MONITORING AND MANAGEMENT OF ENERGY IN PENTEADA BUILDING – A CASE STUDY

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Abstract: This paper describes a low cost monitoring and management energy project that is currently being implemented and tested at the main University of Madeira building in Penteada. The project is composed of a data acquisition system, a communication system, a database, a management tool and an interface for internet access. Data is collected at relevant points through the building over more than 200 meters distance, sent to the database, processed and displayed with the interface. The management tool allows introducing base energy costs, yearly calendar for the university activities and other relevant information and processes this data to compare consumption for similar periods, in different points of the building, under different atmospheric conditions and issuing e-mail and sms alerts to the administrators of the building. The current work is part of a strategy to improve the energy efficiency of the building and its results will be used for decision making about the interventions. Copyright CONTROLO 2012.

Keywords: Monitoring elements, Sensors, Energy management systems

1. INTRODUCTION

Energy efficiency has become a very important issue since several analysis led to an understanding that there is more to achieve by improving efficiency, with less investment involved, when compared with many renewable energy solutions available.

Large public buildings are usually problematic in terms of energy consumption. They are difficult to monitor and manage in terms of energy and usually are not an example of efficiency.

The issue of energy monitoring and management in buildings has been studied in many different research works. As examples it is possible to point out: home (Tompros et, al, 2009); home using power line communication (Chia-Hung et. al, 2009); internet based campus energy monitoring system (Nagata, 2006); Mosque (Al-Homoud et. al, 2005); industrial with Wireless Sensor Network - WSN (Fonda et. al, 2008) and large public buildings (Yongpan et. al, 2009). In (Wei et. al, 2009), national policy for large scale public buildings is also discussed.

The present work, which is still under development, aims to build a generic solution for monitoring and energy management in a building.

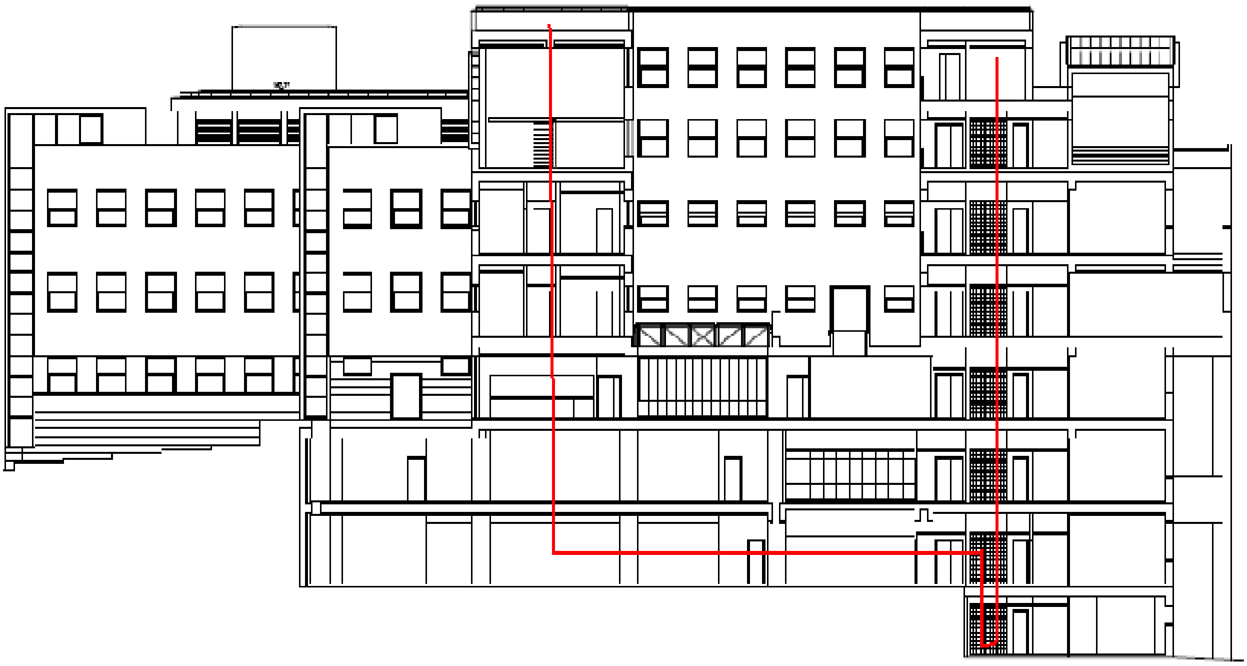

Fig. 1. Lateral view of the building with a red line showing the communication path

The main objective is to develop a system that allows to collect energy data and build a database for future reference and comparison in order to determine the utility of energy intervention in the building (to lower consumption) and the influence of external factors such as temperature, humidity and lighting (this can also lead to intervention in the building).
The project must be developed using generic, low cost components with open software so that its implementation and use do not represent an important additional cost.
The case study chosen to test the solutions developed is the main building of the University of Madeira in Portugal. This building, used mainly for research and teaching has around 3500 daily users and includes classrooms, laboratories, offices, parking, bar, canteen, copy center and commercial spaces.

