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Energy Management by Dynamic Monitoring of a Building of the University of Valladolid

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Abstract: The continuous increase of energy consumption in buildings enhances the importance of implementing energy management systems within the building facilities. These tools allow us to know precisely both energy consumption and use within the building. Monitoring energy consumption provides a clear view not only of the amount, but also of where and when energy is consumed in the building. Besides, a rear analysis of this information allows us to deduce whether there exists an inappropriate consumption, and thus the possibilities of improving building efficiency. A monitoring tool has been implemented within an academic building at the University of Valladolid, applying technological resources of Information Technology and Communication through dynamic monitoring of electrical and thermal parameters. Results obtained are gathered and analysed to directly contribute to improve the use of energy, reduce costs associated with its generation and use, and improve the thermal comfort of the building occupants.

Keywords: Dynamic monitoring, energy performances, energy management, reduction of building consumption.

1. Introduction

To ensure an adequate level of indoor conditions for the occupants of the buildings within its different campuses, the University of Valladolid faces an energy cost that entails one of the highest annual budgets of this institution. Consequently, the University of Valladolid is closely engaged with a problem that also affects the environment and the society, beyond the mere economic issue. Some years ago a project called SMART CAMPUS was launched together with the company TECOPYSA, targeting the optimization of the energy efficiency as well as the environmental care of the University Campus. The main interest of this project lies on the high energy consumption and wide range of possibilities of improvement of the case study, through the implementation of a smart and integrated technological tool for the design of energy management networks in sustainable environments.

The starting point of the project implementation was a preliminary study on the energy costs and conditions of every building. It was observed that the conditions of one of the buildings where the School of Industrial Engineering is set, together with the information available concerning the involved energy costs, showed that energy efficiency was very low. Comparatively to the remaining buildings of the same campus, this one entrained the highest ratio of electricity consumption and one of the highest ratios in terms of thermal energy.

Before the development of this preliminary study, there was no knowledge concerning neither the location of the final energy consumers nor the moment when they consumed such energy. This lack of information also restricted the effectiveness of any measure to be implemented for the improvement of occupant's comfort and systems efficiency, as well as for the reduction of energy consumption and carbon emissions involved.

The consecution of a number of steps, as the gathering of disaggregated consumptions, information analysis, etc. will highlight the adequate practices to optimise the energy use, achieving an efficient exploitation of the available resources [3].

Among the most important functionalities to be achieved through this project, is the possibility of a continuous monitoring of the energy consumption. Being a series of set points targeted precisely, every time they were overpassed the system would send an alarm to the user, informing that a limit of consumption, comfort or cost has been exceeded. In this manner, the energy use can be managed and controlled avoiding superfluous consumptions as well as those occurring beyond operating timetables, which importantly affects the final bills [4].

The solution here proposed can be extrapolated, being possible to stretch the analysis and measures to any building within the campus. The implementation of these systems would result into the acquisition of a high performance level within the international evaluation programs for sustainable certification. This would apply to the whole university campus, comprising all its buildings. It would become a pilot scenario unique in Spain [5].

The main purpose of the project is thus to cover all functionalities and necessities targeted in the university campuses, concerning the knowledge on the final energy consumption, through the implementation of existing technologies directed to the improvement of both efficiency and quality of the offered services.

Implementation of this technology will involve the optimization of both human and material resources, contributing to

(a) The improvement of the energy use and occupant's comfort;

(b) Reduction of costs derived from energy generation and use;

(c) Creation of a multi-platform management tool.

2. Methods

2.1 Target Building: Use, Occupation and Energy Supply

The selection of the building of the School of Industrial Engineering (EII) was made according to the available information, the technical viability for the setting up of the different measurement devices as well as the opportunities of improvement.

The target tertiary building is mainly dedicated to academic and research activities. It was built in the end of the 80s and has a total built area of 20,397 m^2 (useful floor area of 16,715 m^2), distributed into four floors. The main façade faces southwest.

With respect to the different facilities, they are characterised by the following points:

- Lighting: mainly conventional fluorescents with electromagnetic ballast;
- Heating: 2 natural gas boilers, 540 kW;
- Cooling: individual devices (split) distributed throughout the building;
- DHW: (it does not apply);
- Other devices: 19 AHUs (Air Handling Units), 3 lifts, computers and laboratory equipment.

Concerning occupation and timetables: Monday to Friday: from 8:00 am to 10:00 pm. Saturday: from 9:00 am to 2:00 pm.

