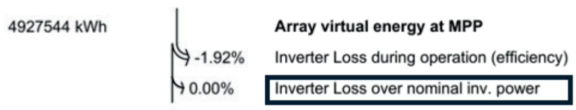


Clipping is influenced by the DC/AC ratio, which is the capacity of the solar modules (DC kWp) with respect to the capacity of the inverters (AC kW). E.g. if I have 12,000 kWp of solar modules and 10 x 1 MW AC inverters, the site has a DC/AC ratio of 1.2.

DC/AC ratios can be any number but are typically between 1 to 1.5.

In higher latitudes (north or south hemisphere), DC/AC ratios tend to be higher as plant designers look to boost production in winter when the sun angle is lower. But of course the higher the DC/AC ratio, the higher the plant cost (more modules and cables etc), so DC/AC ratio design has to consider both increased output vs increased cost.

In PV Syst the clipping losses are defined as "Inverter Loss over nominal inv. Power".



So when looking into the performance of a solar farm, we're comparing the actual losses from clipping vs the modelled losses in PV Syst. For example, if the PV Syst simulation for a solar PV power plant has 0% losses for clipping, then any actual clipping losses are underperformance. If the PV Syst simulated has 1% losses for clipping and we calculate actual losses are 1%, then there is no underperformance.

Grid curtailment can also look like clipping, so when analysing clipping losses it's important to remove any periods when there is a grid curtailment order or zero export limitation. And we should also remove any other outages (e.g. inverter shutdowns) so that we isolate pure clipping losses in our calculation.

Calculating clipping losses when at least one inverter is not clipped

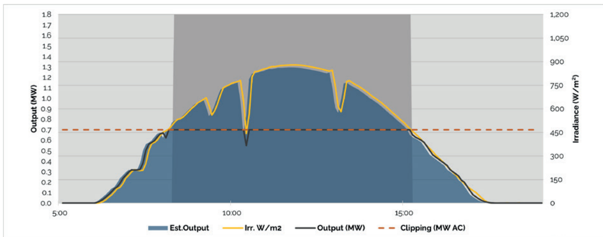
To calculate clipping losses when at least one inverter is not clipped, you can simply compare the output of clipped inverters (pro-rating output if inverters have different DC and/or AC capacity) to the output of non-clipped ("reference") inverters on the same site.

E.g. if a non-clipped inverter produces 1000 kWh per day and the clipped inverter produces 900 kWh per day, assuming there are no other outages or loss differences between the inverters and they have the same DC and AC capacity, then the clipping losses are 100 kWh or 10% for that clipped inverter. Then to get a better idea of overall clipping losses, this exercise needs to be done on multiple days across the whole site.

Calculating clipping losses when all inverters have clipping --> Regression

If all inverters are clipped then the above method doesn't work because there are no reference inverters. In this case we need to use a simple regression model (y = mx + b) based on the relationship between irradiance and output on that site.

Comparing the irradiance and the output of the site during non clipped periods allows us to determine a regression formula (slope + intercept) in order to work out for any irradiance level, what is the predicted output. We can then use this predicted output to evaluate the clipping losses (again assuming all other loss sources have been eliminated from the calculation).



In the above example, clipping starts around 08:00 and continues until around 15:10. We can therefore use the correlation between the irradiance and output before 08:00 and after 15:10 to obtain our regression formula, which can then be applied to the periods when there is clipping to calculate the expected output.

Again as with the other sources of losses we have looked at, it's important to track clipping losses to compare against the financial model and as a feedback loop for future projects. E.g. if clipping losses are too high then for future projects of similar design, a lower DC/AC ratio could be favoured.

3.4 Soiling

Module soiling is also a major influencer of underperformance, and soiling can be caused by many factors generally classified between:

1. Human, e.g. factory exhaust fumes (the worst of those being cement dust), kerosene from airplanes etc.
2. Natural, such as sand, leaves, lichen, rocks, snow, minerals from rain or bird droppings.

Soiling management is a critical part of a solar power plant's operational strategy, as dirty modules lead to (1) site underperformance and importantly (2) long term module damaged caused by hot spots.

Contrary to certain people's ideas, solar modules are not sufficiently cleaned by rain, even in tropical zones, and regular cleaning anywhere between 6-monthly to weekly frequency is needed. This can be combined with drone infrared thermography to pinpoint area with specific soiling like leaves or bird droppings.

Whilst soiling can generally be detected through performance monitoring by «less than expected output», the accurate performance impact of soiling on a solar site is very difficult to determine by (1) SCADA or performance data or (2) visual inspections as the soiling is generally very widespread and there are no reference strings or inverters that have no soiling at all.

