A study of interactions between anticipative and reactive building energy management systems

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ABSTRACT. In this paper, a perspicuous definition of reactive energy management approach for building energy management has been presented. It uses real time data coming from the buildings and tries to follow an anticipative plan. Reactive management will provide an efficient management of resources and reliable plan for anticipative energy management. Here we present how reactive energy management is useful in the context of building energy management and try to integrate with anticipative energy management.

KEYWORDS : Building, Energy management, Anticipative energy management, Reactive energy management

1. INTRODUCTION

Nowadays, buildings account for 40% energy consumption of total available energy resources. Different anticipative approaches have been proposed for one day energy management. The key problem with anticipative energy management is that, it is not able to anticipate efficiently under the high volatile condition such as weather change, occupancy profile, turning on or off home appliances as well [Duy Long Ha, 2006].

Indeed, present building energy management system (BEMS) should be reactive to manage all kinds of non-modeled fast dynamics related both to occupant behaviour and to environment. It uses to works on the principle “if condition then action”. Reactive energy management collects anticipative plan and detects discrepancies between the plan and the actual situation. Once the cause of discrepancies diagnosed, it also determines the possible corrective actions so that the occupant’s comfort and total available energy constraints not get violated. The key objective of the reactive management is to achieve long term and short term goal as well, while keeping the integrity of previous achieved goal from the anticipative plan [Victor M. Zavala, 2010].

The model used for reactive management might be different from the anticipative one. In each sampling period, reactive management gets set points from the anticipative plan and modifies the plan according to current situation. Reactive energy management specifies how the building energy management system reacts to its environments. It generates alternative plans to handle the discrepancies and compares them with the anticipative plan to choose the best possible solution.

The paper is structured as follows. First we provide a gist about the predis-MHI platform and then discuss about the anticipative BEMS. The model used for simulation is also discussed. Finally we will analyze the discrepancy between reactive and anticipative strategies in order to propose possible solutions.

2. PREDIS-MHI PLATFORM

Predis-MHI is a dedicated platform for the building energy management, located at ENSE3, Grenoble-INP. It has two zones one is named “openspace” reserved for researchers and a study area reserved for the students named "classroom". This platform allows to study several aspects of smart homes including building modeling with analysis of the differences between model and reality, understanding of distribution of energy in management issues under different scenarios. It also demonstrates the interaction between the smart home and the smart grid. Predis-MHI is equipped with sensors to monitor the occupant’s presence, indoor temperature and CO2 concentration as well. Moreover the lighting management takes into account the presence of human being

The platform has a heating and double flow ventilation system. The ventilation system regulates the air quality of internal atmosphere and also helps to regulate the ambient air temperature for occupants. HVAC system provides the clean air to the platform and removes the stale air from the inside. The need of ventilation depends on the occupancy profile and use of platform. A hot water based heating system can heat the air injected into the building using ventilation.

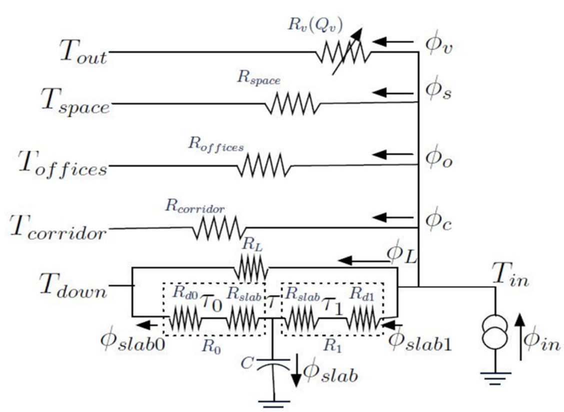

Figure 1: RC equivalent model

The thermal envelope of Predis-MHI is modeled by an equivalent electrical RC circuit with first order dynamics. Here the resistances R_{space}, $R_{offices}$, and $R_{corridor}$ represent the equivalent thermal resistance whereas the time-varying resistance R_v represents the controlled ventilation within the Predis-MHI platform. Its controllable inputs are the heat flow coming from hot water and the ventilation airflow. The main output is the indoor temperature. Only one capacity is used per zone for an easier identification process. In this platform, a system called HAL (Home Abstraction Layer) had been installed, which acts as a software interface between the controller, sensors and actuators [Hoang-Anh Dang, 2013].

3. ANTICIPATIVE BUILDING ENERGY MANAGEMENT

3.1. ANTICIPATIVE APPROACH

The fundamental objective of this approach is to compute energy strategies by computing anticipative plans. The plan computation relies on hourly predictions of energy consumption, total cost, heating powers, inside temperatures, and CO2 concentrations. It also provides a reliable management of services, so that use of home appliances could be planned to optimize the energy cost. It works on a 24 hour time horizon window, with one hour as a sampling period. The anticipative period is denoted by Δ_a. This sampling period is comparatively larger than, that used for reactive approach [S. Abras, 2006].

