Information and Communication Technologies for Smarter Cities

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Introduction to Smart Grids

Nowadays, environmental concerns and the increase of energy costs, due to the scarcity of raw material, are obliging governments and electric utilities to change the energy distribution model towards more efficient and sustainable systems. *Conventional energy systems* are characterized by centralized power generation with unidirectional flow of energy and a modest participation of Information and Communication Technologies (ICT), consequence of limited investment in new developments. Fortunately, recent technological advances allow improving current infrastructures to satisfy new requirements. These latter comprise the integration of disperse renewable sources and storage components, management of more complex energy flows, need of more secure and faster communications for monitoring and control, active participation of consumers, etc. The fulfillment of these challenges demands the creation of the so-called *Smart Grids* (SG), which can be defined as energy systems that make an extensive use of ICT to better coordinate the network components at generation, transport, and distribution levels, including home appliances and customers, in order to increase its quality, safety, efficiency, reliability and sustainability [1].

Some of the main *technical issues* of the SG are: distributed generation (DG), the possibility of generating electricity close to where it is consumed in a decentralize manner (e.g. based on renewable sources like wind or photo-voltaic); advanced metering infrastructure (AMI), which is more than automated meter reading (AMR), including hardware, software and communications; demand side management (DSM), policies to balance the system load by encouraging clients to use energy in off-peak times; energy storage systems (ESS), like plug-in electric vehicles (PEV); building and home energy management systems, etc. Some of these issues affect to the traditional design of energy networks and even solutions abandoned in the past, like the DC distribution systems, are being reconsidered.

Underneath the SG concept, there is a massive use of *ICT* that supports the decentralized management and decision making, with real-time monitoring that permits network automation (not only fault detections and recovery but also load balancing) and continuous customers information (to get their engagement as virtual storage components thanks to a smarter consumption). This requires the spreading of intelligent electronic devices for sensing network quality (like phasor measurement units) and actuators interconnected with power network management systems based on supervisory control and data acquisition (SCADA) [2].

Recent developments related to Smart Grids in Europe

Currently, there is a relevant activity in the field of SG in Europe. This can be considered a response to the *20/20/20 plan* adopted by the European Union, which encourages several initiatives to reach, in year 2020, a 20% improvement of energy efficiency, a 20% reduction of CO_2 emissions in the electric sector, and a 20% increase of renewable sources in generation. The Smart Grids European Technology Platform, partly funded by the European Commission, aims "to foster and support the deployment of SmartGrids in Europe" [3] and promotes, for instance, the European Electricity Grid Initiative or the *Open Meter Project*, whose objective is to specify a new standard for AMI. This last summer, the "Specification of Open Meter OSI Layers and Multi-Metering Networking Interfaces" was delivered. It contains coexistence mechanisms among different *Power Line Communications* (PLC) systems based in commercial modems standards: PRIME [4], S-FSK (spread frequency-shift keying), G3 [5] and Meters & More.

The SmartCity Malaga project

In this context, there exists many ongoing projects under denominations similar to *smart city* and related to the realization of SG, for instance in Boulder-Colorado and Columbus-Ohio (USA), Masdar (Dubai), Malta, and Stockholm (Sweden). Among them, it is worth mentioning the SmartCity project deployed in Málaga (Spain) for the implementation of a fully operational smart grid in a suburb of the city [6]. For this purpose, DG and storage, with micro-systems for wind and photo-voltaic energy, PEV and charging stations, smart buildings and efficient public lighting are being integrated. The project involves about 300 industrial customers, 900 service customers and 12000 domestic customers. The contracted power will be 63MW, with one electrical substation, 5 medium voltage lines (20kV) and 71 transformers (MV-LV) for about 38km of electric cables (excluding indoor customer installations). DG comprises many photo-voltaic systems in buildings and public lighting, micro-wind generators in public lighting, mini co-generation and tri-generation systems in buildings. Energy storage is accomplished by means of distributed battery systems, both at MV and LV levels, and 12 PEV with 6 charging points. The communication system will allow the automation of MV and LV distribution networks, the control of the DG components and the information to customers about their real-time consumption and estimations of ecological footprint, so that DSM strategies can be implemented. Finally, several energy control systems at buildings and homes will be tested, as well.

All the above-mentioned elements will lead to a more efficient energy management and it is targeted, at the project completion, a 20% reduction of the current energy consumption. The project began in 2009 and will last four years, it is led by Endesa (a Spanish utility) and engages 11 companies and 14 research institutions with a budget of 31 millions of euros. Moreover, it is programmed for 2012 the coordination with the *ZeM2All project* (zero emission mobility to all) led by Mitsubishi, which will include 200 electric vehicles and 236 charging points.

