Intelligent Tools for Electrical Energy Domain in Smart City

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***Abstract*— More technological tools that can improve energy efficiency are being used. The generation, transmission, and energy distribution undoubtedly needs management equipment. This article is an effort to expose information acquisition technologies, local service, communications, and service platform. In addition, it explains how artificial intelligence, the Internet of Things and ontology, help to master energy to improve its supervision and thus increase energy efficiency in cities. Developers and engineers in the electricity sector need to know what the new tools can be used in electrical networks and homes. It is important for smart cities that people involved in the generation and distribution of electric power, know and apply these technologies. The main goal of this paper is to present intelligent tools and their characteristics for the people involved in the energy sector that could use these in energy projects or efficiency energy projects.**

Keywords- Electric; energy; intelligent tools; artificial intelligence; communications; ontology.

I. INTRODUCTION

Many technologies have been developed to improve the lifestyle in cities. Technological advance in electronics generate better tools to increase energy efficiency in cities each year. All these electronic devices are connected to the Internet or intranet, where computers store information and organize thousands of data of energy consumption. However, technology has taken another step with artificial intelligence (AI), where computers process information and make decisions. Commonly, when people think in AI, they imagine robots that can speak with humans, make cars, and more recently, help people in physical. But the true development this moment is software, not hardware. Programs are now competent enough that to do jobs that are annoying for humans; for example, in the energy management of electric lines or energy consumption at home, the sensors can communicate in real time and make decisions to solve problems in a few seconds. If the problem is in the electric line and the solution is not possible, the machine sends a signal to the operator to check the fault. That is possible thanks to the communication and the electronic tools that communicate energy data to the computers to build the solutions in real time.

For the energy domain, there are many technical developments to improve management of this sector. One of these is ontology. Ontologies are constructed using appropriate formal languages called ontology languages, based on the logic of first order predicates, frameworks or descriptive logic. According to the literature [1], an ontology language must describe what it clearly means clearly for the machine. Therefore, an ontology language needs to include the ability to specify vocabulary and the means to formally the way it will work to automate reasoning. Especially today, with the fast evolution of the Web and the recent emergence of the Semantic Web, the emphasis is placed on ontology languages suitable for the Internet, which is based on established Web standards. Web ontology languages allow defining different vocabularies, and they are specifically designed to facilitate Web sharing.

Authors in this paper present intelligent tools that help energy users improve energy efficiency. In the first section, the authors talk about the tools in energy domain; in the second section, they speak about the internet of things. The third section is about Artificial Intelligence, the fifth section presents an example of ontology in the energy domain and finally, in the sixth section the conclusions are presented.

II. ICT IN THE ENERGY DOMAIN

Information and Communication Technology (ICT) is one of the key tools for the development of a smart city. The level of the advancement of ICT affects the strategy of planning for the development of smart cities. With ICT, it is possible to have whole digital platforms interconnected that support applications and private and public services. Cities tend toward models that allow reducing the personal and global energy consumption, that support the big imbalance between energy generation capacity and municipal energy consumption [2].

There are many tools that have played a great role in building and developing smart homes and cities. Among these are the internet, wireless networks, and systems such as Wi-Fi, Bluetooth, and Zigbee; Smart Phones including LTE, 3G, 4G, and 5G cell systems; body area sensor networks, smart grids and renewable energy, optical fiber systems and high-speed networks, Internet of Things (IoT),

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wireless sensor networks (WSN), Vehicle Ad Hoc Networks (VANET), global positioning systems (GPS), geographic information systems (GIS), wireless navigation systems, world wide web (WWW), social networks, smart TV, radio frequency ID (RFID), sensor-enabled smart objects, actuators and sensors, cloud computing systems, intelligent transportation systems (ITS), biometric systems, e-based systems including e-commerce, e-government, e-business and e-service systems, network infrastructures, data management systems, analytics. Wireless power transfer (WPT) is used to transfer power over short distances using magnetic fields [3].

Figure 1. Technologies for Smart Cities

Every day, more ICT´s are implicit in our life; smart city devices (SCDs) have increased the influence of technology in our work, friends, and family. As a generic approach, SCDs types are divided into two main groups: reactive and active devices. Reactive devices are dumber devices that only receive some information and acts.

