DEMAND RESPONSE IN PRACTICE: OPTIGES PROJECT FINAL RESULTS AND LESSONS LEARNED

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ABSTRACT

In order to unveil the economical and technical viability of demand response initiatives in the Spanish power system, ENEDESA and TECNALIA have joined forces in the OPTIGES research project [1-2]. The project comprises the development of a load control architecture that allows the remote activation of demand response strategies that modify the planned settings of existing EMCSs (Energy Management Control Systems) at customer's premises. During the last year, the system was installed in three commercial facilities in Spain. This paper presents the main results and the conclusions extracted from the tests.

INTRODUCTION

The OPTIGES system is based on a central controller and on a series of OPTIGES local controllers. Each participating customer has one locally installed.

Each customer's existing EMCS is specifically programmed allowing them to understand the outputs from the OPTIGES local controller. The strategies that are programmed in the EMCS are particular for each customer and depend on the capabilities of the EMCS, the loads (possibilities of reduction) and the tolerance to the discomfort. An energy audit will help decide on this. Typical strategies are modification of the normal setting of the thermostats of building zones, and the dimming or interruption of non-critical lights. Strategies for both summer (air conditioning) and winter (electric heating) are considered.

The central controller calculates the optimal control actions according to the constraints introduced by *ENDESA ENERGIA* (electricity supplier) or *ENDESA DISTRIBUCION* (distribution company), and the control strategies programmed in the EMCS of each customer. The calculated control actions are then sent to each OPTIGES local controller using GPRS communication.

The power consumed by each building is measured by the OPTIGES local controllers in 15 minute intervals, and sent to the central controller using the same two way communication channel.

The figure shows a graphical representation of the system:

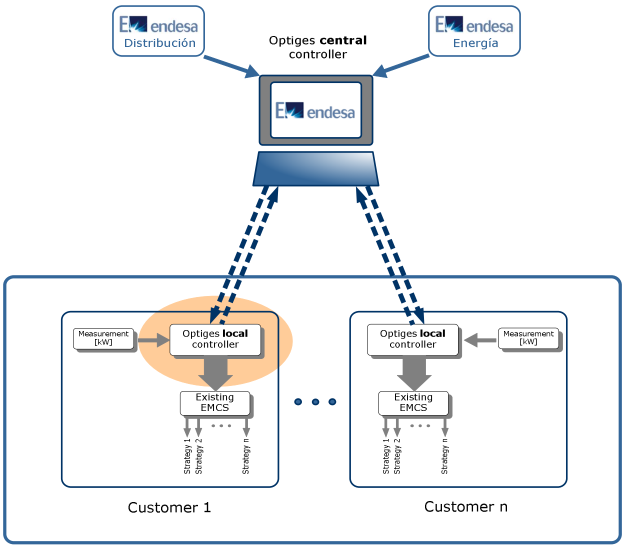

Figure 1 System architecture

The system was installed in three commercial facilities sited in three different Spanish regions (Barcelona, Sevilla and Bilbao), and test were developed. The objectives of the tests were:

- Evaluation of the reliability of the developed hardware/software architecture.
- Evaluation of the cost and complexity of the installation on different buildings.
- Establish the load reduction potential of different demand response strategies on different buildings.
- Evaluation of the predictability of the load shape of individual buildings for different baseline calculation methods.
- Evaluation of the comfort degradation experienced by building occupants.
- Evaluation of the "payback" effect on the load shape.
- Evaluation of the economic viability of the demand response program.

SITE DESCRIPTION

Site 1, Barcelona

It is a recently built office building. The building is small with 1,800 m^2 separated into four floors. The EMCS system is very advanced and combines the control of HVAC and lighting systems in one console. Heating is electric by means of a heat pump. This provides demand response potential both in summer and in winter. The EMCS system is based on the KNX standard [3].

Different demand response strategies were implemented, including independent thermostat setting modification for different floors, and exterior lighting disconnection.

The figure shows the installed OPTIGES local controller:

Figure 2 OPTIGES local controller installation in Barcelona

Site 2, Sevilla

Tests were performed on one of the four floors of an office building sited in the sunny city of Sevilla. The surface of the floor is 1,000 m^2. Heating is provided by heat pumps, and therefore summer and winter demand response potential is available. Thermostat setting modifications and terminal unit disconnections were performed. The EMCS system is LONWORKS based [4].

Site 3, Bilbao

The test building in Bilbao is significantly bigger than the other two with a surface of 15,000 m^2. Most of the building space is used for office activities, but there is also an industrial storage area. Heating is provided by two gas boilers, and therefore there is demand response potential available only during the summer season. The EMCS system is from HONEYWELL.

On this building the control actions were very aggressive, and mainly involved the complete and periodical disconnection of the main water chillers. The figure shows the OPTIGES local controller installation in the building:

Figure 3 OPTIGES local controller installation in Bilbao

TEST RESULTS

Simultaneous tests were performed on the three buildings during the second half of 2009. During those six months the central controller has been continuously running and communicating with the three local controllers every fifteen minutes.

Even if the three sites were completely different (different sizes, different HVAC system architectures, different control systems, different type of internal organizations and interlocutors, …) the methodology, effort and cost required to install the local controllers and program the EMCS systems have been similar.

