Use of Web Based Meters to Improve Energy Efficiency and Power Quality in Buildings

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Abstract. During the work conducted, several buildings were analysed, in terms of energy efficiency and power quality. Two case studies are here presented: an educational building and a museum. Most of the studies were conducted recurring to traditional measurement equipment, forcing the person to travel to the site to install equipment and every time he wanted to collect data. But one of the case studies, the museum, comprised the development of an analyser (hardware and software) able to measure electric energy, temperature and humidity. This analyser has the capability to register values on a database available in the internet and issue warnings to the building manager. This allows real-time information, supporting some energy efficiency actions. The objective is to improve this model and expand its use for several buildings, providing savings in terms of time and other resources, taking advantage of cloud-based systems.

Keywords: Energy Efficiency, Cloud-based System, Energy Management Systems, Power Quality, Smart City.

1 Introduction

At present time, the availability of information on energy use for customers is, in most of the cases, limited to the monthly utility bills. The information provided by the utilities is generally limited to quantitative aspects, neglecting the qualitative issues. This diminutive information, along with the time gap between the effective consumption and the delivery of the bill constitute barriers to immediate actions. The widespread use of energy analysers, with metering and power quality analysis capabilities, connected to cloud-based systems would enable real-time knowledge and it could benefit the benchmarking of different building and processes.

The knowledge of individual data and the benchmarking of several similar processes or buildings, based on web systems, empowers the manager to the development of strategies for intervention to improve the energy efficiency of the building or process, within the concept of Smart City for sustainability.

This deals with a methodology shift in the energy auditing. It is intended to set off from the classic energy auditing, with individualized analysis requiring onsite data collection, to a more systematic approach, based on spread analysers dispatching data to a common database through the use of web-based systems.

2 Benefits from Cloud-based Engineering Systems

Data and programs are part of the world of computing in the desktop PCs, but the current trend is to relocate them and integrate the usually server room to the cloud computing service or on-demand computing/software. The platform used is the Internet with exceptional growth and the common element is a shift in the geography of computation. For example, each time someone uses a search engine service, the main software is lodged computers on unseen to the user, possibly distributed across different continents. [1]

In a wider context we can say that cloud is a large-scale, distributed Information Technologies (IT) facilities available over the internet and is transforming the way intrinsic IT services are delivered and managed.

The use of cloud-based systems tends to reduce overall cost and increase efficiencies, especially when replacing an organization's locally operated system and supported with local servers. This detail is reflected in energy and environmental benefits. Also the cloud-based systems have a huge potential, improving efficiency and business agility, therefore contributing to a more sustainable world [2].

Industrial or services companies acting in energy audit, that use suitable equipment to collect energy consumption and/or power quality data variables will gather the inherent business benefits of this technology, mainly from the remote and possibly real-time data availability. The ease of data collection, data sharing and information delivery, boosted by the rising use of mobile devices, is another relevant benefit for users. Another impact of the use of this computing platform is the reduction of costs related to technical staff involvement in on-site data collection and system maintenance. All of this can play a crucial role in making IT more sustainable by significantly reducing energy consumption, raising levels of energy efficiency [3].

3 Motivation of the Work

The energy data from multiple sites, such as industrial, services and residential buildings has to date been collected on an individualized approach and on site, recurring to temporary placement of portable energy analysers. Although many installations are already fitted with smart meters for electric energy, they are only used in remote metering by the utility and the data isn't usually delivered to the customer in a timely way. Also, they only measure total energy at the point of common coupling, therefore they don't allow the disaggregation of energy (electric and thermal) consumption by different sector or areas of the facility under study.

This high volume of data collected is related to main energy consumers in the buildings, highlighting the appliances, machinery, HVAC, lighting, compressed air. Also, data related with the activity in the building (production, occupation, building structure ...). Also some other data is linked with consumer behaviour, market and technologies, measurement methods, public procurement, market transformation programs, end-use metering, demand response, smart meters, smart homes and smart appliance, consumer electronics, ICT, residential lighting and home automation.

On this field, the disaggregation of energy variables, with several consumers and several parameters, is necessary. In each case study, sampling intervals of 5, 10 or 15 minutes are used, resulting in a large collection of data a t the end of a campaign up to several weeks. This data requires to be treated and interpreted quickly, in order to promptly take actions, in terms of energy efficiency and/or power quality issues.

This individually collecting of data, along with individual data processing is time and resource consuming associated with the travelling to the site and losses of time due to computer media used and different software that perform the data processing. The main objective of this work is to demonstrate that the data management with resource to cloud-based systems can raise the performance in the analysis energy data.

Based on several case studies in urban and industrial environment, related with the researches developed on last years, to retrofit the energy systems and achieve better energy efficiency in these buildings and industrial activities, putting into practice the smart city concept. These studies are part of a set of actions to achieve the assimilation of the national programme which implements these requirements for greater energy efficiency (the 20/20/20 Plan) by the various economic and industrial players. This 20/20/20 Plan predicts a cut of 20% in GHG emissions for the EU by the year 2020, a share of 20% of energy from renewable sources and a 20% increase in energy efficiency and implementing smart grids and cities, for a low carbon a and sustainability [4] and [5].

