Launching Plug and Play Distributed Energy Resources Into the Future

Thinking Beyond Silos and Embracing Universal Technology Integration

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1.0 Executive Summary

Today, the nation's electric power sector is undergoing more disruptive change than at any point since its inception more than a century ago. The proliferation of distributed energy resources (DERs) and new models of customer engagement is adding significant complexity. New technologies, innovative companies and business models are transforming the traditional generation, transmission & distribution and consumption of electricity. Under such dynamic conditions, what matters beyond the shift in the generation portfolio and the rapid adoption of DERs, is how the operation of these systems can be intelligently and cost-effectively coordinated.

A key challenge to realizing the benefits of this transformation is enabling these new technologies to work together or interoperate. Without interoperability, the vision of energy systems connecting and communicating easily will remain difficult and expensive. Interoperability will require individual configuration between components that are developed by different manufacturers in different industries. Take Bluetooth as an example. When you rent a car, you are prompted to connect your phone to gain the benefit of hands-free calling, GPS, among other features. This enhanced experience comes from two different industries, cars and phones, but Bluetooth facilitates the exchange. Similarly, the benefits from energy interoperability include improving grid reliability and resiliency; smoothing and shifting load; reducing carbon emissions; deferring expensive grid infrastructure investments; and empowering consumers to better manage their energy consumption and costs.

1.1 The Promise of a Plug and Play DER Future

Envision a household with an electric vehicle (EV) charger, solar panels, an energy storage system, a smart thermostat (and other connected loads), a utility smart meter, and a home energy management system. Solar generation is directed to EV charging and storage during times of high production and low costs, and when the sun sets, stored energy is used to meet increased load, reducing stress on the grid and maintaining comfort and convenience for the customer.

"Broad interoperability of DERs and related control technologies is a key building block for building the resilient and flexible grid of the 21st century," said Chris Irwin, Program Manager at Department of Energy (DOE). "The Plug and Play DER Challenge is just one example of how DOE – through multiple Offices and National Laboratories – is working with industry, developing solutions to the key crosscutting challenges of grid modernization."

In order to achieve these outcomes, technologies need to be interoperable and provide a seamless and low-friction experience for users. However, many of these new and disruptive technologies do not have standard ways to integrate with utility operations. Common service definitions do not exist and devices or systems may use proprietary or specialized interfaces, making it difficult and sometimes impossible to work together effectively.

1.2 Progress Achieved by the Plug and Play DER Challenge

The Plug and Play DER Challenge (the Challenge) was created to propel the idea of visionary interoperability into a real-world working solution while engaging the energy industry to imagine new possibilities. See http://plugandplayder.org for more background. The Challenge yielded two key outcomes:

- Building Awareness to Think Beyond DER Silos. The Challenge deepened awareness of the opportunity and benefits of thinking beyond a particular silo of technology. The solutions generated from the Challenge can work for any type of DER and reflect the expanding scope and convergence in the industry.

- Live Demonstration of Three Different Working Energy Services Interfaces. The Challenge focused on the development of an Energy Services Interface (ESI) that specifies the information exchange to simplify the integration of DERs, no matter what type. Using specific technical criteria, participants in the Challenge developed concepts and detailed plans (see Phase 1 concept papers) and built software and hardware solutions to demonstrate the “plug and play” integration process (see Phase 2 technical interface specifications).

1.3 Next Steps to Launch Plug and Play DER Into the Future

The energy industry needs continued focus on making DER integration simple and reliable. Developing innovative approaches to enable these technologies to work together at scale with the grid and other energy management technologies will create broadly shared economic, environmental, and quality of life improvements.

Core Principles:

- Focus on the interface, where systems connect

- Establish community agreement on requirements

- Develop processes that improve the integration experience

- Codify quality technology standards

Four Key Actions:

1. Define common, high-value use cases.

2. Design an interoperability demonstration with multiple “reference” implementations supporting the same Energy Services Interface specification.

3. Work with standards bodies to address the Energy Services Interface requirements.

4. Launch the Grid Modernization Laboratory Consortium (GMLC) Grid Services, Energy Services Interfaces & Grid Connected Devices Project.

