What's an Ideal PV System Granularity?

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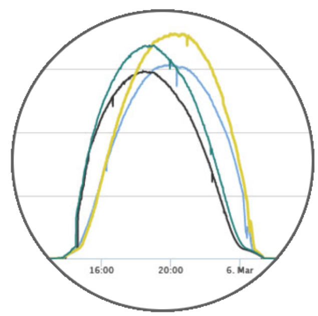
Introduction: Aspects of Granularity

What is the ideal granularity for a PV installation? Here we're talking about the addressability of a number of system factors including:



- Monitoring (enough data to maximize energy production, but not too much to consume resources unnecessarily)
- O&M strategy (lowest cost for maximum energy harvest)
- MPPT harvest
- Power conversion block size (tolerance for shading, failures, etc)
- Arc detection (safety)

How much granularity is enough? As with many questions like this, the answer is "it depends…."

Granularity impacts initial install cost and O&M differently.

- For the install, as an example, the power conversion block size is one factor and this will impact material and labor costs etc.
- For later O&M it comes down to how much of the output of an array can underperform before it impacts revenue - and revenue is impacted by energy production and O&M costs. For example, if one module in a residential install of 16 modules dies, a 17% drop in production will be noticeable and result in an urgent need to fix it. If that same module is one of 10,000 at a utility scale install there is less urgency over fixing a 0.01% hit. Granularity has a significant effect on the impact of PV module issues.
- As another example, if you have per-string MPPT and a plant with 100 strings of 10 modules each, a module issue will impact less than 1% of plant output. That same plant with per-module power conversion (micro inverter or power optimizer), the impact will be 0.1% of total plant output. So power conversion comes into play.

So why not just monitor/ power convert every module? As we'll see, for small installs that could be the right answer but there's more to it.

Native Granularity by Inverter Type

The choice of inverter has a big impact on monitoring and MPPT granularity, and is usually driven either by a focus on the lowest first cost or lowest installed cost. Figure 1 gives an example of how the native granularity varies with inverter type, highlighted with the orange modules. Granularity can be enhanced through the addition of module level power electronics such as optimizers, but at extra cost and a reduction in reliability. Also, the eventual failure of electronics mounted under the PV module results in significantly higher repair cost. In general the lowest installed cost for many commercial projects comes from the largest 3-phase string inverters but the granularity of both monitoring and MPPT gets coarser as the power rating climbs.

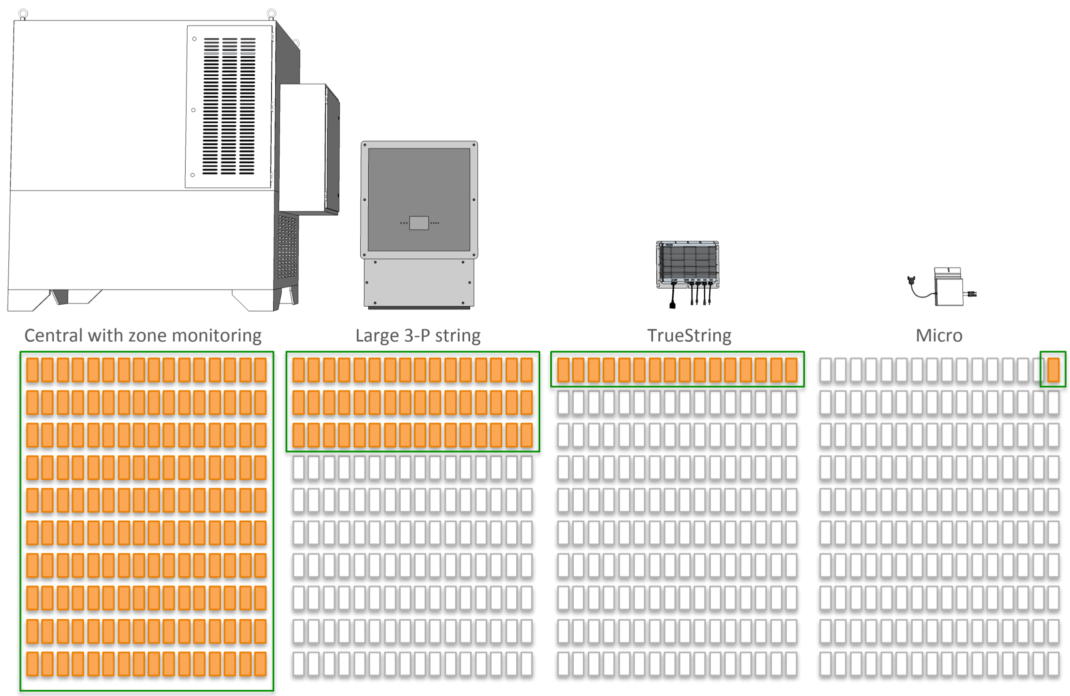


Figure 1: Granularity by inverter type

Pushing for **more** granularity

- Better performance visibility
- Better pinpointing for troubleshooting
- Better MPPT granularity/ harvest

