Power Control Hardware

Empowering Distributed Energy Systems

Simple yet intelligent energy management is the key to unleashing the full operational and economic potential of distributed energy resources.

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Recent years have seen remarkable evolution in renewable energy and distributed generation. From stand-alone solar arrays, wind turbine farms and engine- or turbine-generators feeding power to buildings and campuses or to the utility grid, we've advanced to sophisticated energy systems that may incorporate multiple resources – renewables, battery-based energy storage, fuel cells, generators and more, off the grid or grid-connected.

These systems can bring a wide array of benefits to their owners, including:

- More reliable and resilient power supplies
- More economical electricity at less volatile prices
- Potential revenue and profit from export of energy to the grid
- Recognition for green energy and sustainable business practice

Meanwhile, society benefits from lower emissions of pollutants and greenhouse gases, and utilities potentially gain resources to deploy for peak demand reduction, voltage and frequency regulation and other purposes.

MANAGING WITH INTELLIGENCE

Growth in renewables has been driven largely by falling prices (especially for solar PV), government programs like renewable portfolio standards and societal demands for cleaner power. Distributed generation has proliferated as utilities look to postpone the cost of large central power plants and reduce stress on transmission and distribution systems. However, the greatest enabler of sophisticated hybrid power systems is intelligent energy management, meaning technology that enables disparate energy sources – grid, distributed generation, battery storage – to work in synchrony, all continually prioritized and optimized to utilize the most reliable, most cost-effective and cleanest power source available at any given time.

That technology is available in the form of a modular, scalable energy control platform designed specifically for commercial, industrial and multi-tenant buildings, especially those located where utility power is unavailable, or where there is a high penetration of renewable generation. The system integrates all AC and DC system inputs and automatically routes the generated electricity in the most efficient and cost-effective manner, into or out of the facility. Once deployed, the system can be easily scaled up, scaled down or reconfigured to meet the owner's changing requirements. It provides an essentially future-proof energy management solution that:

- Ensures that the most cost-effective power sources available are given priority
- Enables users to take full advantage of time-of-use pricing and market price fluctuations
- Allows smart and profitable export of power

- Lets users execute demand charge clipping, demand/supply response, and peak shaving
- Enables maximum power point tracking to optimize distributed generation from renewables
- Provides voltage and frequency regulation and power factor correction
- Firms renewable sources to eliminate variability and allow utilities to plan for known output

CONVENTIONAL APPROACH HAS LIMITED CAPABILITY

The conventional approach to distributed generation power electronics provides very limited capability in optimization, efficiency, scalability and flexibility. A “stick-built” conventional approach is inherently inflexible in what is now a dynamic world of electricity generation and load management.

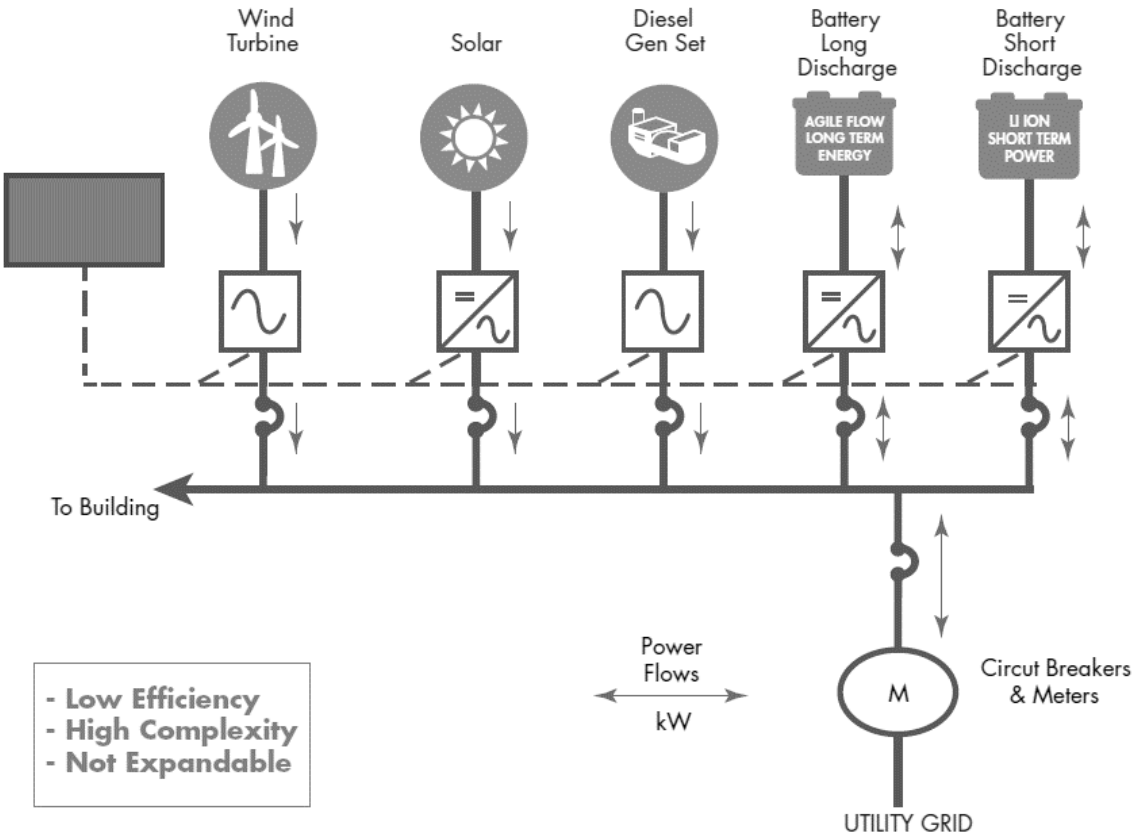
Conventionally, each component of the power system – solar array, diesel generators, wind turbines, energy storage and others – comes with its own power conversion equipment and its own proprietary software and communication protocols.

