LESSONS LEARNED FROM INSTALLING BATTERY ENERGY STORAGE INTO AN EXISTING PV ARRAY

Why retrofitting battery energy into existing PV arrays makes sense and what some of the challenges to overcome in doing so are as explained by a major utility who has really done it

Abstract

In this white paper, we sit down with Tom Fenimore, Business Development Manager at Duke Energy to discuss his views and practical experience with installing battery energy storage into an existing PV array.

Alencon Systems
info@alenconsystems.com
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Lessons Learned from Installing Battery Energy Storage into Existing PV Arrays

*Why retrofitting battery energy into existing PV arrays makes sense and what some of the challenges to overcome in doing so are as explained by a major utility who has really done it*

Solar plus storage. If you are in the energy business, not just the alternative energy business, it is a term you likely hear every day. Maybe even multiple times a day. One logical target for coupling batteries with solar is hiding in plain sight: Our gigawatts of already installed PV resources. Duke Energy, one of U.S.’s largest utilities, based in North Carolina, is seeking to tap into this opportunity. Duke has installed energy storage into some of its existing PV arrays with a view to doing more in the future.

In this article, we unpack the learnings gleaned from these efforts with Tom Fenimore, Business Development for Duke Energy in Charlotte, North Carolina. Fenimore has led a number of these efforts for Duke and has chosen to share his experience with executing such projects for the benefit of the industry more broadly. That knowledge includes the incentives for installing storage into existing PV plants and the practical, technical challenges to be aware of when doing so (as well some solutions to those challenges!).

**Why would a utility or any other PV plant owner want to install storage into an existing PV asset?**

According to its website, by the end of 2020, Duke Energy will have over 15 GW of renewables in its power generation portfolio, a major part of which of course includes solar.

“As more renewables come onto a circuit, the need to optimize that circuit, from the need to provide voltage and frequency stabilization is going to increase. One of the easiest ways to do that is to utilize energy storage and allow that storage to interact with solar, explains Fenimore. “Providing grid stability is an explicit part of our charter as a regulated utility.”

The largest part of Duke Energy’s regulated service territory is in the state of North Carolina. North Carolina is second in the nation, only to California, in terms installed solar PV. One of major differences between North Carolina and California is that roof top solar is a very small part of North Carolina’s solar installations, meaning PV plants are typically larger, ground mounted systems. This fact means each PV installation is a larger individual contributor to the power on a given distribution or transmission circuit.

**Why DC Coupling of Solar + Storage Makes Sense for Installing Storage into Existing PV Plants**

When looking to add storage to existing PV assets, system owners like Duke Energy have two options – AC or DC coupling. AC coupling of solar and energy storage is achieved when the solar panels and the batteries are connected on the AC side of the inverter, i.e. “behind the inverter.” By contrast, in a DC coupled topology, solar and storage are connected on the DC side of the inverter, i.e. “in front of the inverter.”
While there can be viable reasons to use the AC or DC coupled approach for different solar plus storage applications, when it comes to installing storage into existing PV systems, Mr. Fenimore believes DC coupling presents some very compelling advantages to AC coupling.

One of the major advantages DC coupling offers as a technique for integrating storage into existing PV plants is the opportunity to take advantage of the trend of ever-increasing DC:AC ratios. The DC:AC ratio refers to the amount of installed PV panels relative to the AC name plate of the inverter, which is dictated by the size of the AC interconnect to power distribution grid.

In recent years, due the falling price of PV panels and improved inverter technology, there has been a trend to increase DC:AC ratios. Years ago, PV plants were designed with modest DC:AC ratios, typically between 1.05 to 1.1. Based on the factors just explained, in more recent years, DC:AC ratios for larger scale solar plants have increased from anywhere between 1.5 to 1.8 DC:AC. There are some PV inverters even capable of handling DC overbuilds of two times the PV to the plant’s rated AC capacity.

All that PV overbuild leads to the possibility of extensive amounts of potential clipped energy, i.e. PV production that is curtailed by the inverter when PV generation exceeds the inverter’s power rating. The DC coupling technique of combining solar and storage allows that excess generation to be diverted into a battery during periods of overproduction. This captured generation can then be discharged later in the day or in the evening to smooth out the production from a PV plant, turning an intermittent energy resource like solar into a truly dispatchable one. When you are a regulated utility that contracts with millions of end users to assure the lights turn on whenever they flip a switch in their home or business, being able to accurately control the dispatch of your generation capacity is critical. DC coupling of solar and storage helps offer Duke Energy this benefit.

In addition to the opportunity to capture what might otherwise be clipped (i.e. thrown away) energy, DC coupling also offers a system owner some unique financial benefits. According to current government regulations (see https://www.nrel.gov/docs/fy18osti/70384.pdf), energy storage can only be claimed under the investment tax credit (ITC) when charged directly from the PV.

