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Energy Auditing Using a Building Energy Simulation Program BLDSYM

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Abstract

The objectives of this study are to introduce the energy simulation program BLDSYM, to verify the approach, and to demonstrate the energy saving opportunities. A case study model for Hoover Middle School, OK, USA has been introduced as a base case simulation. Air-side variable air volume (VAV) and water-side variable flow hydronic (VFH) system have been recommended, modeled and simulated to quantify the energy savings compared with the base system, which is typically constant air and water flow system. More than 30% of energy savings could be obtained with the optimum variable flow system.

Ⅰ. Introduction

Many computer programs are available to carry out for energy auditing simulation. Among these are: DOE-2, developed by the federal government; TRNSYS, developed at the University of Wisconsin and BLDSYM, developed at Oklahoma State University[1]. The program named as BLDSYM uses the transfer function thermal response method described in chapter 16 of the 1981 ASHRAE Handbook of Fundamentals.

The major input data required by BLDSYM is atmospheric dry bulb temperature (F), wet bulb temperature (F), and solar radiation (langley/min) on an hourly basis. The addition of subroutine called ENERGY to model the heating/cooling equipment will predict energy requirements. The program manual [2] describes the major data to simulate either the cooling or heating perious. The last key output data is the electricity consumptions each from chiller (kWh), light (kWh), miscellaneous items including fan, pump and other equipments (kWh), and total electricity (kWh) during a cooling season from June to August.

The purpose of this study is to introduce the energy simulation program BLDSYM, to verify the approach, and to demonstrate the energy saving opportunities with the recommended variable flow systems compared with the base system, which is typically constant air and water flow system.

Ⅱ. Base Case Simulation

As a base model for energy audit simulation study, Hoover Middle School case has been considered [3]. The climatic conditions for the school are 36.1 degree latitude and 97.1 degree longitude, 2.5% high dry and wet bulb temperatures are 36℃ and 23℃, and the daily range is 13℃. [1]. WYEC weather location data with a tape of T4172A was used. Overall schematic diagram of the middle school is shown in Figure 1, which has three school building zones, one cafeteria, and a centralized plant. The plant has chiller and boiler for cooling and heating, and the each zone has a air handling unit (AHU) to condition each zone. The AHU has a constant speed fan to circulate the air through the duct system and the water chiller has a constant speed pump to circulate the water through the chiller and AHU.

Modeling of the central cooling and heating plants can be quite complex but a useful. A simple way of modeling all types of cooling and even heating equipments is to normalivz the energy input and the capacity with the rated full load input and capacity. Figure 2 is an example of such a model for a centrifugal chiller. To construct the curves, it is necessary to have performance data at partial load conditions.

The cooling load can be estimated by a program LDCAL3 [4]. which bases are procedures and algorithms published in the ASHRAE Handbook of Fundamentals (1972−1985) and Dr. McQuiston's extensive experience in load calculations as well as other published works. The model for the central plant must also include pumps, fans, cooling towers, and auxiliary equipment that uses energy. The energy consumed by the lighting is also often included in the overall equipment model. The estimation of the total energy consumption of the building is the overall objective. Total energy consumptions calculated of other components by hand are [3] :

$$Total_{hand} = Chiller + Light + Misc$$
$$(Fan, Equipment, Pump)$$
$$181.4 + 58 + (17.9 + 4.71 + 5.9)$$
$$= 734 kWh/day$$

Total energy consumption calculated by BLDSYM is :

$$Total_{code} = 743 kWh/day$$

Monthly total energy consumptions are :

$Total_{hand}$ = 22,759kWh/month

$Total_{code}$ = 22,810kWh/month

Therefore, results from the code are verified with hand calculation and, now, can be applied for alternative energy system simulation study.

Ⅲ. Alternative Case Simulation

One of certain recommendations for energy savings from the constant air and water flow systems are the air-side variable air volume (VAV) system and water-side variable flow hydronic(VFH) systems. These technologies have been already widely understood and adopted as the first alternative for a better system retrofit [5]. Since VAV system allows the air flow to be reduced as the load decreases, the variable fan shaft power will be :

$$P = \frac{Qv \times H \times SG}{3.67(Ep)} (kW)$$

where Q_v(ft^3/min), H(inch of H_2O), E_p(Fan efficiency), SG(specific gravity)

Affinity laws as in Figure 3 for variable speed fan and pump would allow the following power relationships :

$$P_{new} = P_{old} * (\frac{Q_{vold}}{Q_{vnew}})^3 (kW)$$

This equation can be coded in the program EMERGY, and, then, the electricity saving in August is calculated as :

Electricity saving = Base case − Alternative case
= 50,108.2 − 34,991.9
= 15,188.3 kWh

