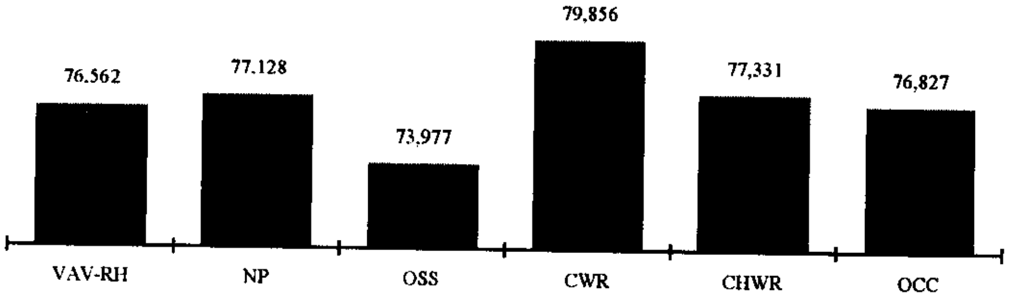
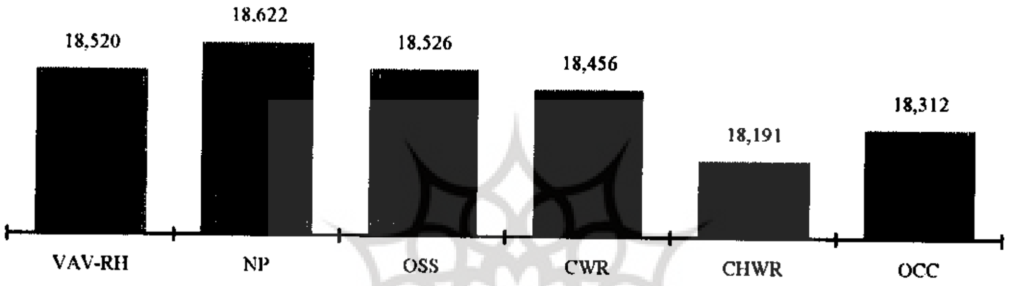
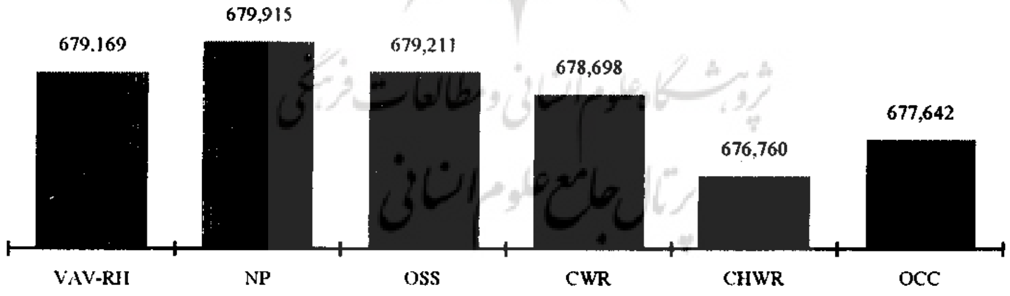


(a) Annual energy consumption (Btu/ft2-yr).

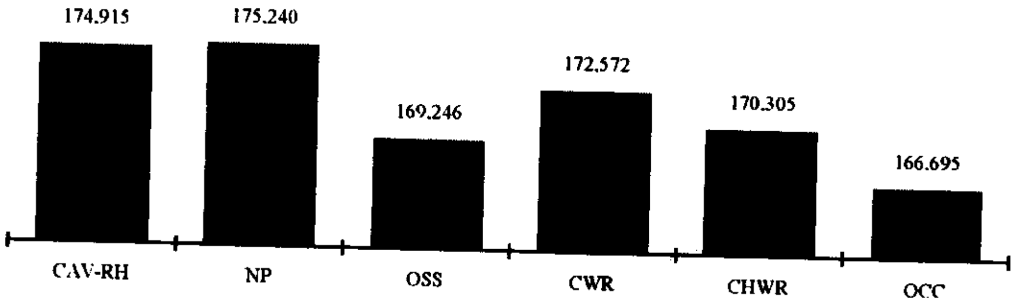


(b) First year utility cost ($).

