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ENERGY STORAGE (M KINTNER-MEYER, SECTION EDITOR)

Open Communication Standards for Energy Storage and Distributed Energy Resources

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Abstract

Purpose of Review This article reviews the status of communication standards for the integration of energy storage into the operations of an electrical grid increasingly reliant on intermittent renewable resources. Its intent is to demonstrate that open systems communicating over open standards is essential to the effectiveness, efficiency, reliability and flexibility of an electrical grid composed of an intelligent network of distributed energy resources.

Recent Findings Grid-integrated energy storage is expected to increase dramatically over the next 10 years, a prediction which assumes substantial industry alignment to a common set of communication standards that will make this growth possible. Four industry alliances have emerged in recent years as the dominant players in the development of open standards for energy storage systems and distributed energy resources: the MESA Standards Alliance (mesastandards.org), the SunSpec Alliance (sunspec.org), the OpenADR Alliance (openadr.org), and the Open Charge Alliance (openchargealliance.org).

Summary Historical and pragmatic evidence demonstrates that industry-wide adoption of freely accessible and industry-driven open communication standards is essential to maintaining the grid's flexibility and responsiveness. Two case studies—from Snohomish PUD in Everett, Washington, and at Austin Energy in Austin, Texas—illustrate the application of open communication standards to grid-integrated, utility-scale energy storage, and to the management of circuits with a high penetration of residential solar photovoltaic and actively managed loads.

Keywords Modular energy storage architecture · MESA · Energy storage standards · Distributed energy resources standards · DER standards · Doosan GridTech

Introduction

Networking protocols and specifications have, since the 1970's, referenced system architectures conceived as *open systems* of component layers communicating over *open standards*. The layers can be thought of as the level playing fields on which market forces drive innovation in core technologies, like the peripherals and device drivers, routers, and network-attached storage (NAS) servers on your home network. The boundaries between the layers are crossed by a common language, the specifications of an open standard which can be thought of as a plug and socket, as with electric cords or light bulbs.

This article makes the case for open communication standards for energy storage and distributed energy resources. By giving a brief history of standardization in general, and of computing, networking and telecommunications standards in particular, we intend to lay out an argument that open standards create new market opportunities for suppliers, increase customer choice and flexibility, and drive innovation. Further, their industry-wide adoption has been shown to generate effects far greater than the sum of the interoperable parts they have commoditized.

Open standards...

1. **Create new market opportunities**, allowing a greater number of small manufacturers of core technologies to enter the market. This, in turn, ...
2. **Increases customer choice and flexibility** by mixing and matching components from a variety of vendors. The competition in core technologies...

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3. **Drives innovation**, and the innovations cascade throughout the system to...
4. **Create synergies of complementary technologies**. Twenty-first century technologies are almost all a testament to the value of open standards. From the plug-and-play personal computer to the Internet protocols of the Worldwide Web, open standards have enabled highly disparate technologies to interoperate in ways that would have been difficult to imagine had the industry remained locked into monolithic architectures.

A Brief History of Open Standards

Few people today would argue against the necessity of telecommunications and networking standards. And most would allow that market solutions to standardization, especially in the public infrastructure, can be greatly accelerated by the free and open exchange of pioneering solutions developed by entrepreneurs with an enlightened self-interest in advancing their field. This wasn't always the case, as Andrew L. Russell makes clear in his book, *Open Standards in the Digital Age* [1]. Closed systems with proprietary standards dominated much of industry in the late nineteenth and early twentieth centuries. Systems were synonymous with the supply chain, and supply chains were locked up by major players, like Western Union or the railroad monopolies, vertically integrated corporations with standards and protocols that were imposed from the top down on their manufacturers, suppliers, and retail distributors.

The professional societies and trade associations that were formed in opposition to monopoly control of standards established the values of openness, transparency, consensus, and inclusion that have come to be associated with the computing, digital networking, and telecommunications standards of the present day. But the concept of "open systems" did not emerge until the 1970's, when the principles of open access and the free exchange of information mobilized the opposition to IBM and the telecom monopolies' dominance of computer networking standards. One of the first mentions of "open" and "closed systems" in the context of network communication standards comes from Jack Houldsworth [2], an early proponent of what became the *Open Systems Interconnection (OSI)* project. Networking standards, he argued, were needed for "open working," which he defined as "[t]he ability of the user or program of any computer to communicate with the user or program of any other." He contrasted this with "closed systems with little regard for the interworking with one another."

