On the potential of Internet based energy services in Greece during cooling season

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ABSTRACT

Existing advanced and sophisticated building systems combined with emerging IT technologies create the opportunities for e-based energy management. Driven mostly by the deregulation of energy market, e-based energy management systems have the potential to help both energy utilities to manage power load and reduce peak loads and end-users to reduce their consumption and possibly increase their comfort.

As the real time/time-of-use price of distributed energy fluctuates over a day, significant savings can occur for both utilities and customers; there are some appliances manageable over time, in the sense that it is possible to shift their energy use in time (away from periods with peak prices) without compromising their function. This holds, for example, for heating and cooling equipment (slow distributed processes, responsible for most of the energy use in buildings).

This paper describes the infrastructure for e-services under test within a European research project and present a set of e-energy services, tested and prototyped in Greece. The provided energy services are linked with the remote monitoring of environmental parameters, the remote control and actuation of cooling equipment and the on line prediction of energy consumption and environmental conditions (using Artificial Neural Networks).

The services focus mainly on the cooling season, as this period presents an important potential from various points of view; energy distribution companies can importantly improve the energy management by having a prediction of the cooling energy consumption of different areas of buildings while remote control of cooling equipment during the hours of peak power demand, gives the means to effect orchestrated energy management and load shedding, as well as minimize the contingency of construction and operation of new plants or a feature danger of a black out.

1. INTRODUCTION

The service gateways combined with new local network technologies creates opportunities for new energy services that will help both utilities to load management and residents to reduce their consumption and possibly increase their comfort. New energy services that are enabled vary from automated metering and billing, remote control of appliances and energy load management to indoor climate control.

Obviously, there are many opportunities as well as uncertainties here, leading to a clear need for design and analysis. Electronic energy services have special features compared to conventional systems; as on-line energy services involves yet non existing activities, at least not at a great or commercial scale, the requirements have to be created rather than educed (Cordijn et al., 2000). Also, as services and technology are strongly linked, the design decision about energy services and the associated systems architecture cannot be made in a decoupled way.

Potential energy services involve many different actors. Consequently, identification of energy services and decision making demand the specification of all actors role.

A possible grouping of the energy services can be realised by considering two actors:

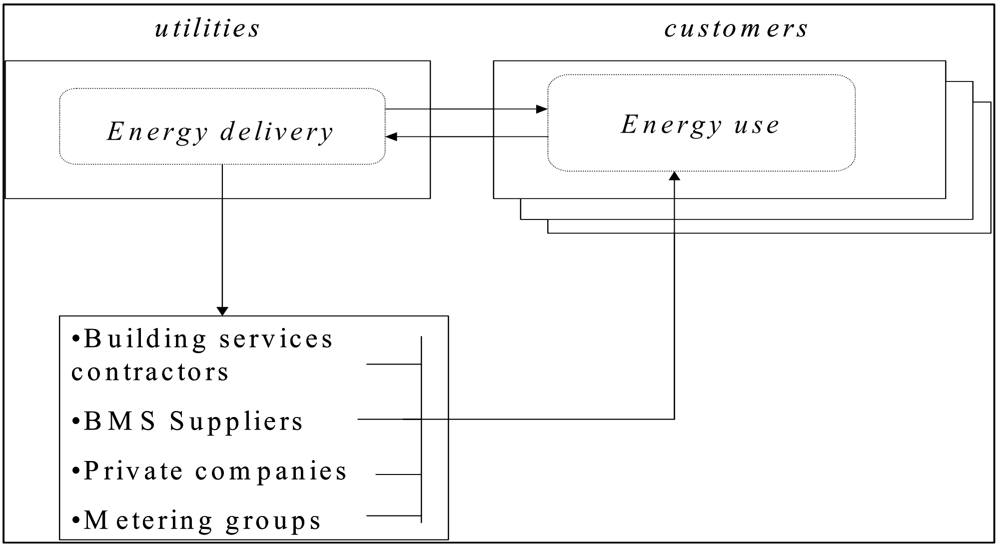

Figure 1: Identification of the actors.

- Service Providers -which implicitly could be utilities, private sector companies, local authorities.
- Customers.

Of course, energy services could as well provided from an utility to private companies, from private companies to local authorities and vise versa etc (Fig. 1).

In the frame of this analysis the energy services that are provided in Greece include both actors: Service Providers and Customers, and aim to make available services that are linked with the following topics:

- Remote monitoring of various resources and environmental parameters;
- Remote control and actuation of appliances;
- On-line prediction of energy consumption and environmental conditions.

