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Integral Management System for the energy efficiency improvement in commercial facilities: Application to the Polytechnic University of Valencia

G. Escrivá[1], M. Alcázar[1], C. Álvarez[1]

[1] Instituto de Ingeniería Energética
Universidad Politécnica de Valencia
Camino de Vera S/N, 46022 Valencia (Spain)
Phone:+0034 963 877 270, Fax: +0034 963 877 272, e-mail: guieses@die.upv.es, malcazar@iie.upv.es

Abstract.

One of the best ways to improve the energy efficiency in any system is by using more properly the energy resources in different facilities. Using them only when they are necessary is one of the most promising strategies.

The aim of this paper resides on presenting a new Integral Management System (IMS) which is being installed in the Campus of the Polytechnic University of Valencia. The structure of the IMS is presented, as well as the different components, actions of management and obtained results. Reductions of about 15-20% in energy consumptions have been achieved [1], that implies important results since the economic and environmental point of view [2].

Key words

Energy efficiency, control systems, control strategies, Web interface.

1. Introduction

The goal of the developed system resides on the implementation of new tools and techniques in order to improve the management of the different energy resources used in existing infrastructures at universities and similar facilities, the energy efficiency and the control of distributed loads. It implies that important energy and economic savings could be achieved, that means a reduction in the environmental impact (reduction of CO2 emissions and in building of new power plants and transport lines)**.** These tools allow the customer managers to measure energy consumptions, to store and manage data, to control energy consumptions (i.e. by adjusting the timetable for different loads) and to watch power not to exceed a pre-fixed set point. The IMS is based on a web site, which permits the information to be processed and to be available where the manager is at any time.

Additionally, these tools allow to obtain reports and results about energy consumptions, so energy demand forecast can be easily performed. In conclusion, a new information place to improve the energy efficiency and the interaction between different energy agents is being created.

IMS also offers the possibility to inform and to get in touch with different agents that could be interested in the use of available distributed energy resources, as generation, storage and demand response. A scheme is shown in figure 1.

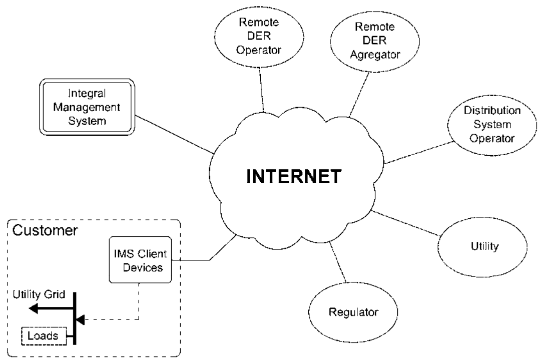

Figure 1: IMS components

It seems evident that the installation and development of the IMS opens the gate to new possibilities in energy management for the different facilities in a site. Once main loads are controlled and centralized, the access to them through a web site provide the place where the operator of the grid, utilities and the consumer are able to interact.

The development of this project provides the infrastructure with the ability to participate in electricity markets where disconnection of power could be offered as a service to the grid. Furthermore, since the manner in which energy is consumed by the different facilities can be perfectly known, the electricity contract could be optimized, so that the electricity bill would be reduced.

In this new framework, energy consumers could have influence on the price and quantity of generated energy, so customers may offer energy not by producing it, but by not consuming it. In this way, this system would allow demand response to be monitored by different agents, and price signals may be provided

2. IMS Architecture

One of the fundamental characteristics of the IMS is the possibility of communication with facilities which are far away each other, and all the gathered information is put in a central unit [3].

TCP-IP Ethernet Communication is used, so an easy and fast access to any part of the IMS is possible.

The system components are located in two different sites: firstly, inside the buildings, where power measurements are taken and control actions are performed. The other site is the central control centre, where data are stored and a Web server manages the different applications.

Customers:

In order to get the necessary measurements and to interact inside the facilities, the following devices have to be installed:

- Communication device User-Server. A TCP-IP protocol is used.
- Data Acquisition Central unit. This device measures the most relevant electrical magnitudes as power, current and voltages, and other ones related to wave quality since the initial status of the site is required to analyze future actions. Additionally, it allows to evaluate the success of adopted actions by comparing the final and initial situations.
- User interface. The user must be capable to interact in both digital and analogical ways. That makes necessary equipment which allows to take control decisions by using data from the central server but in an independent way.
-Switchgear. In order to adapt the signals from the PLC to the circuits and vice versa, it is necessary to install devices as switches, relays, etc.

Control Centre:

- Main server. This device works as a database and applications server. Gathered data are stored in this server, as well as the software used to analyzed and manage them. Additionally, it works as Web server, so it is the support for a secure communication via Internet.
- Auxiliary server. It is used as development server, where all the new applications are checked and work data are stored. Its main mission is based on centralizing the information, which implies a higher level of security. Moreover it keeps the backup copies from each work station. For that reason, the auxiliary server is also a redundant station, so it could work as an autonomous server if the main one fails.
- Work stations. They will be used to implement the software which is going to be integrated in servers, as well as the necessary engineering to carry out the different applications.