Acknowledgments

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Contents

2.0 Background: Why a Plug and Play DER Challenge & What Transpired?

2.1 Origins of The Challenge

The Challenge arose from a United States Department of Energy GMLC project on grid interoperability. Interoperability is the capability to reliably and safely integrate different components of systems and devices together, and have them work.

The bottom of Figure 1 (below) depicts the ideal "plug and play" situation where two devices are connected and start to work together automatically.

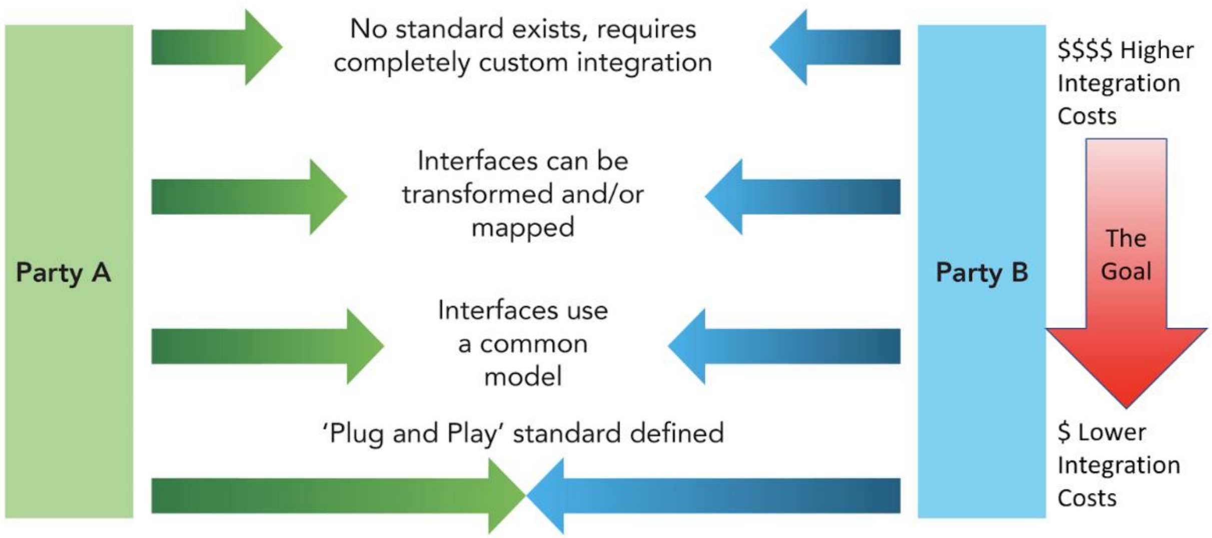

Figure 1: Steps to a Plug and Play DER Future (Source: derived and modified from GMLC[1] and Gridwise® Architecture Council[2])

Defining standards, tests, and integration guides that cover complex interactions, such as needed for DERs, typically requires a long, involved process. Projects often begin with a custom, single-use integration, but this approach is expensive and time-consuming. To simplify the process, designers define the general components and connecting interfaces of a system. The interfaces clearly define responsibilities and agreements for proper operation on either side of the interface. Standardization requires agreement on these interface specifications within a community of stakeholders.

The GMLC interoperability project developed a vision to improve the integration of DERs with the grid using the ESI. The ESI specifies how "DER facilities" (such as buildings or EV charging

1 *Note.* From "Interoperability Strategic Vision: A GMLC Whitepaper" PNNL-27320, Pacific Northwest National Laboratory, Richland, Washington, March 2018. Accessed December 2019 at https://gmlc.doe.gov/sites/default/files/resources/InteropStrategicVisionPaper2018-03-29.pdf.

2 *Note.* From "GRIDWISE Architecture Council Position Paper" by. S. Neumann Accessed December 2019 at https://www.gridwiseac.org/pdfs/interop_papers_0407/papers/neumann.pdf

centers) interact with the electric grid, including possible third-parties, based on a service-oriented paradigm that uses messages to specify what to do, but not how to do it. As an example, an ESI service may request a DER facility to change its consumption or production of power during specific periods. The type or combination of DERs used does not matter as long as the DER facility's operation is coordinated to meet an agreed-upon change in energy use or production.