2. ON-LINE PREDICTION OF ENERGY CONSUMPTION AND ENVIRONMENTAL CONDITIONS

The first category of services that were provided in Greece is mainly focused on the cooling season as this period presents an important potential from various point of view. It is estimated that the impact of cooling, during summer months, is around 1.8 GW of peak power demand, representing the necessity to operate for this season additional six power plants, of 300 MW each.

From the energy distribution companies' perspective (that can play also the role of a service provider), it is possible to importantly improve the energy management by having a prediction of the cooling energy consumption of different areas of buildings the next 24 hours.

2.1 Prediction of the cooling energy consumption for the next 24 hours in an hourly basis

The prediction of cooling energy is based on an artificial neural network model (ANN) that executed on line and estimates the cooling energy consumption the next 24 hours (Karatasou et al., 2004; Clarke et al., 2004). The input requirements for this model are the cooling consumption measurements 5 days before the prediction day and the ambient temperature of the previous day. The accuracy of the model is close to 7% (Fig. 2), giving a useful tool to Energy Distribution Companies for the energy management between different building areas. Also, building energy managers have the possibility to evaluate and decide various energy conservation measures based on this forecasting. It is important also to underline that when the schedule of use of the cooling equipment is repeated on a daily basis (a common situation in office buildings) the accuracy of the ANN approach is increased (close to 4%).

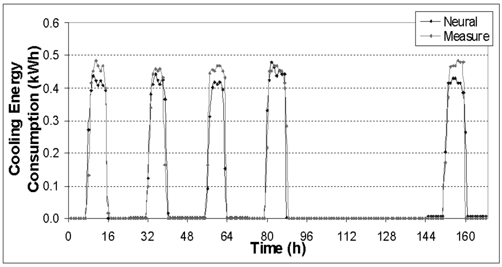

Figure 2: Accuracy of the ANN approach.

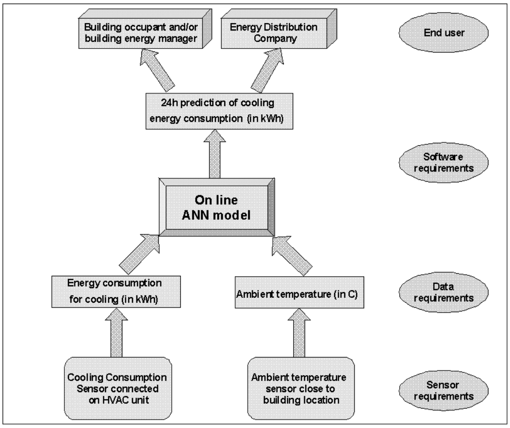

Figure 3: The model of the “Prediction of cooling consumption” service.

In order to provide on line predictions using ANNs, Matlab web server tool is used, installed on a server (located in NKUA) that plays the role of the service provider. Each time the user desires a prediction, Matlab requests the previous measurements (required for the forecasting) from an SQL server and executes the corresponding ANN model, presenting the results to the user (Fig. 3).

2.2 Ambient temperature prediction

One of the measured parameters at the three areas where the selected buildings are located is the ambient temperature. This information is used as an input to an ANN model that can forecast the next 24 hours with accuracy close to 6% (Fig. 4). The ANN model requires measurements of 5 days before the day of prediction and it is executed on line upon the user request (Fig. 5). It is developed under Matlab environment and the system that supports the service is similar to the prediction of cooling consumption.

3. REMOTE CONTROL AND ACTUATION OF COOLING EQUIPMENT

Joint with on line prediction of cooling consumption, the remote control of cooling equipment during the hours of peak power demand, gives the means to effect orchestrated energy management and load shedding, as well as minimise the contingency of construction and operation of new plants or a feature danger of a total “black out”. The service concerns also the occupants of the building as it gives them the possibility to organise remotely the schedule of the cooling unit operation.

This service is provided with two different versions, depending on the control strategy that is implemented to control the cooling equipment: schedule or intermittent control.

The first strategy (Fig. 6) allows the users to define a weekly schedule of operation on an hourly basis. After the activation of the service the operation of the A/C unit follows the defined time schedule. By using this service the

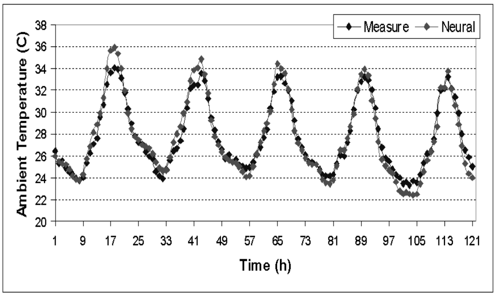

Figure 4: Comparison between measurements and predictions of the ANN model for the ambient temperature.

