The triple play: Achieving commercial benefits of PV and energy storage

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ABSTRACT
Beyond lowering energy costs and demand charges, Superstorm Sandy demonstrated the frailty of centralized power generation. Building owners/operators throughout the Northeast in the USA are evaluating distributed power generation options for supporting building-critical loads during future grid outages. Those options (many of which also incorporate commercial-scale grid storage solutions) include on-site diesel generators, micro-turbines, fuel cells and solar PV systems. As electrical vehicle (EV) charging is added to the mix, the grid requirements and demand costs will further increase. This article will discuss specific value streams for integrating energy storage with PV for commercial buildings, and technologies – specifically, advanced power converters – that will enable those benefits to be achieved.

Introduction
Commercial buildings consume approximately 40% of the electrical energy produced in the USA, but the utility cost to building owners/operators is disproportionately high owing to punitive peak demand charges (kW) and peak demand rates (kWh). These charges and rates are rising, and the trend is unlikely to reverse in the near term because of the USA's ageing energy infrastructure and ever-growing energy appetite in the commercial and industrial sectors.

The peak demand charge is normally calculated as the highest peak demand during the monthly billing cycle, based on a 15-minute sample interval. Although the average commercial retail rate in the USA is \$0.10/kWh, the marginal cost of energy during these peak periods can be \$1.00/kWh or more, making demand reduction an attractive opportunity for saving costs. A commercial customer may have 30%, 40% or more of their monthly utility bill structures as peak demand charges.

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The first step: reduce, measure and schedule loads
Before a commercial building adds solar and storage capabilities, the first and most cost-effective strategy for reducing commercial energy costs begins with addressing energy efficiency *and* demand management. Lighting as well as heating, ventilation and air conditioning (aka HVAC) upgrades are obvious choices, followed by the scheduling of heavy intermittent loads, such as large industrial motors and chillers when appropriate. Beyond such physical upgrades, energy management tools should be deployed for tracking and monitoring energy consumption in real time. Such tools are available from a number of companies, and are a critical component in the demand-reduction equation. Note that utilities often contract with large industrial and commercial customers in order to curtail load during peak demands: the compensation received generally justifies the cost of the management tools noted above.

The second step: deploy on-site energy generation
The remainder of this article will concentrate on the utilization of on-site generation resources, focusing specifically on the integration of PV and energy storage, and the related power conversion and management technologies required for delivering the highest value solution for demand reduction, and other high-value services.

Demand reduction
Adding on-site PV generation to a commercial building reduces utility energy (kWh) charges, but can have minimal effect on peak demand (kW) charges. Here is why: in the USA, summer peak demand occurs during the late afternoon, just when PV generation is declining rapidly. Commercial customers with large rooftop PV arrays will dramatically offset peak energy use (kWh), but may achieve no reduction in peak power (kW) demand. Adding storage to the PV array significantly improves this situation (Fig. 1).

Other value streams
While integrated PV and storage solutions can significantly reduce both energy (kWh) and peak demand (kW) utility charges, they may also bring

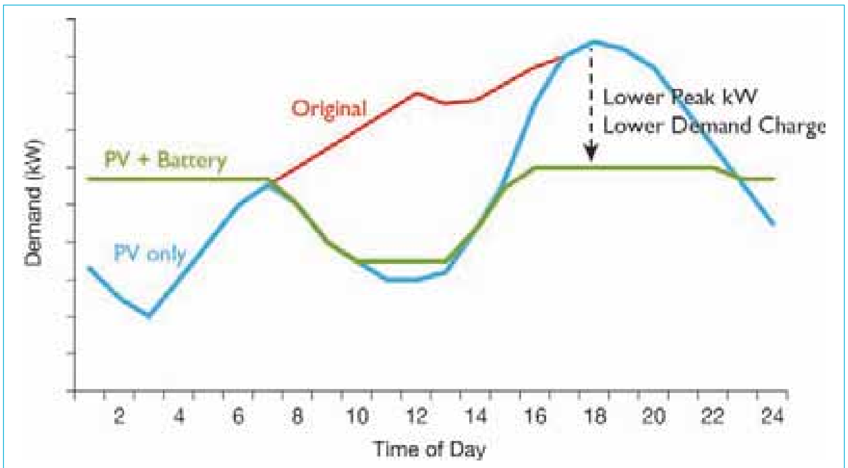


Figure 1. PV with storage delivers lower energy (kWh) and lower demand (kW) costs.