The best method to accurately calculate the soiling losses is to perform a module level test on a sample of modules, where some modules are cleaned e.g. weekly and some modules are not cleaned at all. Then module-level I/V curve measurements between the cleaned vs non cleaned modules will determine the soiling losses. We will publish a post on the methodology for this shortly.

In addition to determining the performance losses from soiling, it's important to look at the source(s) of soiling and how to minimise that.

When simulating soiling losses in PV Syst, it's important to have visited the site before construction to have a general idea of fumes and dust at the project.

And also it's important to take into account seasonality; I've been involved in one project where the engineering team neglected to consider snow in the soiling losses, which led to dramatic underperformance (against budget) in the winter months!

As a few examples:

- On solar floating sites, it's common to have bird nesting as a floating site provides the ideal sheltered habitat away from predators which in turns leads to module soiling from bird droppings. In such cases it's important to look at bird deterrents such as removing nests or trying to scare the birds away.
- For solar rooftops affected by factory exhausts fumes, it's good to discuss with the factory owner/operator about minimising the fumes, either by adding filters to chimneys or running certain machines less often.
- On low tilt projects, it can be helpful to have solar "clips" placed on the downward sloping edge of the module, that help to drain the water and prevent the stains often caused by minerals in the rain.

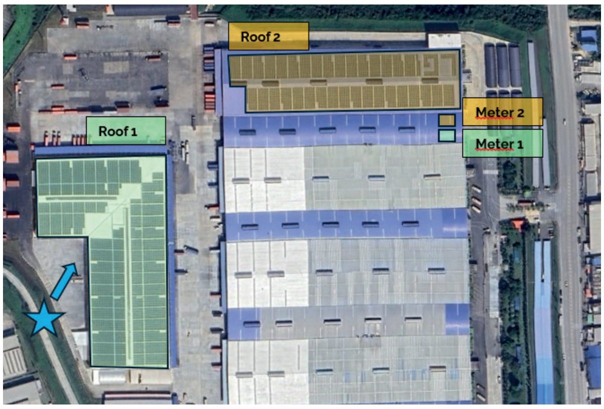
4.
CASE STUDY

Case Study

We've been through some of the major sources of underperformance of a solar PV site during the previous posts, but each site has its own particularities and potential sources of underperformance based on design or local site conditions.

Today we'll take a concrete real-life solar PV plant and analyse it to assess the performance and corrective actions. This example is a rooftop solar installation with zero grid export, but the same principles apply to any type of setup (grid feeding or ground mounted or floating).

Here is an overhead layout of the site, there are two rooftops connected to two different meters:



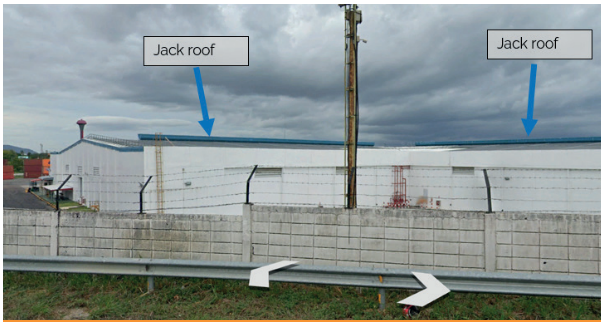
For this case study we assume that there is no inverter or string level unavailability, therefore any low PR is caused by underperformance of equipment compared to PV Syst or other model simulation.

When looking at the inverter PRs, we see the following patterns:

1. Generally lower PRs for roof 1 inverters vs roof 2 inverters.
2. Some inverters with lower PRs and late starting in the mornings
3. Some inverters with lower PRs and early finishing in the afternoons.
4. Dips on all inverter production at midday.

To start with, even if you have already physically visited the site, it's still good to do a virtual tour to understand anything that could impact performance.

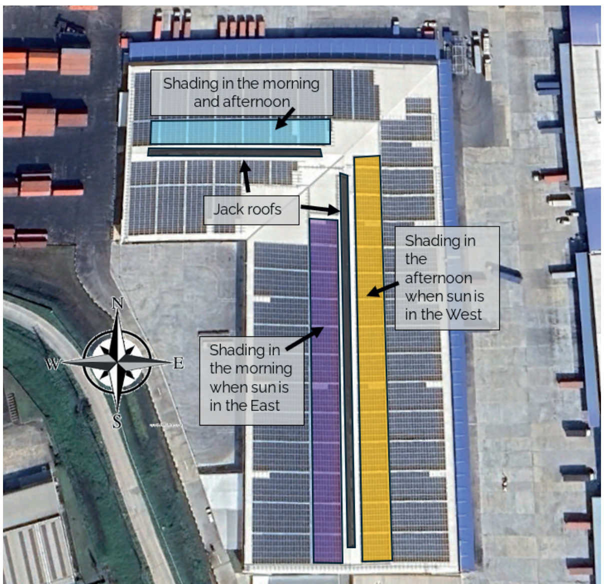
The easiest way to do a virtual tour is using Google Maps or Google Earth, we take the GPS coordinates of the site and place ourselves at the street view. In this case we stand at the blue star indicated on the layout above, looking in the direction of the blue arrow:



Street view of the site showing jackroofs

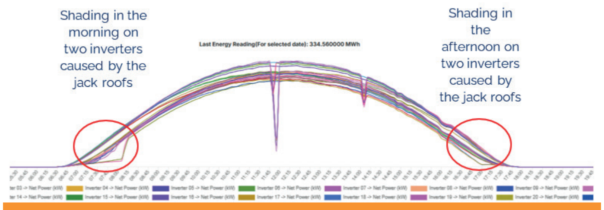
From this we can see the roof has a gentle north/south orientation but has jack roofs (raised roof sections) at the apex which will cause shading to surrounding modules.

If we now focus on roof 1 we can plot out the areas that will be shaded at different times of the day. Then using the inverter & string layout (as-built) of the site, we can work out which inverters/string will be shaded at what time of day:



Indicating the impact of jackroof shading.

From that we can compare the performance of the non-shaded inverters to the performance of the shaded inverters to calculate the estimated shading losses. These losses should then be compared to the PV Syst / financial model assumptions. In our case the shading was not factored into the budget so this shading is an underperformance.



Monitoring data showing shading

In the above monitoring chart we see shading on two inverters in the morning and shading on two inverters in the afternoon, this is caused by the jackroofs highlighted in the layout above.

Shading is difficult to remediate once the modules are installed, but rewiring strings (e.g. having the string linear close to the jackroof) could be an option to help reduce the impact of the shading.

Generally modules should be wired linearly and parallel to shading objects, to minimise the impact of the shading.

Also the feedback loop needs to happen to the engineering team to ensure better simulation of losses during site design (and specifically the engineers doing the PV Syst simulation should have visited the site beforehand!).

So going back to our conclusions from the inverter PR analysis, we found the following:

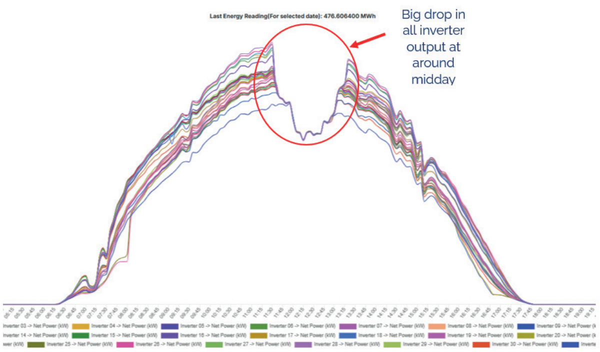
1. Lower PRs for all roof 1 inverters vs roof 2 inverters.
2. Some inverters with lower PRs in the mornings.
3. Some inverters with lower PRs in the afternoons.
4. Dips on all inverter (roof 1 & 2) production at midday.

This shading helps to explain points 2 and 3. But it doesn't help to explain point 1, as not all roof 1 inverters are affected by shading and therefore they shouldn't all be underperforming vs roof 2 inverters. It also doesn't help to explain point 4.

For point 1, when looking at the layout, we notice that roof 1 is further away from its injection point (meter 1) vs roof 2. Roof 1 modules are around 600m away from meter 1. As we know that longer DC cable leads to higher resistance and higher voltage drop along the cable, then longer DC cable runs will lead to lower performance.

In our case the same 6mm2 DC cable has been used for all strings, and with the 600m distance this leads to approximately 1.5% voltage drop and impact on performance. This helps to explain why PR is generally lower for meter 1 inverters than meter 2.

Again this wasn't captured during the design phase so this is real "underperformance" which is now costly to remedy, because it would require a complete re-string using e.g. 10mm2 DC cable. The gains in energy would surely not justify the cost of the exercise (to be confirmed with a cost/benefit analysis). So this is a feedback loop towards engineering on future projects to factor this in when doing the simulation.



Drop in all inverter output around midday

This isn't related to irradiance as the irradiance curve is a perfect bell shape (not shown here). Also we know that this isn't clipping as the inverter output would flatline rather than drop (see article 3.3 for more details on clipping).

