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Internet of Everything (IoE) in Smart Grid

Abstract: *The paper consists of three parts: the first one briefly presents the history and the main characteristics of Smart Grid (SG), the second is devoted to big data generation, while the third introduces the idea of Internet of Things, Internet of Everything and their role in the whole life cycle of the SG.*

Streszczenie: *Artykuł składa się z trzech części: pierwsza przedstawia krótką historię i główne właściwości sieci inteligentnej, druga poświęcona jest problemowi dużych zbiorów danych, zaś trzecia wprowadza pojęcia: Internet rzeczy , Internet wszystkiego i ich zastosowanie w całym cyklu życia sieci inteligentnej.* ***Internet wszystkiego w sieci inteligentnej)***

Keywords: Internet of Things, Internet of Everything, Big Data, Smart Grids
Słowa kluczowe: Internet rzeczy, Internet wszystkiego, generacja danych, sieci Inteligentne

1. Smart Grid

According to [16] Southern California Edison (SCE), the need to develop a smarter grid was identified more than 20 years ago as a result of several operational power events and issues in the USA, such as blackouts, insufficient transmission capacity, etc. Consequently, the Federal- and State legislation has addressed the need for a smarter grid to support state and environmental policies.

The implementation of this policy requires the following expectations towards the Smart Grid (SG), which represent its key characteristics [10]:

"It is self-healing (from power disturbance events).
- It enables active participation by consumers in demand response.
- It operates resiliently against both physical and cyber attacks.
- It provides quality power that meets the twenty first century needs.
- It accommodates all generation and storage options.
- It enables new products, services and markets.
- It optimizes asset utilization and operating efficiency."

In order to fulfill the above expectations, the SG "involves complementing the grid with millions of smart electronic devices, such as phasor measurement units (PMU), fault indicators, smart meters, electric vehicle chargers, which will send and receive millions of pieces of data per minute to produce actionable information and use this information to enhance the operations and control of the electric system" [16].

The PMUs are installed not only in the grid nodes but, according to [4], also in Power Plants to obtain better (and cheaper) characteristics of generators necessary for designing such grids. Introduction of the Internet Protocol version 6 (IPv6) [7,9] removes the technical limitations of the number of devices that can be connected to the Internet, theoretically allowing for trillions of trillions (10^{38}) growing number of data [7,12].

In 2004, the SCE began to develop a new distribution circuit design named the Circuit of Future, and based on the development and operation of this circuit and additional required elements, a new project entitled the Irvine Smart Grid Demonstration (ISGD) was launched after several years (ISGD). It was expected that it would be introduced in 2013.

Development of the SG idea implied the need to address the following tasks:

1. upgrading the existing grid – to smart distribution grids (SDG),
2. need of the Renewable Energy Sources (RES) utilization,
3. microgrids development and their connection (or not) to the SDG,
4. building new Information Communication System (ICT) enabling two- directional contact Consumer – Retailer,
5. creating a new smart sensor network,
6. building a new Integrated Energy Market.

The SG implies an increase in the number of big data circulating inside the grid and exchanged with the environment. This fact has only been considered in relation with the SG development [16]. In reality the increase in the big data concerns not only other industrial branches, but also scientific disciplines which generate [2], filter and store not only digital- but also analog data, which is sometimes converted to digital. The Big Analog Data can be considered as a subset of the Big Data, however they are of different characteristics, as for the information systems they require digitizing with rates as fast as tens of gigahertz, often at a large bit width. The second difference is more important, as the Big Analog Data information is constantly generated by natural and man-made sources. Physics experiments can generate tens of terabytes in just a few seconds. For instance testing of jet engines or electric power turbines generates similar amounts of data in a matter of hours; The SG measurements can generate terabytes of data over the course of a month, which implies that the "amount of data produced and communicated over the Internet and the Web is growing rapidly. Every day, around 20 quintillion (10^{18}) bytes of data are produced". [3]

The following citation is interesting: "By connecting billions of devices to the Internet each other, and the cloud, businesses can save trillions of dollars each year in operating costs." [1]. The number of connecting devices is growing in the following rates: 2006 – 2 billions, 2015 – 15 billions, 2020 – 50 billions and the data growth by 2015 should reach 90% application thus it is necessary to use new tools for the big data management. It is necessary to remember that inclusion of a device means necessity to use sensors dependent on the device.

2. From Internet of Things (IoT) to Internet of Everything (IoE)

2.1. Basic Considerations

Most publications elaborated in the global scale are devoted to the IoT to facilitate a better understanding of the IoE, and the Author also begins with two of the IoT definitions published in [14]:

*"**Internet of things (IoT):** A global infrastructure for the information society, enabling advanced services by interconnecting (physical or virtual) things based on existing*

interoperable information and communication technologies”[1].

Vermesan and Friess wrote in [14], as well as the IERC stated that the IoT is “*A dynamic global network infrastructure with self-configuring capabilities based on standard and interoperable communication protocols where physical and virtual “things” have identities, physical attributes, and virtual personalities and use intelligent interfaces, and are seamlessly integrated into the information network”.*

The Digital Agenda for Europe [6] has introduced the following explanation: “*Internet of Things (IoT) is a technology and a market development base on the interconnection of everyday objects among themselves and applications. IoT will enable an ecosystem of smart applications and services, which will improve and simplify EU citizens’ lives.”*

The term: Internet of Things was proposed in 1999 by Ashton Kevin who wrote in 22 June 2009: “The Internet of Things in the real world thinks matter more than ideas” (RFID Journal). The IoT idea implied other concepts, such as *Internet of Service (IoS), Internet of Everything (IoE), Web of Things (WoT),* which of course represent the IoT, etc. When we consider the relations *M2M (Man to Man), M2T (Man to Thing), M2P (Man to People), P2P (People to People), and D2D (Device to Device),* we ultimately reach the *IoE (Internet to Everything).* The IoT refers to uniquely identifiable objects and their virtual representation in the Internet structure whereas currently Internet supports human connection only. The IoT idea fascinates scientists, engineers and a number of renowned companies, e.g.: CISCO, Google X, IBM, Intel, and Oracle, which are elaborating necessary software. It results in a growing number of conferences, workshops, seminars; the EU support of the IoT-A projects.