The utility industry is unsure, or at best unsettled, about the set of grid services to seek from DER facilities, how to coordinate with them, and what level of control or visibility to have into individual DERs. DER vendors are unsure of the necessary/needed grid services required for their products. Suppliers of hardware and software systems that coordinate DER at a facility level, (that is, systems that implement the facility side of an ESI) are unsure what information and services to optimize within the building versus communicate and share externally to the grid. To overcome this uncertainty, the industry needs integration mechanisms that span DER technologies, and a solution like the ESI concept is an essential mechanism to produce a common approach. A common approach will dramatically reduce the burden and cost of integration. To the extent the ESI concept can isolate the complexities of the grid from those in DER facilities, and vice-versa, it dramatically reduces the burden and cost of integration and enables greater interoperability.

The Plug and Play DER Challenge was conceived to encourage bright minds to propose an ESI specification that could work for any type of DER. The Challenge required participants to demonstrate advanced interoperability mechanisms that would improve the integration experience of any DER deployment scenario. This requirement was meant to drive ideas that increase the maturity of interoperability. The GMLC Interoperability project offered an Interoperability Maturity Model (IMM) as a tool to measure the level of maturity of an interface specification, and the resulting IMM criteria were foundational for evaluating Challenge submissions.

2.2 What Took Place

The Challenge was comprised of a concept phase and a demonstration phase. The concept phase challenged industry to submit written proposals describing innovative ideas for advancing interoperability. The Demonstration Phase brought those ideas to life through the development of a working interface specification. More than 20 individuals and companies shared abstracts and nine written concepts yielded three competing teams. These three teams developed solutions and showed working solutions in the demonstration phase of the Challenge.

Concept Phase	Demonstration Phase
More than 20 individuals/companies shared abstracts and nine written concepts yielded three competing teams to develop practical and visionary solutions to the Challenge problem.	Three teams demonstrated hardware and software for DER integration and coordination with a simulated utility grid entity and DERs.
	
Photo from Concept Phase Presentations and Discussion at North America Smart Energy Week 2018	Photo of Setup Prior to the Challenge Demonstration at North America Smart Energy Week 2019

3.0 Comparison of Challenge Solutions

The three finalist teams developed the following demonstrations for the Plug and Play DER Challenge:

- Open Distributed Energy Management (OpenDEM)
- ESI Server
- Open Demand Side Resource Integration Platform (openDSRIP)

3.1 Overview of the Three Challenge Solutions

The OpenDEM team was made up of Amzur Technologies, DER.Net.Soft, and RTI. This team began with an existing energy information exchange model, OpenADR, based on progress made internationally by utilities and technology solution providers. The OpenDEM solution added auto-enrollment and auto-discovery to make onboarding a DER as easy as registering your cellphone with a telecom provider. The OpenDEM team substituted XML, a standard used within OpenADR, with JSON (JavaScript Object Notation, a lightweight data-interchange format) to encode data because JSON is less verbose and enables higher performance.

One area of focus for this team was location awareness through a concept of nested coordination nodes. This added the ability to know both when and where resource capacity is available, whether at a specific substation, distribution circuit or section. This also added locational awareness for needed dispatchability to provide congestion management, service restoration, or support for non-wires alternatives. Finally, the OpenDEM team used a pub-sub protocol, Data Distribution Service (DDS), to enhance scalability, cybersecurity, performance, resilience and reliability. One of the partners, RTI, worked with Duke Energy in the development of open Field Message Bus (openFMB). For more detail, read OpenDEM's Phase 1: concept paper and Phase 2: technical interface specification.

The ESI Server team was led by Ecogy Energy. Their solution took a clean slate approach and focused on addressing what is missing from existing technologies such as Modbus, DNP3, and IEEE 2030.5. This approach produced a straightforward interface. The ESI Server team leveraged gRPC as the core of the interface, which by default, allows for backwards compatibility. The key parameters were time, location, energy and money. This allows parties using the interface to not worry about the hardware they are using as long as they are managing these four dimensions. In addition, the team included an easy and fast registration process to sign up and connect infrastructure, whether it be a building, inverter, or battery system, to participate in the market. For more detail, read ESI Server's Phase 1: concept paper and Phase 2: technical interface specification.