2. MONITORING SYSTEM

The monitoring system comprises environmental data, such as temperature, humidity and luminosity. The environmental data is provided by a pre-existent Wireless Sensor Network (WSN), which is connected to the main database.
The data acquisition system is going to be installed along the building. Figure 1 shows a lateral view of the building. The red line represents a possibility to build a communication system through the building using service areas to pass the communication cable. After studying the building it was immediate to conclude that WSN was not an option due to the obstacles and price that such a solution would cost with this large distance to cover.

Ideally it would be of interest to measure all the lighting consumption to analyze the influence of external light and evaluate future improving in the lighting system (replacement of the actual equipment for more efficient one). Unfortunately, for this building this would imply measuring every partial circuit breaker panel (many different points in each floor, including one in each laboratory) and this would be both too expensive and difficult to implement in terms of communication system.
After detailed analysis the measurement points are:
- Common lighting (main halls and corridors), three-phase measurement – Measured next to the energy entrance at the lower level of the building;
- Classroom lighting, measure at the partial circuit breaker panel – 10 measurements in 5 floors.
- Heating, Ventilation and Air Conditioning (HVAC), three phase measurement – Measured next to the energy entrance at the lower level of the building;
- Main power supply, three-phase measurement – Measured next to the energy entrance at the lower level of the building;
In total, this amounts to 19 measurement points and data transmission along almost 200 meters.

2.1 Type of communication system

The desired monitoring system needs to be cheap so that the economic benefits introduced by monitoring and improving the efficiency are not absorbed by its cost. The system also needs to be stable and reliable in order to attain low operating costs.
In order to choose the communication system several solutions were considered, including the following ones:
- Power line – Advantage: allows transmission at reasonably long distances. Disadvantages: cost and difficulty to find multipoint solutions. The basic

communication elements were found starting at 44€ (approx.).

- Wireless – although there are many technical solutions for wireless transmission, there are 3 main obstacles: i) periodic replacement of batteries; ii) difficulty to guarantee that the position of the elements in the technical areas is not changed, blocking signal transmission; iii) the number of transmission points necessary to guarantee the appropriate transmission in an environment with many obstacles. XBee is one of the most popular solutions that can be used to implement this protocol and the basic communication elements costs 27€ (approx.).
- Ethernet – Advantage: stable, reliable and low maintenance costs. Disadvantages: there are no connection points next to the measurement places. To implement this solution there is a huge variety of connectors with prices starting at 9€ (approx.).
- Controller Area Network (CAN) – Advantage: can be implemented over different transmission media, has many low cost hardware platforms, developed by different manufacturers. To implement this protocol there are some microchips available, with prices starting at 2€ (approx.).

The latter solution was chosen to implement the communication system and some of its relevant aspects are pointed out in the following section.

3. CONTROLLER AREA NETWORK

CAN communication protocol was developed during the eighties for industry applications, namely the automobile industry, with real-time requirements (Antunes and Mota, 2001). CAN protocol is regulated by standards such as ISO 11898-1, 11898-2, 11898-3 and 11898-4 (Road Vehicle 2003a) (Road Vehicle 2003b) and had a rapid growth of use in the industry, namely in industrial control applications.

CAN protocol is serial, with multi master capabilities, follows the producer-consumer paradigm and presents a high performance and robustness. Since it is a serial protocol, a single bus is used to connect all the nodes (Antunes and Mota, 2001).

The conceptual architecture of CAN, used with CAN Open, defines 3 layers from the Open Systems Interconnection (OSI) model: Application layer, Data Link layer and Physical layer (Antunes and Mota, 2001).

CAN has several advantages but one of the most interesting ones for the present work is the possibility to work over long distances. Table presents the relation between distance and maximum baud rate.

Table 1 - Distance and maximum baud rate relation.

Baud Rate (kbits/s)	Maximum distance (m)
1000	30
500	100
250	250
125	500
62.5	1000

3.1 CAN Hardware

CAN hardware chosen for this project is the mbed board that can be seen in figure 2. This hardware offers:

- Development environment and compiler accessible through the internet;
- Libraries with examples;
- Simplicity of use: the software works as an USB pen. It is sufficient to drag and drop the files for compilation, files in mbed website (www.mbed.org);
- Small size: Dual In-line Package (DIP) format with only 53mmx30mm.
-Accessible price: with transceivers for the selected bus, it costs about 50€.