One of the main challenges of implementing a program like the one developed on this project is persuading facility managers. Facility managers are often reluctant to leave control decisions in the hands of external elements such as the OPTIGES central controller. In order to provide the necessary confidence to facility managers, prior to the execution of a control event, the central controller always notifies by email and SMS the relevant information. The local controller was then fitted with an "event override" button that could be pressed by the facility manager before or during the execution of the control event. This will stop the event.

During the tests, the override button was pressed on less than a 10% of the occasions by facility managers, but it proved very useful providing them with the necessary confidence.

In order to establish the effective load reduction obtained by the execution of demand response actions, a baseline has to be calculated for each building and event. The baseline is defined as the estimated whole building electrical load curve if no control action is executed. The baseline for each building has been calculated using different statistical methods [5-6] that take into account outside air temperature. On average the obtained estimation errors are on the region of a 5%. There is sensibility to the calculation method used, and the longer the historical data series, the better.

Next figure shows the result of the execution of a control action on the building in Barcelona. The control action involved a 2ºC rise in the thermostat settings of three of the floors during an hour and a half. After the event, the thermostats were set back to their normal state floor by floor in 15 minutes intervals. This strategy minimises the load recovery effect at the end of the event. The figure shows the measured and estimated load curves. The area inside the circle indicates the event period.

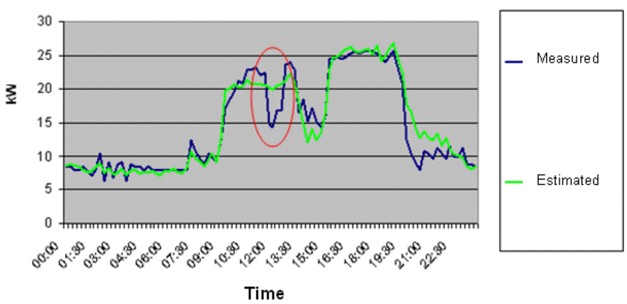

Figure 4 Barcelona building load curves during one particular control event

The difference between the measured curve and the baseline represents the actual control margin that was obtained during the event. The obtained control margin is around 8kW which represents approximately a 30% reduction.

Next figure shows the resulting load curves when executing an event on the building in Sevilla. The event involved a 2ºC rise in the thermostat settings during one hour. On this occasion no special measure was implemented in order to minimise the load recovery effect. The estimated and measured load curves show that even if during the event 5kW were reduced (a 33% reduction), most of it was recovered when the thermostats were reset.

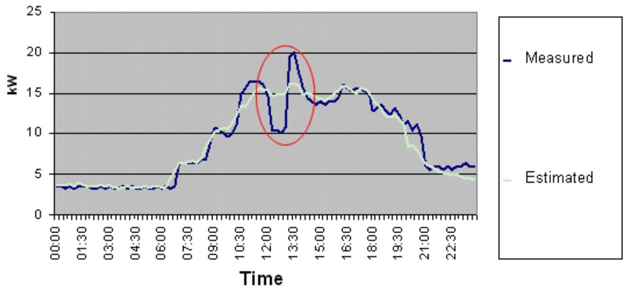

Figure 5 Sevilla building load curves during one particular control event

Experiments in Bilbao were more aggressive. Next figure shows the result of the disconnection of the water chillers during two hours. Measures were taken in order to avoid load recovery. In this case a control margin of more than 200kW is obtained during the two hour control period, representing a 25% reduction.

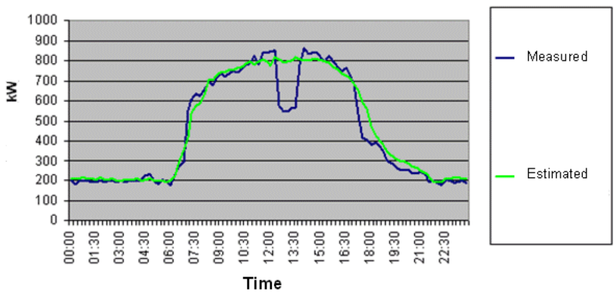

Figure 6 Building building load curves during one particular control event

It has to be said that after every control event, the facility managers were contacted and feedback about the internal occupant comfort was requested. In general the comfort degradation was acceptable. It has to be noted that demand response events like these ones are designed to be executed only a few times per year.

CONCLUSIONS AND FUTURE WORK

The results of the project have shown ENDESA that commercial facilities can provide automated response in an aggregated way. It is certainly more cost effective to target bigger buildings with high HVAC load.

The implementation of a program like the one tested on the project could bring interesting benefits to both electricity suppliers and distribution companies, such as:

- Short term reduction of the investment requirement on transmission, distribution and generation infrastructure. Demand response could reduce or postpone the need for investment on new peak capacity. We are moving towards a more electrified world, and electricity demand is expected to continue growing over the next years.

- Greenhouse gas emission reduction. The load reduction at peak load periods can avoid the highly pollutant generation that is used at those time intervals.
- Minimisation of transmission and distribution losses.
- Increase in the amount of renewable resources that can be integrated in the network. The penetration of renewable electricity sources continues to grow, and load control capability will allow a more flexible management of the load/generation imbalances.

These and other issues are being further analysed by ENDESA in the "Smart City Malaga" project [7].

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