Conventional systems tend to be costly to install and likely require multiple grid connections, as well as a communications control scheme to control all the inputs. They also lack the flexibility to adapt to the changes that are inevitable over two to five years, and certainly over the 20-plus years for which today’s power systems are routinely expected to perform. Such changes can include evolution in government or utility policies, changes in electric rate structures and changes in the application itself, such as adding or removing components and accommodating significant changes in load.

Furthermore, in conventional control operation, inputs and outputs are managed by reactive algorithms that are complex to program; any change in the system requires re-optimization. Users need to set up control dispatch for load following. In grid-connected systems, delivery of renewable energy to the grid can be erratic. Loss of controller communication can crash the system.

CONVENTIONAL POWER CONTROLS SET UP

- Central system controller coordinates all inputs and outputs off the AC grid; can disrupt the grid
- Inputs and outputs managed by reactive algorithms. Complex to program, and changes in the system require re-optimization
- Low efficiency – storage suffers extra ‘round-trip’ across inverters
- Customer must set up control dispatch for load following
- Erratic renewable energy delivery into the grid
- Loss of controller communication crashes the system



CONTROL MADE SIMPLE

On the other hand, today's energy management systems enable comprehensive functionality without the limitations of conventional power electronics. The systems use auto-synchronized DC-bus modular controls that enable integration of all AC and DC system inputs. No central system controller is required; all control is active and in real time. There are no inverters inside the bus level. All available electrons are drawn onto the single DC bus. Proprietary algorithms then understand what the load needs and what energy sources are available; power is then drawn from the asset that is most advantageous at the time. Such systems provide:

- Active energy synchronization for any or all DC and AC inputs and outputs
- Prioritization and optimization of all generating assets without system controllers and complex algorithms
- Modular, scalable, efficient and future-proof energy management
- Management of every power and energy storage application and asset in simultaneous operation

The energy management system is flexible and scalable by simply adding drawers to a cabinet; each drawer is designated as solar PV, DC lighting, diesel generator or storage, to list a few options.