In 1983, OSI published The Basic Reference Model for Open Systems Interconnection, the standard usually referred to as the OSI Reference Model, or simply the OSI model. It consists of two major components: the 7-layer reference model for networking, or OSI-7 and a set of protocols. Though the specific protocols have largely been superseded over the years, OSI-7 can fairly claim to be the mother of all subsequent system architectures. No one since has been able to discuss communications standards and protocols without reference to some sort of multi-layered model. The layers differentiate transparent "open" systems that accept off-the-shelf components from any number of vendors, from monolithic "closed" systems with proprietary interfaces and few interchangeable parts.

PC architecture has followed a similar trajectory from closed to open systems. About the same time that IBM was fighting for its proprietary networking standards, they introduced their first personal computer. The IBM PC was built with off-the-shelf components that enabled IBM to quickly move their product to a market where Apple and others were already established. Ironically, the open-standard model for their PC ignited a personal computing revolution that eventually weakened the market for IBM's proprietary mainframe systems.

A personal computer consists of a wide range of diverse components, delivered by a global ecosystem of companies. Each supplier specializes in its core expertise: integrated circuits, graphic displays, networking, disk drives, system software, application software, etc. As Fig. 1 illustrates, open standards are the glue that makes it all work together.

Open Standards as Industry-Driven Innovations

In 1990, the U.S. Government hoped to stimulate the market for OSI-compatible technologies by enforcing its use in government operations. In the same year, the National Science Foundation (NSF) assumed control over the internet backbone after the ARPANET was decommissioned, and the rapid adoption of its internet protocols quickly undermined the market for OSI products. The battle between the two systems is illustrative of the back-and-forth common to standards development before the current century, between top-down and *anticipatory standardization* of the OSI, and the bottom-up *codification*

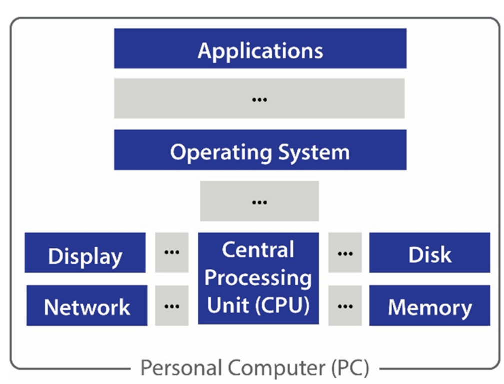

Fig. 1 Open standards (*light gray bars*) in a personal computer

of existing practices in the Internet community. The deliberative and democratic *design* of compatibility standards by inclusive bodies of consulting engineers and representatives from industry has proved to be too slow for the information age. Instead, coalitions of self-interested entrepreneurs have emerged in recent years with the objective of bringing their *existing* standards to market as quickly as possible.

Though the process has been streamlined, the large standard-setting bodies still serve important functions, bringing coherence to industries when needed, ratifying and promoting standards, and certifying the technologies that abide by them. But the standardization process itself is increasingly driven by the enlightened self-interest of entrepreneurs, whose promotion of open standards is driven by a conviction that open system architectures and open standards lead to greater innovation, better technologies and, hence, larger markets than the monolithic architectures of closed "black box" systems.

The standardization process for information technology seems to be settling out to include three classes of players, each tending to focus on just one of the following:

> **Public Policy**—Organizations like the National Institute of Standards and Technology (NIST) provide coherence and oversight, education and outreach, and facilitate international consensus.
> **Creation**—Entrepreneurial-minded innovators, via industry consortia and trade associations like W3C, and those we'll be discussing later, provide the essential creativity and ambition needed to move standards to market at the pace the market demands.
> **Ratification**—Professional societies and public technical agencies like the Institute for Electrical and Electronics Engineers (IEEE) and the International Electrotechnical Commission (IEC) enable the wide adoption and persistence of industry-driven standards through ratification, dissemination and certification programs.

The most successful and enduring standards in telecommunications and computing emerged with a small group of ambitious and pioneering innovators, and were gradually moved from their early licensees and industry promoters to the ratification venues of the large standards organizations. Prominent examples include the standards for Postscript, WiFi, Bluetooth, and the Ethernet, all of which originated inside private companies. Their patents eventually moved to the ratification venue to be published as ISO/IEC 9541 (for Postscript), IEEE 802.3 (for Ethernet), IEEE 802.11 (for WiFi), and IEEE 802.15.1 (for Bluetooth).

