Web services for integration of smart houses in the smart grid

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Keywords: Smart grid, smart houses, distributed resources, web services, interoperability

Abstract

Radical changes in the energy system, at the lower network level, will require integration of smart houses in the smart grid in order to realize the full potential. Introduction of renewables, an increase of distributed generation, and the trend towards an all-electric infrastructure lead to an increase in complexity, system management effort and cost that the smart grid should provide an answer for. This calls for houses that are pro-active and flexible participants in the smart grid. The home will no longer be an extension of a utility or energy service provider, but serve as an autonomous building block in a smart grid and determine autonomously how and to whom it will accept from and deliver energy services on the smart grid.

1. INTRODUCTION TO SMART HOUSES

Homes, offices, and commercial buildings have always been treated as isolated passive units (black boxes) connected to the electricity grid. In the last years utilities have recognized the potential of the building environment to be included into their operation. Demand response programs have been initiated, especially in the USA, with promising outcomes. This is, however, only the first step towards building the envisioned smart grid of the future. Introduction of renewables, an increase of distributed generation, and the trend towards an all-electric infrastructure all lead to an increase in complexity, system management effort and cost. These radical changes in the energy system (consider that there have hardly been any changes on the overall architecture the last 100 years), at the lower network level, will require integration of smart houses in the smart grid. Houses need to become pro-active and flexible participants in the electricity trade and infrastructure, as well as service providers for utilities and system operators.

Utilities and system operators can make use of these home-based services by organizing their client base into an intelligent networked collaboration of homes. This organization will heavily rely on Information and Communication Technologies (ICT). Thus, an ICT architecture has to be developed, to effectively take advantage of the latest developments; It has to address interactions both within the smart house as well as between the smart houses, the smart grid and the enterprises. The architecture would allow information to be directly accessed by the interested parties in an event based way. As this information dissemination and exploitation must be done in an open and interoperable way, IP-based technologies and especially service oriented approaches e.g. web services are considered to be promising candidates to interconnect all of the components of this system.

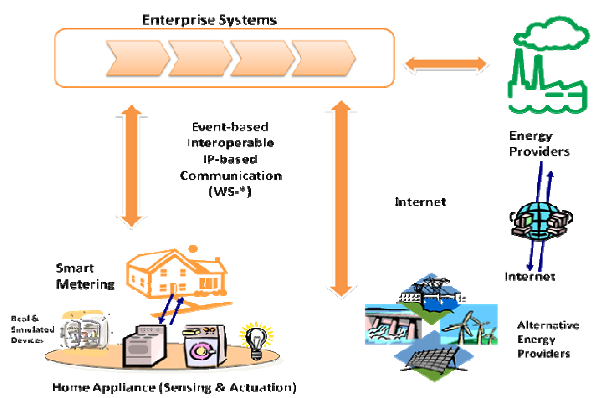

Figure 1 Service-based architecture for smart houses in a smart grid

The contribution of services delivered by smart houses to the business processes of utilities, energy service providers and system operators is part of the ongoing European Commission co-funded research project SmartHouse/SmartGrid [1 - 3]. This project focuses on an ICT architecture for smart houses situated and intelligently managed within a smart grid.

The resulting service-based ICT architecture for smart houses will be tested in three different field tests, supporting a variety of business applications for future smart grids. Variable tariff pricing schemes are an important underlying fundament for all field tests. Furthermore, a main objective is to show that the developed technology will have significant potential for mass application across Europe. This objective can be translated into low entry barriers regarding adoption and diffusion of the technology. As a result, it could create a solid business case for energy utilities, energy service providers, system operators, and participating households to adopt the ICT-enabled energy-efficiency technology.

2. A SOA-BASED APPROACH: WEB SERVICES

The current market for control networks is characterized by proprietary protocols that lack the ability to communicate and interoperate. The Internet Protocol (IP) has been identified as a potential solution for standardized communication. We understand that several other protocols are applicable and may be used. However, we expect that at some level (e.g. gateway level) IP will be the common denominator, especially when connecting to enterprise services. Additionally, within SmartHouse/SmartGrid, we have recognized that a service oriented approach in conjunction with an event based infrastructure is the way to go. As such, we have decided to experiment with web services in order to ease interoperation. For device interaction several technologies will be investigated, including web services on devices (e.g. DPWS), REST and BEMI.

