LOAD ALLOCATION THROUGH DETAILED SIMULATION CALIBRATED WITH MONITORED DATA

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ABSTRACT

Detailed simulation programs can be used to enable the comparison of the energy performance of a building with average performance of similar buildings, and to evaluate the energy savings of energy conservation measures. For the simulations to be meaningful, they should be calibrated with actual data. Utility bills are not sufficient to produce a "calibrated simulation" since they can only capture seasonal changes in the energy use. In order to capture the diurnal and hourly changes, hourly monitored data is required. Another limitation that often exists with utility bills is that institutional buildings (campus buildings) usually share utility bills, and therefore utility bills can not be used to calibrate the simulation of a specific building. Measured data in this instance can solve the load allocation problem. A study is conducted on a campus building that addresses the limitation of utility bills, and illustrates the importance of using monitored data to calibrate the building energy simulations. While this paper addresses the limitation of utility bills, a future paper will discuss the calibration procedure of the energy simulation.

INTRODUCTION

Building energy simulation programs have been improving during the last twenty years to address more realistic details related to the dynamic energy balance of the building structure and systems, in the design stage. However when a simulation is developed for an existing building to base-model its energy use and study the effects of different energy conservation measures, one needs to calibrate the simulation with real data. Usually analysts resort to utility bills that may be sufficient to capture the seasonal changes in the energy use. However, if one needs to capture the hourly and diurnal changes, the only solution would be to monitor the energy channels within the buildings (monitoring the main building meters as a minimum).

A real problem that is often associated with institutional buildings (university and hospital campuses) is that two or more buildings usually share one utility bill. The use of such bills to calibrate the energy simulation of a separate building does not offer the required information. Monitoring the energy channels in an individual building helps allocating the loads to individual buildings, and also helps obtaining meaningful calibrated simulations. This paper focuses on the monitoring operations of a dormitory building and the findings. A future paper will discuss the calibration of the energy simulation and the savings potentials of appropriate energy conservation measures.

BUILDING DESCRIPTION

The building under study is a university dormitory and comprises a total of 103,470 ft^2 of conditioned floor space: twelve floors of dormitory rooms, a main floor for management and security, a cafeteria, a kitchen facility, a small area for shipping/receiving, and a basement used mainly as electrical and mechanical rooms. The dormitory rooms are not cooled; they are heated and ventilated only, since very few summer classes are offered, and the weather in the location (Southeast Wisconsin) is not extremely hot during the beginning and the end of the school year, September and May, although students usually complain that the rooms are not very comfortable during these mentioned periods. The building is a brick-clad heavy construction with a 19.4% window-wall ratio. All the windows are facing east and west.

Since only the main area (management and cafeteria) has mechanical cooling, the building is equipped with three screw-type chillers of 30 Tons capacity, each with two 15-Ton stages (90 Tons Totals). Two chillers normally run on a hot day, with the third serving as a stand-by unit. There are two passenger elevators, 37.5 hp each, and a 15 hp freight elevator, totaling 90 hp (67kW).

The lighting in the building is all provided with T-12 fluorescent tubes.

BUILDING ENERGY MONITORING

The project was initiated as a study aiming at analyzing the building energy performance of an urban university campus. A dormitory building was chosen as a pilot project. A walk-through survey was conducted, and a questionnaire was completed by the building manager and energy operator. The blue prints of the building (built in the late 60's) were also checked – some modifications in the partitioning and the mechanical equipment took place and can't be seen on the floor plans. A base-case simulation was developed (using a DOE2-based software). In order to calibrate the simulation, one-year worth of utility bills (gas and electricity) were collected. This generated a challenge. There are three adjacent dormitory buildings on campus. The local utility company bills each building for gas separately, while it bills all three buildings with one electricity bill. The university officials, based on information from the utility company, assume that the building under study uses 65% of the total billed electricity.

A monitoring project was initiated in order to substantiate the "65%" claim, as a load allocation question, and also to be able to disaggregate the total electricity consumption of the building itself.