Anticipative energy management is based on an anticipative model use to compute the plan according to available predictions. Anticipative model includes the user expectation profile and predictions of occupation and weather, anticipative service model for appliances and cost model as well. These are modeled with slow dynamics and typically use one hour as a sampling period. From the information of above prediction models, the anticipative model yields a plan to anticipative energy management using an optimization algorithm. Anticipative model includes discrete, continuous as well as hybrid model for different kinds of services. Discrete events are modeled by finite state machine (FSM), continuous services are modeled by differential equations, whereas the hybrid services consider both modeling scheme [Duy Long Ha 2012].

3.2. REACTIVE APPROACH

A system is defined as reactive if it is able to adapt to any change that occurs in the real world, while system is running. Reactive plans are different from the anticipative approach. In the latter approach, goal statements are defined over the trajectory while reactive management interacts with the unpredictable environment: it has to be able to achieve both short and long term objective while system is running. Reactive management results usually from decision-making rules such as "Condition- Action" or "if-then" rules. These rules are associated with the conflicts between current situation of plan and final objective. Alternative methodology have been proposed for general reactive planning, like Markov decision process, fix point calculation algorithm and theorem proving technique; however each method has its own limitation and application [F. Kabanza, 2010]. To get a better understanding of the problem energy management has to tackle, different situations are going to be analyzed.

4. ANALYSIS OF DISCREPANCIES

In the next, in order to get a better understanding of what reactive energy management should do, it is assumed that the actual situation is different from the one computed for the anticipative plan. Anticipative plan relies on some past experiences but reality may be different because of sudden changes like occupancy, weather or the unplanned usage of some appliances. These changes cause discrepancies with anticipative plan. In order to simulate these sudden changes, we used a fine simulation model with a sampling period: T_s=60sec. This model is a third order model. It uses three capacitance to represent the inertia of platform (see figure 3).

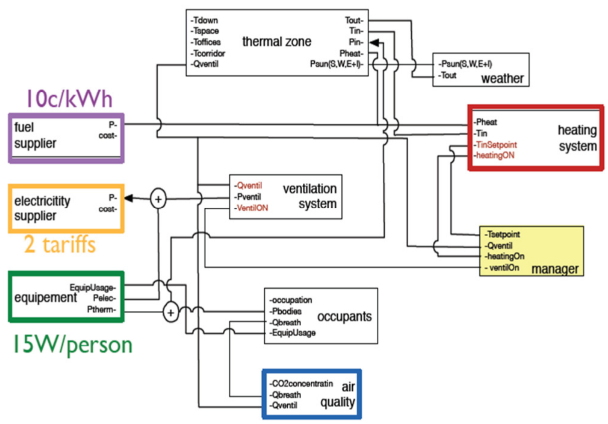

Figure 2: Fine simulation model

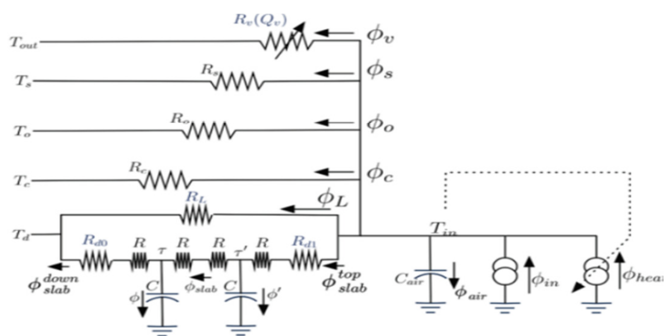

Figure 3: RC equivalent model

For the moment, we emphasizes only on occupant profile and weather change. The anticipative energy management has provided a plan for occupancy but it is different from the actual occupancy. For example, if some events are scheduled in the afternoon but nobody comes, in such case, plan must be re-computed. In the same way, sudden changes in weather could cost more energy because the need of extra heating or cooling system. Here both situations have been compared i.e. planned and unplanned situations and effects are analyzed.

4.1. DISCREPANCY IN OCCUPATION

Discrepancies in the occupation profile are analyzed. The variations in occupation profile is depicted in figure 4, where the figure a represent the small variations and figure 4b represent the large variations

