The Energy Systems Integration Facility (ESIF): A Smart Power Platform for Product Interoperability Development, Test, and Evaluation

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Abstract

The Energy Systems Integration Facility (ESIF) at the National Renewable Energy Laboratory recently opened and will provide a standards-based and open source platform for the testing and evaluation of multiple vendor's products within a common framework or system for the home or small building environment. The platform is based on new international standards: ISO/IEC 15045-2 "Gateway", and ISO/IEC 18012-2 "Guidelines for product interoperability". The expandable modular architecture of the gateway system will support interfaces to any communication network that might be found in homes and buildings and will provide a platform for application services that use such networks. The new platform will include an expanding open source library and registry of client network protocol stacks and interface code. It will also include an open source library of basic application objects and object types for developers wishing to code modular test or service apps using the platform and its resources. A goal of the ESIF is to enable and foster the growth of an ecosystem of interoperable in-home devices and software applications to support distributed renewable energy use, generation, and storage within homes and small buildings. Typical devices/applications might include solar PV systems, smart inverters, smart appliances, energy management systems, smart thermostats, smart batteries, micro-turbines, metering devices, and electric cars.

1. INTRODUCTION

The National Renewable Energy Laboratory (NREL), part of the U.S. Department of Energy (DOE), has established the Energy Systems Integration Facility (ESIF) where scientists and engineers will research and test integrated energy systems, devices, and concepts for electric supply and demand systems. One of the purposes of this research is to overcome challenges related to the interconnection of distributed energy systems and the integration of renewable energy into the electricity grid.

This paper describes a specific standards-based hardware/software platform that will be implemented within the ESIF Smart Power Laboratory to enable the development, testing, and evaluation of premises-based energy systems and equipment. The focus of the platform will be facilitation of the commoditization of energy-related appliances as commercial/consumer products and their integration with the local electricity supply grid. The platform is an extension of DOE-funded research presently continuing by Evolution 7 Labs.

2. BACKGROUND

The ESIF Smart Power Laboratory focuses on the development and integration of smart technologies including the integration of distributed and renewable energy resources through power electronics and smart energy management for home and building applications. The 5,300 sq. ft. laboratory is designed to be highly flexible and configurable, essential for a large variety of smart power applications that range from developing advanced inverters and power converters/conditioners to testing residential and commercial scale appliances, home automation systems, HVAC, lighting controls, energy management systems, meters, and other control technologies. The Smart Power Lab includes four test bays capable of supporting a variety of household appliances. Each bay represents the load of a house and has connections for 120/240 Volt electric service, water, and natural gas.

Typical application services anticipated at the Lab include development of power converters for integration of distributed and renewable energy resources; development of advanced appliances and controls for smart power electronics; testing prototype and commercially available power converters for electrical interconnection and performance, advanced functionality, long duration reliability and safety; and hardware-in-loop development and testing of power electronics systems in smart distribution grid models. From the perspective of the home or building, electric vehicles can be viewed as appliances for the generation, storage, or use of electricity. The NREL Vehicle Test and Integration Facility (VTIF) is also anticipated be engaged as part of the smart power platform described below.

2.1. The challenge of home and building systems

Residential and commercial building energy integration includes the integration of premises-based electricity use, generation, and storage elements. Some of these elements might typically include photovoltaics, windmills, small gas turbines, batteries, heat storage, electric vehicles, smart thermostats, energy management systems—as well as the integration of these individual premises systems with other neighboring systems in a local microgrid configuration. The general purpose of this approach is to take an outward-looking view of the electricity grid from the premises/user level to enable a renewable-based, semi-autonomous, reliable, secure, efficient, and resilient electricity system.

The present market for home and building products appliances is diverse and somewhat chaotic. Historically such systems employ a wide diversity of network protocols, control languages, and functionality. New generations of "smart" appliances are emerging or are anticipated, but they interconnect or communicate using a wide variety of home area networks (HANs) that are generally not interoperable in either their communication protocols or their application services. Efforts over decades to standardize home and building systems have experienced very limited success for a variety of reasons. These include market diversity, regional differences, business strategies, and technological advances. The platform described here directly addresses the above problem of interconnection and interoperability of distributed energy systems and equipment within or associated with homes and small buildings or facilities.

2.2. A standards-based solution

New international standards have recently been developed specifically to achieve interoperability and support application services among virtually all manufacturers products without requiring their modification. The new ISO/IEC gateway and interoperability standards [1], now at publication stage, were specifically developed for the above purpose and initially prototyped and tested in various DOE projects including the "Olympic Peninsula Trial" in 2008 and more currently in the "Pacific Northwest Smart Grid Demonstration Project." The platform described here is a fundamentally new approach to network and product interoperability that will take advantage of these new standards.