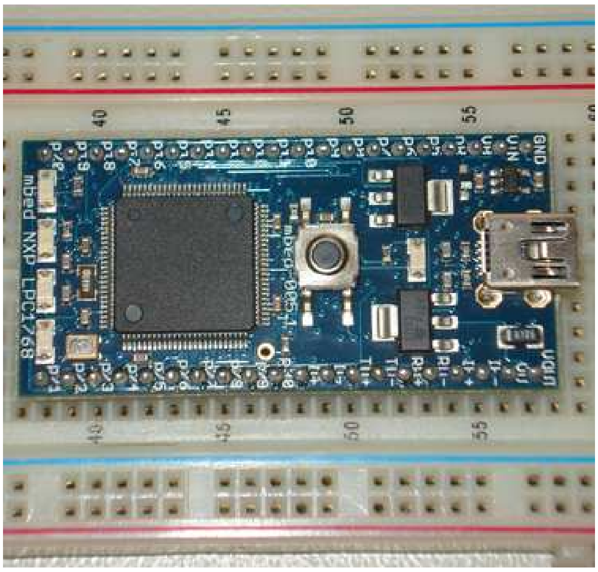

Fig. 2. mbed Microcontroller

4. DATA ACQUISITION SYSTEM

The data acquisition system is under development and is composed of:

- 10 current transducers of 200 Amperes for each of the partial circuit breaker panels;
- 9 current transducers of 5000 Amperes for the main energy supply, HVAC and common lighting;
- 10 mbed microcontrollers for processing data and CAN communication, with 18 CAN Bus transceivers for rolled pair telephone cable. Most mbed boards will use 2 CAN Bus transceivers, with the exception of the main and the last mbed;
- 1 personal computer that holds the database and connects to the main mbed via router, which receives the measured results from the transducers.
- 200 meters of rolled pair telephone cable;

Rolled pair telephone cable was chosen because it is cheap and offers some protection to interferences. In total, the cost of this solution without labor cost amounts to 2500€, which is quite inexpensive when compared to the commercial solutions available in the market.

Figure 3. Current transducer of 200 Amperes.

Figure 4. Current transducer of 5000 Amperes.

Figures 3 and 4 show the current transducers used in this work. The transducer in figure 4 was selected due to its diameter. The maximum current it supports is probably too high but due to the diameter of the cables present in the electrical network, this transducer was the only one capable of embracing it.

The reactive power is not measure since the installation of the building already includes compensation.

The measurements are done in real-time and sent to the database for registration each hour. This time period can be changed, depending on the building needs.

The final system is going to output the energy consumption data along with environmental data. The energy will be tagged with the following variables: energy consumption in kWh, measurement point identification, hour and date.

At present, the acquisition system is reaching the end of the development phase. The first weeks of operation will be used for test purposes, where the final system is going to be assessed by comparing the obtained results using the developed system against the data obtained with commercial equipment and the official electric invoice.

5. DATABASE AND MONITORING INTERFACE

As mentioned earlier, the monitoring data is concentrated in a database. It is associated with this database that most of the functionalities of management can be operated.

The database information can be accessed through a web interface with a local application of data flow control.

Figure 5. Main window of the web interface.

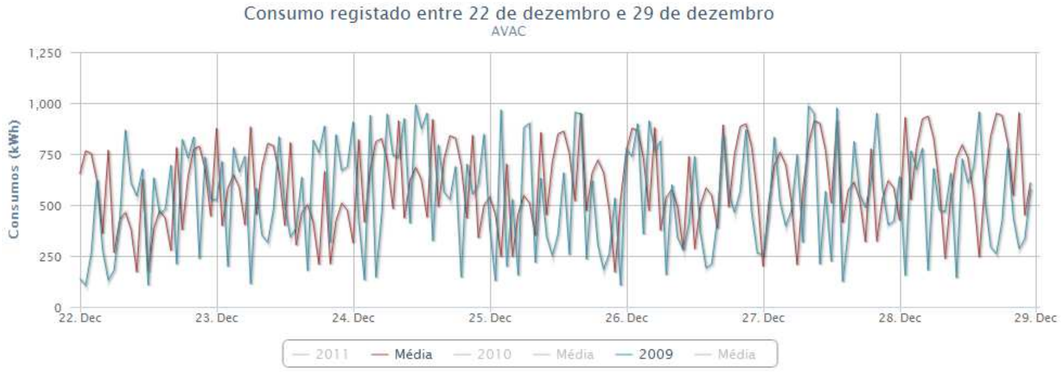

Figure 6. Example of comparison of yearly consumptions during the same week.