Pushing for **less** granularity

- Visual and analytic data overload
- Customer visibility of minor issues
- Cell modem data bandwidth
- Failure of components under modules
- Lower weight on rooftops
- Cost

Large group of strings — Several strings — String level — Module level

Figure 2: Competing factors affecting the degree of granularity

Competing Factors

The higher the granularity, the better the outcome, right? Figure 2 shows that while this is true up to a point, there are factors pushing in the other direction also. Some of the issues in both directions are:

- Monitoring is expensive, and more data is more expensive – hardware to do it, mechanisms for gathering the data, data storage, time and processing to analyze it, etc. You want the minimum that allows you to perform your job and optimize PV plant energy generation.
- Note that the minimum accuracy for revenue grade metering (RGM) is +/- 2%, although relative measurements comparing relative outputs of strings or inverters day to day are usually more useful and do not require irradiance and temperature data to be meaningful, assuming no shading. And, revenue grade metering is usually only used for total PV plant output, so the granularity of this measurement is insufficient to identify problems at a module or string level.
- Arguments abound on the topic of failures – is it better to have fewer points of failure that are more significant if they die, or many more but with any one failure having less impact on energy production? This is where the power conversion block size comes into play – how much of the system needs to be replaced when something goes wrong, and how big a job is it to transport and fit a replacement? One piece of feedback from installers we hear is that, either way, levering up individual PV modules in an array to replace electronics is time consuming, expensive and a safety risk. If your module-level monitoring is primarily used to locate failed module level electronics, it tends to defeat the purpose (and initial expense).
- Weight on a roof can be an issue. Central inverters are heavy, but when added up, the total weight of an array of micro inverters of the same total kW is actually heavier, just more distributed.
- In plants where output is measured and governed by a contract guaranteeing the energy production (PPA), the granularity should be small enough so that an issue can be noticed far enough in advance of a crisis that maintenance can be scheduled rather than becoming an emergency. For example, often modules take time to die, and soiling can be quantified so washing of the array can be scheduled optimally.
- Troubleshooting is vastly easier when it can be pinpointed to as small an area as possible. For larger plants the position of individual modules is unlikely to have been recorded, but isolating the issue to string level is a very helpful and practical place to start from. This results in reduced maintenance time and cost.
- With low MPPT granularity (many strings in parallel) if one module fails, it can affect the output of parallel strings. And, even discovering the problem can be a challenge, let alone finding the specific failure and fixing it.
- There is a big leap in the amount of data that is gathered and processed for each step moving between array, group, string and module level. Many plants are starting to use cellular modems as the most reliable form of backhaul communication, but the economic viability partly depends on keeping monthly data usage low.
- There is also the separate issue about the granularity that the company responsible for O&M might wish for, and the (usually much less detailed) information they wish the end customer to see to avoid excessive nuisance calls about one PV module output power being lower than a neighboring module output.
- Installed cost is directly affected by granularity.

Example Commercial 300 kW Installation

For a 300 kW install, 300W modules and 16 module strings, we'd have the following:

- Module Level (micro or optimizer system) – per module, 0.1% or 0.3 kW granularity for monitoring and MPPT
- String Level (for example small string inverter, HiQ TrueString™) – 62 strings, 1.6% or 4.8kW granularity for monitoring and MPPT
- Paralleled Strings (large string inverter, can be 2-12 strings in parallel) – say 21 groups with 3 strings paralleled together, 4.8% or 15 kW granularity
- Large groups (central inverter, say 300 kW) – 1 MPPT, 6 monitoring zones – 17% or 50 kW monitoring granularity

Implementations of these topologies are described further in Table 1.

