Energy Storage Systems

Enabling Faster Response to Changing Energy Demands with Power Modules

Stefano Gallinaro, Product Marketing Manager, Vincotech GmbH, Unterhaching

1 Introduction

Tomorrow's power supply is sure to be all about smarter, more responsive grids. In fact, better energy management is already a big deal today. Conventional coal and nuclear plants' power output is difficult to adjust at short notice, so they end up dumping excess energy when demand dips. What's more, over-engineered transmission and distribution lines are larger than they need to be to handle briefly spiking demand. And without the means to store wind and solar power, energy that cannot be put to immediate use is wasted.

The antidote to the energy crisis on the far horizon is a mix of remedies that makes the most of all available technologies, specifically:

- More efficient and cleaner fossil-fuel energy sources
- Hybrid systems that draw on both renewable and fossil fuels
- Legacy infrastructure that evolves and gives way to streamlined transmission and distribution systems
- Better time-of-use management and technologies to keep the scales of energy supply and demand balanced.

But the success of all these advances hinges on one key factor, energy storage. Battery powered devices' ability to store excess energy for use when it is needed will have to be scaled up to the magnitude of power plants and huge grids. These energy storage systems (ESS) can cut back the amount of energy wasted today, ramp up to peak power in no time at all, and relegate oversized transmission lines to the dustbin of history.

ESS will also close the gap between renewable energy production and deployment. The irony of wind and solar sources' remarkable upswing is that the more renewable energy is generated, the more often it is being curtailed, mainly because of transmission congestion. Storing that excess energy relieves congestion, reduces power curtailment, and ensures all this greener energy is put to good use. As an added bonus, ESS can also be set up at many points along the grid, close to the power plant as well as near the companies and small communities that use the energy. Storage capability can thus be rolled out rapidly and incrementally, which slashes costs and speeds up ROI. Both are powerful incentives to go all out in deploying energy storage systems, and once that rollout picks up momentum a smart, distributed grid will be within easy reach.

Energy storage solutions come in many guises ranging from small batteries to big pumped water systems. This article narrows the focus down to electrical energy storage, and more specifically, to power electronic subsystems, which for present purposes, shall simply be called systems. Mechanical, hydraulic and chemical storage systems' different power ranges and technologies put them out of the scope of this paper. And although application level controlling units, metering and cloud integration units are clearly important, they too are beyond the scope of this article.

2 Breaking energy storage systems down by power level

Energy storage systems come in three main categories—utility/grid, industrial and residential—as determined by the level of power they are called upon to handle. Batteries are becoming the first choice for storing energy, and the future belongs to lithium-ion technology. Anything from kilowatt-hour residential systems to multi-megawatt-hour for utility/grid systems is possible.

2.1 Utility/grid (>MWh)

Energy storage systems can be a good fit for renewable power plants, on-grid and off. For example, a sizable solar/wind farm with integrated energy storage can reap the benefits of energy arbitrage, locational capacity and infrastructure upgrade deferral. These terms may sound exotic, but the concepts are straightforward:

- Energy arbitrage involves storing excess electricity that is produced cheaply at night for later use, when demand peaks during the day. Revving up plants to run at peak capacity is dirty, inefficient business, so arbitrage cuts both costs and emissions.
- Locational capacity, in a nutshell, means leveraging long-term storage capability to source power locally, at on-site load centers where it is needed most. This keeps the frequency of supplied energy constant and power generation cleaner, more cost-effective and easier to deploy.
- Infrastructure upgrade deferral is a fancy way of saying that energy storage serves to trim peak loads and alleviate congestion, sparing utilities and consumers the financial burden of expensive upgrades to transmission and distribution networks.

Energy storage requires power electronics systems that include high-power AC/DC and DC/DC converters. In the main, the power module topologies consist of three-level inverters, high-current half-bridge-based inverters, and high-power battery chargers. The given battery configurations determine what types of boost and inverter topologies are needed.

2.2 Industrial/commercial and midsized communities (10kWh-1MWh):

Commercial and high-tech industrial facilities run complex machinery that demand high-quality power. ESS are best at delivering power reliably and at a stable frequency, even at peak loads. They can furnish plenty of back-up power to ride out temporary outages. And they provide a central accumulation point so that renewable energy generation can be reconciled with high-quality power generation. Even a self-sufficient micro-grid that can power a facility for weeks on end is a viable option. The most cost-effective solution for both on- and off-grid systems will be sized according to how much energy is stored during times of low demand and displaced during peak hours of the day.

Energy storage in this power range requires power electronics systems that include medium-to-high-power AC/DC and DC/DC converters. In the main, the power module topologies consist of single- and multi-phase PFC, high-current half-bridge-based inverters, and high-power chargers.