PLC technology overview

The realization of SG necessarily involves many ICT technologies, among which PLC may play a relevant role [7]. It consists in using the power grid for communications purposes, by using frequencies above the 50/60Hz of the mains voltage, and presents many advantages for SG. It constitutes a unique physical medium for both delivering energy and carrying communications (saving material and deployment costs, as with wireless solutions). It is the most direct path between sensors and controllers of the power network and the common flow of power and information can offer some networking advantages. Even more, PLC modems could serve also as sensors (they somehow scan the medium and can detect problems in the energy distribution system). Utilities, wisely, always claim for redundancy for protection and control functions, and PLC offers a direct alternative to any other communication technology by re-using the wired infrastructure. Besides, it is a communication network that is under a complete control of utilities.

However, power networks were conceived for distributing energy by means of large-voltage and low-frequency signals, and are not well conditioned for communications that require high-frequency and small-voltage signals. For this reason, *power line channels* exhibit many non-desirable characteristics that can be summarized in that signal attenuation is quite high (even for short-distance, like in indoor links); the channel response is very dependent on the network and location (not only in different countries, but also at different points of the outdoor network or sockets at the same home); it is very frequency selective (the quality of the usable band is not uniform) and exhibits time variation (for instance, when appliances are switched on and off) [8]. There are also many disturbances of diverse nature like colored background noise, narrow-band interference from radio signals, impulsive noise coming from appliances (with a cyclostationary behavior synchronized with the mains cycle), etc. Moreover, PLC systems have to face with many electromagnetic compatibility issues because electrical cables act as antennas that capture and emit radio waves, which obliges to avoid several frequencies in the available spectrum.

Taking advantage of power lines for more than energy service is an old idea. During the first years of twentieth century, pioneer PLC systems were proposed for reading meters at remote locations and some decades later, PLC was successfully used for data and voice transmission (e.g. a first commercial trial is dated in 1918 in Japan) [9]. However, it was at the end of the 1990s when research in PLC attracted significant attention, to some extent boosted by the fall of telecommunication monopolies in Europe. Since them, many *broadband transmission systems* have been developed with sophisticated transmission techniques achieving up to 200Mb/s (at best conditions) for home area networks, usually to share Internet access and distribute multimedia information, competing and collaborating with WiFi. Nevertheless, it has been *narrow band PLC* the technology commonly employed by the electric utilities. In this context, there are different standards world-wide. In Europe, the CENELEC EN 50065-1 norm allows transmission between 3kHz and 148.5kHz [10], while in USA, Japan, or China the limits extend up to 500kHz approximately. Since no common transmission techniques are defined in those standards, this frequency band is used as a shared medium (similar to ISM -industrial, scientific and medical- radio bands) and coexistence strategies have to be adopted that prevent interference. Traditionally, these systems are based on single-carrier modulations for low data rates (around some kb/s), although, at present, some new devices compliant with commercial standards like PRIME [4] or G3-PLC [5], implement multi-carrier modulation for higher data rates (up to hundreds kb/s). Hence, they can be employed in SG for other applications apart from AMR.

ICT and PLC in the SmartCity Malaga project

ICT are essential in the development of the SmartCity project and several technologies are concerned at different levels. In particular, *PLC systems* have a remarkable presence. At MV level, there is a communication network based on broadband PLC that connects all the distribution transformers for control and automation purposes, and also connects each of them with the different DG components and important loads. This heterogeneous network complements, and gives redundancy to, a *fiber optic* ring that is deployed among substations and control centers. These two constitute the IP-based core network of the project. At LV level, there will be 7000 meters provided with PLC modems, their data will be combined at a concentrator at the distribution transformer and transmitted via wireless to the control center (by means of *GPRS* -general packet radio service-). These modems use a proprietary solution (by Meters & More) that works in CENELEC A band, with BPSK (binary phase-shift keying) at a rate of 4.8kb/s. Likewise, public lighting is controlled by means of energy managers that incorporate also narrow band PLC and whose objective is to reach up to 80% energy saving. Other wireless modems based on *WiMAX* (worldwide interoperability for microwave access) are employed to integrate in the energy management system some emblematic distant buildings, which are out of the project substation area. Finally, it is also noteworthy that, for home energy management, sensors networks based on *ZigBee* (a wireless technology for small scale networks) are being offered to the customers.

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