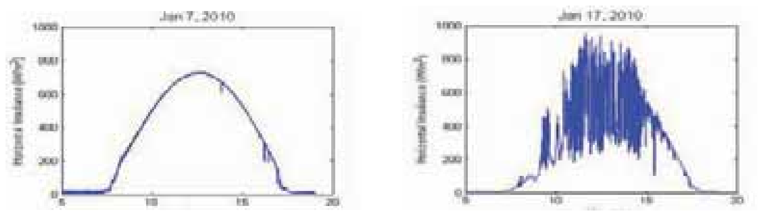
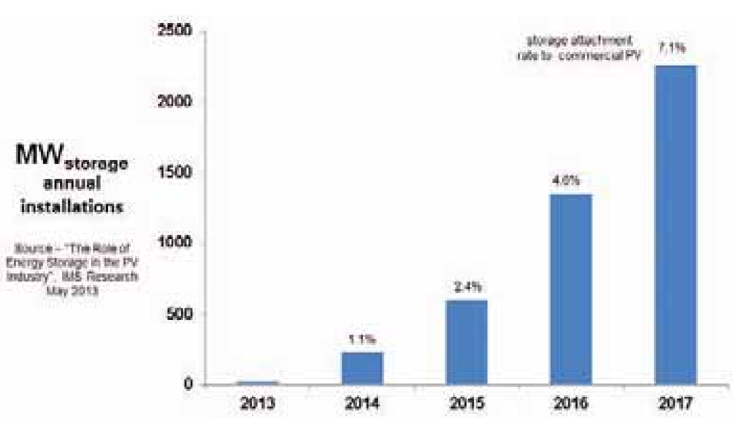


Figure 2. Impact of variable irradiance on power production.



Source: IHS

Figure 3. Commercial storage with PV option.

additional value streams. One such stream is providing ancillary services support, including frequency regulation and reserve requirements, back to the utility operator. These create additional high-value revenue streams for the system owner/operator, which may be the building owner or a separate entity that finances the system and shares these benefits with the building owner.

During periods of highly variable irradiance, such PV with storage systems should also support a PV smoothing algorithm. Highly variable irradiance is the result of moving cloud cover, and the rapid swings in power output in PV arrays can disrupt grid quality, specifically in areas of high PV penetration. Irradiance and PV output power are highly correlated: as seen in Fig. 2, array power can drop more than 50% within seconds of a fast-moving/variable cloud event.

Although utilities have not yet monetized the value of smoothing, several national labs have modelled its impact, and generally agree that it facilitates deeper levels of PV penetration, while also improving grid quality relative to PV systems without integrated storage.

Last, but not least, these systems will eventually evolve to support building-critical loads during grid outages – a capability that today's PV inverters cannot support because of UL1741 anti-islanding requirements.

Triple-play systems

The value streams of integrated PV and storage solutions include:

- Managing and mitigating peak demand in order to reduce operating costs.
- Delivering high-value support services back to the grid operator to improve grid power quality and availability.
- Providing emergency backup of critical loads during grid outages.

This triple play of value streams improves return on investment (ROI), and facilitates cost-effective commercial-scale grid storage solutions.

Two major technical impediments have limited the practical deployment of these systems until very recently: 1) the high cost of batteries has limited the size and cost-effectiveness of the system; 2) the power conversion and power management systems have been costly and inflexible. These systems are – at best – described as single-function devices incapable of efficiently interleaving the AC and DC power flows in an integrated PV/storage system. Moreover, the power conversion equipment dedicated to critical-load support was bulky, heavy and expensive. As discussed below, these impediments are diminishing because of several factors.

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The California opportunity

Continuing price reductions and efficiency improvements in battery systems mean that it is now economically attractive to deploy integrated PV and commercial energy storage solutions for demand reduction alone. As one might expect, the initial markets for these systems are areas where peak demand rates and demand charges for commercial buildings are significant.

In addition, a recently enacted Self-Generation Incentive Program (SGIP) in the State of California rebates up to 40% of the installed cost of battery storage systems. This incentive should accelerate market demand for commercial storage over the next few years. It is also likely that the SGIP will lead to similar incentive programmes in other states.

In California and New York, demand charges may exceed 30 to 40% of the monthly bill of commercial customers. Moreover, without local storage to 'buffer' the grid during EV charging, fast-charging providers could possibly have peak demand (kW) costs exceeding 70% of their monthly electric bill. The possibility of such a high instantaneous power requirement is frightening retailers and utilities alike.

