IMPACT OF INTERNET OF THINGS AND CLOUD COMPUTING TO SMART GRID

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Abstract*: The grid of most countries is set up to be centrally controlled, but in last decade more researches explores solutions to gradual reorganization the power system to resemble the Internet. In this paper we discuss about emergent technologies for smart grids deployment with the focus on middleware for Internet of Things in the Cloud.*

1. INTRODUCTION

The electric utilities have to regulate the grid's frequency and voltage by maintaining a balance between power generation and changing demand, but the grid of most countries is set up to be centrally controlled and is more and more difficult to manage this complex system in the advent of Distributed Energy Resources (DER) and increasing amount of data supplied by recent devices.

If Smart Grid focus on idea of data flow and information management, one of the most important changes in the power systems architecture will be two-way power (and data flow) due to the usage of more renewable sources of energy [1],[2]. Also, a new term "*prosumer*" emphasizes the combination of the terms "producer" and "consumer", and refers to the dual role of an energy entity by being both an energy generator and an energy user [1]. The Smart Grid Dictionary [3] define the term prosumer as "a term coined by Alvin Toffler to describe a producing consumer. From a Smart Grid perspective, it would apply to distributed energy resource situations in which the owner of electricity production or storage assets may also have a consumer relationship with a utility, aggregator, or other energy services provider".

It is considered that Smart Grid relies on the design, development, and deployment of information networks to allow data exchange between devices, applications, consumers and grid operators. For this desire, communication and networking seems to be key technologies for achieving automation and interactivity [4].

In last decade researchers started to explore solutions to gradual reorganization of the power systems so that it resembles the Internet functionalities [5]. Bob Metcalfe, co-inventor of the Ethernet, in his ***Enernet***(Energy-Internet) concept stated that the future power grid should have its own TCP/IP stack of protocols, as well as be highly distributed and asynchronous in nature [6]. In other words, there is a growing interest of taking lessons from the Internet and applying them to the future power grids [7].

2. STANDARDIZATION ACTIVITIES IN SMART GRIDS

There is a considerable effort in the standardisation activity for Smart Grids and part of them related with Internet technologies, some examples will be given.

The document RFC6272 [8] provides an overview of the Internet Protocol Suite (IPS) and the key infrastructure protocols that are critical in integrating Smart Grid devices into an IP-based infrastructure.

The Organization for the Advancement of Structured Information Systems (OASIS) is a non-profit consortium that drives the development, convergence and adoption of open standards for the global information society. „OASIS promotes industry consensus and produces worldwide standards for security, Cloud computing, SOA, Web services, the Smart Grid, electronic publishing, emergency management, and other areas.” (OASIS) collaborative energy standards are designed to address information exchange across the smart grid [9] such as Energy Interoperation - an information model for demand response (DR) and distributed energy resource (DER) event information, as well as messages for DR, market interactions, and price quotes.

Open Automated Demand Response (OpenADR) provides a non-proprietary, open standardized DR interface (based on OASIS) that allows electricity providers to communicate DR signals directly to existing customers using a common language and existing communications such as the Internet.

Another examples are IEC61850-a standard for electrical substation automation and inter-substation communication (the abstract data models defined in IEC 61850 can be mapped to a number of protocols running over TCP/IP, support XML and Web Services) or IEC61970 - Common Information Model (CIM) providing a semantic layer in an enterprise architecture. The IEC61499 [10]function blocks architecture is a convenient abstraction for modeling *distributed multi-agent control* system. IEC 62351 is a standard developed for „handling the security of a series of IEC protocols, include authentication of data transfer through digital signatures, ensuring only authenticated access, prevention of eavesdropping, prevention of playback and spoofing, and intrusion detection”.

The European Telecommunications Standards Institute (ETSI), „produces globally-applicable standards for Information and Communications Technologies (ICT), including fixed, mobile, radio, converged, broadcast and internet technologies.” ETSI standards relative to Smart Grids includes Machine-to-Machine communications (M2M); Applicability of M2M architecture to Smart Grid Networks; Impact of Smart Grids on M2M platform; Open Smart Grid Protocol (OSGP) [11].

3. MIDDLEWARES FOR INTERNET OF THINGS

It is commonly agreed that smart grid networks will rely on a wide scale monitoring and sensor infrastructure in addition to the ongoing deployments of smart metering infrastructures [11]. Therefore, there is a global effort to incorporate pervasive sensors, actuators and data networks into national power grids. [12].

The term Internet of Things (IoT) describes a "world in which physical and virtual objects are networked together, enabling them to “talk” to each other to exchange data and services"[13]. As identified by Atzori et.al.[14], Internet of Things can be realized in three paradigms: *things oriented* (sensors, actuators), internet-oriented (*middleware*) and *semantic-oriented* (knowledge).