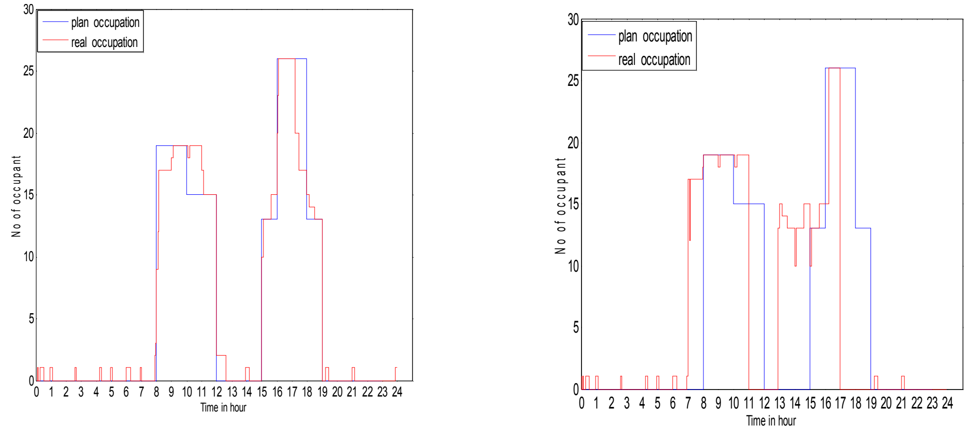

Figure 4: Occupation profile for winter (a) small variation (b) large variation

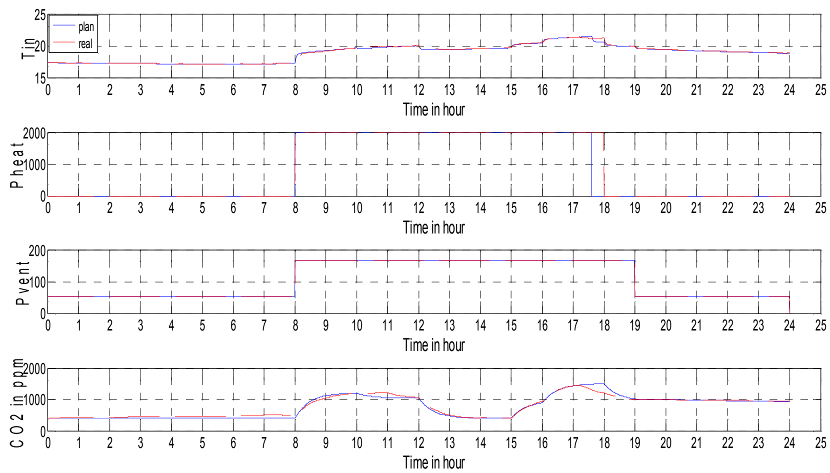

Figure 5: Planned and simulated results for small variation in occupation

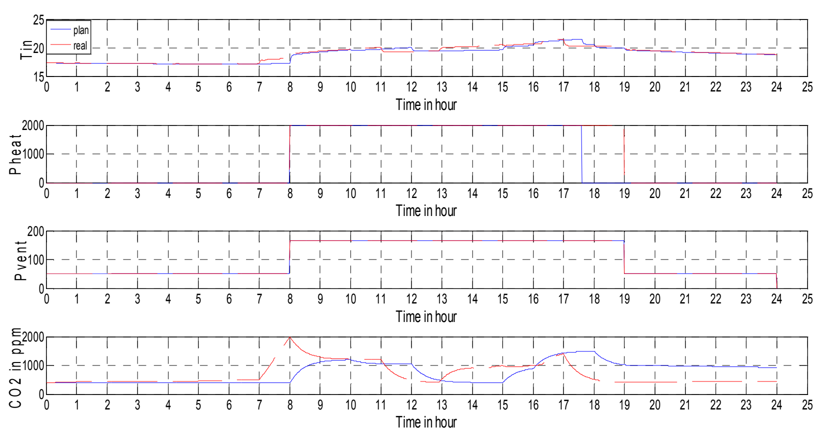

Figure 6: Planned and simulated results for large variation in occupation

The simulation results (figure 5 and 6) show that the discrepancy in occupation causes significant changes in the CO2 concentration and heating power. However there are only small variations in inside temperature because of temperature control (±0.5°C) in the fine simulation model. For the small variations in occupation profile, the CO2 concentration and heating power varies closely to the anticipative plan, but for the large variation in occupation profile, these variables are far from the values of the anticipative plan. So the variation in the occupant profile in winter would increase or decrease the heating cost and also the CO2 concentration. The discrepancies could occur within the anticipative period or at the end and start of the period. The reactive energy management has to identify the cause of the discrepancy as well as the duration of discrepancy, so that it can be corrected within the desired anticipative period.