The openDSRIP team included EPRI, Dig.y.Sol, IntechEnergy, and Sentient Buildings. This solution originated from a California Energy Commission funded project. The team sought to address major utility concerns regarding scaling customer programs and gaining visibility into customer actions. They wanted to ensure programs can "pay for performance" not "pay for participation." To achieve the "pay for performance" outcome, it is necessary to understand what actions customers have taken, correlate those actions to grid-service requests, and through granular data produce verifiable results.

The openDSRIP team also wanted to alleviate privacy concerns associated with behind the meter data containing personally identifiable information. The team wanted to move beyond a bring your own device approach based on a single technology type such as a thermostat to something more coordinated and orchestrated. This approach would cover multiple DER technologies using a single registration entity. The team solved the problem by starting with existing data models for various types of DERs and developed a normalized model of how data can be collected from various DERs and sites. Then they applied an abstracted control model to run requests for services from the grid and deliver these services with the DER. The openDSRIP solution becomes a bridge between the DER and the grid to enable data flow and service transactions. For more detail, read openDSRIP's Phase 1: concept paper and Phase 2: technical interface specification.

Photo from Plug and Play DER Challenge unveiling at North America Smart Energy Week 2019

3.2 How Were the Challenge Solutions Similar?

The three teams embraced common approaches to solve the Challenge using an open, non-proprietary interface that could apply to any DER technology while being vendor agnostic (Table 1). Many of these similarities were driven by the initial requirements in the call for Plug and Play DER Challenge solutions. The three Challenge teams also included several other approaches that were not explicitly required. First, was the ability of the interface to register devices. All teams agreed ease of DER registration is essential for participation. Second, teams included a notion of locational awareness. DERs are uniquely positioned to provide location-specific services, making this a high-value feature.

Table 1: Similarities in the Plug and Play DER Challenge Solutions

Approach taken:	The solution is an interface, not an implementation.
Ownership:	Open, non-proprietary interface
Applicability:	DER technology and vendor agnostic
Interface Functions:	Included registration of devices and locational awareness of resources, communication of events/prices to provide grid services

3.3 How Were the Challenge Solutions Different?

The three teams had some variation in their approach and the functionality of their Challenge solutions (Table 2). For example, the ESI Server team started with a clean slate and built their interface from the ground up. Meanwhile, OpenDEM started with OpenADR and openDSRIP used and normalized several demand response (DR) / DER standards.

Table 2: Differences in Plug and Play DER Challenge Solutions

	Open Distributed Energy Management (OpenDEM)	ESI Server	Open Demand Side Resource Integration Platform (openDSRIP)
Where did you begin?	Leveraged and extended an existing DR/DER standard (OpenADR)	Developed a clean slate specification leveraging existing ICT standards	Used and extended existing DR/DER standards
Level of interface connecting to…	Aggregator, facility or specific DER	DER facility to interfacing party with external responsibility (e.g., aggregator or utility)	DER facility to interfacing party with external responsibility (e.g., aggregator or utility)
Solution focus on…	Auto-enrollment, auto-discovery, and locational awareness, cyber security	Self-registration process, plus the four dimensions of time, location, energy and money, backwards compatibility, cyber security	Time and rates, customer data privacy; utility customer program focus; demand-flexibility scenario, identity management, and cyber security.

4.0 Insights and Lessons Learned

Interoperability is a difficult topic and demonstrating interoperability in action is like watching a commuter train run on time. When it works, things proceed naturally and as expected; when it does not work, people are frustrated. The Challenge tasked teams to demonstrate advanced interoperability capabilities. Each group produced an interface specification that allowed different types of DERs to integrate with features beyond what is found in existing standards. Examples included location awareness, discovery mechanisms, ease of registration, and support for the evolution of the interface specification itself. While their successes brought greater visibility to interoperability concepts, communicating the tangible benefits and an appreciation for their advancement remains difficult.

An important objective of the Challenge was to engage industry to pursue activities to advance interoperability. Separating the Challenge into a concept phase and a demonstration phase worked well. The concept phase allowed interested parties to become familiar with the objectives and designs of the Challenge, and offered opportunities for clarification, feedback, and iteration. An early point of confusion, with nearly all the proposals, was the inclusion of implementation platforms despite the Challenge focusing on the development of an interface. To be clear, a platform is a group of technologies that are used as a base upon which applications are implemented; whereas, an interface is a shared connection point across which two or more separate components of a system exchange information.