The cost saving with OG&E's PL−1 rate (0.032$/kWh) during only August is :

Cost saving = Base case − Alternative case
= 15,118.3(kWh)*0.032($/kWh)
= 488.79($)

The similar concept can be applied to VFH system case. Since VFH system also allows the water flow to be reduced as the load decreases. The pump shaft power and affinity law for variable speed pumps could be coded in the program ENERGY, and, then, the electricity saving in August is calculated, again, as :

Electricity saving = Base case − Alternative case
= 50,108.2 − 46,206.3
= 3,973.9 kWh

The cost saving with the same OG&E's PL−1 rate during only August is

Cost saving = Base case − Alternative case
= 3,973.3(kWh)*0.032($/kWh)
= 127.16($)

Typically, VAV system would be designed with VFH and, then, the saving can be added to about $615 during cooling months. The saving of about $1,845 per year can, then, be obtained and investment to a variable flow system improvement below $10,000 would promise the payback within five or six years for this Hoover Middle School energy audit simulation study.

Ⅳ. Conclusions

A typical energy audit simulation approach has been introduced. A specific HVAC plant and building model as well as weather data are required for energy diagnostic analyses. A quantitative computer simulation study was possible with a flexible energy simulation program, BLDSYM. The approach using BLDSYM was verified with a hand calculation in a typical summer day. Several opportunities of energy savings including VAV and VFH system have been proposed and recommended to save the motor electric power as the load decreases.

A case study for OKC Hoover Middle School was conducted to demonstrate the energy saving opportunities with the alternative systems recommended. For August 30% of the electricity consumption (50,108 to 34,992 kWh) can be reduced with an optimal VAV system and 8% of the electricity consumption(50,108 to 46,206 kWh) can be reduced with a proper VFH system. An optimally combined system of VAV and VFH can promise five or six years of ROI for this constant air and water flow HVAC system in Hoover Middle School.

Future study should focus on global energy audit program for public buildings : district government building and school. For instance, Texas, USA has been conducting this work for their government buildings so called "Texas LoanSTAR program". The LoanSTAR program is Texas' own program designed to "Save Taxes and Resources" by monitoring energy use and recommending energy-saving retrofits. As of January 1995, LoanSTAR has saved $15 million for Texas taxpayers, and the program is projected to save another $250 million over the next 20 years. [6]

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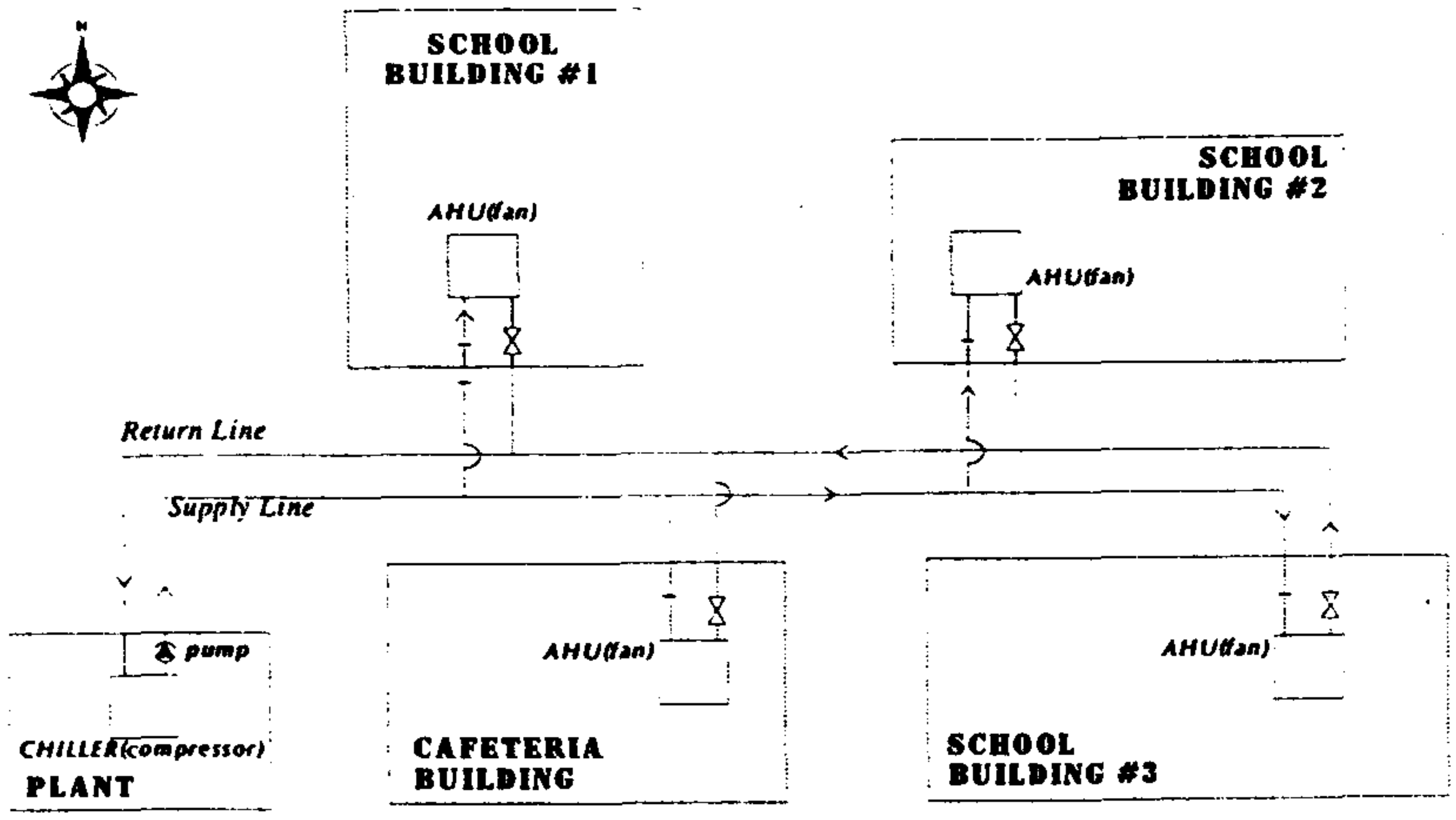