4.2. DISCREPANCY IN WEATHER

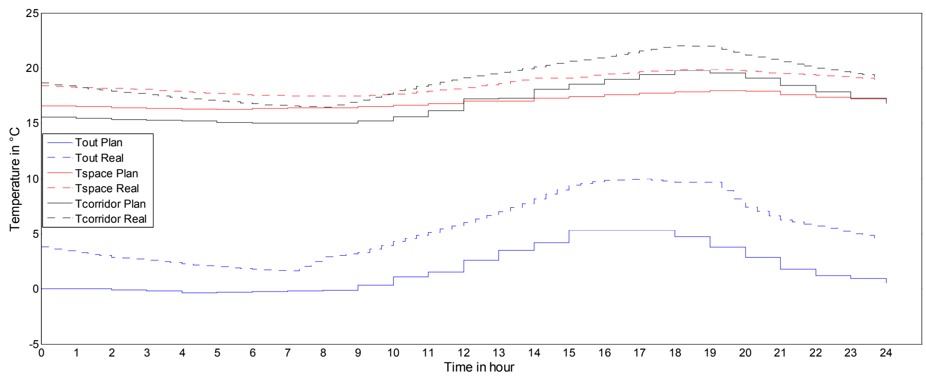

Figure 7: Average variation in weather for a winter day

The changes in weather also cause discrepancies. Anticipative energy management uses weather information from the weather prediction model and plans the use of heating appliances. The modified use of these appliances affects the energy cost. So discrepancies in weather require an update energy consumption plan. Here only winter situation is considered. During winter, people may require extra heating appliances that were not planned in the anticipative energy management. The use of such kind of unplanned appliances will increase the energy consumption and cost as well. Here the simulation results (see figure 10) show that how much extra heating power, will require because of unplanned heating appliances. It also represents the variations in inside temperature. On the other hand, CO2 concentration and ventilation power do not significantly change.

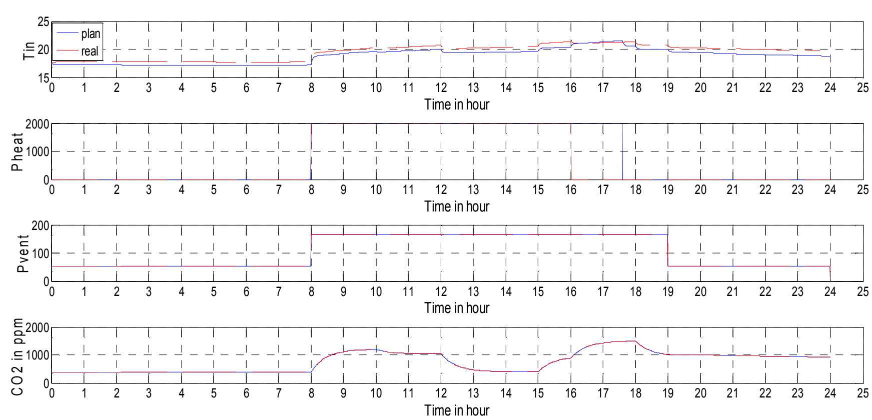

Figure 8: Planned and simulated results for variation in weather

5. PROPOSITION OF REACTIVE STRATEGIES

In the context of building energy management, reactive management is very useful in terms of better prediction and planning of the usage of home appliances. The modern energy efficient building must have to include all kinds of disruptions from the different sources. So the Building energy management system should have both to anticipate but also to adapt to actual situations. In order to consider all the discrepancies, a reactive period should be defined. The reactive period is denoted by Δ_r and it must be smaller than, the anticipative one i.e. $\Delta_r < \Delta_a$. A very short reactive time period is not meaningful because it is difficult to correct or modify the anticipative plan in very short interval, like one minute. The controller internal dynamics also do not allow the very short reactive period as well because reactions could interact with controller. More significantly, the proposed reactive time step could be about 10 minutes.

According to the previous analysis, reactive management consists is the following steps: detects a discrepancy between planned and actual situation, diagnose the cause of the discrepancy and identify its characteristics (duration, importance,...), and finally determine corrective actions. The following table proposes some reactive actions for different type of discrepancies, along with the possible feasible solution. For example the opening the doors or windows will cost more to occupants, it also affect the inside temperature and CO2 concentration. The possible corrective actions in this case are temperature and CO2 control

Possible cause for discrepancy	Possible Variations			Possible solution
	CO2 Concentration	Energy cost	Inside temperature	
1-Positive variation in occupation profile	Positive	Positive	Positive	CO2 control Temperature control
2-Change in outside weather	No change	Positive/Negative	Positive/Negative	Temperature control
3-Use of unplanned appliances	No change	Positive/Negative	Positive/Negative	Compute the anticipative plan
4- Opening the doors or windows	Negative	Positive	Positive/Negative	CO2 control Temperature control

Table 1: Explanation of discrepancies with possible solution

6. CONCLUSION

In this paper, the role of reactive building energy management has been presented; it considers the declarative goal from the anticipative energy management. Discrepancies have been between the both planning approaches i.e. reactive and anticipative in order to point out the problem the reactive management has to manage. The results point out the need of reactive energy management in buildings that will incorporate fast and slow dynamics from the occupants and environment as well. In this paper, a general reactive management approach for building has been proposed. Inclusion of reactive energy management with current BEMS will improve its robust performance.

Acknowledgement

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