The generic objective of the reactive devices (R-SCDs) is increasing their energy efficiency without sacrificing performance [4]. One difference between reactive devices and active (A-SCDs) is that smarter devices can pursue a complete communication amongst other SCDs and operators.

Nowadays, people need energy for almost all activities in their daily life. SCDs have various elements that can be used in our lives, such as listening to music, talking, playing, shopping, health, financing etc. The apps now are very common, with infinite possibilities to achieve more energy efficiency. There are apps about house energy, car energy that indicate energy consumption and how many calories one's body has burned. This information could be analyzed and processed to improve our energy consumption. SCD´s are possible to use in all energy cycles; when energy reaches a home, many sensors, capacitors, Data logger and other devices are working to obtain the most efficiency possible. The Smart city must use elements, information management and interconnect various platforms that operate locally and autonomously. The layers of smart city models, from the technology point of view, are the following:

A. *Adquisition of information*

The layer of information acquisition uses sensors that receive information from the environment where they are integrated. The local service layer stores and registers the information of sensors with date and hour to transmit to the services platform. In all cases, this layer does not exist because the sensors and actuators are intelligent and are controlled directly by the services platform.

The sensors are elements, which collect information from different types and are transformed into an electric signal that could be sent and proceed. The digital signal only has two possible values or states, all or nothing, for example, 0 V o 24 V. The analog signal has a continuous range of possible values, for example of 0 to 10, equivalent a measurement range of a physic variable, temperature 0 to 100 ºC [2]. Besides, the data readers as detectors that perceive a determinate value. The simple sensors collect one or more measurements must be considered. Complex sensors collect information from a huge number of aspects. Identification sensors allow the identification of an object incorporating information from it. At Industrial level, we can see the example of ENDESA that leading smart meter installation in Spain with over 8 million smart meters, accounting for 72 % of the current fleet of 11.6 million meters [5].

The capture devices of complex data are elements that captured data through cameras or lectors. The actuators are elements that transform a digital or analog signal through data bus in one action there. Exists all or nothing actuators of the digital signal, as relays or contactors, that allow, for example, the turning on or turning off a group of lamps. The regulation actuators of the analog signal generate one analog outlet, which allows moderating the light level. Many of these sensors and actuators can be consulted and active through the Internet, each grid used their own standards, protocols, and formats of data representation. This is a problem when it wants to homogenize a solution, that is why it is important to try to open standards or have one platform that help to manage and interconnect these heterogeneous devices.

B. *Local Service*

There exists equipment that collects the signals of the sensors or detectors and sends the orders to actuators located in the installation. It also reports the information recollected from the sensors to the services' platform and receives orders from this. The number of sensors that are controlled by the equipment comes from digital inputs for the detectors and analogue inputs for the analog sensors. In Figure 2, we can see the basic structure of interconnection of these control elements.

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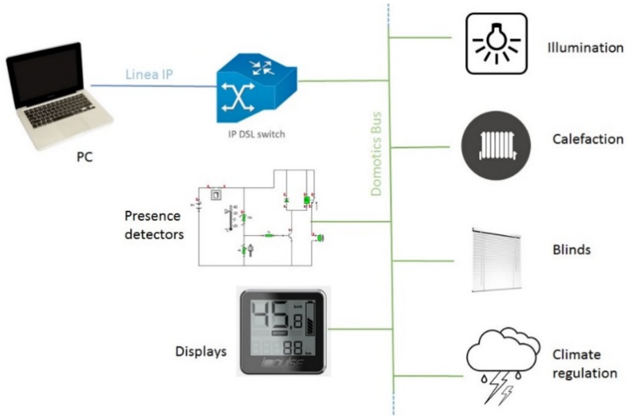

Figure 2. Control Elements

The principal equipment in the local service is the Data logger, which is a device that stores information for the sensors and detectors, with the date and the hour when it has been produced. The Data logger does not receive orders neither signals for realizing functions of actuation, but only gives information to the service platform. However, there exists programmable automata that functions with specific programming. This type of equipment gives to the smart city the advantage of the flexibility, being able to adapt the individual form to the needs of each installation.