While platforms are important for deploying DER coordination systems, this issue proved that clear interface specifications, supported by different platforms, create important points of demarcation. This helps connect interactions between different platforms or modularize aspects of the same platform supporting the ultimate goal of having different devices and different platforms, produced by different vendors all being able to coordinate.

One of the greatest successes of the concepts phase was allowing different parties to discuss their ideas and offer teaming opportunities. The distillation of many initial draft proposals to three solid concept papers created a manageable demonstration phase. The demonstration phase allowed team members to get to know each other, appreciate their ideas, and hopefully will lead to continued efforts to move the best ideas into standards and practice.

Despite the difficulty of communicating about interoperability, publicity remained an important objective of the partners and participants. Webinars, papers, announcements, blogs, conference presentations, and the demonstration event itself increased appreciation of interoperability, and created a greater audience for the concepts and future work. The result has been an increased appreciation for gathering relevant stakeholders to prototype integration approaches, work with standards development organizations to create and enhance standards, and move these standards into full-scale practice.

5.0 Next Steps to Launch Plug and Play DER Into the Future

DERs are transforming the power grid and animating the consumer energy experience. By developing innovative approaches to enable these technologies to work together at scale with the grid and other energy management technologies, we can create broadly shared economic, environmental, and quality of life improvements. To capture these benefits, the energy industry needs to continue to focus on making DER integration simple and reliable by following these principles:

Core Principles:

- Focus on the **interface**, where systems connect
- Establish **community** agreement on requirements
- Develop **processes** that improve the integration experience
- Codify quality technology **standards**

The Plug and Play DER Challenge succeeded in raising industry awareness beyond single DER silos as well as interoperability more generally, including the demonstrated visionary solutions of interoperability. The following steps will continue this momentum.

Four Key Actions:

1. **Define common, high-value use cases.**
   Work with industry and Challenge participants to identify ESI use cases that provide significant value. This is happening as part of the Smart Electric Power Alliance (SEPA) Energy Services Interface (ESI) Task Force. We encourage individuals and organizations interested in this topic to join the ESI Task Force.

Simultaneously, SEPA and the National Institute of Standards and Technology are working with industry partners to define interoperability implementation profiles based on existing standards to achieve interoperability and desired functionality. This is part of the SEPA Testing and Certification Working Group effort being deployed through the SEPA Interoperability Profile Task Force. A sample work stream as envisioned by the task force would start with a standard like OpenADR, extend this standard to include ESI functionality, and then deliver an EV fleet charging solution. We encourage individuals and organizations interested in this topic to join the Interoperability Profile Task Force.

2. **Design an interoperability demonstration with multiple "reference" implementations supporting the same ESI specification.**
   This demonstration would have different implementers use the same specification in the high-value use cases outlined above. The similarity and differences in the "reference" implementations would provide useful insight into the ESI specification.

3. **Work toward standardization of an ESI specification with a standards development organization.**
   Items #1 and #2 above can be used as references or information for standardization work. Likely this would augment one or more existing standards that could be tested and then supported by a greater community.

4. **Launch the GMLC Grid Services, Energy Services Interfaces & Grid Connected Devices Project.**
   To support and facilitate the advancement of the ESI concept and standardization efforts in Item #3, a new US Department of Energy GMLC project will work with industry through SEPA and relevant venues to define a common framework to represent grid services and develop a standard ESI specification to simplify DER integration.

