Multi-Zone Energy Simulation Tool

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Vision

As we develop a demand response-enabled thermostat, we must also develop an environment in which to test it. Before testing the thermostat, control strategies, and other infrastructure in a physical house, we are testing the control strategies in a simulated house environment. For this, we use the Multi-Zone Energy Simulation Tool (MZEST) to simulate the energy use and thermal responses of houses under different control strategies. MZEST is a multizone extension of the simulation code (California Non-Residential Engine or CNE) used by CALRES, the energy simulation software distributed by the California Energy Commission used for demonstrating compliance with state residential Title 24 energy standards. We chose MZEST because it can predict the temperature in several different thermal zones and because we had access to the source code. The tool currently uses 5-minute time steps, which allows us to use our external controller to control MZEST in the same manner that the controller would control a real house. We interface the simulation directly with DREAM (Demand Response Electrical Appliance Manager), our Java control engine for all air conditioning and electrical loads. This will enable us to predict the effect of our demand response control strategies on the energy use profile of a range of house types located in any California climate zone.

MZEST requires certain input parameters, including the specification of a weather file and designated house construction information. The weather file is hourly climate data in the form of a TMY2 (Typical Meteorological Year) file, but may be composed of weather data collected on site. The house construction parameters are specified in input files, and include construction material properties, wall and roof constructions, window specifications, infiltration rates, and adjacencies of walls, rooms, and zones. To tune the simulated house to a physical house, the shading coefficient of each window may be specified as an hourly variable. Internal gains, the results of specific equipment use and occupant schedules, can also be specified hourly. The size and efficiency of the physical house's HVAC equipment must also be specified.

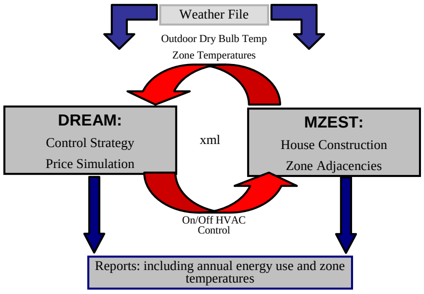
In the same way a standard thermostat controls a real house, MZEST currently conditions the simulated house to meet the needs of only one zone. In a real house, that zone is the one in which the thermostat is located; in MZEST, a "control zone" must be designated. The other zones are also conditioned but, as in a physical house, will generally not exactly meet the control zone setpoint, since solar gains, occupancy, and other internal gains differ from zone to zone.

The output of MZEST includes several types of information such as report spreadsheets and graphs depicting annual energy use, cost, and so on. For this project, one of the most important reports is the temperature of each thermal zone at each time step. MZEST also reports the energy use of the HVAC system and the energy balance of each zone at each time step.

Methods

The Demand Response Electrical Appliance Manager (DREAM, our Java control engine for all air conditioning and electrical loads controller) can run MZEST the same way it will operate in a house. To test the DREAM on a real house requires the installation of sensors, actuators, a communications network, and the replacement of the original thermostat with the new controller. However, testing DREAM with a simulated house merely requires the simulation of these sensors and actuators. We interface the simulation directly with DREAM via an XML data transfer. MZEST writes outdoor temperature and zone temperatures to a file. DREAM then reads those temperatures as if they came from sensors and, using its control strategies and our price simulation, determines how to condition the house. DREAM then dictates to MZEST, through the same file, whether to heat or cool the house. MZEST thus simulates heating or cooling in the house and calculates the house's thermal response.

DREAM controlling MZEST:



Because we can simulate many different kinds of houses, we will be able to predict the effect of our demand response control strategies on the energy use profile of a range of house types located in any California climate zone. We can then train the controller to "learn" the behavior of the house and the simulated preferences of the occupants and optimize its control strategies to each individual house and its occupant accordingly.

Research Questions

Before using MZEST to test our control strategies, we wanted to confirm that we could create an accurate model. To do so, we built a model of our test house while gathering real data at the house for comparison.

Test House Model Calibration:

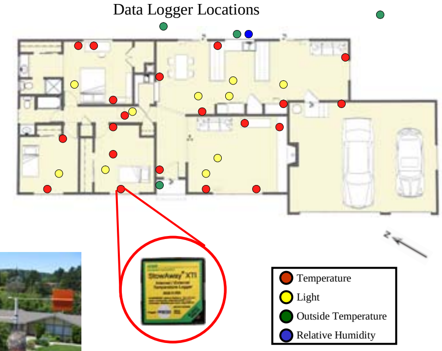
An independent datalogger-based monitoring system was used to validate mote sensors and to provide weather and house temperature data for initial simulation model calibration. The loggers, shown below, measured temperature and relative humidity. Some of the temperature loggers were located next to the electric lighting fixtures at the ceiling to determine when these lights were turned on as additional internal gains to the house.

In addition, the weather station (below to the left) measured the site microclimate. This recorded weather data was used to create weather files for the simulation so that behaviors of the house and the simulation could be compared under the same weather conditions.

Some of the temperature loggers were located at floor register locations to record both heating and cooling from the HVAC system, so that conditioning behavior could be scheduled into the simulation to ensure that the house room and surface temperatures would be accurate.

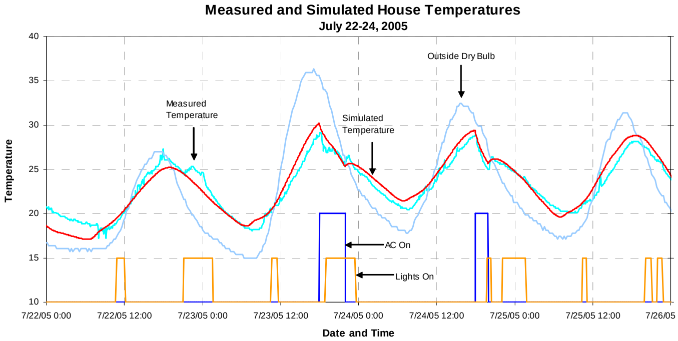
Data Logger Locations

The location of the data loggers in the house are shown to the right, while the weather station is below.



Findings

The graph below shows that the simulation results closely follow the data recorded in the house. While we scheduled MZEST to control the HVAC system according to our house data, we did not schedule the lighting. Therefore, the simulated data varied slightly from the actual data when lights were turned on.



Ongoing work:

After confirming that we could create an accurate simulation model of a real house, we have begun to use DREAM to control MZEST. We have altered our original simulation model to create models of a number of typical California house types. Various control strategies are now being tested and compared on these house models.

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