C. Communications

The transmission information layer is the infrastructure of communications that sends and receives necessary data for the application of global service. With the communication networks, the interconnection of the energy domain is possible and facility the collection of data through sensors for its later treatment and makes decisions. The networks implicated are very heterogeneous, the interoperability and transparency are very important. To support information collection, distribution, automated control and optimization of the power system, the smart grid communication system will rely on two major subsystems: a communication infrastructure and a middleware platform. The communication infrastructure consists of a set of communication technologies, networks, and protocols that support communication connectivity among devices or grid sub-systems and enables the distribution of information and commands within the power system. Basic requirements for such communication infrastructure are scalability, reliability, timeliness, and security. The middleware platform consists of a software layer, which is situated between the applications and the underlying communication infrastructure, providing the services needed to build efficient distributed functions and systems. A middleware runs on the devices that are part of the smart grid communication infrastructure. It supports data management services for example data sharing, storage, and processing, standard communication and programming interfaces for distributed applications and computational intelligence and autonomic management capabilities [6].

The storage and analysis of the information layer is where all data are stored and also where it takes place the process for the analytic system to improve the management platform of the different services. The storage, in some cases of long duration, as the capacity of the process, allows the huge volumes of information generated for the grids of sensors and control equipment. As Guelzim says "Smart homes and cities will rely on the Internet of Things (IoT) devices, sensors, RFID chips, and smart electric meters, among others, to provide added value services to citizens and homeowners. However, these devices generate a large amount of data, big data, data sets, which are so big that traditional data processing techniques are not adequate to manage them" [7].

The technique known as Big Data allows adding the information flows that come to the huge sensor network of the city, convert it to useful and apply knowledge to make decisions of management of the smart city services. Big Data is a term, which design growth the availability and the exponential uses of structured and disorganized information. A definition of Big Data could be "Big Data is not about size, but it's about granularity". The ability of software systems to identify individuals and personalized data is the ironic implication of "Big". It is the ability to focus on the minutiae of the individual, in real time [1]. Data are fundamental in all service in the framework of the smart city. The data management is a complex job because normally they are consumed in real time, are diverse and present different formats. A tentative estimation of the amount of digital information produced by mankind is 280 EB of data [8].

D. Service Platform

Finally, the services' platform is the principal platform in the smart city domain, which is formed by various modules and management platforms and have interfaces with the final user. This platform offers a set of common modules to the multiple service and allows the operators to have a better and efficient service. The platform receives the processed information and interprets them, then it performs the actions according to the service of their destination. In the whole process, ICT increase the efficiency of the application of the generation, distribution, and energy consumption. Also, the control center could process the information and give to humans the possible failures solutions. With this technology, now the computers not only send and store information, also process the information. This implies guarantee of the interoperability at different levels; in hardware, the sensors, capacitors and data logger will be connected inwardly, and in software, the communication protocols, data structure and semantic will connect.

When talking about energy efficiency in smart cities it is important to talk about the ICT tools standardization, that allow increasing the security and clarity of energy sector,

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through of the contribution and information in real time between installations and the users. On the other hand, it encourages the multidirectional communication amongst different persons that influence in the energy consumption of the installation and the buildings. The main challenges of the future applications of SCD networks in smart cities can be listed as follows: lack of central control that has a complete information about the topology, integration and application simplicity, excessive amounts of system need, compatibility between SCDs and networks. To overcome these challenges, software-centered control structures need to be developed [9].

III. INTERNET OF THINGS

As utilities seek to modernize their grid infrastructure and day-to-day operations and services, enabled technologies are gaining increasing importance in enabling digitization and delivery of new energy models. The IoT is one of the major technologies that will shape the future of the digital world including Smart World, and Smart Cities and Homes. It is a mesh network of physical objects that either exchange data in P2P mode or communicate and relay information with the service provider [10].

There are many connected objects today such as electronic appliances, laptops, cameras, meeting, news as can see in Figure 3 that rely on RFID technology. IoT objects can be sensed and controlled across local area network or wide area networks.