3. PREMISES SYSTEMS INTEROPERABILITY PLATFORM

Specifically, the Smart Power Lab will build a standards-based and open source hardware/software platform for the testing and evaluation of multiple vendor's products within a common framework or system for the home or small building environment. The platform is based on new international standards: ISO/IEC 15045-2 Gateway [2], ISO/IEC 18012-2 Guidelines for product interoperability [3], and ISO/IEC 15067-3 Model for energy management [4]. The expandable modular architecture of this gateway system will support interface modules for to any communication network that might be found in homes and buildings and will similarly support modules for application services (i.e., "service agents") that use such networks and resources. The new platform will be supported by an expanding open source library and registry of client network protocol stacks and interface code. The platform will also be supported by an open source library of basic application objects and object types for developers wishing to code modular test or service apps using the platform and its resources.

The gateway platform grew out of research initially sponsored by the U.S. DOE to support the integration of microgrids where electric vehicles, premises systems, distributed solar PV, and renewable power systems converge. It will be further developed and tested within the ESIF facility as a collaborative project with NREL by Evolution7 Labs [5] with the goal of eventual consumer and industrial commercialization.

3.1. The energy management model

A generalized energy management model for homes and buildings, described in ISO/IEC 15067-3 Energy management model for HES, is depicted in figure 1. The basic elements include energy-using devices, energy producing devices, energy storage devices, electricity conversion or conditioning devices, and control and communication devices. The bold lines represent flow of electric power and the dotted lines represent the flow of information.

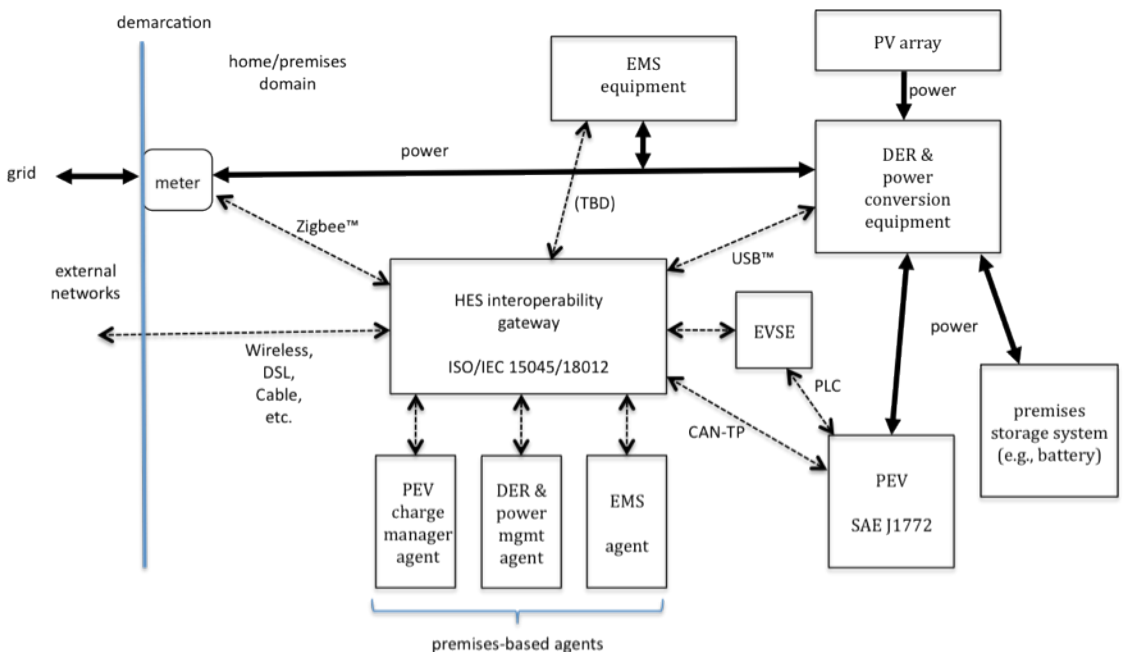

Figure 1 — Premises energy management model

3.1. Gateway platform architecture

The basic physical and logical architecture of the ISO/IEC 15045 HES Gateway platform is depicted in Figure 2.