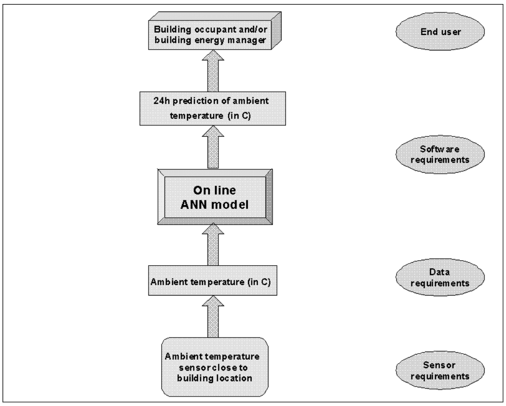

Figure 5: The model of “Ambient temperature prediction” service.

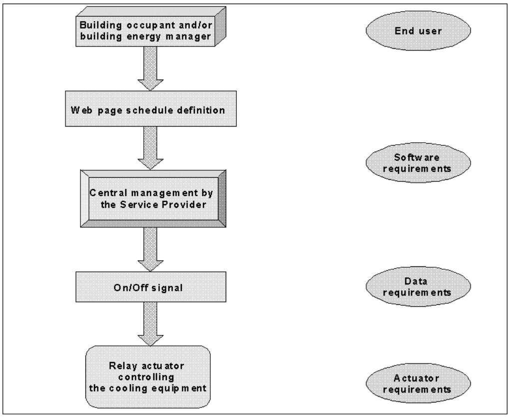

Figure 6: The model of "Scheduled Control" service.

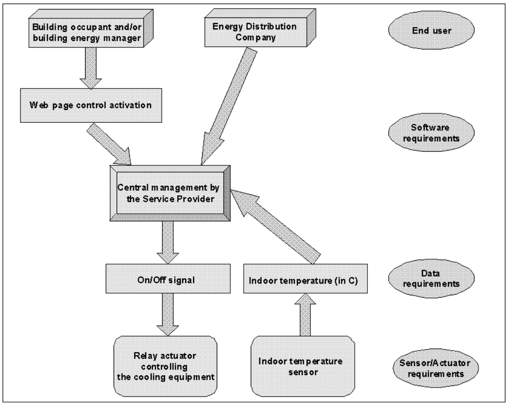

Figure 7: The "Intermittent Control" model service.

occupant of the building can remotely operate an A/C unit. Also, this service is appropriate for building energy managers who want to control remotely a large number of local A/C units.

The second control strategy (Fig. 7) concerns mainly building energy managers and Energy Distribution Companies rather than building occupants. This strategy enables the intermittent operation of the controlled cooling equipment, an approach that leads to energy conservation and permits to improve the energy management.

From the point of view of Energy Distribution Company's, this kind of control joint with the cooling consumption prediction permits to enhance the management of the energy distribution in a city or region level. The knowledge of the next day cooling energy requirements and the ability to reduce the peak energy load of a whole region by using intermittent operation of the A/C units give the possibility to better distribute the energy and avoid "black out" problems, a dangerous situation that big cities in south Europe facing during the summer season.

The strategy on which intermittent control is based requires the definition by the user of a threshold value of the indoor temperature under which the A/C unit operates intermittently. When the service is enabled, the infrastructure that supports the control services check every 15min if the indoor temperature is lower than the threshold value. If this is true, the A/C unit is turned off for 5 min. It is not allowed to turn off the unit more than 2 times per hour and the time interval between two turn off operations cannot be less than 20 min, in order to respect in a certain degree the preferences of the user. This kind of intermittent operation of A/C units can lead to cooling energy conservation up to 17%.

4. REMOTE MONITORING OF VARIOUS RESOURCES AND ENVIRONMENTAL PARAMETERS

This category of energy services concerns mainly information services that require the remote monitoring of various parameters. The end-users (the occupants of the building or a specific indoor space) can have information on the set of the monitored parameters such as ambient and indoor temperature and energy consumption for cooling (Fig. 8). They have access to previous measurements and the corresponding services offer a graphical representation from any time period in the past. Therefore the user can compare different time periods and evaluate the influence of various energy related strategies on the indoor thermal environment and the energy consumption for cooling.