What we do know is that this is a zero export site, and at lunchtime employees will go to lunch and factory production will slow, leading to a reduced demand for electricity. So this drop in output is a curtailment loss. Based on the PPA contract with the client, this loss may be claimable as part of the client's annual minimal consumption commitment.

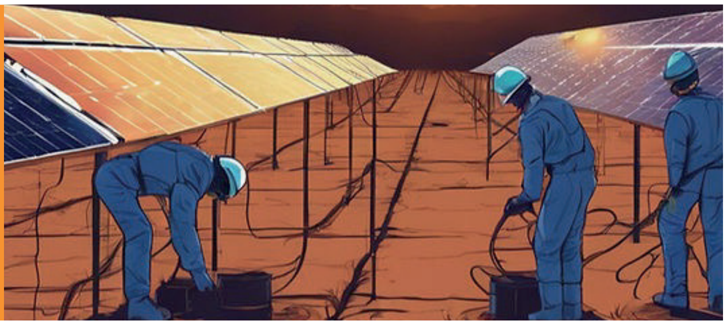
For this site we have reviewed some major sources of undeperformance:

1. Lower PRs for all roof 1 inverters vs roof 2 inverters --> **because of 1.5% voltage drop caused by longer DC cable route.**
2. Some inverters with lower PRs in the mornings --> **because of jackroof shading.**
3. Some inverters with lower PRs in the afternoons --> **because of jackroof shading.**
4. Dips on all inverters (roof 1 & 2) production at midday --> **because of factory curtailment when workers go to lunch.**

5.

ACTION PLAN AND TRACKING

Action Plan & Tracking



In the previous sections we have reviewed:

1. **How to check for data availability and correctness.**
2. **How to check for equipment availability, ensuring inverters or strings are all producing.**
3. **How to check for sources of underperformance.**

The last phase is now:

4. **Putting together an action plan with expected % performance increase for each action and following up with the local O&M team to track that actions are put in place correctly.**

Putting together an action plan is arguably the hardest part of the performance analysis, the action needs to be specific enough to avoid confusion, and also needs to be cost-effective and achievable. If for example inverter 5 has low PR, the action should not be "investigate inverter 5 performance on site". This is too generic. The action needs to be specific enough that the team on site can go directly to the problem without wasting time.

A better example of a corrective action is "inverter 5 has 2 strings not producing, numbers #5 and #6, check these strings on site for loose module connections, broken cable, disconnected MC4 connectors, broken modules, blown fuses".

Each action should be quantified with a % performance gain (where applicable) so that a manager or the client knows how much benefit each action will bring. Some actions may be too costly to justify the expected gain in performance. For example, when dealing with shading losses, a typical solution is to rewire strings to minimise shading losses. Depending on the quantity of shading on a site, it may not be cost effective to rewire strings once the site has been built. Rather this information should be fed back to the Engineering team for better design on new projects.

Below we see an example action plan for one site. All actions are listed one by one, the Asset Management team then needs to organise works on site by creating a work request to be assigned to the local O&M team. Target completion dates need to be added along with actual dates when the actions have been completed, for tracking.