The idea of abstraction layer – to interoperation of heterogeneous devices with a common protocol is actually a trend in pervasive computing and IoT applications. With the advent of sensor-cloud and sensor-grid architecture, appear the concept of *sensor network virtualization*, where multiple, heterogeneous, wireless sensor networks can be controlled as a single, unified, virtual sensor network [15].

In [16] are identified *Virtual Sensor* (VS) as a software entity serving as “an aggregation point for multiple sensors, using physical sensor entities and a computational model to combine their measurements”, and *Sensor Network Virtualization* as collaborative wireless sensor networks providing the common layer to the interaction of the “Things” with processes and people, rather than just connecting the things. The Knowledge-Aware and Service-Oriented Middleware (KASO Middleware) presented in [17] aims to integrate embedded networks in the future Service Cloud, to provide access to pervasive services related to sensors and actuators. KASO Middleware introduced Perceptual Reasoning Agent (PRA) programming model providing REST services to register, expose and discovery, composition and orchestration of services; the model has been validated through a real healthcare tele-monitoring system.

4. SMART GRID CLOUD APPLICATIONS

The most common cloud computing service models that vendors can offer are Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). By IaaS the physical infrastructure(storage, hardware, servers and networking components) are provided by the vendor, in a scalable manner. The users are responsible for providing and managing the operating system, middleware and application stack. PaaS is a paradigm for delivering operating systems and associated services over the Internet without installation. In SaaS distribution model the applications are hosted by a vendor (service provider) and made available to customers over the Internet.

Applications like Advanced Metering Infrastructure (AMI) Energy management is expected to be available as SaaS model [18]; soon, perhaps will be also, distribution management system (DMS), volt/VAR optimization, outage management, or asset management. General Electric (GE) already offers advanced metering, data management and demand response applications via it's GridIQ Service.

Big Data is the term currently being used to describe the situation a company faces when the size and/or complexity of their data make it difficult for traditional data management technologies to handle. The advent of AMI has increased the level of data collection dramatically. Data set that are terabytes to exabytes in size and come from a range of sources puts the management and analysis beyond the scope of traditional IT tools. In a pilot project [19] meters can provide more than 43,000 data points per customer per month. Distribution automation is another source of Big Data in utilities: real-time monitoring and control requires much more granular readings than those taken by smart meters. A GridSim simulation used a sample rate of 30 samples per second, per sensor [19].

The combination of Cloud Computing and Smart Grid was investigated also in [20]; here it is considered that data processing can be provided as a pure IaaS service. Data processing services can be used for analyzing energy consumption patterns in the area of demand response or forecasting. Demand response is a technology to intelligently switch off devices at peak consumption levels, but can influence the consumption by price corrections. Based on continuous data analysis and grid monitoring, the cloud or service provider can send signals or change customer prices by web services. In contrast to demand response, demand forecasting is not reacting on consumption but predicting the future demand by processing various data like grid control data and consumption data.

Process analytics is the multivariate analysis of a process to develop a statistically based understanding, leading to process improvement and/or optimization. A process analysis can be used to improve understanding of how the process operates, and to determine potential targets for process improvement [12].

High Performance Computing (HPC) applications tend to migrate into the cloud, and obviously SCADA systems can be instances of HPC applications. However, in [21] are identified three styles of power computing: applications with weak requirements, Real-time applications, Applications with strong requirements. Today's cloud is well matched just to first category of applications (by example - applications that maintain maps of the physical infrastructure).

Recently SmartCloud company has developed a technology that unify stream, processing, Semantic Web, and multi-agent architectures - intended to improved the real-time data processing in Big Data environments. The company implemented „first situation awareness system" to monitor power system and alert staffs about emerging situations that could impact reliability. „The system takes real-time data from 30,000 data points and identifies and displays critical trends."

Semantic Web technologies applied for IoT are a fundamental approach in the problem of interoperability of the "things". By linking Semantic Web technologies with sensor networks has emerged Semantic Sensor Web and the main features of it are ontologies. In [22] Context-Aware Sensor Configuration Model (CASCoM) provides context discovery functionalities by using semantic knowledge and fusing raw sensor data. Susel et. al. presented in [23] „a system for ontology alignment in the Semantic Sensor Web which uses fuzzy logic techniques to combine similarity measures between entities of different ontologies."

5. CONCLUSIONS

In this paper we have tried to figure a trend in energy systems in close cooperation with Internet technologies, offering possible directions for multidisciplinary research. Few important arguments presented are standardizations such as IEC61850, IEC61970 or IETF6272 and recent development of the first applications in this field.

The Internet and the Cloud Computing appear to be the natural trend in power grids evolution and first changes have quickly appeared, despite of some compatibility issues.