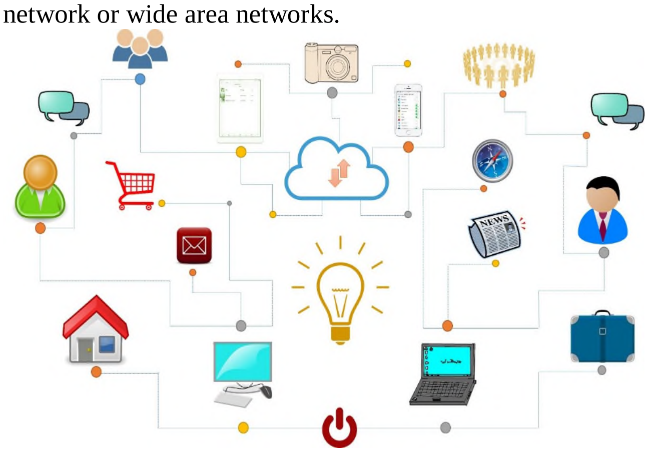

Figure 3. Internet of Things

This allows the creation of many products and opportunities to better integrate the physical infrastructure with the digital systems. Many experts expect >10 billion IoT objects by year 2020 [7]. Big industry players such as Microsoft, IBM, Cisco, Siemens, and Google already play an important role in helping draft and put in place such technologies by offering cloud-based IoT services and devices.

IV. ARTIFICIAL INTELLIGENCE

A step forward is using artificial intelligence (AI) to improve saving and efficiency energy. With AI, citizen can delegate the decision to improve efficiency to the computer. At the home level, computers can take the decision about the information of the Smart energy management system (SEMS). When SEMS detect a high consumption at night at home, the system could turn off a home appliance that is guilty of the excess. The computer could also turn on the home appliances when the cost of energy is low, for example, the washing machine could be turned on at night.

As the authors said, the energy domain needs the optimization of the resources, this achieves with the measurement, monitoring of the grids and the used energy analysis at buildings. Besides, with the concept of the green city, a city without greenhouses gases, with green transport, green buildings, include more variables to consider. This creates serious limitations when it comes to analyzing the data, especially if the analysis requires data from different fields, for example: technical, political, social, economic, environmental [11]. On the other hand, the difficulties of accessing multiple data sources and integrating them into a unified data model increases in the case of large volumes of data stored in data sources that support the models. Data describing the characteristics of similar articles using different standardization systems, different units of measurement applied [12]. As Keirstead said, it requires a systemic approach to understand “The combined process of acquisition and use of energy to meet the demands of a given urban area” by means of an urban energy system model, i.e., "a formal system that represents the combined processes of energy acquisition and used to meet the demand for energy services” [13].

Because of these difficulties, many researchers are using ontology to facilitate the interoperability between data model, which have been constructed by different experts from several domains using multiple techniques [14]. The Ontology is a taxonomy of concepts with attributes and relationships that provide a consensual vocabulary to defining semantic networks of units of information. Specifically, it is formed by a taxonomy that relates concepts and by a set of axioms or rules of inference, through which new knowledge can be inferred [15]. In the field of urban energetic systems, a shared ontology could facilitate the interoperability between data models building for different experts of various domains that use multiple techniques. There are various examples where are ontologies used. In the SEMANCO project for example, the semantics technologies have used standard tables to create models of urban energy systems, capable to evaluate the energy efficiency of urban zone. A semantic energy information framework brings together data sources at different scales and from different domains [16]. Another developed ontology with a similar objective is DogOnt [17], which aims to represent the different forms of energy production, depending on the construction, the number of occupants living in it, the devices, etc. DogOnt offers the ability to describe the location and capabilities of a home automation device and its possible configurations, device/network support, description of houses

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independently, including architectural elements. Another example is SynCity (short for "Synthetic City"), a platform for modeling urban energy systems [13]. The SynCity Urban Energy Systems (UES) ontology serves primarily as a library of domain-specific components, consisting of a series of object classes that describe the main elements of an urban energy system and specific cases of these classes.

V. THE ENERGY ONTOLOGY

The Energy Ontology (EO), shown in Figure 4, provides a flexible and extensible structure for modeling information about energy consumption, generation and storage, able to combine easy usage with the possibility to provide detailed descriptions. The ontology introduces a basic set of properties and classes to encode the most common energetic information used for system energy management that can be easily further extended using more specialized subclasses. The capability of OWL language can be also exploited to link EO with other ontology as ELM/OWL.