These case studies included, among others, plastic and mould industries, public library, sports hall, museum, comprising a vast diversity of data (numerical data; thermal images) to be processed. Here, the cloud technology can play an important role in data processing and in the dissemination of results [6], [7], [8] and [9].

4 Case Studies

The base of the studies consists of energy audits. The acquisition of existing energy consumption and other data was carried out with the use of various energy and power quality analysers, thermal camera and other equipment, aiming to characterize not only the energy consumptions, but in also the buildings structure and materials (walls, roof, warehouse and office). The energy audit consists of several aspects that will allow us to identify critical parts of this facility and that should be improved in order to achieve a higher level of performance. In this context, the energy facilities and activities associated with them were characterized according to the standard Energy Management Systems [10] and [11].

The energy audit of all sectors and all forms of energy, and its pursuance requires knowledge of the electrical, thermal, mechanical and environmental areas of the building. Thus, energy audits provide specific information and identify the actual energy savings, consisting primarily of a critical examination of how energy is used based on the available records of energy consumption and costs. An energy analysis was carried out, leading to the characterization of energy consumption in recent years. This consisted in the use of existing energy bills from the utility and the use of several energy analysers.

In several audits, especially the ones in industrial facilities, power quality issues were also addressed. In some cases, prior to the studies, the building manager didn't relate the malfunction of some equipment to power quality events, while others hold responsible the electricity distributor for every malfunction, even if it was not to blame. In general, one can conclude that the awareness of power quality issues is short. In most cases, this work contributed to the rise of awareness among industrial managers.

Given the diversity of buildings and activities analyzed, only two cases in the service area (library and museum) are presented here, being a sample of the objectives to increase energy efficiency, sustainability in the context of Smart City. One of them was conducted in the traditional manner and the other includes the development of a web-based meter.

4.1 Public Library

Approximately three quarters of the population in EU lives in cities or nearby. It is necessary to improve the energy efficiency of buildings, since about 40% of the primary energy consumed in the European Union, results from energy use in buildings [12] and [13]. Therefore, it is important to promote good practice in the application of renewable energy combined with energy efficiency measures. The EU has developing a long-term strategy to a low-carbon economy and to make better use of its energy systems and scarce resources. Urban areas consume 70% of the energy in the EU and emit about the same share of greenhouse gases. The Smart Cities Initiative is a new European task force, whose objective is to make Europe's cities more efficient and more sustainable in the area of energy.

This case study comes up with a new energy model that retrofits the present system in a public library building, as a way to the dissemination the Smart City concept and development of energy production based on a sustainable and autonomous process. Taking into account that to implement this concept, constant monitoring of energy data is essential and only installing measurement equipment, and consequent rapid dispatch data to be analyzed and stored in the cloud-based platform if able to achieve high levels of energy efficiency in buildings.

This work related to the ongoing research is based on an energy audit, comprising a survey on energy consumption by type: electrical and thermal (gas), recurring to portable energy analysers, as shown in Fig. 1, Another relevant aspect of this audit was the identification of anomalous situations in energy infrastructures: electrical and thermal, by means of a thermographic analysis of multiple parts of the installations, focused on electrical switchboards, as shown in Fig. 2, and thermal energy pinping. This consists of gathering information for determine energy savings from a perspective of energy determination of equipment that can induce forced stops away the power supply, for wear and tear or malfunction resulting from higher operating temperatures and lead to a rapid degradation.

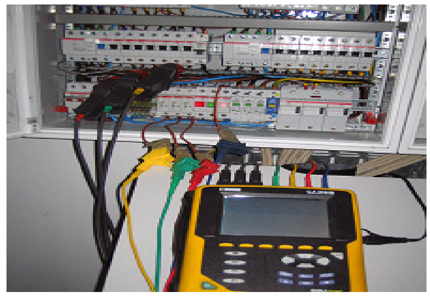

Fig. 1. Measuring Equipment - Power Analyzer in the Collection of Consumptions.

This energy of the building library consists of a photovoltaic (PV) plant and a biomass energy source to replace the gas that is currently used.

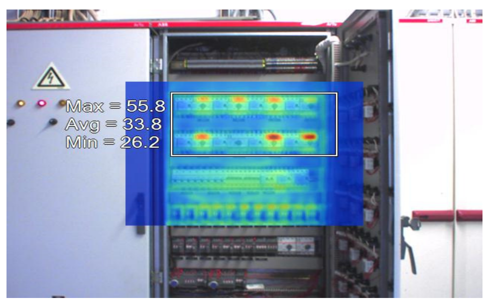

Fig. 2. Thermografic image of switchboard and temperatures (maximum; average; minimum).