Standards for Distributed Electric Energy

The clean energy system is predominantly electric. Its core assets are: distributed energy resources that provide generation, primarily from solar photovoltaic (PV); energy storage; and actively managed load. Unit prices for solar PV and battery storage have fallen dramatically in recent decades. A recent Navigant Research report [3•] forecasts 14,000 MW of additional installed energy storage capacity worldwide over the next 10 years. The adoption of open-standard-based communication interfaces between energy storage components and systems (ESS), distributed energy resources (DER), actively managed load (Demand-Response or DR), and distribution management systems (DMS) is increasingly being recognized as a key prerequisite toward making the leap to the scalable, affordable systems foreseen by this report and others.

The existing electric distribution infrastructure is, arguably, the most comprehensive and complex machine ever built by humans. It has been building intelligence into its systems for generations, and communication protocols like DNP3 have greatly improved the ability of control centers to manage the devices on their circuits. But as the grid transitions from the fossil-fuel based generation of the past, to distributed and intermittent renewables, actively managed loads, plug-in electric vehicles, etc., this intelligence will need to be decentralized and distributed along with the resources.

What will make the grid "smart" will necessarily include collaboration between widely distributed, open and intelligent systems which, while working for the benefit of their own domain, will be enabled through open system architectures to collaboratively maintain the integrity of the larger grid.

Integrating DER with the power system requires new methods of control and system integration. New intelligence will need to be introduced to integrate its legacy circuit devices, such as voltage regulators and capacitor banks, with the smart inverters and control systems of its distributed energy resources.

Several industry alliances have formed over the last several years to establish open standards for the distributed electrical grid. Each have approached standard development with the enlightened self-interest of entrepreneurs, and with the collaborative disinterest that is essential to the free and open exchange of pioneering solutions. They acknowledge de facto standards of industry leaders while collaborating with industry, standard-making organizations, and governments, to formalize and broaden their relevance. They include:

- **The SunSpec Alliance** (sunspec.org), which publishes standards for solar inverters, meters, modules, string combiners, environmental monitors, data acquisition systems, and management applications;
- **The MESA Standards Alliance** (mesastandards.org), which publishes standards for energy storage systems;
- **The OpenADR Alliance** (openadr.org), focused on behind-the-meter demand-response standards; and
- **The Open Charge Alliance** (openchargealliance.org), whose interest is in building a standard-based electric-vehicle charging infrastructure.

SunSpec and MESA have formed a partnership to establish standards for intermittent resources working together with energy storage to provide reliable and dispatchable power. The MESA-ESS specifications for utility-scale storage align with the abstract data models of IEC 61850. [4].

Standards for Grid-Integrated Energy Storage

The leaders in the development of standards for grid-integrated energy storage are the Modular Energy Storage Architecture (MESA) Alliance, and the SunSpec Alliance. MESA is an industry trade association of utilities and vendors whose mission is "to accelerate the growth of the energy storage industry through the development of open, non-proprietary communication specifications for energy storage systems." The SunSpec Alliance is a trade alliance of developers, manufacturers, operators, and service providers, pursuing open information standards for the distributed energy industry. Two technical working groups have been established—MESA-Device and MESA-ESS—which solicit input from stakeholders in the industry, hold conferences, and publish draft specifications for review:

- The SunSpec ESS/MESA-Device Specifications

In September of 2014, the MESA Standards Alliance in collaboration with the SunSpec Alliance released the first open, non-proprietary energy storage system specifications for public review: the *SunSpec Energy Storage Model Specification* or *MESA-Device*. Based on the Modbus protocols, it laid out a standardized approach to integrating the batteries, inverters, and software control system with one another and to the larger distribution network.

The MESA-Device Energy Storage Workgroup, run by SunSpec Alliance with contributions from MESA members, worked through 2015 and 2016 to produce an updated draft specification for MESA-Device/SunSpec Energy Storage Specification (Draft 4). The specification was released in DRAFT status for feedback and testing in July 2016 [5•].