The World Wide Web Consortium (W3C) describes a web service as a software system designed to support interoperable machine-to-machine interaction over a network. Web service architectures have a number of characteristics that can be seen as advantageous for building open systems. Different components may vary in design and run on separate platforms. Web services allow numerous vendors to interact with each other based on high-level standards. Also, services can support a multitude of different applications. Also a service component acts as an autonomous entity. Thus services delivered by smart houses can enforce customer autonomy and even device autonomy. The power of control is with the end-user, while devices remain responsible for local issues such as security. This enhances acceptability and is also easier to implement from a legal perspective.

The use of web services requires the definition of a common ontology [5] that can be used as a basis for a model for description of web services as provided by the Web Service Description Language (WSDL). For the smart grid, existing models may be useful as a starting point, such as the IEC 61970/IEC 618968 Common Information Model (CIM).

Traditionally, one tends to consider services as being delivered by large companies and hence, service oriented architectures tend to focus on enterprise platforms. If the above described paradigm shift becomes reality, and smart houses become service providers in the smart grid, different needs will arise in the development of architectures aiming at restricted resources with a thin footprint. Already, a number of initiatives propagate web services at the device level, and their coupling with enterprise systems [6]. This aim is also supported by the IPSO alliance, promoting IP as a protocol for Smart Objects, creating the "*Internet of Things*" [7]. At the device level itself, the Device Profile for Web Services, DPWS, defines a minimal set of implementation constraints to enable secure Web Service messaging, discovery, description, and eventing on resource-constrained devices. This has already been evaluated for the smart meters [14].

The WS-DD OASIS Standard (which incorporates the original DPWS) was approved as recently as June 2009 [8]. Also, industries are working on support for the IP protocol for wireless communication standards for home automation, such as ZigBee and Z-Wave. Internet Protocol version 6 (IPv6, the next-generation Internet Protocol) and its embedded version i.e. IETF standard 6LoWPAN (IPv6, low-power, and wireless personal-area networks) is in progress [9], while others, e.g. the ZigBee alliance, are working towards providing integrating IP standards.

3. SMART HOUSE BUSINESS CASES

The creation of an open, web service based environment should not only meet today's needs, but should support new types of business in future smart grids as well. As a guideline for new products and services, Figure 2 will be used. This figure describes the relation between the technical measures that may emerge in the smart grid and seven impact categories. These technical measures, which need to be translated to business applications, are described below:

End User Feedback: Aims at an interface to the end user in order to give feedback on his/her energy behavior and the availability of locally generated clean electricity. It is important to be able to monitor energy usage and increase the awareness of end users by offering tailored information on usage patterns and suggestions on how to further lower consumption. Feedback may encourage the end-user to shift part of their electricity consumption towards periods when locally produced clean electricity is highly available. Experiences with small-scale tests show a potential for this type of feedback [10].

Automated Decentralized Control of Distributed Generation and Demand Response: Aims at a better local match between demand and supply, customer acceptance of management strategies, a more effective reaction to near-real time changes at the electricity market level (e.g. due to fluctuations in large-scale wind energy production) and with grid operations (e.g. for congestion management and reserve capacity operations). Balancing demand and supply requires