Figure 1. Overall layout of Hoover middle school

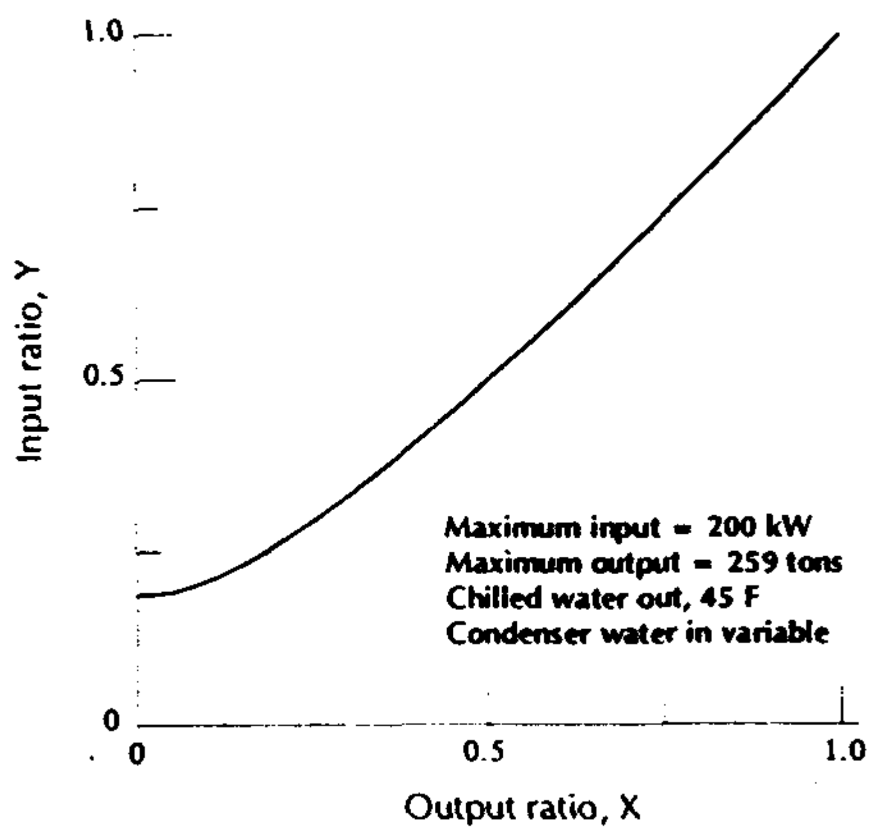

Figure 2. A simple centrifgal chiller energy model

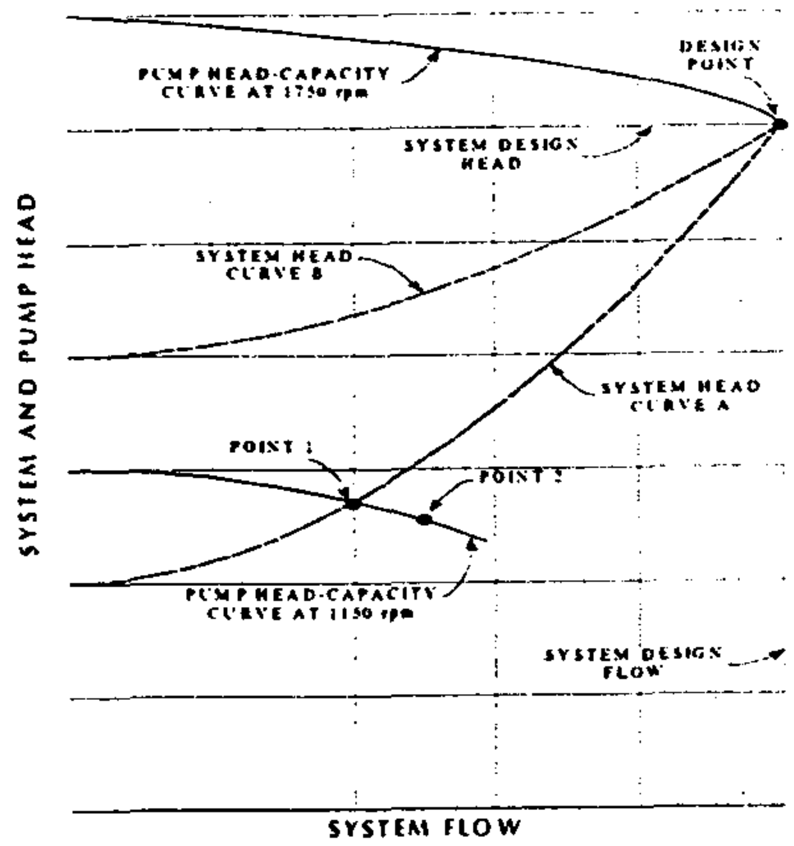

Figure 3. Affinity laws

