White paper

# Minding P's and Q's: Addressing power quality issues in solar PV installations

**From a strictly technological standpoint, it's safe to say that solar power, specifically photovoltaic (PV), has reached maturity. Panel manufacturers are now engaged in refinements to boost efficiency and long-term reliability, and the cost of an installed system continues to drop. PV systems are proliferating at every level, whether residential, commercial or utility-scale. The challenges faced by solar developers now have less to do with the core technology and more to do with questions around integrating PV systems to the grid. This paper will focus specifically on utility-scale solar.**

The growth in PV, coupled with similar expansion in wind power and the closure of some coal-fired plants, is having an impact on grid operations across the country. Grid operators face shifts in load patterns and peak demand which creates a scenario where generators are being called upon to ramp their output up and down more often, perhaps more than they were designed for. This has put pressure on the solar owner/operator to make their facility behave more like a conventional thermal power plant.

## Grid codes

The requirements for grid interconnection, known as grid codes, are a matter of regulation at the state and federal level but they also include rules set by local utilities. Meeting these requirements, particularly those at the local level, can have a major impact on the success of a commercial or utility-scale PV project.

Specifically, what PV developers must address are issues of power quality, but not necessarily in the same sense that a large consumer of electricity would use that term. For example, harmonic filtering is not typically something that a PV plant would be expected to provide, but would certainly be found in the specification for the power system of a manufacturer of sensitive electronics. For solar developers, "PQ" has more to do with the plant's ability to manipulate active and reactive power output over varying timescales.

Perhaps the most vexing challenge for solar PV lies in adhering to mandatory ramp rates, restrictions stipulating how rapidly the plant is allowed to increase or decrease its power (MW) output to the grid. For example, some utilities might call for no more than 10 percent of the plant's nameplate capacity to be added or dropped over the course of a minute. Passing clouds, then, pose a daunting challenge since PV system output drops precipitously when the sun is obscured before shooting back up once the clouds pass.

The obvious solution is energy storage so that you can keep the plant's output within the required range. The process is simple: draw power from the storage device when the cloud moves in, and skim some off the plant's output after it passes. In practice, ramping up is typically handled at the grid level by limiting inverter startups or defocusing trackers. Currently there are no limitations for ramping down in the US. (It should be noted that PREPA in Puerto Rico does specify ramp-down performance.)

Battery energy storage systems to meet ramping requirements are still unusual. Smaller systems might use flywheels, but in truth, each facility is unique in terms of the combination of the plant itself and the ability of the surrounding grid to handle variations in output. Indeed, in many cases, a centralized solution might make more sense than having each PV installation address the problem individually.

Energy storage is appealing, however, for reasons aside from ramping like:

- Frequency regulation – fine (<1 sec) adjustments in active power to maintain system balance
- Voltage regulation – similar adjustments in reactive power to maintain voltage levels
- Capacity firming – smoothing the plant's output over the course of the day to make it appear more like conventional generation to grid operators
- Black Start Capability
- Ability to island in Microgrid applications

## Taking the long view

These all come with implications for the PV developer regarding equipment, engineering, maintenance and operational considerations. However, the owner/operator of the system (typically not the same entity that builds the facility) might have some additional needs.

For example, meeting voltage regulation requirements is one thing, but optimizing active power output while still complying with the rule is another. This is where the interests of the developer and owner/operator potentially diverge. The developer is concerned with first cost, delivering a fully operational and compliant system that meets the final owner's needs at the lowest cost. The owner/operator, on the other hand, must take a longer view and that might mean additional investments that, while not technically required, make sense in the context of the long-term economics of the plant.

Load shifting, for example, might be of particular importance for a given PV installation. But the energy storage capabilities needed for that are much different than those required for ramping. The difference comes down to time. Ramping requires high power (watts) over a short time whereas load shifting is more about energy (watt-hours), in other words, power delivered over a longer time.

In some cases, a PV installation might be located in an area where the grid is weak and connecting to it would require upgrades that might not be cost-effective. Instead, the plant might engineer an "inside-the-fence" solution that obviates the need for changes to the surrounding grid. This is known as congestion relief, and in fact is similar to the transmission system action of the same name. Instead of trying to get power into a load center with limited transmission capacity, congestion in the world of solar implies trying to get power out via a less robust point of interconnection.

## Technology at the ready

There are, in addition to energy storage devices, a number of well proven technologies that PV plants can use to address congestion issues and other grid code requirements. Synchronous condensers historically have been used in many applications to provide reactive power for voltage support, for example. However, as these machines are essentially the same as conventional generators, they incur the same issues with fuel costs, maintenance and even noise. Alternatively, voltage support can be provided by static vAR compensators (SVCs), which mitigate all of these issues.

STATCOMs can similarly meet many grid code requirements for PV plants. However their capabilities extend farther and this is another instance where the long-term economics of the plant must be considered. For example, it might be particularly useful if the PV installation provided transient and dynamic support, voltage regulation, or harmonic filtering. These capabilities might not be part of the relevant grid code—or the code might call for a less robust version of them—but there might be a business case for including them in the plant design.

Making that assessment, not to mention engineering the system, is likely to require more expertise and/or experience than the PV developer or even a major utility has at their disposal. For this reason, it's best to bring in an expert who can make recommendations not only about equipment selection but in the overall design of the plant so that its long-term viability is best served. Any given solution should be thoroughly modeled and tested, and this again is likely to force a developer or utility outside of their comfort zone—all the more reason to engage a consultant with the requisite expertise at the outset of the project.

## Solar PQ – what's next?

Today, solar PV faces a number of challenges and we've addressed some of them here. But the energy world is changing rapidly, particularly with regard to the proliferation of PV and the implications it has on grid operations. The next step is to apply greater intelligence to these systems so that PV owner/operators can realize the greatest return while navigating an evolving patchwork of grid code requirements.

One example lies in the interaction between different types of equipment and the unforeseen consequences. A capacitor bank switching inside the MV circuit of a power plant can create impulses that can cause damage to other components on that circuit. While the components may last for years, the question becomes what impact daily transients will have over the long term. Issues like this have the potential to seriously impact plant economics, particularly if the facility is securitized in some way.

Optimization is really the key to success for any PV installation, but the formula for it will be different for each facility. The ability to use intelligent control solutions along with the technology mentioned in this paper is crucial to achieving an optimized system.

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