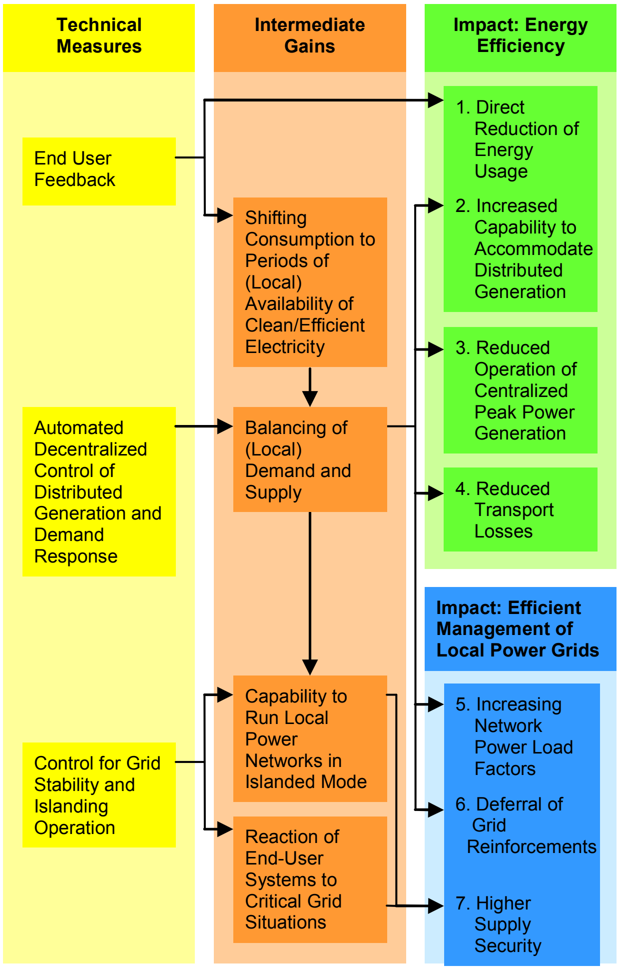

Figure 2 Technical measures impact energy efficiency and efficient network management.

multiple solutions at different time frames. Optimized scheduling of devices based on variable electricity prices will support the day ahead and intraday load scheduling of utilities. As a show case, the Bidirectional Energy Management Interface (BEMI) technology [11], as developed by Fraunhofer IWES in Germany (formerly known as ISET e.V.), is utilized. Reaction to near-real time changes at the electricity market level and grid operation requires control of devices based on real-time events in the system. Here, the PowerMatcher technology [12] as developed by ECN, The Netherlands, is adopted.

Control for Grid Stability and Islanding Operation: Aims at the delivery of services by smart houses in critical situations, and is used by network operators to maintain or restore stability in (distribution) networks. Here, the particular focus is on the capability to run local power networks in island mode. The transition to the island mode is automatic and neither end users nor the system operator interferes with it. The ICT system manages the energy within the island grid and it is assumed that all nodes within this isolated grid will participate in the system. Reconnection with the upstream network, in order to support black start operation of the main grid, is also considered. As a reference, experiences with the multi-agent platform control system Magic, developed by National Technical University of Athens, are used [13].

In the SmartHouse/SmartGrid project, a number of business cases have been identified based on the technical measures. These business cases are used to get a proper overview of business operations by different actors (trader, retailer, aggregator and system operator) in order to develop an integrated vision of the context of smart houses in a smart grid. New business models, however, also require supporting applications in order to enable business operation. Therefore, the following category is added to the three technical measures in Figure 2.

Smart Grid Business Support: This category contains supporting services that have no impact on the electricity level, but enable new business models. It encompasses management and control of components and services as offered by networked collaboration of households, and includes data collection for variable tariff based billing.

4. SERVICES DELIVERED BY SMART HOUSES

Designing a service-oriented architecture for smart houses requires a mind shift from integration to interoperation. Integration requires putting several concepts together into one overall system. If not done in an open way, this might lead to restricted degrees of freedom and can hardly accommodate new developments. Take for example an environment that allows smart houses to place demand or supply bids in a market. If a utility integrates this 'client' bidding process into its own proprietary system, it would make it difficult for the client to switch to another utility, or for the Distribution System Operator (DSO) to make use of the information contained in these bids. Standard compliance, focusing on the functionality and not just simple integration can help avoid the vendor-lock.

A preferable model is based on differentiation between responsibilities. Device manufacturers should be responsible for the device. Service providers (a role that partially may be assumed also by specific device manufacturers) should embed services for creation of a bidding function and reception of market prices. Utilities and DSOs can be made responsible for a correct handling of bidding functions. Devices and utilities/DSOs can interoperate to exchange the bid functions and the resulting market outcome. Interoperability requires development of an ontology for the smart grid domain, i.e. a language that is understood by all actors. Web service standards provide the syntax for this language.