REFERENCES

1. D. S. Markovic, D. Zivkovic, I. Branovic, R. Popovic, D. Cvetkovic, *Smart power grid and cloud computing*, Renewable and Sustainable Energy Reviews, **24**, pp. 566–577,2013.

2. P.G.D. Silva, S. Karnouskos,D. Ilic, *A survey towards understanding residential prosumers in smart grid neighbourhoods*, Innovative Smart Grid Technologies (ISGT Europe), 2012 3rd IEEE PES International Conference and Exhibition on, vol., no., pp.1-8, 14-17, 2012.

3. C. Hertzog, *Grid resiliency as a social benefit,* 2013, www.smartgridlibrary.com

4. Cisco, *Internet protocol architecture for the Smart Grid*, http://www.cisco.com/, 2009.

5. J. Boyd, *An Internet-inspired electricity grid*, Spectrum, IEEE, Vol.50, Issue 1, pp.12-14, 2013.

6. R. Metcalfe, "*Enernet:Internet Lessons for Solving Energy*," in ConnectivityWeek, Santa Clara, 2009.

7. T. Shibata, *Power routing switches toward energy-on-demand home networking*, ConsumerCommunications and Networking Conference (CCNC),pp. 844-845. IEEE, 2011.

8. RFC6272, *Internet Protocols for the Smart Grid*, IETF, http://tools.ietf.org/html/rfc6272, 2011.

9. D. Holmberg, W. Cox, D. Sturek, *OASIS Collaborative Energy Standards, Facilities, and ZigBee Smart Energy*, Proceedings of 2011 Grid Interop, Phoenix, AZ, Dec 5-8, 2011.

10. G. Zhabelova, V. Vyatkin, *Multi-agent Smart Grid Automation Architecture based on IEC 61850/61499 Intelligent Logical Nodes*, IEEE Transactions on Industrial Electronics, 59(5), pp.2351-2362, 2011.

11. ETSI, *The European Telecommunications Standards Institute*, http://www.etsi.org/

12. Y. Simmhan, S. Aman, A. Kumbhare, R. Liu, S. Stevens, Q. Zhou and V. Prasanna, *Cloud-Based Software Platform for Big Data Analytics in Smart Grids*, Computing in Science and Engineering, vol. 15, no. 4, pp. 38-47, July-Aug., 2013.

13. A. Crapo, R. Piasecki, Xiaofeng Wang, *The Smart Grid as a Semantically Enabled Internet of Things*, Grid-Interop Forum, 2011.

14. L. Atzori, A. Iera, G. Morabito, *The Internet of Things: A survey*, Computer Networks, **54**, pp. 2787 – 2805, 2010.

15. Md. Motaharul Islam, Md. Mehedi Hassan, Ga-Won Lee and Eui-Nam Huh, *A Survey on Virtualization of Wireless Sensor Networks*, Sensors, 12, pp.2175-2207, 2012.

16. A. Merentitis, F. Zeiger, M. Huber, N. Frangiadakis, K. Mathioudakis, K. Sasloglou, et.al., *WSN Trends: Sensor Infrastructure Virtualization as a Driver Towards the Evolution of the Internet of Things*. In UBICOMM 2013, The Seventh International Conference on Mobile Ubiquitous Computing, Systems, Services and Technologies, pp. 113-118, 2013.

17. I. Corredor, J.F. Martínez, and M. S. Familiar, *Bringing pervasive embedded networks to the service cloud: A lightweight middleware approach*. J. Syst. Archit. 57, 10 (November 2011), pp. 916-933, 2011.

18. G. Deshpande, Smart Grid Applications go on Cloud, Technology Trends,2012.

19. J. Deign, C.M. Salazar, *Data management and analytics for utilities*, smartgridupdate.com, 2013.

20. O. Ruf, *The Appliance of Cloud Computing in a Swiss Smart Grid*, master thesis,University of Applied Sciences and Arts Northwestern Switzerland, 2013.

21. K. P. Birman, L.Ganesh, and R. van Renesse. *Running Smart Grid Control Software on Cloud Computing Architectures*, Workshop on Computational Needs for the Next Generation Electric Grid, Cornell University, 2011.

22. M. Compton, P. Barnaghi, L. Bermudez, R. Garca-Castro, O. Corcho, S. Cox, et.al.,"*The SSN ontology of the W3C semantic sensor network incubator group,*" Web Semantics: Science, Services and Agents on the World Wide Web, vol. 17, no. 0, pp. 25 – 32, 2012**.**

23. F. Susel, Ivan Marsa-Maestre, J. R. Velasco, B. Alarcos, "*Ontology Alignment Architecture for Semantic Sensor Web Integration*," Sensors, 13, 12581-12604, 2013.