Disaggregation of Total Energy Use (constant speed vs. variable speed equipment)

Since three buildings are billed together by the utility company, it would be difficult to assume that that a simple fraction could be used to "split" the bill. While the suggested fraction might be accurate in term of energy consumption, it could be less than accurate in terms of demand, even though all three buildings are dormitories (same function). For instance, the building under study has a large kitchen facility with a lot of exhaust fans and electrical cooking equipment, while the other two buildings do not. Taking into consideration the schedules in the operation (hours of operation) of various equipment, it would be difficult to know which building contributed in the peak demand value and to what percentage.

Furthermore, the correct answer to the load allocation can only be answered by monitoring every energy channel in the building which proves to be very costly. A cost-effective solution was used where the monitoring plan covers the main three meters in the building under study:

- Meter-1: feeds the chiller and the motor control center (MCC) load (480 Volts).
- Meter-2: feeds the kitchen, elevators and fresh air fans (480 Volts).
- Meter-3: feeds the lighting and receptacles (208 Volts).

Since all the fans and pumps are constant-speed type, one-time measurements (kW) together with the schedules of operation, are enough to enable a complete energy disaggregation of the total load on the meters. A complete disaggregated load makes an accurate calibration of the energy simulation possible. In addition the load allocation question would be answered. If some of the fans and pumps were variable-speed type, the load allocation would be more complicated and would require more detailed monitoring (submetering), and thus more costly. Figures 1, 2, and 3 show the 480 Volts bus (Meter-1), the 480 Volts bus (Meter-2), and the 208 Volts bus (Meter-3), hooked with the three-phase 300 Amps, 1600 Amps, and 2400 Amps power transducers, respectively. Figure 4 shows a complete connection with the current transducers and the voltage wiring (tapping). Figure 5 shows the transformer cores (13,200 Volts to 480, 277 and 208/120 Volts) with the incoming high voltage lines. Figure 6 shows the data acquisition system connected to the power transducers and producing initial readings. The readings showed very low power factor values on two meters (1 and 2).

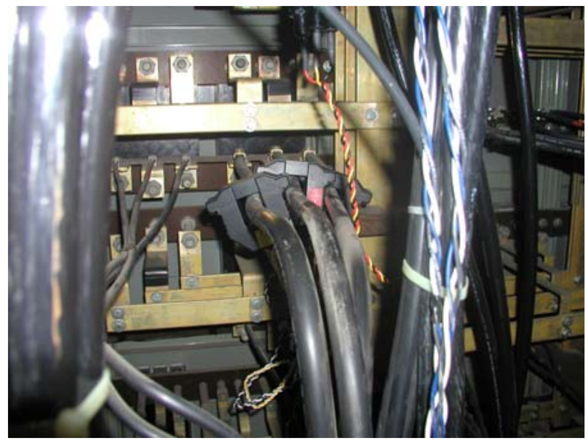

Figure 1. Three-phase power transducer installed on the 480 Volts bus, feeding the chiller and the motor control center.

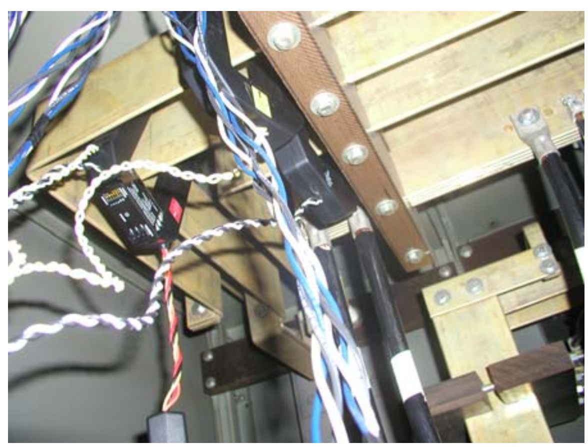

Figure 2. Three-phase power transducer installed on the 480 Volts bus, feeding the kitchen, elevators and the fresh air fans.

Power Quality

An additional advantage of monitoring the energy performance of the building was discovering