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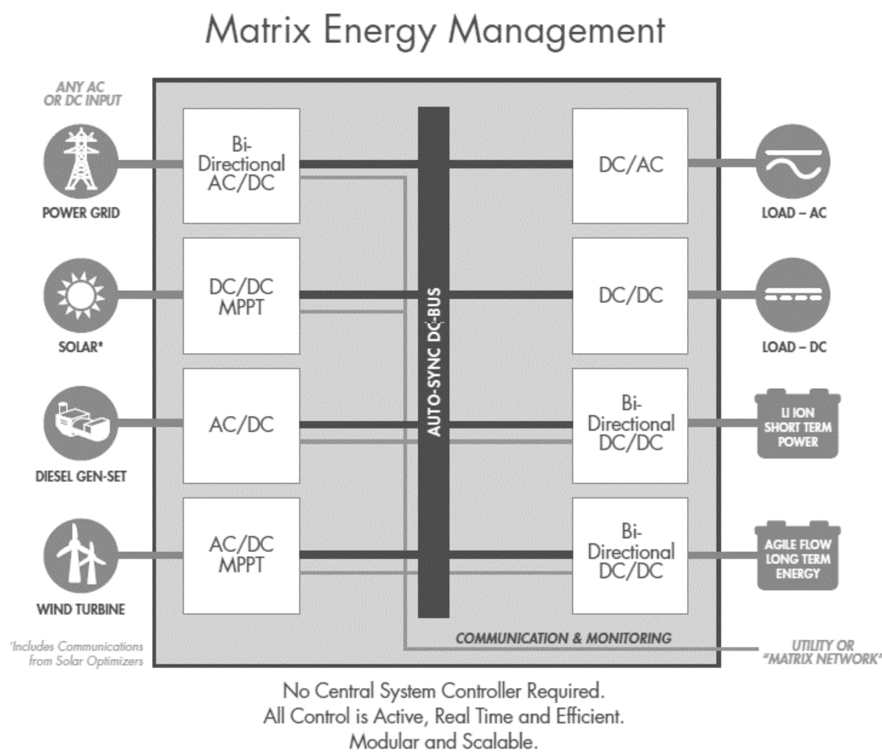
This approach is particularly valuable in countering the conventional one-size-fits-all approach to energy storage. While a given distributed generation scheme may or may not include energy storage, the modular approach to energy management allows for the integration and simultaneous control of more than one storage technology; a hybrid battery can be available to serve both power and energy applications. The control scheme effectively auto-segregates power and energy applications and pulls from the optimal battery technology to do the job without the complexity of a central control system – a highly complicated task accomplished simply and cost-effectively.



The macro ability to leverage the optimal use of electricity from the grid, distributed generation resources and storage is itself powerful; the ability to monetize numerous applications behind the meter provides the micro-level ability to leverage almost any combination of applications imaginable, including supply response, time-of-use, frequency regulation and back-up power.

Besides serving off-grid applications, the technology enables complete distributed generation asset-to-utility communication for smart export. It allows installations in different locations to be clustered in a secure network as a set of assets that enable real-time spot market electricity sales. One bi-directional power converter provides a single point connection to the utility grid, and the ability to alternate between on and off-grid operation. This configuration also allows energy generation to continue in the event the grid is down, feeding the batteries up to the point where they are fully charged. This can occur because while the inverter connected to the grid must shut down, a path remains to move the generation to the batteries. In addition, where another inverter is placed on the bus to serve critical loads, those loads continue to be served. In conventionally designed systems, generation must halt during an outage due to the hazards of back feed to the grid. This is because the grid is used to transport power to the batteries (if in place).

In the modular concept, DC-DC, DC-AC, and AC-DC transformer drawers and the communications are quickly and easily configured to the same universal architecture in single or multiple cabinets. When a change is to be made to a system, an application engineer simply chooses from a limited number of standardized building blocks and configures the system for the site by adding the appropriate hot swappable drawers – a true plug-and-play concept.

DCentrIQ™

Serviceability is simple, as drawers can be replaced without taking the entire power system offline. For example, on a PV system that includes four separate arrays, a technician can shut down one array for service while the others continue generating power.

HIGHLY RESPONSIVE

One standard module in this control scheme is a DC-to-DC converter that can be loaded with software for maximum power point tracking, such as for a solar array. This device sends solar energy onto the auto-synchronized DC bus. Another identical DC-to-DC converter can be loaded with software to interface with battery storage. A modular DC-to-AC converter then can be added for grid connection. Additional modules can be installed for other microgrid assets.

Multiples of each module can be installed to scale the system up. The configuration is similar in concept to a motor control center.

Control is executed simply by using information on the actual DC bus voltage. For example, in a microgrid that includes battery storage, a DC-to-DC converter is programmed with upper and lower voltage setpoints; the converter's role is to maintain the DC bus voltage between those points. If the voltage goes high, the converter absorbs energy off the DC bus to charge the batteries. If the voltage goes low, the batteries discharge to hold the bus voltage up. Each separate converter or inverter in the system functions similarly and independently.

In the case of a grid-connected 100 kW solar PV array with battery storage, suppose that the system is programmed to deliver constant 100 kW to the grid. If a cloud passes over, the PV array output may drop to 30-40 kW for a time. Now, since the PV array cannot hold up the bus voltage, the battery system's DC-DC converter senses that condition, and the batteries discharge. The output to the utility grid remains at a constant 100 kW regardless of the PV array status.