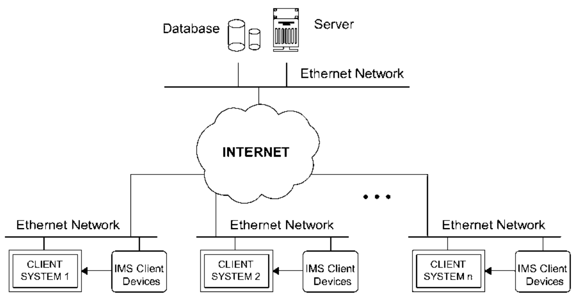

Fig. 2 Architecture of the IMS

3. Software components in the IMS

This part shows the implementation of the different applications which have been developed:

- Consumption data gathering from customers
- Performance of Control actions in facilities.
- Storage and management of all the information in a secure database
- Development of applications for users.

The IMS is based **o**n a web site in Internet, so data could be reviewed in every computer without having to install any specific software. That also allow**s** users to accede to friendly data bases in an easy-to-use way. This website is available at the following address: www.derd.upv.es.

The Integral Management System which has been developed consists on different applications. Some of them allow the customer a more adequate management of the energy demand; other ones are focussed on improving the energy efficiency. All this applications are necessary for any considered demand programme. The most promising applications are the following:

- Building Monitoring: A reliable monitoring system is used in order to avoid data loses. For that purpose, an adequate maintenance of the measurement devices and data bases has to be performed. The existing Ethernet network is used for communication and control purposes, so it is not necessary any other specific wiring. For that reason, installation costs are reduced.

-Vigilance service: The aim of this service is to watch the daily electricity consumption for each facility every quarter-hour. When the tolerance threshold is overloaded, an advice message is sent to the manager cell phone or e-mail. It is very important for this purpose to establish properly the threshold to be applied. This information was gathered in specific audits in each building in order to determinate the most adequate value.
As this service is carried out permanently, anomalous situations can be detected very quickly, that permits important time and cost saves.

- Peak power control: This service allows to control the maximum power which is demanded anytime, so penalties due to values higher than the contracted power are avoided.

- Maintenance: This service checks periodically the status of the lines, meters and other devices, so any incidence is communicated to the energy manager immediately.

Other additional services that are provided by this system are:

- Definition of consumption thresholds during nights and holidays.
- Responsibilities assignation.
- Suggestion of an action plan for resource managers and maintenance managers
- Formation to students and professors about the proper use of energy.
- Definition of investments in order to improve the energy efficiency.
- Verification of energy and economic savings.
- Raising awareness and sensitization about energy savings.
- Interaction between the different users.

4. Impact on energy consumptions in facilities

Usually, the electricity cost in universities and similar infrastructures is very high, mainly due to the following causes:

- There is not an optimum management. Usually the person who manages the electricity in a building is the same that manages other services (water, air conditioning, general maintenance of facilities)
- Electricity contract is not the optimum (it is not enough studied)
- There is not any place where users and maintenance managers could get in touch.
- Users are not aware of the energy problem.

The development of this system improves the energy management, because:

- Energy consumption is measured, so it can be controlled and reduced. In addition, there is a responsibility assignation that means that the responsible manager is more careful because he knows that energy consumptions in the building for that he is responsible is being measured.
- Electricity consumption is perfectly known, so the electricity contract can be optimized.
- New guidelines on energy use may be proposed.

Previous studies carried out about energy management in universities [4], [5], [6] have shown up that decrements of 8% could be obtained by only watching consumptions. Total reduction could be up to 20% if additional active control is performed.

5. Impact on the electricity system

This IMS is expected to contribute to the improvement of operation and management in electricity systems, since the access to centralized and controlled loads through a website provide the place where the operator of the grid, utilities and the consumer are able to interact.

Management options proposed here may imply the reduction in the necessity of new generation plants and new transport lines, that means a significant reduction of the environmental impact (reduction of 1 Ton CO_2 emissions per MWh) and a reduction of needs and costs of electricity transport and system operation.

For example, in Europe there are about 4,000 colleges and universities, so this project has a huge potential for this type of infrastructures [8].

6. Impact on human habits

Other important impact is the achievement of a social energy commitment. This project promotes the best use of energy by the different components of the university community (professors, students, resource managers, services and administrative staff (SAS)) or the infrastructure. Thus, responsibilities for each collective are promoted in the followings areas:

- Maintenance service: Control of air conditioning system, common areas lighting.
- Resource managers: Common areas and classrooms lighting. They are provided with specific use patterns for each building.
- Students: Air conditioning and lighting in classrooms. Lighting in restrooms.
- Professors and SAS: Lighting, air conditioning and power points in office rooms.