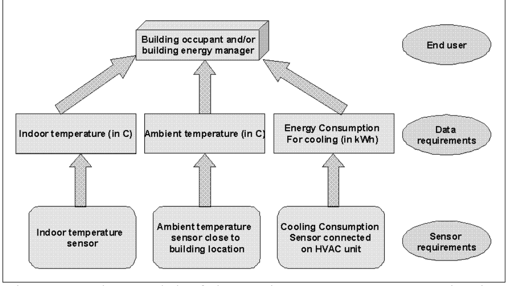

Figure 8: The model of the various parameters monitoring services.

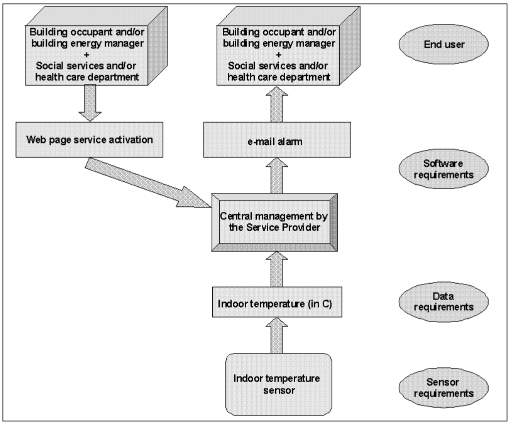

Figure 9: The "Indoor temperature alarm" service.

The monitoring of the aforementioned parameters enables in addition the following two services.

4.1 Indoor temperature alarm

This service (Fig. 9) concerns an indoor temperature alarm for overheating by comparing the monitored indoor temperature with a predefined threshold value. A specific receiver is then automatically notified about the overheating conditions. This service focus on occupants of buildings that need a real time monitoring of the indoor conditions, but it is also important for specific applications in cases where the temperature conditions are crucial (e.g. a computer server room where the air temperature affects the operation of the equipment). Furthermore, potential users of the service are health care and social services departments that support elderly people in Greece. During summer, a number of elderly people present unstable or dangerous health conditions due to the increased levels of temperature (especially during heat waves). By using the present service, health care and social services can have a real time image of apartments that the indoor conditions are exceeded specific levels according to criteria based on the specific health conditions of each person (heat exhaustion, asthma suffering, etc.) and perform all the necessary actions.

The concept of the service is based on the monitoring of the indoor air temperature which is compared with a threshold value defined by the user in his private web page. When the indoor temperature is higher than the threshold value an e-mail message is send automatically to the e-mail address that is also required when the service is activated. The message includes the actual indoor temperature, the threshold value and can include any desirable text or information.

4.2 Energy rating for cooling

In the frame of the EU directive for Energy Performance Regulation (EPR) in buildings, Greece prepares a new regulation based on this directive. Part of this work is the energy certification of buildings according to their energy consumption for cooling and heating. According to the annual energy consumption of the building (in kWh/m^2) for heating and cooling, the category of building (residence, office, school, hotel, etc) and the climatic zone where the building is located (there are 4 climatic zones in Greece), the buildings are classified in 5 categories (A to E). Based on this approach that will be a national regulation, a service (Fig. 10) that concerns the energy rating for cooling is provided. By measuring the real energy consumption for cooling and by knowing the necessary parameters (type, location and floor area) it is possible to classify the buildings under monitoring.

5. CONCLUSIONS

The services provided in Greece are mainly cover two general areas: the one concerns the energy and the indoor thermal conditions, while the other is related to the environmental condi-

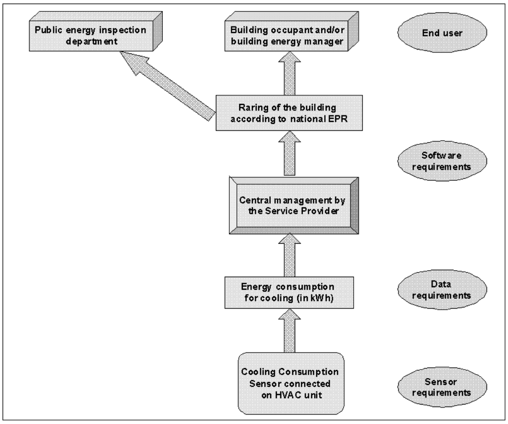

Figure 10: Aspect model of the "Energy rating for cooling" service.

tions. Concerning energy, the related services are focused on the cooling energy of buildings as it presents an important potential from the management point of view (but the services can also be expanded to the heating energy too). There are various end users according to service such as building occupants, building energy managers, energy distribution companies, social services departments, health care departments and public departments that are involved with the energy rating of buildings.

The experience gained from prototyping and testing the described services, shows that obstacles arise from the access network requirements. Yet, the massive rise in home Internet connections, gives the means for a range of e-based energy service, as well as a range of other services too.

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