As shown in Fig. 2, a spot with high temperature was detected on the bottom of a connection. This high temperature is due to a bad tightening and if this situation persists, the material would suffer a marked wear, leading to his destruction and possibly trigger a fire. The standards established by InterNational Electrical Testing Association (NETA) rule that a quick action is required, when the difference between electrical components exceeds 15ºC or the difference between air temperature and the electrical component exceeds 40ºC [14]. Besides bad electrical connections, thermal imaging can be used to detect the correct sizing of electrical components. An oversized (or underloaded) component would result in a low temperature, while an undersized (or overloaded) component would result in a high temperature. The innovative proposed model consists of a mix of energy production processes based on photovoltaic panels and biomass boilers. Economic analysis of the energy model already achieved some results regarding the payback of the investment, as well as to achieve decarbonisation of cities and a strategy for competitive and secure energy.

4.2 Museum

In the context of improvement of energy efficiency in public buildings, this case study comprised a small museum with an exhibition space of around 200 square meters and other areas (archive, administrative area, ...). This museum occupies a public building that was not built specifically for this purpose. The space underwent a minor retrofitting to receive the assets of the museum fifteen years ago. This implied some constraints on the use of the museum. Also, the energy bills were rising, becoming a major concern for the museum direction.

As a first approach, and after an energy audit conducted by the traditional method, the largest energy consumers were identified: lighting, dehumidifier and space heaters. The first step was the substitution of around 100 halogen spots (25, 35 and 50 W) by LEDs (4.4 W). The expected payback time is around 1.25 years, while increasing the light level in some spaces and minimizing the ultra-violet emission that fastens deterioration of some assets of the museum. Also, emissions of 1130 kgCO_{2e} per year were avoided due to energy consumption reduction. In addition, some motion detectors were installed in the museum, mainly improving the convenience of the museum staff and, in addition, enabling additional energy savings in the lighting system.

The next step in this case study was the development of a low cost web-based meter, primarily for temperature and humidity supervision, but energy measurement features were included in the first iteration. The basic configuration of the system is shown in Fig. 3. A module with a humidity and temperature sensor and signal conditioning communicates with the central processing unit (CPU) using the wireless technology *ZigBee*®. The energy measurement module is based on three current sensors and three 230/12 V and signal conditioning circuits that communicate with the CPU via a cable. The central unit, based on an *Arduino* processor, is responsible for processing the data received from the separate modules and record the data on a database. It is connected to the switch of the museum IT system via an Ethernet cable.

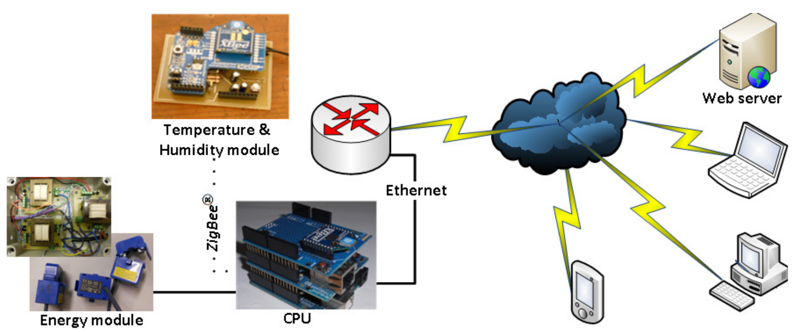

Fig. 3. Developed prototype of a web-based meter

The database created records the averaged values of temperature, humidity, voltage, current, active power, reactive power and power factor with an interval of 10 minutes. This data is available on an open web site. The system is also programmable with warning emission, by email, when the reference value of temperature and/or humidity is exceeded and anomalous energy consumption or power failures occur.

The central unit is scalable allowing to aggregate data from more temperatures and humidity modules or energy modules with slight changes in the software. Other changes, such as real-time power quality events recording are planned and possible without significant changes in the hardware of the meter.

The data recording and easy remote access to it, along with the warnings issued by the system, enables the manager of the building to take swift actions for a better energy efficiency.

5 Conclusions

With the increasing concerns for energy efficiency, a more efficient control of energy use is required. The timely availability of data, if possible in real time, constitutes a key factor in decision-making in all areas, including the energy management. Therefore, the traditional energy monitoring systems, sometimes limited to energy billing and periodic measures, constitute a barrier for the development of a proper energy management system focused on the best possible efficiency. Using the services provided by the cloud, the data could be attained more rapidly and the energy data handling can be simplified, using a common platform, optimizing processes for managing projects and opportunities. Also, with the use of cloud-based systems, the data may be available to different people wherever there is an internet connection.

As the efficiency of cloud computing increases, more services are developing, while each service or transaction tends to use less energy with several studies referring that cloud-based systems are more energy-efficient than on site IT systems. Bringing this energy saving together with the activity of energy auditing, further efficiency can be attained.

But sometimes the costs of buying and maintaining a system connected to the web can be an obstacle to the dissemination of these systems in buildings. The current work described here included the development of a low cost energy meter (including other parameter metering capabilities, such as power quality events, temperature and humidity). The dissemination of this kind of meters can play an important role in assisting the transition of locally available energy data to the web available data, allowing real-time information and benchmarking of different sites. These tools can play an important role in boosting the energy efficiency of buildings and processes.

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