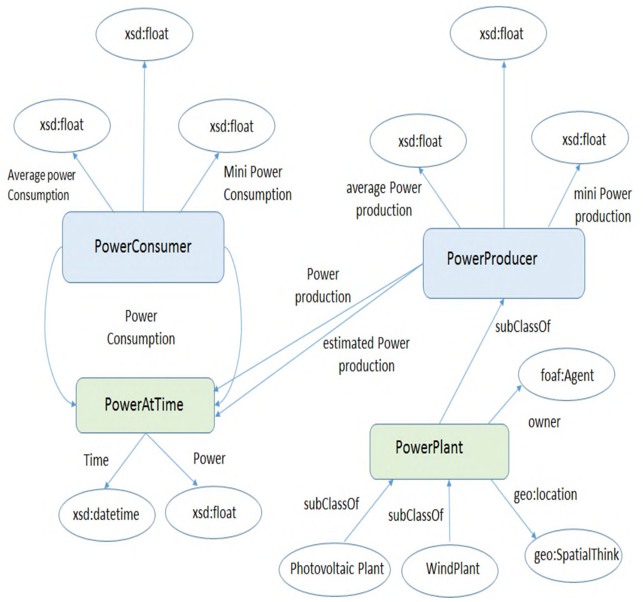

Figure 4. A graphical representation of same classes and properties of the Energy Ontology

EO introduces two basic classes representative of the two main categories that classify the energetic behavior of devices and plants: Power Consumer and Power Producer. These classes expose basic properties to encode information about power production and consumption features like the minimum, maximum and average amount of power consumed/produced. Dealing with energy management it is important to store information of power consumption/ production combined with time information. In this way, for example, historical power consumption can be created and maintained to be use for estimating future consumptions or for defining the user consumption profiles. With such purpose, EO provides the Power at Time class that allows describing the amount of power at a certain time [17].

An intelligent energy management for a complex home environment requires encoding and processing a wide number of information about actual and expected energy consumption and production. Dealing with solar and wind energy generation, the power output changes remarkably according to season, daytime and weather conditions. Particularly, the power output of a photovoltaic installation varies considerably on season scale, due to the different solar irradiation and weather conditions. Even more dramatically on a daily scale, due to solar irradiation ranging from the zero during the night to a maximum during the central hours of the day. Therefore, commonly, the system draws energy from the grid when the production is not sufficient to cover the energy needs, while releases energy to the grid when the produced energy exceeds the needs. Maximizing the amount of produced energy that is consumed locally in the house, is convenient both in terms of efficiency, avoiding energy loss in grid transportation, and profit, because the price at which energy is bought from the grid is higher than the price at which energy is sold to the grid, since power companies add delivery charges to energy price. In addition, reducing the request of energy from the public grid, which mostly relies on fossil sources especially in the rush hours, means to reduce pollution [18].

A dynamic and intelligent task scheduling it is then necessary to exploit at best the produced energy for performing more tasks as possible when there is a surplus of produced energy and to limit later energy draw from the grid when energy production is scarce or null. This requires the management of a wide number of information, relying on them to implement intelligent control logic. It's necessary not only to have a real-time measure of the consumed/produced energy but also to esteem how much energy will be produced in the next hours or days and how much energy the users will consume. Solar irradiation forecast curves, based on an average esteem of the solar irradiation measured on a region in the previous years, and weather forecast services can be used to get a row esteem of energy production. Forecast energy consumption can be evaluated using user's energy consumption profiles, derived from the statistical analyzing of system logs of energy consumption, and considering the energy requested from already scheduled task. It's necessary also to rely on services descriptions to infer if and how much a service can be deferred or performed in advance and consider the time required for task completion. Moreover, it is necessary to evaluate the amount of energy required to perform each service to assign a priority for task execution and to manage eventual conflicts.

VI. CONCLUSIONS

The digitization of city infrastructure is already a fact and is opening a world of opportunities in which all the stakeholders are called to be positioned and create value from that. For example, the development of the Smart Grids should adapt the regulatory framework and do big investment in the grids, such as monitoring, equipment of consumption and smart meters in the consumer installations.

A smart city of the future should have more participation of renewable energy than hydro and fossil fuels. In this city the transport and energy distribution will be through superconductors, all the energy system will be supervised by a master center that analyzes the information that arrives from the sensors and remote terminal units (RTU). This expert system solves the problems and failures, informs the operators if it is necessary to fix a point of the line. The Master learns the new cases and stores the cases for futures problems. So, when the energy arrives at homes, it comes with a few losses thanks to master center and then it is up to the user to be efficient.

In the cities, every day there are installed various energy efficiency technologies, whereby electric utilities and companies in the sector must make known the operation of these tools. For this reason, the decision makers in the electricity sector should create programs to disseminate this technology, and with the help of users, achieve significant reduction that minimizes the bill cost.

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