Summary of Performance Related Issues for Example Site
Updated: 02/01/2025

Not Done: 16
Done: 0

#	Issue	Priority	Category	Keyword	Solution	Responsible	Comment	Status	Work Order #	Target Compl' Date	Actual Date	% PR impact
1	36 strings down from a check of the Monitoring Software.	High	Production	Strings Down	Need to do clamp checking across the whole site to then fix non producing strings	AM	Organise for a team to go to site	Not done				5.24%
2	7 inverters not communicating (#5, 11, 12, 13, 40, 41, 49) at least 2 of these appear not to be producing (1x 25kW, 1 x 60kW)	High	Production	Outages	Discuss with AM which inverters are not producing, check on site if required	AM	Based on the comparison between meter and inverter output	Not done				3.00%
3	Trips on inverter 46 on 02/12, 03/12, 05/12, 06/12 and 07/12, why?	High	Production	Outages	Potential RISO faults. Need to get alarm log	AM	Need to get inverter alarm log to understand faults further	Not done				1.00%
4	Inverter 45 with many days of low PR - frequent trips (e.g. 23/11, 03/12)	High	Production	Outages	Potential RISO faults. Need to get alarm log	AM	Need to get inverter alarm log to understand faults further	Not done				0.50%
5	Unusual behaviour on inverter 38, MPPT2 between 09:40 and 14:40	High	Production	Outages	Doesn't appear to be shading as there are no shading objects in that area	AM	See annotated site layout. Check with AM team if they know of any shading in this area.	Not done				0.25%
6	No alerts in the Monitoring Software for this site, why?	High	Longevity	Monitoring	Cannot quickly detect if equipment is not producing	AM	Check with Asset Management (AM) team what the status is	Not done				0%
7	Inverter 5 down from 15/11 to 28/11	High	Production	Outages	Restarted on 28/11. Check with AM what the issue was as predictive for other inverters	AM	Potential RISO fault? inverter stopped in days leading up to 15/11. No data in the Monitoring Software to check strings	Not done				0%
8	Exhaust from factory chimney appears to be soiling modules on inverter 30	High	Production	Soiling	Possible to reduce exhaust fumes?	AM	Check with AM team what the status is	Not done				0%
9	No string monitoring for 60kW inverters in the Monitoring Software?	High	Longevity	Monitoring	Cannot quickly detect if strings are not producing	AM	Check with AM team what the status is	Not done				0%
10	Inverters 40 & 41 set up in the Monitoring Software as 29kW but actually 60kW inverter?	High	Longevity	Monitoring	No monitoring on these inverters	AM	Check with AM team what the status is	Not done				0%
11	Inverter 49 is not set up in the Monitoring Software, why?	High	Longevity	Monitoring	This inverter is not in the drop down list	AM	Check with AM team what the status is	Not done				0%
12	SLD distribution of inverters per meter doesn't match with the layout. E.g. inverter 08 is indicated as being on meter B4 on the layout and then it is in B3 from the SLD	High	Longevity	As Builts	Discuss with AM team which is correct	AM	Check with AM team which is correct. Need to update drawings	Not done				0%
13	SLD distribution of inverters per meter doesn't match with the layout. E.g. inverter 28 is indicated as being on meter B3 on the layout and then it is in B4 from the SLD	High	Longevity	As Builts	Discuss with AM team which is correct	AM	Check with AM team which is correct. Need to update drawings	Not done				0%

In the last column the % PR (performance ratio) impact is added, the actions are filtered from highest to lowest. Highest priority actions are those that either have high performance impact (e.g. strings or inverters not producing) or a potential safety risk to equipment or personnel (e.g. insulation resistance faults or negative current).

Meetings should be held at regular intervals (e.g. at a minimum weekly) to review all actions and track progress. If new performance actions are found, then these should be added to the list.

Below is another example site once the performance actions had been carried out. On this site the actions allowed for a 13.2% improvement in the PR! But even when all initial actions are completed this doesn't mean the site performance cannot improve! The asset management and O&M teams should be continually checking site performance for ways to optimise output.

#	Issue	Solution	Type	Status	When	Site PR Impact
1	Meter 724-2 with one blown phase	Rewire phase	Production	Done	09/04/2024	6.0%
2	Heavy module soiling (sticky rubber "dust"). Particularly meters 436 and 524-1-6. Affects around 3.5MWp of the site	Chemitek trial done on 17th June. Concentrated solution found to help remove rubber dust. To be used going forward	Production	Done	17/06/2024	4.0%
3	15 strings not producing	Done	Production	Done	12/05/2024	2.0%
4	Inverters tripping on grid overvoltage	Increased voltage on 125-1-7 to 243V. Since then no more trips	Production	Done	12/06/2024	0.5%
5	Curtailment of inverter 474-1 to 67kW. Possible monitoring limitation or inverter fault	Deeper clean of inverter fan carried out and inverter at full production. To be monitored	Production	Done	25/04/2024	0.3%
6	2 strings not producing on the carport	Intervention carried out on 8th June 2024 to repair 2 strings	Production	Done	08/06/2024	0.2%
7	Mismatch on strings on the same MPPT (orientation mismatch)	4 strings swapped over to reduce mismatch	Production	Done	12/06/2024	0.2%
8	No comms with meter 436 (affects perf. analysis)	Solved	Comms	Done	30/04/2024	0.0%
9	No comms with all meters except 125-2 and 474.	Solved	Comms	Done	09/05/2024	0.0%
10	No comms with several inverters (e.g. meter 125 SMDB 2-2,3,4,5, 724-1-6,9)	Solved	Comms	Done	21/05/2024	0.0%
					Overall PR+	13.2%
					Carried out	13.2%

Contact us to find out how we can help you optimise your PV performance.

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Based on this study, 8.2 Advisory can assist you with all aspects of analysing the performance of your photovoltaic plant.

SOLAR PV
PERFORMANCE ANALYSIS

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