2.3 Residential (1-10kWh):

Residential ESS are real energy-savers that can serve to connect mainly photovoltaic systems to the power grid. Storing solar energy at home can slash the consumer's electricity bill, so residential ESS are certainly gaining traction. They are also a reliable source of emergency power during outages.

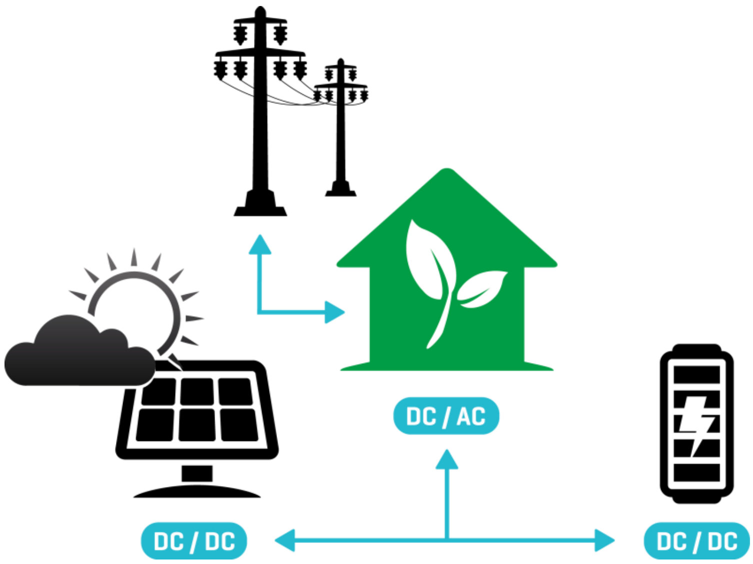

Figure 1 - Block diagram of residential ESS

Residential storage requires these power electronics systems:

- Compact medium power DC/DC and DC/AC solar converters (such as three-phase boosters and three-level, three-phase inverters)
- Low-power, single-phase solar inverters (single-phase H-bridge)
- Bidirectional DC/DC and AC/DC battery chargers to charge the battery from the PV system and grid, and to feed energy back to the house and grid (half-bridges and H-bridges as the basic building blocks, plus boosters for battery management)
- Compact, highly efficient bidirectional DC/AC converters to connect the home energy storage system to the grid

Although various designs for converters with different purpose-built topologies are in the works, they all aim to achieve the same objectives: utmost efficiency, reliability, cost and robustness.

There are applications where these three categories intersect, and this common ground is readily covered using the same building blocks and a modular approach to design. Tremendous benefits may be achieved by multiplying and scaling up these basic building blocks. This modular approach can even be revisited within the design of each block, and the best-in-class solution is undoubtedly an electronic design centered on power modules. A reusable core expedites all other processes and ups the overall system's efficiency and reliability.

Vincotech's modus operandi follows much the same pattern. The company develops standard products and rapidly customizes solutions to cover all ESS categories' topologies, power ratings, housing technologies and performance requirements.

3 Market potential

Demand for energy storage solutions is strong and picking up steam around the world. The market for PV inverters may be up and down, but many players are rushing to integrate energy storage systems with their PV systems. The biggest markets for ESS are North America, China, Japan and Europe, and projected annual sales of storage technologies is growing fast from €6 billion in 2015 to €26 billion in 2030.

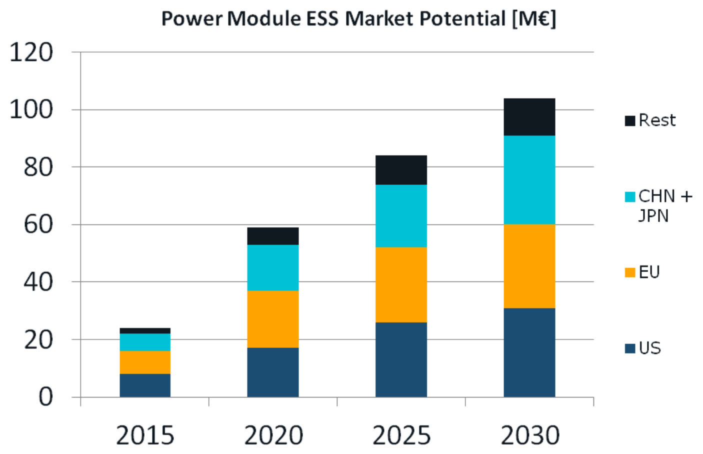

Figure 2 - Power module ESS market potential

Taking the percentage of business accounted for by power module components as the baseline, Vincotech's total addressable market will grow from €24 million in 2015 to €100 in 2030.

4 Power modules for ESS

All standard and customer-specific topologies can be integrated into any Vincotech housing, whereby low-power solutions generally come in small, compact ***flow* 0** and ***flow* 1** housings, while high-power systems ship in ***flow*SCREW** housings engineered to achieve high power density.