“The key to successfully installing energy storage is doing so with favorable tax or other financial benefits. Once we figure out how to do that as an industry with regularity, we’ll really see the needle move,” explains Fenimore. “One of the challenges we’ve had with storage is capitalizing on investment tax credits. DC coupling allows that to happen more easily than AC coupling because we are only able to charge the battery from the solar. Doing so makes it a clear-cut case from a financial perspective where the kilowatt hours charging the battery are coming from.”

Practical Challenges of Installing Storage into Existing PV systems

Like so many new endeavors, while installing batteries into an existing PV array using DC-coupling makes a lot of sense, “it always looks easier on paper,” notes Fenimore.

“One of the challenges for executing a DC coupled retrofit of storage into an existing PV plant is understanding and dealing with the wiring practices of the existing site and all of the physical infrastructure. It’s always easier on a block a diagram. Once you get into the field it can be more challenging to make it all work,” explains Fenimore.
One such unforeseen challenge, the issue of incorporating floating batteries into a grounded PV array, arose at a storage retrofit Duke Energy executed in 2019 at its McAlpine Solar plant.

“We ran into the problem of DC coupling storage with positively grounded solar panels. Overcoming that challenge required the installation of Alencon Systems’ galvanically isolated DC optimizers to create a floating ground between the PV systems and the batteries. That was completely unexpected when we started,” explains Fenimore.

“This unanticipated need was required by the panels. Initially, we thought we could overcome this problem by just making changes at the inverter level. It turned out the only solution was creating isolation between the PV array and the batteries. The era of the solar modules’ manufacture can complicate the installation of storage into an existing PV array.”

Figure 1 In 2019, Duke Energy deployed a DC coupled solar plus storage whereby they installed a battery energy storage system into an existing PV array. One technical key to doing so was installing Alencon’s galvanically isolated DC-DC optimizers to isolate the positively ground PV system from the floating batteries on a common DC bus.
How Galvanically Isolated DC-DC Optimizers Facilitate Retrofitting Storage into Existing PV Plants

As mentioned above, one of the technical lessons learned by Duke Energy in its last storage DC-coupled retrofit storage into an existing PV plant is the need to isolate the grounding of the PV system from the newly installed battery. This is not generally an issue with AC coupled solar plus storage systems as the individual inverters behind the PV and batteries create this grounding isolation automatically.

To unpack this challenge in greater detail, installed PV systems, particularly those connected to central inverters are typically grounded. In many cases, installed PV systems are negatively grounded. In the case of Duke Energy’s recent McAlpine project, the existing PV plant had an older vintage of SunPower panels that had a positive grounding requirement. PV panels may need to be grounded for any number of reasons, including the need to maintain their performance over twenty to twenty-five years and guard against conditions like potential induced degradation (PID).

![Image](image1.png)

**Figure 2** A typically found call out on as built drawings on older, installed PV systems with SunPower panels. Such call outs indicate the importance of maintaining the array in a positive grounded configuration. On the contrary, batteries are generally required to float for safety purposes.

On the flip side, battery energy storage systems need to have floating grounds. The need for floating grounds is a key safety requirement for batteries. Specifically, this requirement is necessary with large battery systems because having a floating ground allows for two faults to occur for a serious safety situation to arise. By allowing for two faults, the first fault can be detected by the on-board fault detection systems and safely disconnect the battery before a problem occurs. With all the attention being given to ESS fires in the wake recent incidents in South Korea, Arizona and elsewhere, heeding the safety guidance of battery manufacturers is of course critical.

![Image](image2.png)

**Figure 3** Galvanic isolation is used where two or more electric circuits must communicate, but their grounds may be at different potentials. Alencon Systems’ DC-DC converters consist of an inverter and a rectifier section with an isolation transformer between them to achieve full galvanic isolation between input and output. The application of silicon carbide power electronics allow Alencon’s devices to be very efficient and small.

![Image](image3.png)
Galvanic isolation is used where two or more electric circuits must communicate, but their grounds may be at different potentials. Galvanic isolation is an effective method of breaking ground loops by preventing unwanted current from flowing between two units sharing a ground conductor. When DC coupling solar and storage, a DC-DC converter is required to map the voltage differences between the PV system and the battery. A galvanically isolated DC-DC converter, such as those manufactured by Alencon Systems, serve the dual purpose of mapping PV voltage to battery voltage while isolating the differential grounding schemes that could be present. In the case of Alencon’s products, they are able to achieve this benefit in a highly compact and efficient package through the application of cutting-edge silicon-carbide power electronics.

Figure 4 Alencon’s DC-DC converters serve to map the differential voltages between PV systems and batteries placed on the same DC bus. This mapping is demonstrated above.

Conclusion
As more PV comes onto the electrical grid, there will be greater need and incentive to pair batteries with our already installed PV resources to assure the reliable operation of the utility grid and maintain the viability of clean sources of generation to help us win our battle against climate change. However, how we achieve these benefits is not without technical challenges. Fortunately, commercialized, scalable technological solutions exist to solve these problems. One of those challenges is the need to combine grounded PV systems with floating batteries, which can be overcome through the application of galvanically isolated DC-DC converters from Alencon Systems. Thankfully, innovators like Duke Energy are open to sharing their experiences in overcoming these challenges.