7. Implementation of actions in facilities

Following, they are included some proposals about different equipment that usually is not controlled in this type of infrastructures. In order to manage these devices some actions have been implemented:

- *Autonomous air conditioning devices* (split units, roof-top…):

Problem: Some AC individual devices, installed in offices and little rooms, remained switched on during nights or weekends.

Solution: Permission relays have been installed in series with the control circuit of machines. These relays are connected to the control system, which avoids that AC devices remain connected during night or weekends. The payback is shorter than 2 years.

- *Centralized HVAC systems*

Problem: Some HVAC centralized devices remained switched on during nights or weekends. Nevertheless, the control of these systems was usually centralized and easy to adjust, but timetables were no optimized.

Solution: Permission orders are given by the IMS to the local control system installed for chillers/heaters and groups of fans. This option avoids that HVAC devices remain connected during nights or weekends. Moreover, other control options have been performed, as disconnection of chillers/heaters on peak hours, since fans can use the thermal inertia of the system for one or two hours. The payback is shorter than 2 years.

- *Lighting*

a) In common areas

Problem: Usually, lighting in common areas was excessive during the day. Additionally, some lights were switched on during all the day.

Solution: Permission relays have been installed in series to main lines of common lighting areas that are switched off sometimes. These lines are switched off when lighting in the area is not necessary (during night, weekends, holidays…). In addition, twilight switches have been installed and timetables for connection are now adapted in order to optimize the level of luminance (adaptation of switching timetables in accordance with seasonality)

b) In classrooms/conference halls

Problem: Sometimes there were empty classrooms in that lights were switched on.

Solution: Presence detector units have been installed in series with switches in order to control the lighting.

c)In restrooms

Problem: Light in restrooms was switched on during all the day.

Solution: Presence detector units or timer switches have been installed. Energy saves about 60% are being achieved. The payback is not higher than 3 years.

- *Electronic Equipment*

Problem: Obviously, the electronic equipment (computers, printers, videos) in offices, in general, and in university buildings, in particular, is very important. Demand of electronic devices in universities represents up to 15% of overall peak demand [4] and [7]. Sometimes, electronic equipment was switched on during all the day.

Solution: Permission relays have been connected in series with the control circuit of printers, photocopiers and similar devices in common areas in order to switch off them during night. UPS devices have been installed for electricity storage and disconnection of some electronic devices on peak hours.

8. Obtained results

The beginning of this project is located in February 2007. It is interesting to point out that since this date, savings have been estimated in more than 400 k€, while the total cost of the project has been in about 1 M€. Higher savings are expected when the IMS is completely operative. Nowadays, there were already 45 buildings of UPV integrated in the IMS.

Sixty two control boxes and 138 meter points have been installed, while 1.273 lines are now controlled. The IMS carries out more than 1.000 control actions every day.

Savings have been mainly achieved by controlling the HVAC devices. By comparison between the consumption during a normal day before and after the installations of the IMS, reductions of consumption in working days in this type of devices have been calculated in 163.098 €, whereas savings of 43.473 € and 87.709 € were achieved in Saturdays and Sundays or vacations.

Savings are very important in lighting of common areas like restrooms, corridors or halls, where reductions of 18.126 € have been got.

Following, some figures directly obtained from the IMS reports are presented to illustrate some interesting effects in the load curve of different facilities now which are being controlled. These results are used for the calculation of the energy and economic savings, according to the control actions performed by the IMS.

Fig. 3 shows the effect of switching off the cool production 30 minutes in advance, so the thermal inertia of the system is used to keep the temperature range under control. Additionally the starting time is delayed 1 hour in the morning.

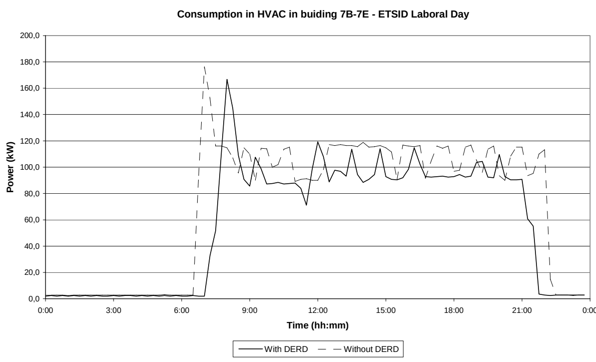

Fig. 3 Energy consumption in building 7B-7E ETSID

As it is shown in the figure, consumptions is reduced from 1.720,9 kWh to 1.392,1 kWh, that implies savings of 19%. If only periods from 0:00 to 8:00 and from 21:00 to 24:00 are considered (valley periods), savings of 179 kWh are achieved.