Appendix A: Terms

- **Application Programming Interface (API)** is an interface or communication protocol between different parts of a computer program or between different devices to simplify the implementation and maintenance of software.
- **Behind the Meter (BTM)** refers to an energy device's position in relation to the site's electric meter. A BTM device is on the customer side of the meter.
- **Bring Your Own Device (BYOD)** refers to utility and non-utility programs that encourage customers to buy their own pre-approved devices from a vendor of their choosing (rather than the program providing the device). Customers can enroll the devices into demand response or energy efficiency programs managed through the utility, an energy supplier or a third-party systems integrator.
- **Distributed Energy Resources (DER)** are physical assets (responsive generation, storage, and load) deployed at the distribution grid level, usually behind the meter. They can be used to provide value to the grid, customers, or both.
- **Distributed Network Protocol 3 (DNP3)** is a set of communications protocols used between components in process automation systems.
- **Data Distribution Service (DDS)** for real-time systems is an Object Management Group (OMG) machine-to-machine (sometimes called middleware or connectivity framework) standard to enable dependable, high-performance, interoperable, real-time, scalable data exchanges using a publish–subscribe pattern.
- **Energy Services Interface (ESI)** is a bi-directional, service-oriented, logical interface that supports the secure communication of information between entities inside and entities outside of a customer boundary to facilitate various energy interactions between electrical loads, storage, and generation within customer facilities and external entities.
- **Extensible Markup Language (XML)** is a markup language (data interchange format) that defines a set of rules for encoding documents in a format that is both human-readable and machine-readable.
- **gRPC Remote Procedure Calls (gRPC)** is an open source remote procedure call (RPC) system initially developed at Google. It uses HTTP/2 for transport, Protocol Buffers as the interface description language.
- **IEEE 2030.5** - Standard for Smart Energy Profile Application - defines an application profile for an interface between the smart grid and DER. The application layer protocol includes demand response, load control, time of day pricing, management of distributed generation, electric vehicle charging, and more.
- **Interoperability Maturity Model (IMM)** is a tool to articulate a baseline level of interoperability and to identify the gaps and priority aspects to consider for evolving toward higher levels of interoperability maturity.
- **JavaScript Object Notation (JSON)** a lightweight data-interchange format.
- **Open Automated Demand Response (OpenADR)** is a standard protocol for coordinating between grid entities, or the grid and customers. It enables a wide variety of customer interaction models from simple shed commands, to dynamic pricing, to bidding and auction schemes.
- **Open Field Message Bus (OpenFMB)** is a framework, to enable grid edge interoperability and distributed intelligence, and is a North American Energy Standards Board (NAESB) standard.
- **Personally Identifiable Information (PII)** also known as personal information or sensitive personal information is any information relating to identifying a person.

Appendix B: Plug and Play Resources

Overview Resources

- Visit the Plug and Play DER Challenge (plugandplayder.org) and the GMLC Interoperability Project (gmlc.doe.gov/projects/1.2.2) webpages
- Watch Launching Plug and Play DER Into The Future recording (Q4 2019)
- Watch Plug and Play Demonstration Video at North America Smart Energy Week
- Read SEPAPower Blog, Sowing the Seeds of Grid Interoperability. (Q3 2019)
- Download Plug and Play DER Challenge One-Pager. (Q2 2019)
- Watch an overview of the Plug and Play DER concepts in this webinar. (Q1 2019)
- Read Phase 1 Final concepts, available to download. (Q4 2018)
- Read SEPAPower Blog, The Plug and Play DER Challenge: A peek at the next industry game changer rolling out at SPI (Q3 2018)

Technical Resources

- Download the Phase 2 Demonstration Interface Specifications (Q4 2019)
- Watch the Plug and Play DER concepts webinar recording (Q1 2019)
- Download Phase 1 Concept Papers (Q4 2018)

For the history of the challenge

- Download the Plug and Play DER Challenge Call for Concepts, details including submission requirements and the frequently asked questions document. (Q3 2018)
- Watch the Introduction to the Plug and Play DER Challenge Webinar recording and learn about the Concepts Phase requirements for submission and general rules/guidelines. (Q3 2018)
- Read SEPAPower Blog, Smart Ideas Wanted for Grid Modernization (Q3 2018)

Appendix C: Plug and Play DER Challenge Teams

Energy Services Interface Server (ESI Server)

Open Distributed Energy Management (openDEM)

Open Demand Side Resource Integration Platform (openDSRIP)

Appendix D: DER Plug and Play Challenge Partner Organizations and Supporters

This challenge was organized and administered by Pacific Northwest National Laboratory (PNNL) and Lawrence Berkeley National Laboratory (LBNL) for the Department of Energy's Grid Modernization Laboratory Consortium (GMLC), as part of an initiative to improve Interoperability, in collaboration with the Smart Electric Power Alliance (SEPA).

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