The energy supply is provided by

- Electricity: supplied by Iberdrola, with tariffs discriminated in 6 time periods;
- Natural Gas: supplied by Gas Natural Fenosa. Access tarif: 3.4.

Fig. 1 shows the consumption of electricity and gas in 2014.

2.2 System's Implementation and Development

A number of steps are developed in order to meet the objectives:

- Study of the existing facility. In this step the systems are analysed to know deeply how energy is being generated, distributed and used within the

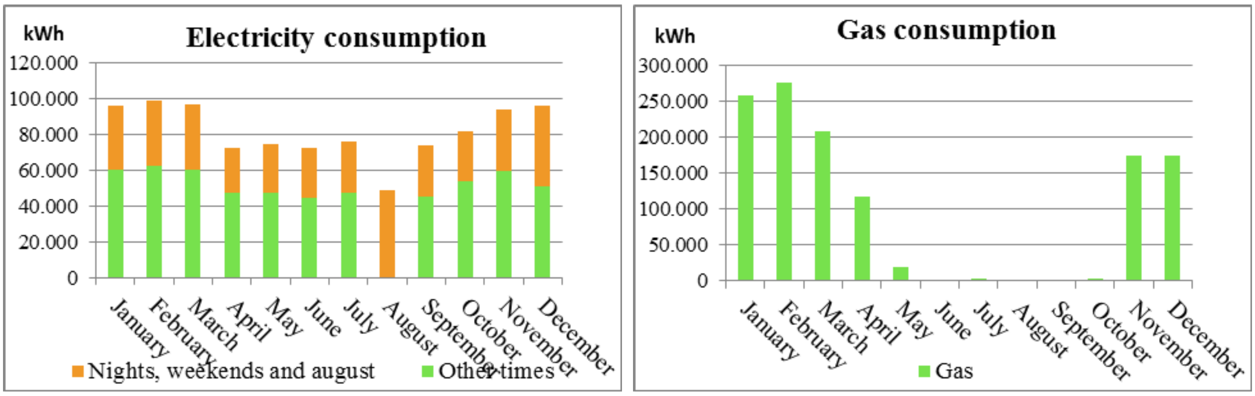

Fig. 1 Consumption chart.

building; both through the thermal and electrical distribution systems. This would enable a global view of the project and the existing possibilities of energy management;

- Identification of the main points of consumption. Facilities to be monitored are determined in terms of theoretical partial consumptions or power installed, as well as the equipment required for a total energy management of the existing system;
- Study on the location of sensors for comfort measurement. The most significant spaces are determined for the measurement of the thermal comfort factors, as well as the number of spaces to be monitored;
- Study of available sensors in the market. A market survey is made to find the most adequate solution for the monitoring and energy management, in economic and technological terms, agreeing with the requirements established in the previous step. Communication protocols to be used are decided, together with the exact number of devices to be employed, their location, data flow and operation schemes integrated in the existing facility;
- Installation of the selected sensors;
- Installation of control and data reception systems into the switchboard. In this step data reception devices and signal concentration systems are installed to receive the information from the sensors installed in the previous step. They are installed in an existing switchboard with enough space or within an extra specific switchboard for energy management [6];
- Wiring installation. Interconnection of every element participating into the sensor network, depending of the communication protocol selected for each case;
- Software implementation. Energy management software is provided in one of the local servers or in an additional server with that particular aim;
- Sensor configuration. Implementation of the sensors installed in the energy management software;
- Operation checking within a series of tests and validation. The system is then subject to an exhaustive set of tests to check and validate its operation according to the requirements specified in the project;
- Study of the results obtained and generation of proposals. After the validation, operation checking and data reception during a significant period of time, a study of the obtained data is developed. Then, improvement measures are proposed, combining existing generation systems with renewable sources in order to efficiently supply the building energy demand and reduce costs. In the same way, further measures will be proposed aiming to conceal timetables and energy efficiency policies within the most consuming facilities, or within those consuming more energy than the strictly needed [5].

2.3 Consumption Monitoring: Parameters and Equipment Used

It is always intended to measure as many parameters as possible according to the technical and economic restrictions. For the present case, the monitored variables are specified next [2]:

- Concerning the electric facility, the measured parameters have been: active power, reactive power, power factor, cumulated consumptions, period excess and THD (global). The points of analysis at different levels are

- Whole-building level (global): electric global consumption; air conditioning consumption in the Left Wing (Heat Pumps); air conditioning consumption in the Right Wing (Heat Pumps); roof AHUs consumption; outdoor lighting;

- Second floor: lighting consumption; power consumption; power consumption at the laboratory QO.