	Power Conversion Block Size (Nom.)	MPPT	Monitoring	Arc Detection
300 kW Central	300 kW *(100%)*	300 kW *(100%)*	50 kW *(17%)*	*Almost impossible without additional AFCI equipment*
Large String	27.6 kW *(9%)*	15 kW *(5%)*	15 kW *(5%)*	15 kW *(5%)*
TrueString	8 kW *(2.7%)*	4.8 kW *(1.6%)*	4.8 kW *(1.6%)*	4.8 kW *(1.6%)*
Micro/ Optimizer	0.25 kW *(0.08%)*	0.3 kW *(0.1%)*	0.3 kW *(0.1%)*	*Not required for <80V*

Table 1: Granularities for the example 300 kW system

In this example, string level or sub-string level with modules grouped together would make the most sense as a compromise between visibility, modem charges and clarity. The calculus would be very different for a 5MW or a 5 kW system but the ideas hold true. The granularity that is acceptable in a given install will vary, starting points for each of the parameters are shown in Table 2.

	Power Conversion Block Size	MPPT	Monitoring	Arc Detection
Suggested Ranges	1-10%	1-5%	0.5-2%	Single string level or better

Table 2: Suggested ideal granularity ranges for different plant parameters

Perspective from a Commercial Installer

As one experienced commercial installer in California said to us recently: "I have no use for module level monitoring – if I was doing mostly residential it might be different. Anything module level – I have no need for it, I don't want it….. It's too much data – I hate having that much data, I just get buried in it, it takes too much cell modem bandwidth, and it's just too much visual noise; I certainly don't want my customers looking at it….. and reliability will be an issue eventually, too. String level is great."

Summary

There are many factors that affect the ideal granularity of a particular system. As with all other aspects of system design the answer is a compromise between install cost, maintainability and many other factors as we've seen. The ideal granularity could be different for power conversion block size, MPPT, monitoring and arc detection, and we've suggested some starting ranges in Table 2.

Advertising

Obviously we believe that single string monitoring, arc detection, and MPPT for commercial installs makes so much sense we designed the HiQ Solar TrueString™ inverter family with this in mind. It is cost competitive with large string inverters while offering much better monitoring, MPPT granularity (increased energy harvest) and safety functionality. However, the principles discussed here apply broadly.

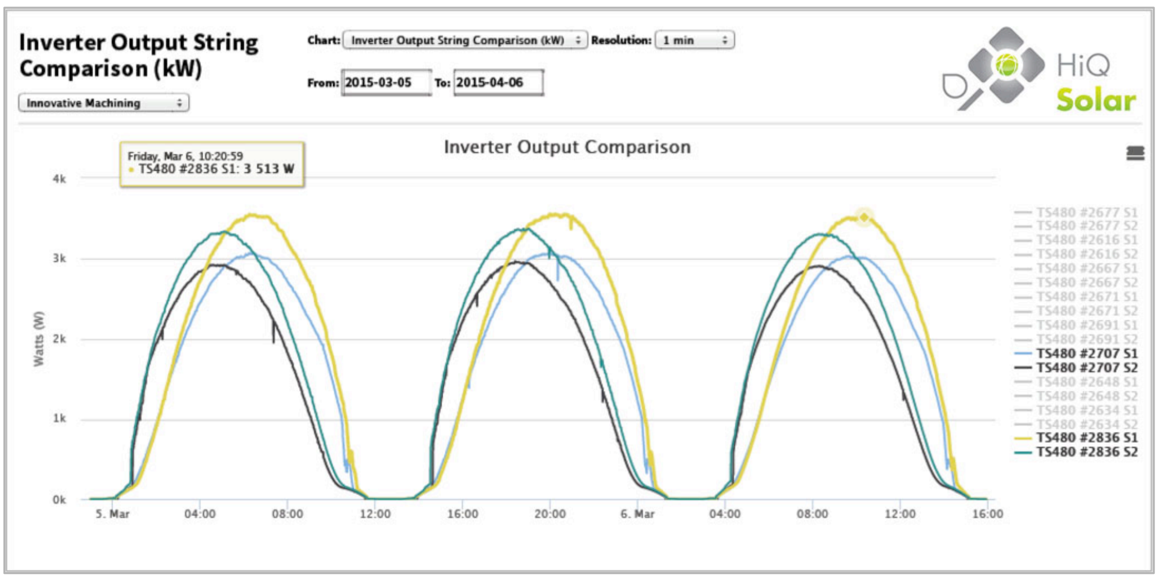


Figure 3: Individual string performance from a commercial rooftop with east/west strings