Taking into account the effect in the whole campus on Saturdays, it could be inferred that consumption during the valley period (mainly on night) has been reduced, unless the total consumption during the day has suffered and increment due to the building of new colleges in the University.

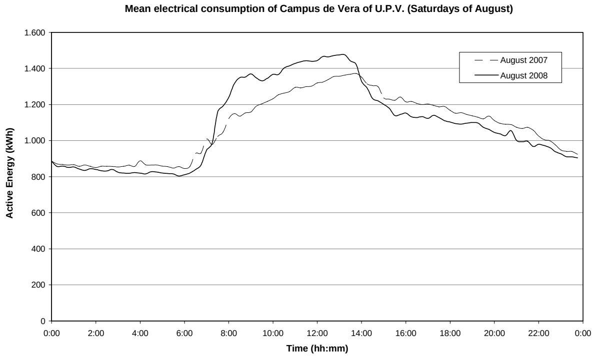

Fig. 4. Consumption on Saturdays in August 2007 and 2008

As it is shown in Fig. 4, the mean consumption in 2007 on Saturdays was 104.008 kWh and 104.347 kWh in 2008. Nevertheless, when only valley periods (from 0:00 to 7:00 and from 14:00 to 24:00) are considered, it is easy to check that consumption has been reduced in about 5% (from 69.614 kWh to 66.458 kWh a day)

A similar effect is obtained in Sundays and vacation periods. Fig. 5 presents load curve for the whole campus in August 15th 2006, 2007 and 2008.

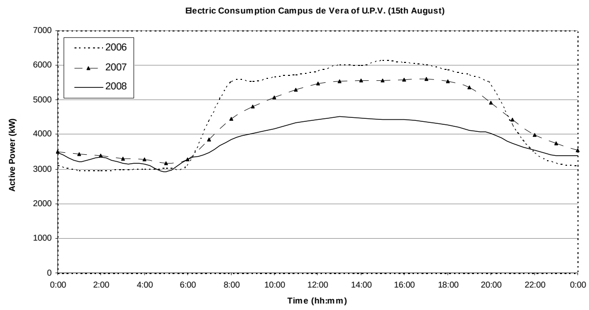

Fig. 5. Consumption on Saturdays in August 2007 and 2008

As it is shown in the figure, consumption was 111.734 kWh in 2006, 108.166 kWh in 2007 and 92.223 kWh in 2008, so a reduction of about 15% has been achieved since the implantation of the IMS. It has been got thanks to the proper management of the space cooling devices, since HVAC machines were switched on during the whole day in vacations before implementing the IMS.

Other important action has been the installation of presence detectors in restrooms, so lighting is switched off when not used. A preliminary study allowed to detect reductions of about 60% in comparison with the initial consumption in lighting. Fig. 6 shows the load curve of lighting in a restroom before and after the installation of a temporized switch.

According to the figure, consumed energy in the first case (conventional switch) was 7,36 kWh a day, while is reduced to 2,55 kWh when a temporized switch is installed, that implies savings of 65%.

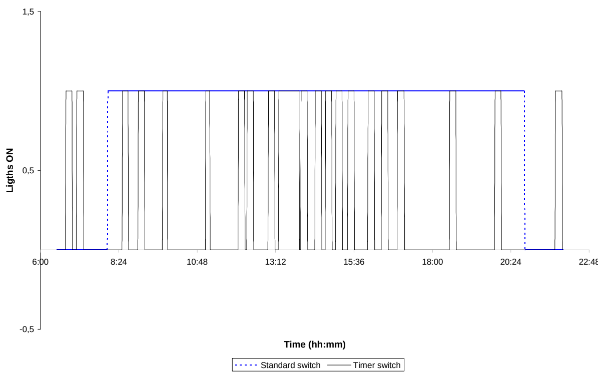

Fig. 6 Consumption before and alter the installation of a temporized switch in a public restroom

9. Conclusion

A new Integral Management System has been created to help the customer to use more properly the energy. This IMS includes a set of new tools and techniques in order to improve the management of different energy resources used in existing infrastructures, resulting in a reduction in energy consumption, increased overall efficiency and the control of distributed loads. The university campus environment is selected since it encompasses many service enterprises including healthcare delivery, sports facilities, businesses and start-ups in research parks, as well as overall faculty and student service, research and educational facilities.

The IMS is based on a secure website to inform and to get in touch with different agents that could be interested in the use of available distributed energy resources, as generation, storage and demand response. It allows the facility managers to measure energy consumptions, to store and manage data, to control energy consumptions and to watch power not to exceed a pre-fixed set point.

Energy consumption would be measured, so it could be controlled and reduced. As it is shown in this paper, the IMS is able to achieve decrements of 20% could with active control.

Lastly, other impact is the achievement of a social energy commitment towards effective energy control in service enterprises.

Acknowledgement

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