- First floor: lighting consumption; power consumption; power consumption at laboratory E and at classroom 1.7;

- Ground floor: lighting consumption and power consumption at classrooms B1 and B6;

- Basement: lighting consumption, power consumption at the pumps room; power consumption at laboratories CF, MR and T.

- Thermal facilities:

- Natural gas consumption in boilers (flow rate);

- Water flow rate in the heating primary loop;

- Supply and return temperatures in the primary loop.

- Water supply facility:

- Whole-building level (global): water consumption.

- Thermal comfort:

- Outdoor air: Dry bulb Temperature (T) and Relative Humidity (HR);

- First floor: classroom 1.7 (T, RH, CO_2);

- Ground floor: classrooms B1 and B7 (T, RH, CO_2);

- Second floor: Library (T, RH), Laboratory QO (T, RH), Corridor (T, RH);

- First floor: meeting room (T, RH), corridor (T, RH), Computers room (T, RH);

- Ground floor: entrance hall (T, RH), Classroom B3 (T, RH), Offices 1, 2, 3 and 4 (T, RH);

- Basement: Laboratories CF, F and M (T, RH), north corridor (T), Hall (T), South corridor (T, RH);

Fig. 2 shows devices and sensors installed for the signal gathering, distribution and treatment:

The partner company TECOPYSA developed a web application that allows the remote access to the monitored variables, also enabling:

- Visualization, representation and evaluation of every monitored variable. Consequently, consumptions and operation within the building can be followed in real time;

- Development of an analysis with the historical data corresponding to any period from its implementation;

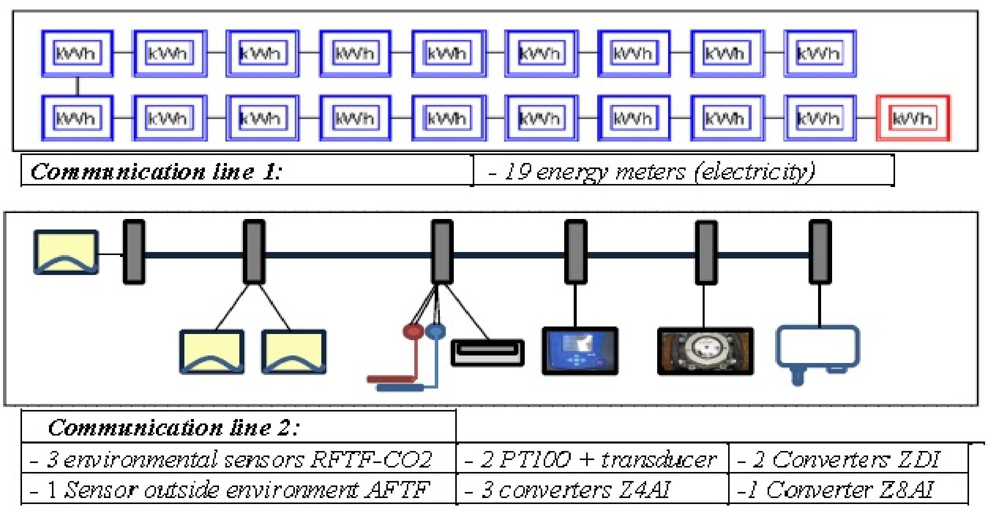

Fig. 2 Installed equipment.

- Generation of predefined and configurable reports;
- Information exportation in different formats for a detailed study in further applications (spreadsheets, simulation, etc.).

Comparison among the various University buildings in terms of the values derived from the measured variables.

3. Results

The analysis of the monitored variables gives information about the energy consumption. Hence, it has been possible to determine the load profiles of the building, knowing when and where it is consumed, as well as the conditions of the target spaces.

An important restriction lies in the gathering of appropriate and useful information about the conditions of the facilities, both thermal and electric. It is possible to link consumptions to particular places within a building, provided that electric networks and switchboards are proper and adequately connected. In some places it has been particularly difficult to differentiate the origin of the different consumptions, due to the number of possible sources. The higher the level of consumer's differentiation is, the more efficient will be the monitoring.

Given that the number of monitoring variables is quite high, the evolution and trends of only some of the most interesting (in terms of electric and thermal consumptions and environmental conditions) are presented next.