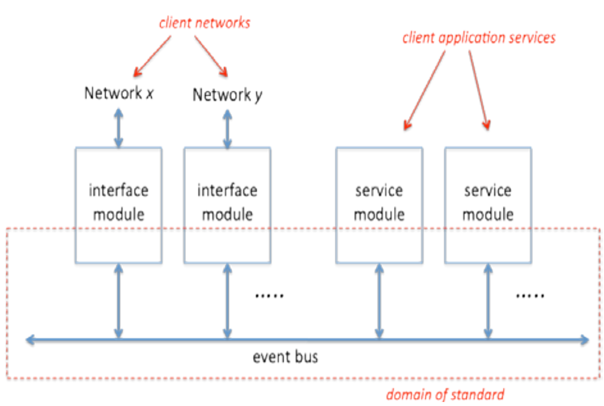

Figure 2 — Gateway platform architecture

The platform consists of an unlimited set of modules interconnected by an event bus. The modules are of two basic types, interface modules or application service modules. The interface modules are specific to a given client network and perform the translation of the client network protocol and application functions into a generic representation or abstract intermediate language that can be transported over the event bus as a message to be shared with other network modules or with appropriate service modules.

3.2. Interoperability architecture

The translation process is performed by a network-specific generic interworking function in each interface module. The ISO/IEC 18012-2 interoperability translation and event bus messaging process is depicted in Figure 3.

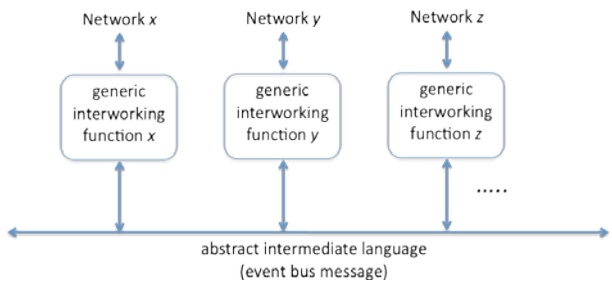

Figure 3 — Interoperability event bus and interworking function

A wide variety of home and building networks, as well as wide area networks can be accommodated by the platform. These include consumer home area network (HAN) devices as well as commercial or industrial products that deal with the common realm of building control functionality. Typical examples of some commonly used client networks are shown in Table 2.

Table 1 — Typical client network interface module examples

Commercial & Industrial LAN/WAN	Home & building/LAN/HAN
BACnet	ZigBee™
LonWorks	SEP 1, SEP 2
Modbus	WiFi™
Ethernet	WiBEEM
CAN bus	HomePlug™
KNX™	KNX™
WSP	Z-Wave™
DSL (many varieties)	Echonet
LR/WPANs	Ethernet
DOCSIS™	UPnP™
GPRS	IGRS™

3.3. Support libraries and registries

The various client network generic interworking functions will be developed in cooperation with specific vendors and standardized in the form of an open source interoperability library. This continually growing library will be available on-line and will include registries of the appropriate client network protocol stacks and the associated generic interworking functions. Likewise, an opens source library and online registry of basic objects and object types will also be created and maintained. These libraries may be created by network equipment manufacturers, appropriate standards bodies or consortia, commercial application vendors, or interested software developers. It is anticipated that the core development environment will use the Java programming language. The Smart Power Lab will also provide support for the development of modular service agents and analytic service applications in cooperation with specific vendors.

4. OPERATIONS

The operations to be carried out by the platform management process include the initial development and ongoing maintenance of the metadata libraries and registries for client networks and for application services.

4.1. Vendor interoperability development and testing process

Vendors of equipment, products, and services for energy systems relevant to the Smart Power Lab will work with lab personnel to develop and maintain appropriate open source libraries and metadata registries for their individual applications. The Lab will host these libraries and provide maintenance and support.

4.2. Other services

As the Lab gains experience, it plans to implement programs for validation and product certification.

5. CONCLUSION

The proposed project will serve an important goal of the ESIF—to enable and foster the growth of an ecosystem of interoperable "plug and play" in-home devices and software applications to support distributed renewable energy use, generation, and storage within homes and small buildings. Typical devices/applications might include solar PV systems, smart inverters, smart appliances, energy management systems, smart thermostats, smart batteries, micro-turbines, metering devices, and electric cars.

It is anticipated that the Lab and its platform can play a significant role in advancing the practical understanding of how to take maximum advantage of distributed energy resources on a highly localized basis and contribute to enabling a new electricity economy. This will include improving grid security, energy security in general and integration of electric vehicles and transportation.

6. REFERENCES

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