Beyond California: lower costs and increased functionality open new markets

Grid storage battery costs, and projects integrating them, are forecast to drop appreciably over the next few years. This is fuelled in part by the cost reduction of batteries used in EVs, including plug-in hybrid electric and fully electric vehicles. There are additional opportunities to integrate used EV battery packs into storage applications. These 'second life' packs are those that would no longer meet vehicle power requirements (rapid discharge rates upon acceleration), but whose energy capabilities are more than adequate to support commercial storage applications as described above.

A study released in May 2013 by IHS/IMS Research [1] forecasts that an increasing percentage of commercial PV installations will also include grid storage (Fig. 3). This global market will begin in North America, and most likely in high peak demand charge utility jurisdictions such as California and New York. However, over the next few years as costs further decline, these same systems are expected to cost-effectively deliver a broader set of ancillary services as well as critical-load support, fulfilling a 'triple play' of value streams. Key to this enhanced functionality are flexible next-generation power conversion platforms.

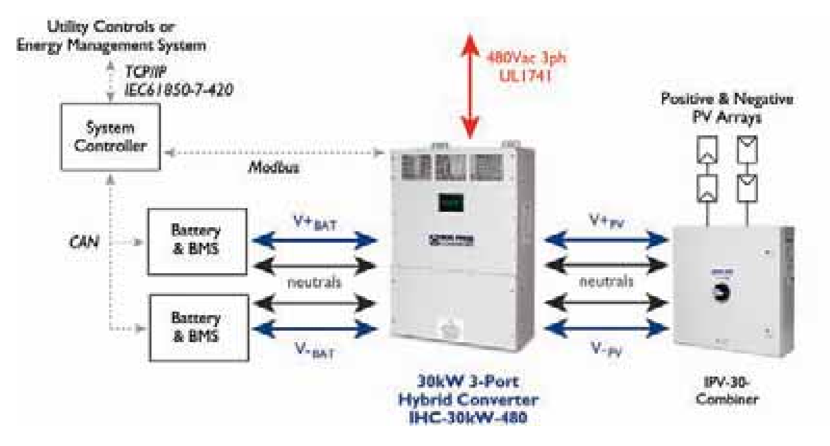

Figure 4. IHC-30kW-480 three-port hybrid converter.

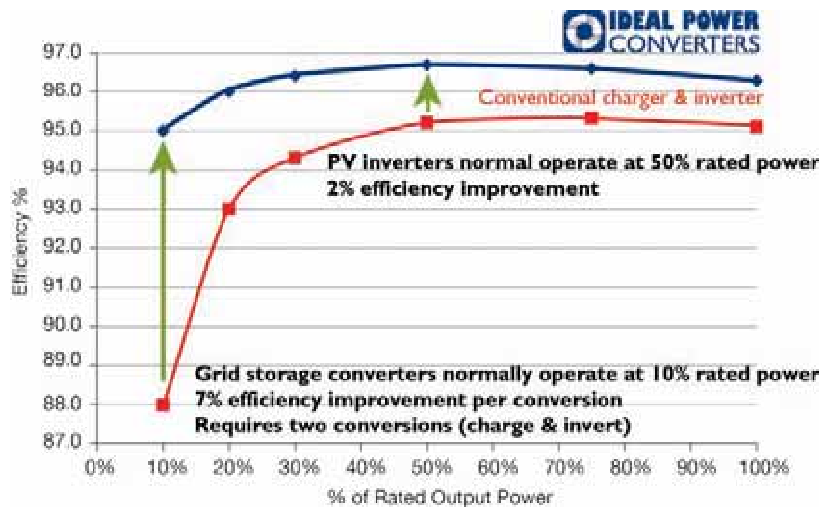

Figure 5. Efficiency of the hybrid converter.

Hybrid converters

Ideal Power's 30kW three-port hybrid converter is one example of new technologies being developed to combine the functionality of a PV inverter and battery converter together in a single hardware platform (Fig. 4). Equipped with two independent DC ports and an independent AC port, transferring power between any of the three ports, including interleaving power in real time, provides an efficient alternative to traditional AC grid-tied or DC bus-tied hybrid converters. There are considerable size and weight advantages relative to other solutions which typically require an external isolation transformer.

