SYSTEM OPTIMIZATION - THE GLOBAL APPROACH TO HVAC CONTROL

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ABSTRACT

System Optimization is a new approach to HVAC control as implemented by Energy Management Control Systems. System Optimization is defined as electronic building control strategies which treat a building's HVAC components as a complete energy-efficient and coordinated system. Trends in the development of HVAC control strategies are briefly discussed. An example which differentiates between conventional and System Optimization approaches is used to illustrate this new approach. The example discusses aspects of cooling season operation for a typical HVAC system. The paper concludes with four basic principles of System Optimization which are essential for effective control of a building environment.

INTRODUCTION

The fundamental objective of any form of building control is to provide a comfortable, efficient, and productive environment. HVAC control strategies, implemented by Energy Management Control Systems (EMCS), play a substantial role in creating these qualities in a building environment.

The effectiveness of various control strategies significantly impacts the degree to which this overall objective is achieved. Thus, it is important to re-examine conventional control strategies and analyze alternative approaches which can go farther in reaching the desired objective.

System Optimization is an approach which can offer better performance in many building applications. It can be defined as electronic building control strategies which treat a building's HVAC components as a complete energy-efficient and coordinated system. This approach is based on a global view of a building and its HVAC components, as well as other factors affecting their operation.

Most conventional control strategies focus on individual HVAC components with an eye towards what should be done to optimize individual component performance. System Optimization is based on a broader perspective. It looks at an individual component's performance, but sees it as part of a larger picture - the performance of the total HVAC system, and on an even larger scale, the performance of the building and its occupants.

The idea of optimizing HVAC operation is not a new one. In the past, limited optimization was accomplished through mechanical means only. Computerized EMCS's made possible through micro-processor technology, have significantly enhanced HVAC optimization techniques. EMCS software allows great flexibility and capability for HVAC control. Many software application programs that manage HVAC energy are now considered traditional in the EMCS industry. Programs such as Programmed Starting and Stopping, Optimal Starting and Stopping, Duty Cycling, and Demand Limiting constitute main line savings strategies today.

In recent years the level of control sophistication has continued to rise. Emphasis has been focused on individual equipment optimization. EMCS software programs which specifically address equipment operating characteristics are becoming commonplace. The goal of these programs is to reduce individual equipment energy consumption. Examples include Supply Air Reset programs for air handling equipment, Management and Optimization programs for chillers, and the increasing use of Direct Digital Control (DDC) for HVAC equipment.

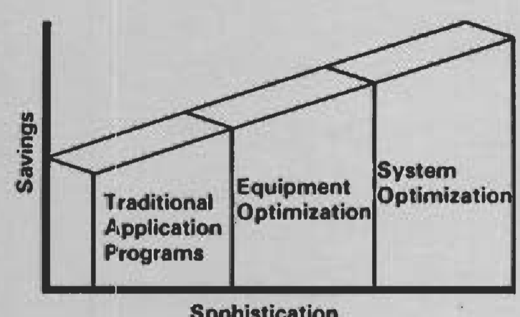

Figure 1 EMCS Evolution

Another aspect of equipment optimization has been the improvement in efficienty levels for HVAC equipment as supplied by the manufacturer. Impressive progress has been made in this area, particularly within the last 5 years. The future points to the integration of microprocessor controls and individual HVAC equipment. Equipment such as rooftop units, chillers, and air handlers, with unit mounted controls are beginning to appear on the market today.[1]

For the most part, conventional control strategies such as traditional application programs and equipment optimization programs have satisfied requirements for comfort and productivity in building environments. However, a question arises as to whether HVAC system efficiency can be improved beyond levels currently achieved through these strategies. As the level of sophistication associated with conventional approaches has risen, so have the corresponding energy savings. System Optimization strategies, taking a global view of the HVAC system, can more intelligently coordinate the individual units to maximize overall system efficiency while maintaining or improving comfort and productivity.

APPLICATION EXAMPLE

An example which differentiates between conventional and System Optimization approaches, analyzes factors involved, and considers questions which arise will help illustrate the concept of System Optimization. The following example discusses aspects of cooling season daily operation for the HVAC system serving a commercial office building. This system consists of a central chilled water plant and a variable air volume (VAV) airside system. Discussions will compare conventional and System Optimization strategies for a typical operating day which includes occupied operation, afternoon shutdown, unoccupied operation and morning start-up.

Occupied Operation

Initially, system operation during the occupied period, after HVAC equipment has been started and desired space conditions have been achieved, will be considered. However, some fundamental relationships must be discussed to understand both conventional and System Optimization approaches.

For a given load condition, VAV airside energy consumption is minimized by keeping the supply air at the design temperature. Also, chiller energy consumption can be minimized by keeping the supply chilled water temperature as high as possible, while satisfying the cooling load, and keeping the condenser water as low as possible.[2]

Conventionally, equipment optimization software is used to reduce individual unit energy consumption according to these relationships. However, these strategies do not consider how altering parameters in one system affects the other system. In fact, a balance exists between airside and waterside energy consumption. Altering parameters to decrease energy consumption on one side may actually increase energy consumption on the other side.