- The MESA-ESS Specifications

In March 2015, MESA launched a technical working group to develop the *MESA-ESS Specification*, a standard data-exchange framework for utility-scale energy storage systems. The draft specification, released in November 2016, is based on work by the Electric Power Research Institute (EPRI) and the DNP User Group, and addresses ESS configuration management, operational states, and the applicable functions from the DNP3 profile, a protocol standardized in IEEE 1815 and used by most U.S. utility SCADA systems for their advanced DER functions. The specification feeds into a larger effort to update the existing DNP3 Application Note on distributed energy and storage in 2017. A draft was released for public review and testing in November 2016. The specification is not limited to batteries and is designed to be used by any system that can store energy and release that energy as electricity [6••].Figure 2 below shows how the MESA-ESS specification combines with MESA-Device communication specifications to build a MESA-compliant energy storage system. The MESA-ESS specification provides the utility's DNP3 interface, and the MESA-Device specifications—MESA-PCS, MESA-Storage and MESA-Meter—provide the Modbus interfaces exposed by the system's parts.

Case Studies

The MESA-Device standard provides the data models and Modbus maps for communication between the individual components of the ESS system and its control software—MESA-PCS for the inverters (the command interface and various high level operating parameters), MESA-Storage for the batteries (nameplate values, state of charge, control state, operating mode, etc.), and MESA-Meter for the meter devices (real and reactive power, voltage, current, frequency, etc.). The MESA-ESS standard enables communication between the control center and the ESS.

The following two case studies illustrate how these standards relate to two real-world examples.

Snohomish County PUD

"We want to buy storage from a catalogue, just like we do with transformers and other gear today."— Steve Klein, General Manager, Snohomish PUD.

At the Snohomish County PUD in Everett, Washington, three separate energy storage systems have been installed, all from different vendors (see Fig. 3 below). At one of their substations, two systems supply 0.5 MW/1MWh each, using lithium-ion batteries from Mitsubishi and LG Chem. At

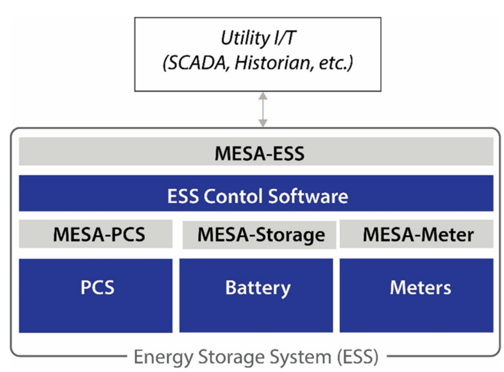

Fig. 2 Open standards (*light gray bars*) in a MESA-compliant ESS

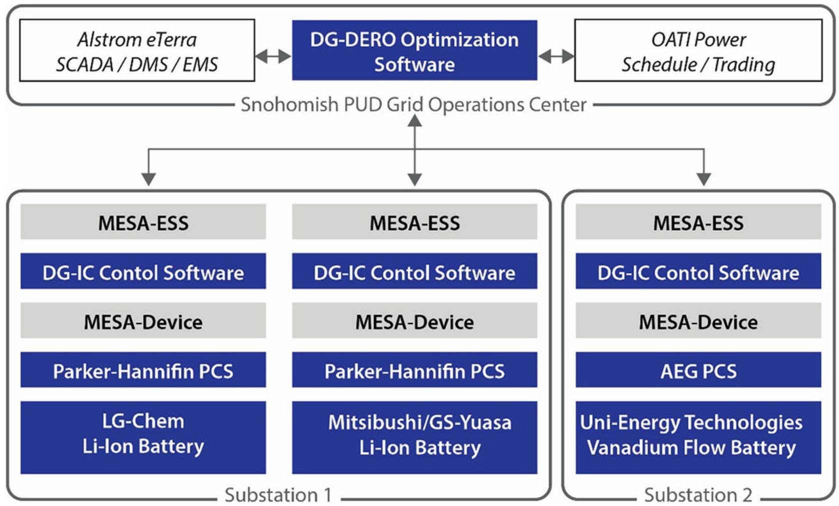

Fig. 3 Open standards (*light gray bars*) at Snohomish County PUD

another substation, a third uses energy-dense 2 MW/8MWh vanadium redox flow batteries from UniEnergy Technologies. Two additional vendors supplied the power conversions systems (PCS): Parker-Hannifin and AEG. The MESA/SunSpec standards enabled the utility to integrate their components seamlessly into their centrally managed energy storage fleet. The batteries communicate over standard protocols with control software developed by Doosan GridTech that schedules its operating modes. The operating modes address grid conditions and use cases which include: renewables integration, frequency regulation, load balancing, peak shifting, and voltage support. The control software, in turn, communicates with the utility's fleet control and optimization software, also provided by Doosan GridTech. The investment should enable Snohomish County PUD to better integrate their distributed resources, minimize their exposure to market volatility, and mitigate voltage and current issues while improving grid reliability, flexibility, and performance.