Concerning electric parameters, the global consumption of the building is shown in Fig. 3 through the representation of the power curve. This highlights the important electric consumption out of the occupancy periods, which falls beyond 100 kW during nighttime and weekends. A subsequent analysis from this profile, together with the ones from secondary switchboards of power and lighting, showed that most of the consumption was due to: air conditioning systems (left operating even when the building was closed), and those derived from data centers, experimental devices running in laboratories, circulation pumps of the heating primary loop and security lighting. Moreover, the trend showed that electric energy demand evolved accordingly to the occupation level, as expected.

Concerning lighting, Fig. 4 shows the power consumed in the first floor during a typical week. It can be observed that from 05.00 a.m. to 08.00 a.m., when the building starts to be occupied, lighting devices are already at a 50% of their power. The only occupants during this period are the staff of the cleaning service (6 to 8 people), who switch on the lights at a time instead of doing it progressively. This is caused by a lack of zonification in some cases, and by an inadequate use in others.

With respect to the electric consumptions highlighted, a set of saving and energy efficiency measures were proposed, some of which are already implemented and their efficiency being checked at present [7]. These are

- Substitution of the existing lighting in corridors, halls and toilets by fluorescents T5 with electronic ballast, also reducing and optimizing their number and disposition. Presence detectors were installed in toilets;

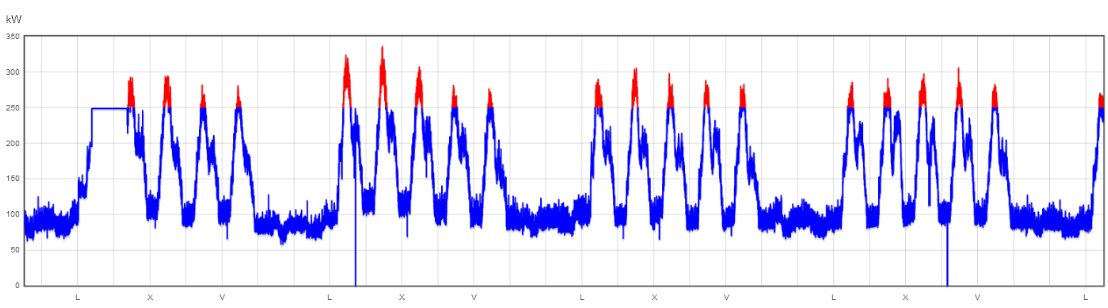

Fig. 3 Electric power consumption of the building (global).

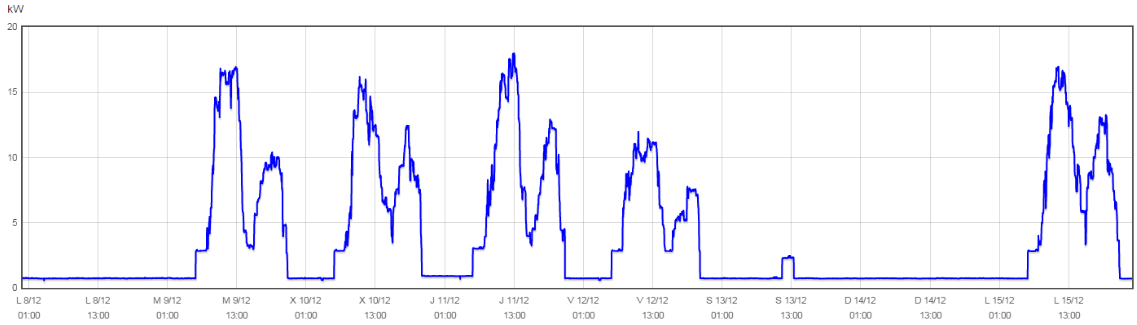

Fig. 4 Power consumption due to lighting in the first floor (typical week).

- Substitution of the lighting outdoors by LED lamps, obtaining a 70% decrease in the power installed at the same time that lightening levels are improved;
- Information to the building users with the aim of enhancing their engagement with the efficient use of every facility: switching on the lighting progressively and accordingly to the actual needs, switching off the air conditioning and other systems at the end of the workday, etc.;
- Provide timetables programmed to connect auxiliary HVAC systems, even enabling the restriction of their use.

Fig. 5 shows the monitoring of thermal comfort and air quality parameters (dry bulb temperature and CO_2 concentration in this case). It demonstrated that a system to regulate ventilation was required in order to maintain the IAQ within recommendable values. The increase in temperature and CO_2 levels in occupation peaks demonstrates that an adequate ventilation system is missed.