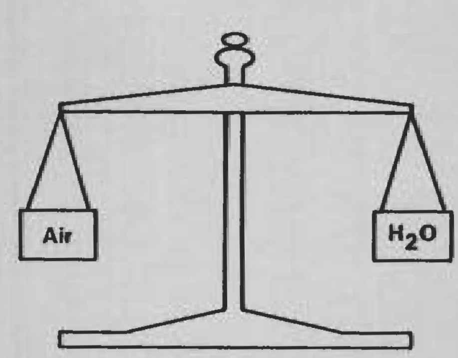

Figure 2 Air Side/Water Side Balance

System Optimization strategies consider this balance and coordinate airside and waterside operation throughout the occupied period. Analysis has shown that under certain latent load conditions it is best to allow the discharge supply air temperature to increase. Overall, the corresponding increase in airside energy consumption is more than offset by chiller energy savings resulting from reduced coil loads. At other times in the occupied period, latent loads may be such that design discharge supply air temperature should be maintained.[3]

Unlike conventional approaches, System Optimization can respond to load and environmental changes and alter strategies affecting airside and waterside energy consumption to maintain minimum overall system energy consumption.

Afternoon Shutdown

Conventionally, Optimal Stop software has been used to reduce HVAC equipment energy consumption by determining the earliest time equipment can be stopped during the last portion of the occupied period. This method relies on the thermal inertia of the structure to maintain desired space temperatures.

System Optimization refines this by globally considering building and equipment characteristics as well as comfort factors associated with equipment shutdown. While conventional methods often stop all HVAC equipment simultaneously, a System Optimization approach can intelligently stagger equipment shutdown. For example, it may be possible to stop the chiller earlier than conventional methods would allow, leaving chilled water pumps and airside systems operating. At a later time, chilled water pumps may be stopped, followed by the airside system.

This approach offers two advantages. It further reduces overall system energy consumption by more effectively using cooling capacity stored in the chilled water loop and building mass. It also addresses occupant comfort and productivity. Comfort is a function of space temperature and humidity, air movement, and psychological considerations. When all HVAC equipment is turned off simultaneously prior to the end of occupancy, people tend to feel discomfort due to lack of airflow and fan noise even though space temperature and humidity may be within acceptable ranges. Staggered HVAC equipment shutdown can satisfy air movement and psychological requirements to maintain true occupant comfort while still reducing overall energy consumption.

Unoccupied Operation

Due to the large number of unoccupied hours in a typical commercial office building, HVAC control strategies during this period have a considerable effect on energy consumption. Because occupant comfort is usually not an issue during this period, space conditions may be allowed to vary from acceptable occupied comfort levels.

Conventionally, HVAC equipment is simply stopped as soon as possible at the end of the occupied period, kept off throughout the unoccupied period, and restarted as late as possible prior to occupancy the next day. This strategy minimizes HVAC equipment energy consumption during the unoccupied period. However, no consideration is given for the effect this may have on morning start-up. Energy savings resulting from equipment shutdown during the unoccupied period may actually be offset by energy requirements during morning start-up and the early portion of the occupied period.

In contrast, a broader perspective recognizes that HVAC operation during the unoccupied period will directly influence operation during morning start-up and even into the occupied period. By understanding characteristics of the building and HVAC equipment involved, System Optimization strategies can reduce total energy consumption consisting of both unoccupied and start-up energy. This can be accomplished through intelligent use of outdoor air "free cooling" during the unoccupied period.

Many variables affect the relative economy of using fan energy and free cooling as opposed to chiller plant energy. Depending upon these variables, it may be advantageous to introduce outdoor air to the building to reduce or eliminate the pull-down load normally handled by the chilled water plant during morning start-up. Under some conditions it may even be possible to "subcool" the building during the unoccupied period. In doing so, not only has the morning pull-down load been eliminated, but cooling capacity may actually be stored by virtue of the building mass. The benefit obtained here is that more economical fan energy and free cooling is used in lieu of costly chiller plant energy.

When only the unoccupied period is considered, this approach consumes more energy than conventional methods which simply left equipment off. However, taking a global view of daily operation and considering both the unoccupied and morning start-up periods, this System Optimization strategy can acutally reduce overall HVAC energy consumption.

<u>Morning Start-Up</u>

Conventional morning start-up strategies use Optimal Start software to start HVAC equipment as late as possible and still achieve desired comfort levels at occupancy. Typically, the airside and waterside systems are started simultaneously at an optimum time. Compared to manual start methods or time clocks, this strategy will result in savings. However, savings are inherently limited by building conditions already established by conventional unoccupied period operating strategies.

With the System Optimization approach, HVAC operation during morning start-up will become a natural extension of the unoccupied period strategies. As in the unoccupied period, System Optimization will consider the relative economy of using fan energy and free cooling as opposed to chiller plant energy. If conditions dictate that airside and waterside systems are needed, System Optimization strategies will coordinate the operation of these systems to minimize their total energy consumption, as explained in the occupied operation discussion.

The underlying benefit to System Optimization here is that unoccupied period strategies position building conditions for morning start-up in order to reduce the combined unoccupied and morning start-up HVAC energy consumption.

CONCLUSIONS

Four basic principles can be drawn from the preceding discussion. These principles are essential to the development and analysis of effective HVAC control strategies.

- HVAC control strategies affect the energy consumption balance between airside and waterside systems in a building.

- HVAC control strategies for a given daily operating period will influence the strategies for the following period.

- HVAC control strategies should be based on actual building conditions, and not models of typical building conditions.

- HVAC control strategies should globally consider all relevant building, HVAC equipment, and occupant characteristics.

The limited focus of conventional control strategies cannot adequately address the system-wide factors brought forth by the above principles. Using these principles as a foundation, HVAC System Optimization can achieve the utmost in comfort, efficiency, and productivity in a building environment.

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