5.1 Database

The database used is MySQL and it was chosen because it is free, supported by the servers available for this work and has extensive functionality for handling the data as needed.
Operating on the database there are two applications: a graphical interface for visualization and a local application that receives data from the CAN network and stores it in the database.
Besides the information received from the monitoring system, the database holds additional information. It has tables about relevant events (example: missing data from sensors); data from the yearly calendar of the university and data about energy costs that can be updated.
The database also holds the environmental data that is provided by a pre-existent WSN, in order to produce correlations with consumption.

5.2 Monitoring Interface

The interface was chosen as a web interface to allow accessing from any point with internet access to monitor the building consumption.
The interface was built using HTML, PHP and JavaScript which are compatible with any Internet browser.
When entering the interface, after authentication, the first page reports data collected during the last week, as can be seen from figure 5. Please note that the current version of the interface is still in Portuguese.
Figure 5 is composed of two graphics, the upper part shows energy values, while lower part shows the cost associated with this energy. Below the graphics a table can be seen that holds daily data for consumption and cost. On the right side it is possible to change the criteria for data retrieving to access different periods, use the yearly calendar and use a smaller or larger window of analysis.
Data from different sensors and period averages can also be superposed for visual comparison or placed in adjacent windows, as can be seen from figure 6. In this case yearly averages are compared.

Additional features:
- access only after authentication;
- different access permissions;
- special area for administrators (enables energy price and calendar editing);
- automatic monitoring and alert emission. With the use of artificial intelligence tools the interface can be configured for issuing warnings and alerts regarding consumption levels. The warnings will be issued by e-mail and sms, according to configuration. This feature is still under development.
- Reports. It is possible to generate reports with data defined by the administrators. These reports are very relevant for measuring the effects of efficiency improvement in the building and can be exported in pdf format and sent by e-mail.

6. CONCLUSION

In a building with 3500 daily users, that has a consumption of 1MWh, which corresponds to costs of more than 100,000€ each year at Portuguese energy prices, monitor and reduce costs is a top priority task.
The energy market tendency points to a rise in electricity prices, moreover, Madeira island has a high dependence on fossil fuels for electricity generation. Therefore, large efforts must be made to improve efficiency in the energy use.
This work makes use of a stable and reliable communication system, composed of a CAN fieldbus, which has been used in the automobile industry and has low cost and easy configuration, to implement a monitoring and management system for a large scale public building.
This project is the initial step of a large energy intervention that must be made in the main building of the University of Madeira. The interventions will cover shadowing, lighting automation, lighting reduction and lighting replacement to more efficient appliances.
The project is still an undergoing project and therefore there is no real data to present yet.

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REFERENCES

Al-Homoud, M. S., Abdou, A.A., and Budaiwi, I. M. (2005), Mosque Energy Performance, Part II: Monitoring of Energy End Use in a Hot-Humid Climate, JKAU: Eng. Sci., vol. 16 no. 1, pp. 185-202

Tompros, S., Mouratidis, N., Draaijer, M., Foglar, A., Hrasnica, H. (2009), Enabling applicability of energy saving applications on the appliances of the home environment, IEEE Network, Vol. 23, Is. 6, pp.8-16

Yongpan, C., Mu Xianmin ; Zhang Jili ; Lu Zhen Development of Monitoring System of Building Energy Consumption (2009), International Forum on Computer Science-Technology and Applications, IFCSTA '09, Vol. 2, pp. 363-366.

Fonda, J. W., Zawodniok, M. J., Jagannathan. S., Salour, A., Miller, D., Missouri S&T Mote-Based Demonstration of Energy Monitoring Solution for Network Enabled Manufacturing Using Wireless Sensor Networks (WSN), (2008), IPSN '08 Proceedings of the 7th international conference on Information processing in sensor networks.

Nagata, T., An electric power energy monitoring system in campus using an Internet (2006), Power Engineering Society General Meeting.

Chia-Hung, L., Ying-Wen, B., Hsien-Chung, C., Chi-Huang, H., Home appliance energy monitoring and controlling based on Power Line Communication (2009) ICCE '09. Digest of Technical Papers International Conference on Consumer Electronics

Wei, N., Yong, W., Yan, S., Zhongcheng, D., Government management and implementation of national real-time energy monitoring system for China large-scale public building (2009), Energy Policy, Vol. 37, Is. 6, pp. 2087–2091

Road Vehicles—Controller Area Network (CAN)—Part 1: Data Link Layer and Physical Signalling, ISO Standard-11898-1, 2003.

Road Vehicles—Controller Area Network (CAN)—Part 2: High-Speed Medium Access Unit, ISO Standard-11898-2, 2003

Antunes, A., Mota, A., "O protocolo CAN", 1as Jornadas Politécnicas de Engenharia, Leiria, 2001.