This approach to control technology is ideal for mixing and matching different battery or other energy storage technologies – those best suited for optimum kilowatt or kilowatt-hour discharge. Controlled by the modular technology, such hybrid storage can perform like the "perfect battery," delivering power for different purposes, at different times and under different conditions on the system. The control even enables the transfer of energy among storage technologies, a valuable capability in optimizing applications.

The control can even be programmed to receive real-time pricing or future pricing information directly from independent system operators and use the data to make automatic decisions on when to store, consume and sell energy.

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FUNCTION OR APPLICATION	EMS
Active energy synchronization for any or all DC and AC inputs and outputs without system controller/complex algorithms	✓
Can manage every power and energy storage application under simultaneous operation	✓
Modular, scalable, efficient and "future proof" for 20-year service life	✓
Demand Response	✓
Frequency Regulation	✓
"Rate Shifting"	✓
"Peak Shaving"	✓
Demand Charge "Clipping"	✓
Renewable Firming	✓
Full data logging and forecasting of generation and storage	✓
Supply response on demand between building and grid network	✓
DC output management and control (e.g. DC lighting, building DC)	✓
Microgrid Operation	✓
Max. Power Point Tracking	✓
PV Panel Optimizer	✓
Power Factor Correction and AC Bus Voltage Regulation	✓
Islanding	✓

TECHNOLOGY IN ACTION

This modular energy control has been deployed in a variety of distributed generation applications, both off-grid and grid-connected. A few examples illustrate its versatility.

University Campus

A grid-connected solar energy distributed generation and advanced energy management system serves an educational campus in Hawaii. The system includes a 412 kW PV installation and 225 kW/320 kWh of hybrid battery storage (four flow and five lithium-ion batteries), with the modular intelligent energy management platform. The total campus peak electric demand is 332 kW. The project objectives are to reduce electricity costs by way of a 20-year power purchase agreement (PPA), protect the institution against power outages, and ease pressure on the electricity grid.

All PV power generated is used on the campus – there is no grid export. The energy management platform enables the organization to leverage the grid, solar energy and energy storage to maximum advantage. In the event of a grid outage, the campus can operate in island mode, then re-synchronize with the grid when service is restored. The battery storage system enables the campus to meet a state requirement of elevator backup power for buildings over seven stories tall without the need for diesel generator sets. The system is also structured so that in case of a grid outage or emergency, the campus cafeteria can serve for an extended time as a shelter for students and employees.

Agriculture

In one of the simplest applications, the energy management platform is integrated with solar PV and Aqueous Hybrid Ion batteries to power pumps around-the-clock for a hydroponics and aquaponics fishery operation in Hawaii. Sustainability is important to the company, whose farming methods are organically certified and food safety certified.

Facing high electricity prices and vulnerability to power outages, the company required renewable energy that could seamlessly connect with energy storage to support a goal of being off grid with sustainable, reliable power. The energy system initially integrated 25 kW of solar PV and 40 battery stacks with a combined 25 kW/92 kWh of energy storage. The power control system allows the operator to store solar-generated energy in the batteries and discharge them to drive 7 hp total pump loads for up to 16 hours per day. The control system's modularity simplified expansion of the system's solar PV component to 75 kW in early 2016.

LOOKING TO THE FUTURE

The possibilities for distributed energy, renewables and battery storage are certainly not limited to self-consumption systems. The modular energy management platform can be easily configured to allow smart export. System owners then stand to benefit from power sales to the grid where feed-in tariffs are favorable. The utility, meanwhile, potentially gains a resource that can be dispatched on demand, at mutually agreeable terms, to help stabilize the grid.

Even the simplest systems can benefit from installing the modular technology as the incumbent platform. A pure solar PV system installed today can benefit from the flexibility to add other capabilities later – battery storage, wind turbine, emergency generator set, electric vehicle charging station, and others. While that could be difficult under conventional technology approaches, the modular energy management system allows control for any of these to be installed simply by adding drawers to a cabinet.

Synchronization of disparate generating assets for power and energy through state-of-the-art energy management systems is opening numerous possibilities, as well as markets, for owners and operators of buildings, microgrids and utilities.

Simply put, not all electricity is created equal, and various options for sourcing electricity are increasingly viable, cost effective and environmentally advantageous. The technology is available today to lower the cost of electricity, create a more resilient grid infrastructure, and prompt economic markets that take the fullest advantage of distributed assets.