The size and weight advantages are principally derived from a novel and patented bidirectional and indirect power-switching topology, which ensures complete isolation between all power ports. Perhaps more importantly, this architecture is totally software driven, providing a significant degree of flexibility with regard to delivering new features and capabilities without changing or upgrading system hardware. This allows functionality to rapidly evolve and grow over time in response to changing applications and market needs.

> "Conversion efficiency is more important in the hybrid scenario than with stand-alone PV applications."

Hybrid converter efficiency

Conversion efficiency (Fig. 5) is more important in the hybrid scenario than with stand-alone PV applications because multiple power conversion scenarios are required: summing PV and battery to the AC grid output, 'splitting' the PV output between battery and grid, charging the batteries from the AC grid, smoothing highly variable PV, and so forth. Conversion efficiency is particularly important at low power levels. PV inverters typically operate at 50–75% of rated power for five or six hours per day, whereas battery storage systems may operate at about 10% of rated power for 12+ hours per day. As a result, the 10% level is a very important system efficiency specification.

Hybrid converters will need to be highly efficient at all conversion tasks: interleaving, or splitting the power sources, and smoothing, as well as charging/discharging the storage array at low power levels. To fulfil broader market need, they should also be compatible with virtually all battery types, including lead-acid, lithium-ion, zinc-air and others.

Hybrid converter power ports

With their wide DC voltage operating range, and battery interface options, battery stacks may be connected as a bipolar array, enabling the support of 1000VDC stacks (±500VDC) in the Ideal Power hybrid converter. Unipolar and floating arrays should also be supported; however, there may be limits to maximum stack voltage in some applications.

When supporting batteries, the DC interface operates in current source mode, and multiple hybrid converters may be paralleled on the DC side to support charge/discharge power levels of greater than 30kW. This feature is specifically useful for larger commercial storage systems, and emerging applications such as EV fast charging, where fast-charge rates of 30kW, 60kW, 90kW and higher are required.

Ideal Power's hybrid converter features a 480VAC, three-phase AC grid inter-tie interface. Building larger systems is easily achieved by paralleling 'n' AC interfaces in a three-phase power panel, supporting designs of 120kW or larger, depending on application requirements.

Hybrid converter configuration, control and monitoring

Control and monitoring of power flow between PV, batteries and the grid is of critical importance. Ideal Power uses the SunSpec Alliance standard, an open standard developed for PV inverters, AC meters, combiner boxes, and other smart devices found in commercial and utility-scale PV arrays. The physical implementation of the Modbus port is RS-485, allowing multiple converters to be controlled on a single 'daisy-chained' communications cable.

Extending the SunSpec Alliance approach into energy storage will ensure that interfaces are open and familiar to a large community of embedded system design engineers, simplifying the development of external control algorithms and software. For our part, this interface is common between all Ideal Power products, further reducing the coding learning curve, which accelerates system design.

Hybrid converter roadmap

Future derivative versions of the hybrid converter are envisioned, including micro-grid compatibility, which can be utilized for supporting building-critical loads, and AC/AC/DC port models to support grid inter-tie of asynchronous distributed AC generators, including wind, diesel, natural gas combined heat and power (CHP) and other sources. The technology is also expected to eventually scale to larger power systems.

> "Systems that integrate PV with battery storage are becoming increasingly attractive to commercial building owners/operators."

Conclusion

Systems that integrate PV with battery storage are becoming increasingly attractive to commercial building owners/operators for a number of reasons. The advantages of reducing peak demand charges with PV-charged battery systems already bring significant value for commercial buildings that struggle with electric utility bills even after installation of a PV system. PV and battery systems also carry the potential for additional value streams, such as ancillary services to utilities and emergency backup for critical load during power outages. With increasing sales of EVs, integrated systems present an additional opportunity for providers of DC fast chargers to avoid exorbitantly high demand charges associated with the high spikes in demand from the EV charging points. As the price declines and battery efficiency continues to increase, advanced power converters that are able to efficiently convert power between the PV array, battery packs and the AC grid will play a central role in enabling these benefits.

Reference

IHS/IMS Research 2013, "The role of energy storage in the PV industry" [http://www.imsresearch.com/report/the_role_of_energy_storage_in_the_pv_industry_world_2013_edition&cat_id=198&type=LatestResearch].

About the Author

John Merritt has over 30 years of technical marketing experience spanning product marketing, product development, engineering, and project management in both high-tech and clean-tech companies. As Director of Applications Engineering at Ideal Power, John is responsible for pre- and post-sales technical support, including system engineering, design review and application fit, and product feedback.