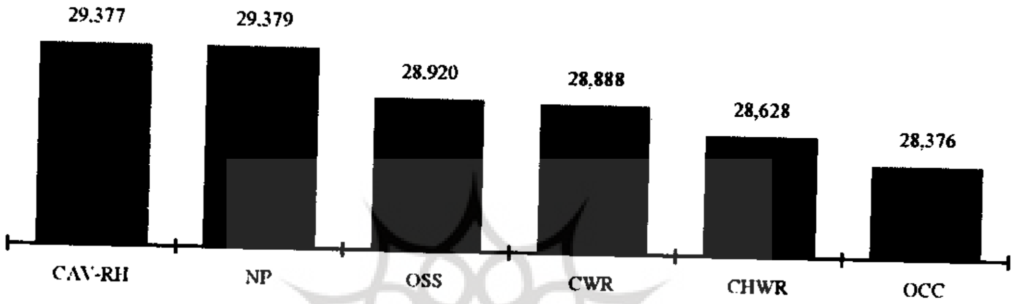


(c) Life-cycle cost ($).

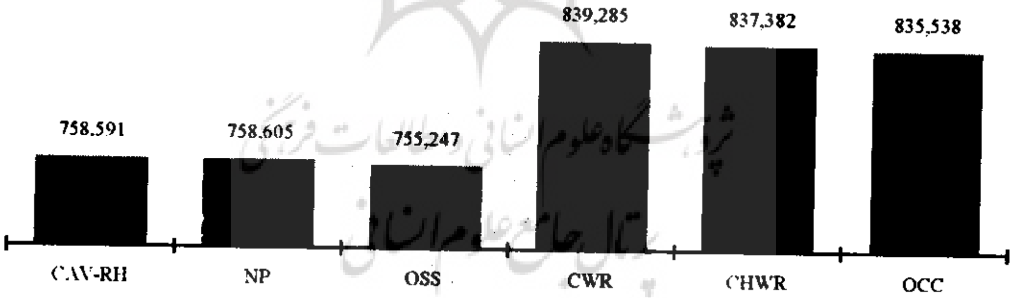
Figure 5.2 Energy and economics of BES: Newer-type building.



(a) Annual energy consumption (Btu/ft2-yr).

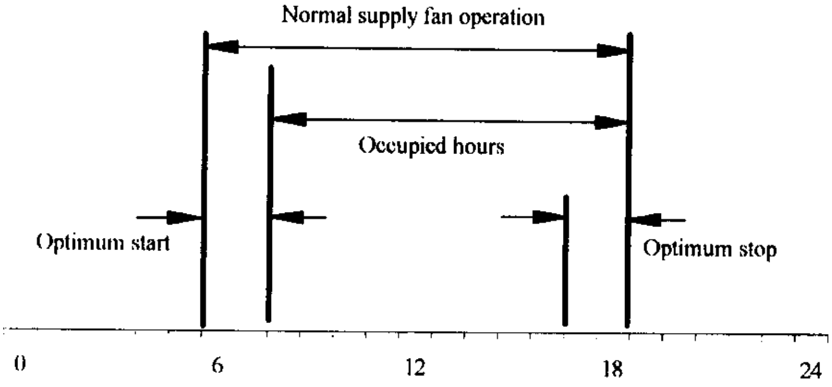


(b) First year utility cost ($).