Furthermore, interoperation must be extended to the level that solutions are found for conflict of interest between market parties who want to make use of the same smart house services. If the smart house receives different incentives from various parties, and the household decides to follow one incentive, financial remuneration should reflect this choice, but security of supply should not be incriminated.

In view of the above, the focus for identification of services is not separate from the respective business cases. The design done using a service based architecture focuses on the identification of responsibilities and collaborations across business applications. Therefore, a classification is made based on high-level functionalities:

System management: This functionality contains all functionality regarding management of services (repository services; registry & discovery), components (configuration) and customers (customer care).

Monitoring: Describes monitoring of components and services and the management of key performance indicators.

Eventing: Outlines creation and handling of system events.

System-wide / location-based information: Provisioning of historical information on load flows and market behavior; forecasts regarding climate, market and load flows, including load forecast from renewable sources.

Market-based planning and control: Handling of price incentives and bid functions, including market based scheduling of devices and real-time operation.

Device Management: Management (control, configuration and monitoring) of all device responsibilities: delivering status information; creating bid functions; handling control commands (incentives).

Metering & Billing: This functionality encompasses automated meter reading and tariff rating combining variable tariff based market control and customer contracts.

In SmartHouse/SmartGrid project ongoing work [2], we list some initial services and their descriptions according to this classification. They are based on the analysis of use cases derived from a set of business applications. As a next step, some of the business applications will be built, and rolled out in three different European field trials. The field tests will focus on the technical measures as depicted in Figure 2, and include mass scale handling of variable tariff metering data. The field trials will deliver proof of concept and evaluate a web service architecture that realizes the interaction of smart houses in the smart grid.

5. CONCLUSIONS

We have identified a trend where intelligence becomes distributed in the electricity network, creating a visionary dynamic and collaborative infrastructure namely the smart grid: smart houses will make use of communication, interaction and negotiation with energy devices, other smart houses, the network operator and energy service companies in their strive for optimal energy usage and cost reduction. Web services provide a common framework that allows data to be shared and reused across applications, enterprises, and community boundaries. They enable the creation of architectures that reflect components' tendency toward autonomy and heterogeneity. Therefore, the concept of service oriented architectures is well suited for the future smart grid. However, a paradigm shift is needed. Enterprises no longer are the only providers of services, but customers become active parties, offering their own services to each other and to enterprises, effectively creating a highly dynamic collaborative ecosystem. Based on local autonomy and internal goals the household determines whether or not an energy service is offered and executes its own control in interaction with external parties.

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Acknowledgements

This work presented in this paper was partly funded by the EU (Grant no.: FP7-ICT-2007-224628), project SmartHouse / SmartGrid [2].

Biography

Cor Warmer and Koen Kok have a long-time experience in research at ECN in intelligent energy grids. Current research focus is on intelligent distributed control mechanisms for electricity grids with a high penetration of distributed generation. Together with colleagues they have developed the PowerMatcher technology, a distributed energy systems architecture, software system, and communication protocol that enables coordinated operation of small electricity producing or consuming devices based on economical value.

Stamatis Karnouskos and Anke Weidlich work for SAP R&D. Anke works on enterprise systems for future energy utilities. Stamatis' research aims at designing and implementing secure open communication infrastructures. He investigates the challenges and benefits that networked embedded devices bring in complex dynamic enterprise systems.

David Nestle is the scientific coordinator and manager of the group “Decentralized Energy Management” at Fraunhofer IWES. This group develops the Bidirectional Energy Management Interface (ISET-*BEMI+*®) for optimizing the operation of locally connected, manageable DER according to variable tariffs. Research areas of Jan Ringelstein and Patrick Selzam concern BEMI hard- and software development, distribution grid services and business cases.

Aris Dimeas is currently researcher at the Electrical and Computer Engineering School of NTUA. His research interests include dispersed generation, artificial intelligence techniques in power systems.

After some 10 years of R&D Stefan Drenkard is involved in renewable as well as fossil-fired energy projects since 15 years, including CHP focusing on technology development and environmental impact mitigation.