Austin Energy

Austin Energy, the nation's 8th largest publicly owned electric utility, has committed to the goal of 55% renewable energy, 200 MW local solar, 100 MW customer-sited solar, and having all city of Austin facilities and operations be carbon neutral by 2025. In 2017, they will be installing two MESA-compliant energy storage systems with control software designed to enable dramatically higher penetration of solar photovoltaic (PV) power in their distribution system.

With a DER fleet of residential PV, managed load, and behind-the-meter storage, all compliant with the open standards of MESA, SunSpec, OpenADR, or SEP, as applicable, Austin Energy intends to vastly improve its ability to manage its circuits with a high degree of flexibility and control. Using open communications standards to address all devices, the utility will be able to communicate with each device, controlling each as necessary to optimize its services while meeting its ambitious clean-energy goals.

What is Next

It is fully expected that the specifications being drafted and disseminated by the industry consortia discussed in this article will eventually make their way to the ratification venues of the IEC and IEEE. MESA and SunSpec are working closely with the International Electrotechnical Commission in its updates of the IEC 6180 Information Model. The IEEE 1547 standard, which is used by most jurisdictions for DER interconnections, is being revised to cover many of the functions addressed by MESA-Device, and the communications protocols of IEEE 2030.5 are also being updated for DER. The Electric Power Research Institute (EPRI) is updating the DNP3 Advanced DER Application Note, which will cover all the MESA-ESS requirements and should be released in late 2017 or early 2018. These professional societies and public technical entities will eventually take on the responsibility of maintaining these open communication standards for energy storage and distributed energy resources, helping to ensure their persistence and broad acceptance by technology suppliers and their utility customers.

Conclusion

As the information technology and telecom industries have shown over the past several decades, any set of modern industrial specifications for a digital, distributed system should support the use of open communication standards, promote interoperability, and minimize the amount of non-recurring engineering required. Recognizing that grid-integrated storage is key to managing an energy infrastructure that relies more and more on intermittent renewables and widely distributed resources, an increasing number of industry leaders are coming together to draft, sponsor, and promote a set of open standards and specifications that will enable interoperability in the energy supply chain, from residential PV and electric vehicles to the utility-scale storage and control systems that orchestrate the distribution network and provide essential services to the grid.

Over 70 organizations are currently members of the SunSpec Alliance, including global leaders from Asia, Europe, and North America. Membership is open to corporations, non-profits, and individuals. MESA's growing membership now includes 28 contributing members and strategic partners, including many large-utility customers who are, or will be, integrating MESA-compliant systems into their operations. Their joined efforts are accelerating the interoperability, scalability, safety, quality, and affordability of energy storage components and systems.

Any utility interested in avoiding vendor lock-in, and wishing to extend the life of their DER investment through modular upgrades—both in the component hardware and the control software—should give serious consideration to those technology and turnkey solutions that are based on the open specifications outlined in this article.

Resources

For more information about the MESA Alliance, download MESA specifications, or to participate in the technical working groups and develop these industry standards, visit www.mesastandards.org.

For more information about the SunSpec Alliance or to download SunSpec specifications at no charge, please visit www.sunspec.org.

For more information about the OpenADR Alliance, or to sponsor or contribute to one or more of their initiatives, visit www.openadr.org.

For more information about the Open Charge Alliance, and to learn more about its open and interoperable communication protocols for the EV charging infrastructure, visit www.openchargealliance.org.

The International Electrotechnical Commission's (IEC) smart grid standards, including IEC 61850 Information Model, may be downloaded, in whole or in part, from their website at: www.iec.ch/smartgrid/standards.

Compliance with Ethical Standards

Conflict of Interest Gregory S Frederick reports that Doosan GridTech has paid, and continues to pay, my salary as their Senior Technical Writer, but I received no other compensation for this article. Doosan GridTech also has patents, planned, pending or issued, broadly relevant to this work.

Human and Animal Rights and Informed Consent This article does not contain any studies with human or animal subjects performed by the author.

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•• Of major importance

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6.•• MESA Standards Alliance. (2016). MESA-ESS specification DRAFT. http://mesastandards.org/mesa-ess-2016/. **The MESA-ESS standards include specifications for the operating modes and scheduling that will enable an energy storage system to provide essential grid-stabilization services through the control center's dispatch commands.**