Figure 3 – A *flow*SCREW 4w housing

Standard topologies such as half-bridges and H-bridges are used in SMPS and charger applications. They constitute the basic building blocks of a classic inverter. Typical applications require 1200 V modules with > 100 A current rating. Off-the-shelf ***flow*PHASE** and ***flow*PACK** modules are rated for these application requirements, and more are in the pipeline.

Four-quadrant, three-level inverters featuring NPC and MNPC topologies (***flow*NPC**, ***flow*MNPC**) are state of the art in terms of both integration and performance. A range of 650 V, 1200 V and 2400 V modules with various current ratings is available now.

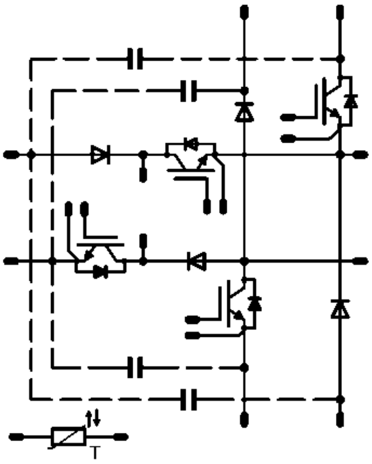

Figure 4 - *flow*MNPC topology

Power Factor Correction power modules (***flow*PFC**) may be integrated into multistage converters and used with battery management modules, even bidirectionally when the storage system—typically the battery—is feeding the grid.

Booster modules (***flow*BOOST**) used in battery management applications factor high conversion efficiency, fast switching and a compact, modular design into the performance equation.

The new ***flow*RPI 1** family is the solution of choice for designing compact, fast and efficient energy storage systems for less than 10 kW. Engineered for welding, charger and SMPS applications, the new *flow*RPI 1 family combines a rectifier with highly efficient, low-voltage drop diodes, a two-leg PFC featuring ultrafast 650V IGBTs and diodes, integrated filtering capacitors and diodes for current sensing via an external transformer, as well as an inverter with H-bridge open emitter topology and optional capacitors. All this comes in a single module that enables engineers to save design-in time and cost. A special version comes with a PFC featuring IGBTs with higher current ratings for a wider input voltage range. It is rated for applications with Vin = 110 – 220 VAC. These painstakingly selected components provide the best solution for high-frequency switching paired with utmost efficiency.

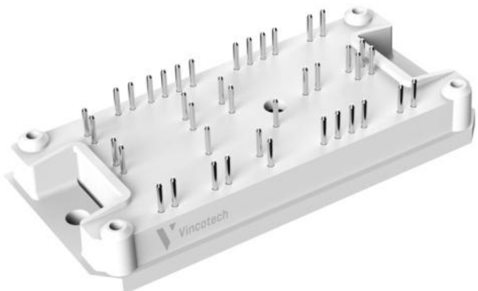

Figure 5 - *flow* 1 housing used in *flow*RPI 1 modules

The new *flow*RPI 1 family's enhanced layout is more EMC-friendly. With the latest IGBT chip technologies on board, the module delivers ultra-fast switching speeds at ultra-low conduction and switching losses. Given the option of three power stages in a single module, engineers will find it very easy to design highly compact PCBs. Various power ratings are available in the same *flow* 1 housing with the same pin-out, so applications may be scaled up with the PCB design remaining intact. This latest generation module covers application power ranges from 1.5 kW up to 7 kW in various steps.

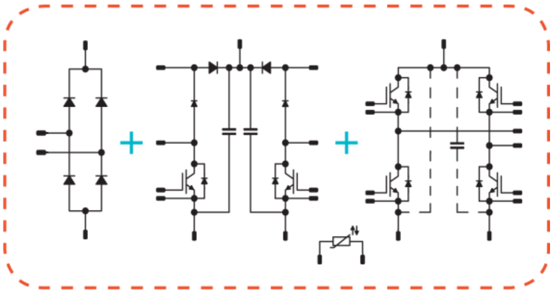

Figure 6 - *flow*RPI 1 schematic

5 The upside of using power modules

The market is growing fast and players are agile, so new developments have to be ramped up swiftly to deliver state-of-the-art technology under great time-to-market pressure.

Power modules outclass discrete components when it comes to reliability and service life. On top of that, they streamline and accelerate the design effort, driving time to market and development costs, and power integration, performance and reliability up.

Customers can design very compact applications centered on the power block and enjoy the fringe benefits of high efficiency, reduced EMI and best-in-class switching performance. An application built on a power module is easier to upgrade and may be scaled up to achieve higher power levels. ESS demand precisely the properties that power modules have and discrete components lack—modularity and flexibility.

Vincotech provides the full range of topologies, power ratings and housings. Our customers can opt for standard products or custom fast-tracked solutions tailored to their specifications. Either way, outstanding quality and performance are always assured.

Please visit http://www.vincotech.com/ for details on all the many products and housings.