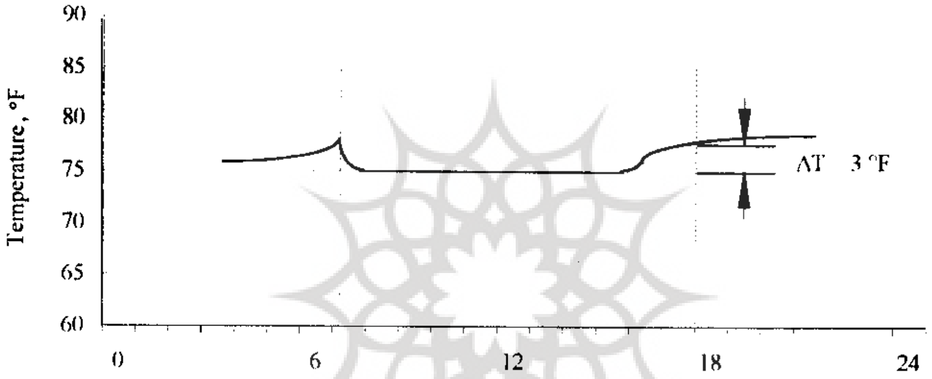


(c) Life-cycle cost ($).

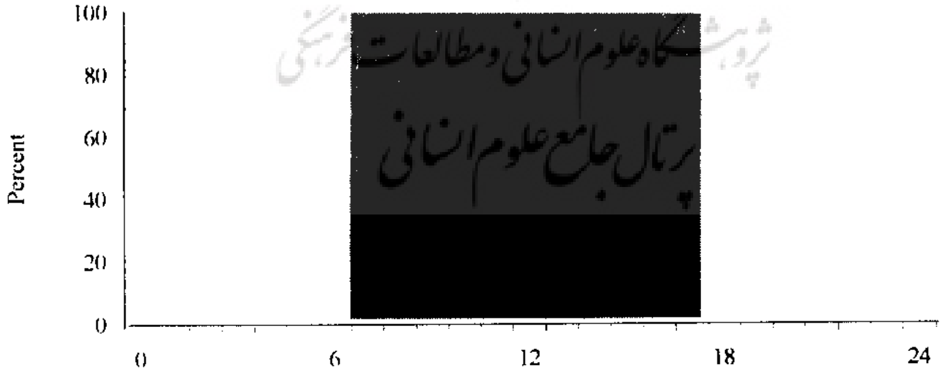
Figure 5.1 Energy and economics of BES: Older-type building.



(a) Scheduled operation periods.

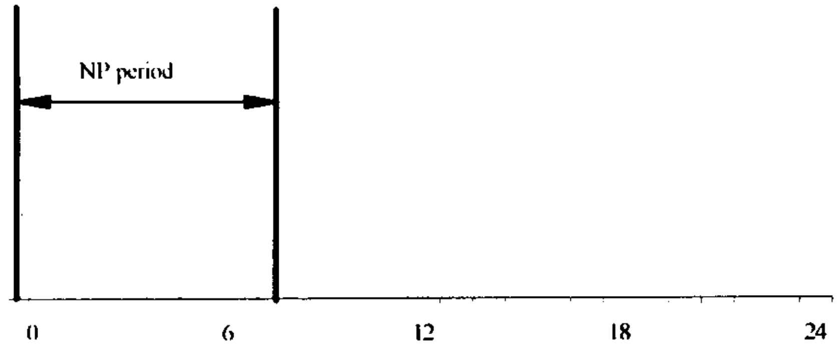


(b) BRAD and setpoint temperature difference .