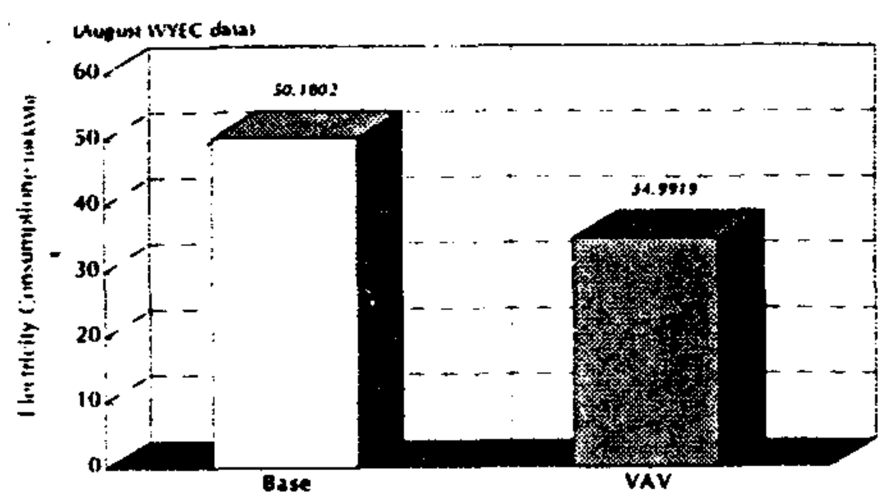

Figure 4. Energy savings with alternative VAV system

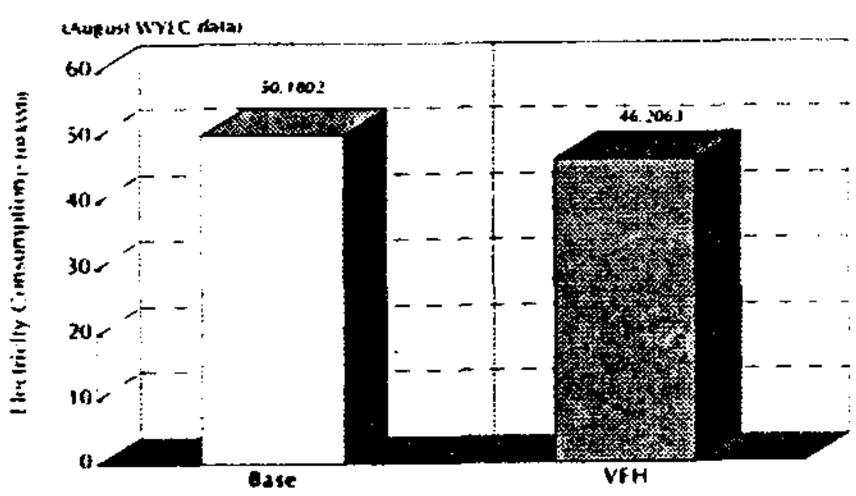

Figure 5. Energy savings with alternative VFH system

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