Concerning the monitoring of the heating system's thermal parameters, a study has been developed to modify the program of boilers availability, which aims to reduce the energy consumption and improve the indoor conditions [1]. A reduction of the operating timetable was thus proposed, adjusted to the occupation period (Fig. 6). Boilers could then operate at higher loads with better performances.

Based on the monitoring tool, it was possible to develop an analysis of the impact of this measure. This is based on the comparison of results after and before its implementation during weeks with similar outdoor climate conditions. Fig. 6 shows that boilers are completely off during weekends and night periods according to the new programmed schedule.

Considering the new data of the boilers energy consumption, an average decrease of 20% during the target week was observed, compared to the previous week of reference. This would result into a decrease of 340,000 kWh in the annual gas consumption.

4. Conclusions

The monitoring of the energy consumption and indoor conditions at different levels has been developed within the building of the School of Industrial Engineering of the University of Valladolid, through the implementation of a monitoring tool developed together with the company TECOPYSA.

Data gathered has permitted the identification of key energy consumers, enabling the implementation of measures that result into a most efficient operation of existing facilities. Some of these measures have regarded the substitution of existing lighting indoors (including zonification and presence detectors) and outdoors. Besides, boilers operation has been reprogrammed to fit to the actual occupant period, incurring into a annual decrease in the gas consumption of up to a 20%.

Furthermore, measures proposed not only have resulted into lower consumptions, but also have demonstrated to meet the thermal comfort targets of the building occupants.

The main interest of the installed devices and the

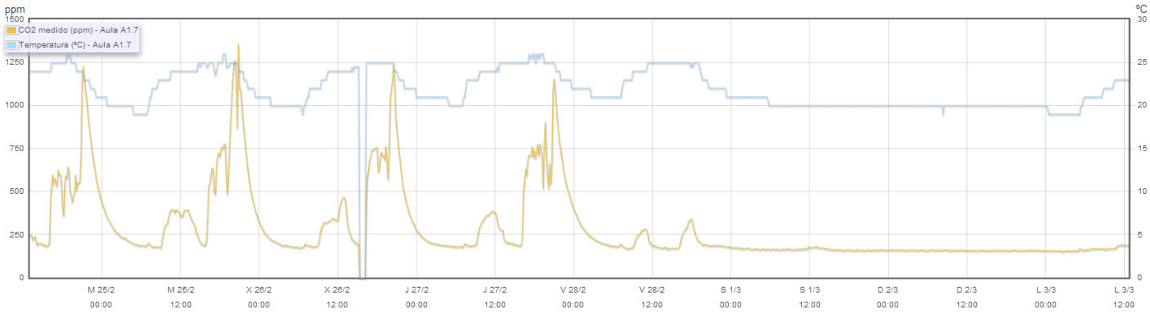

Fig. 5 Temperature and CO_2 concentration in a classroom.

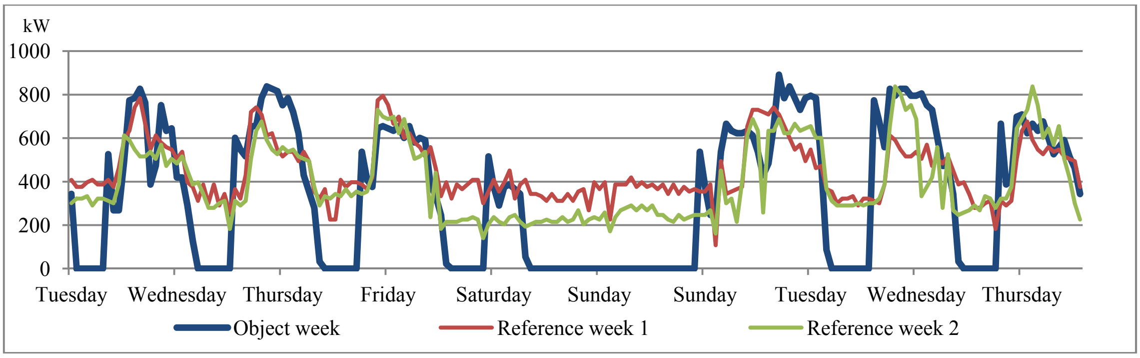

Fig. 6 Boilers thermal power during 3 weeks: (object week: new timetable).

consequent study is the extrapolation of the experience to the analysis of further buildings within the University Campus.

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