A mixed integer linear programming formulation of the home energy management problem

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1 Introduction

A home automation system basically consists of household appliances linked via a communication network allowing interactions for control purposes. Thanks to this network, a load management mechanism can be carried out : it is called distributed control [1]. Load management allows inhabitants to adjust power consumption according to the amount of available energy time to time. This management aim at optimizing the expected comfort, the energy cost and the CO_2 equivalent rejection. For instance, during the consumption peak periods when the used power plants reject higher quantities of CO_2 and when the energy price is high, it could be better to delay some services such as the washing machine or to reduce some heater set points according to the weather forecasts and the inhabitant requests. In this study the comfort is evaluated for every request of service. It is a variable that quantifies how the execution of the service satisfies the inhabitant request. For instance the thermal comfort measures the impact of the difference between the expected temperature and the actual temperature, the comfort associated to the washing machine service measures the difference between the expected ending time and the actual one.

A three layers general framework has been defined to cope with this problem [2]. It is based on an anticipative layer which aims at providing a global optimized plan from the expected data, i.e. weather forecast, predicted requests. Then a reactive layer interacts with the local device control layer. A shortest path solving approach is depicted in [2]. It is based on the exhaustive description of the solutions space. Only the heating services are addressed.

This paper focuses on the anticipative layer. The objective of this study is to setup a general mathematical formulation of the electric energy management problem in buildings. This optimization problem consists in determining the best energy assignment plan, according to financial and ecological costs and comfort. The household load management problem is formulated as an assignment problem in which the energy is considered as a resource shared by the appliances and the tasks are the energy consumptions of the appliances. In order to adapt the consumption to the available energy, the home automation system controls the appliances in housing by determining the ending times of the temporary services and also by computing the temperature set points of the heating systems. The assigned energy planning corresponds to a schedule of the services. Both production and consumptions services are taken into account. Both grid and local energy production can be addressed. A more detailed definition of the different kinds of services is given in the section 2. The optimization problem of the building energy management is modeled using both continuous and discrete variables.

2 Formulation of the anticipative problem as a MILP

The anticipative layer aims at computing a production and consumption plan over 24h from forecast data. A step of 1 hour is assumed. The different loads and production devices are depicted as services to the inhabitant. A service is qualified as *permanent* if its energetic consumption/production/storage covers the whole time range of the energy assignment plan, the heating service is a representative example of the permanent services. Otherwise, the service is named *temporary service*. Using an electric oven is a temporary service.

The anticipative layer can be formulated as a mixed integer linear programming (MILP). The decision variables are the assigned energy of the permanent services at each hour, the ending times of the temporary services and the energy exchange with the storage systems. These variables are depicted in the figure 1 by the double arrows. From the ending time of a temporary service one can deduce the energy consumption at each hour, assuming the execution time and the required energy of the service.

The behavioral model of each appliance is formulated by a set of linear constraints with discrete and continuous variables. By the same way the quality of the execution of the services is formulated, leading to the evaluation of the comfort. These behavioral and quality models can require linearization transformations leading to specific contraints and variables.

This optimization problem is a multi-criteria problem using the following criteria depicted in the section 1 (energy cost, comfort, CO_2 rejected).

This paper mainly addresses the modeling of the mono criteria problem as a MILP and its solvability. The comfort is the only studied criteria.

Illustrative application examples will be presented.

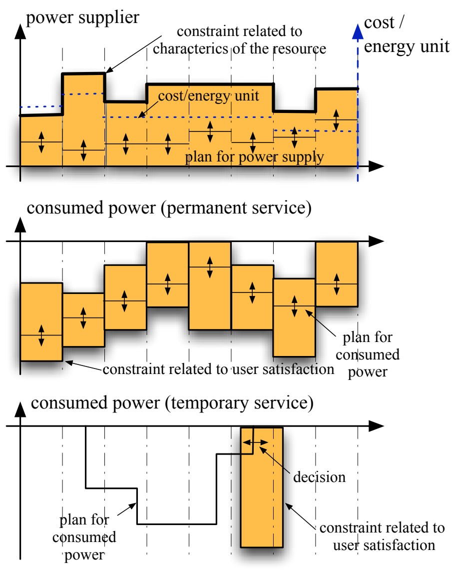

FIGURE 1 – Different kind of services

Références

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