CISCO in [5] collected a list specifying the following steps of development of the IoT:

- “reffered to barcodes and RFID helping to automate inventory, tracking and basic identification,
- currently: strong verve for connecting sensors, objects, devices, data and applications,
- next step called “cognitive IoT” facilitating object and data reuse across application domains, leveraging on hyperconnectivity, interoperaoperability solutions and semantic enriched information distribution, incorporating intelligence at different levels, in the objects, devices, network(s) systems and in the applications for evidence-based decision making and priority setting.”

2.2. Iot Application Areas

According to the bibliography, the IoT may be used in an unlimited application in the field of various areas of people’s activity, such as health, science, technology, social aspects, etc. Examples of more detailed areas can be found in [14]:

- Smart/Food/Water Monitoring – 9 examples,
- Smart Health – 10 examples,
- Smart Living – 8 examples,
- Smart Environment Monitoring – 7 examples,
- Smart Manufacturing – 7 examples,
- Smart Energy – 6 examples (with SG on top),
- Smart Buildings – 9 examples,
- Smart Transport and Mobility – 10 examples,
- Smart Industry – 10 examples,
- Smart City – 11 examples.

In the bibliography devoted to the IoT, one can find an area of that concept application – the Smart Grid. The SG consisting of electric power networks, grid, and massive number of objects, devices, consumers connected through communication and information infrastructure providing value-added services via intelligent data processing, management of electricity production and delivering the electricity to consumers may be considered as a typical Internet of Everything (IoE) system [11].

What is the reason of the growing importance of the IoT (IoE)? Let us consider a city traffic system with sensors in the main nodes of this city. Let us consider a city traffic system with sensors in the main nodes of the city. Data registered by each sensor are transmitted to a dispatch center, whose decision is then sent back to the sensor; if the sensors in the city are smart, then the information exchange among them may control traffic without the dispatch command (except from dangerous accidents). As a result, we shorten the response time, simultaneously decreasing the number of data.

2.3. IoT Application in Management

CISCO performed simulations to test the result of IoT applications of the future. The results for the following areas were presented:

- Opportunity: $14.4 trillion value (net profit) will be at stake over the next decade, driven by connecting the unconnected P2P, M2P and M2M via IoE (Asset utilization $ 2.5 trillion, Employee productivity $2.5 trillion, Supply chain and logistics $2.7 trillion, Customer experience $3.7 trillion, Innovattion, including reducing time of the entry on the market $3.0 trillion.
- Industry Perspective - Energy companies have the largest IoE value at stake in M2M connection. The third and largest value at stake will be generated by providing an opportunity across all the industries, the smart grid is based on the ability to monitor and manage equipment proactively which is a strong point for energy companies [4]. The IoE provides a new business model for companies, which ultimately implies lowering the cost of energy distribution, automate billing and service calls as well as providing proactive response to environmental condition.

2.4. Selected Problems with the IoT Application

Though bibliography on the IoT is expanding it must be remembered that the number of operating systems which use IoT is not too high. The main reasons include:

- The period of developing standards, software, and the lack of experience in designing, installation and operation of the IoT systems.
- Very high investment costs (it has to be remembered that if the IoT is not used, it will also be necessary to spend a huge amount of money as the existing HV networks need the complete reconstruction in Smart Grid).
- According to T. Kellog [8], “HTTP used in old Internet request requires a minimum of nine TCP packets, and even more if we consider packet loss due to poor connectivity; plain text headers can get very verbose, without delivering guarantee and with overhead of energy consuming. As a typical enterprise arrangement will have thousands or millions of sensors using HTTP is no sense and sending telemetrics to a handful of servers that split up the task of processing the data is necessary”.
- According to [14], “today:

Sending 100 bits of data consumes about 5 μJ,
Measuring acceleration consumes about 50 μJ,
Making a complete measurement: measure + conversion + emission consume 250-500 μJ.

[1] *NOTE 1 – Through the exploitation of identification, data capture, processing and communication capabilities, the IoT makes full use of things to offer services to all kinds of applications, whilst ensuring that security and privacy requirements are fulfilled.*
NOTE 2 – From a broader perspective, the IoT can be perceived as a vision with technological and societal implications.

Therefore, with 100 µW harvested continuously, it is possible to carry out a complete measurement every 1-10 one can find very interesting calculations devoted to harvesting energy of autonomous wireless sensor consisting of the harvesting energy transducer, energy processing seconds."

It has to be remembered that depending on the type of measured parameter/process the above calculation may provide different values.

In [11], synchronizing Phasor Measurement Units as a possible area of IoT application has been considered. A very similar proposal of the IoT application is presented.[2]

3. Final Remarks

The development of the Smart Grids is in its early stages and it is an expensive process which requires application of solutions assuring lower operational costs. The IoT applications in the whole life cycle of the SG represent one of the possible solutions.

In the Author's opinion, it is worth applying direct current in low smart distribution grids and in smart buildings. This will eliminate number of AC/DC and DC/AC transformations [17].

Abbreviations:
IBSG – CISCO Internet Solution Group
PE – IEEE Power & Energy

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