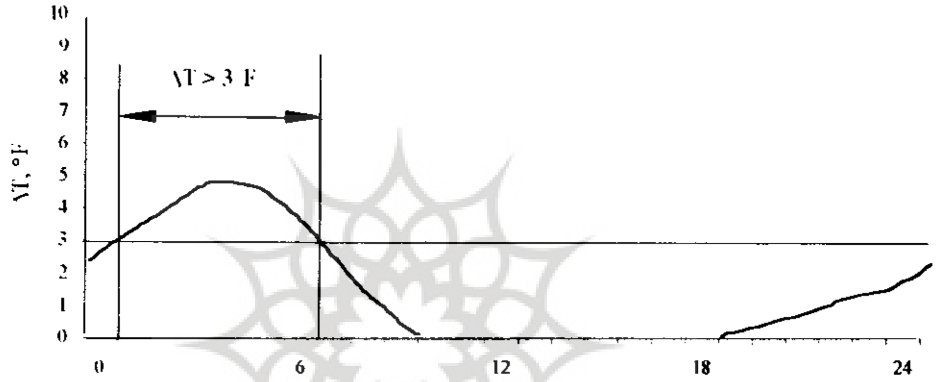


(c) Effective supply fan schedule.

Figure 3.2 OSS strategy and supply fan operation.



(a) Scheduled NP operation period.



(b) BRAD and outdoor air temperature difference.

(c) Effective damper schedule.

Figure 3.1 NP strategy and outdoor air damper schedule.

Mechanical Systems Technologies Proceedings, Istanbul, Turkey.

Ardehali, M. M., and Smith, T. F., 1997, "Evaluation of Variable Volume and Temperature HVAC System for Commercial and Residential Buildings," Journal of Energy Conversion and Management, Vol. 37, No. 3.

Ardehali, M. M., Yae, K. H., and Smith, T. F., 1996, "Development of Proportional-Sum-Derivative Control Methodology with Application to a Building HVAC System," Solar Energy Journal, Vol. 57, No. 4.

ASHRAE IAQ, 1989, Ventilation for acceptable indoor air quality, ASHRAE Standards 62-1989, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., Atlanta.

ASHRAE, 1993, 1993 ASHRAE Handbook: Fundamentals, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., Atlanta.

ASHRAE, 1992, 1992 ASHRAE Handbook: HVAC Systems and Equipment, American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc., Atlanta.

Brandemuehl, M. J., and Kreider, J. F., 1990, "Design and Construction of a University Laboratory for Dynamic Testing of Commercial-Building-Scale HVAC System and Their Controls," ,ASHRAE Transactions, Vol. 96, Pt. 2, pp. 84-91.

Coffin, M. J., 1992, Direct Digital Control for Building HVAC Systems, Van Nostrand Reinhold, New York, N.Y..

EPRI, 1993, Space-Conditioning System Selection Guide, Research Project 2983-13, Palo Alto, California.

Huntley, W. R., 1989, " Design Description of the Large Scale Climate Simulator," ORNL/TM-10675, Oak Ridge National Laboratory, Oak Ridge, TN.

IEC, 1993, Iowa Energy Center 1993 Annual Report, Ames, Iowa.

Kao, J. Y., 1985, "Control strategies and building energy consumption," ASHRAE Transactions, Vol. 91, Pt. 2B, pp. 810-824.

Metha, D. P. and Thumann, A., 1991, Handbook of Energy Engineering, Fairmont Press, Lilburn, Georgia.

Ottaviano, V. B. , 1993, National Mechanical Estimator, Ottaviano Technical Services, Melville, New York.

Trane, 1991, The Trane Company Systems Manual:, The Trane Company, American Standard Company, La Crosse, Wisconsin.

Acknowledgement

The authors acknowledge the support of the Iowa Energy Center.

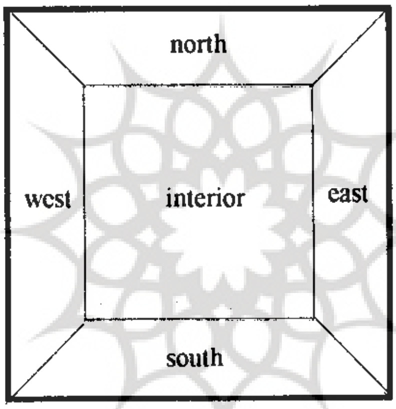


Figure 2.1 Thermal zones of a typical building floor.

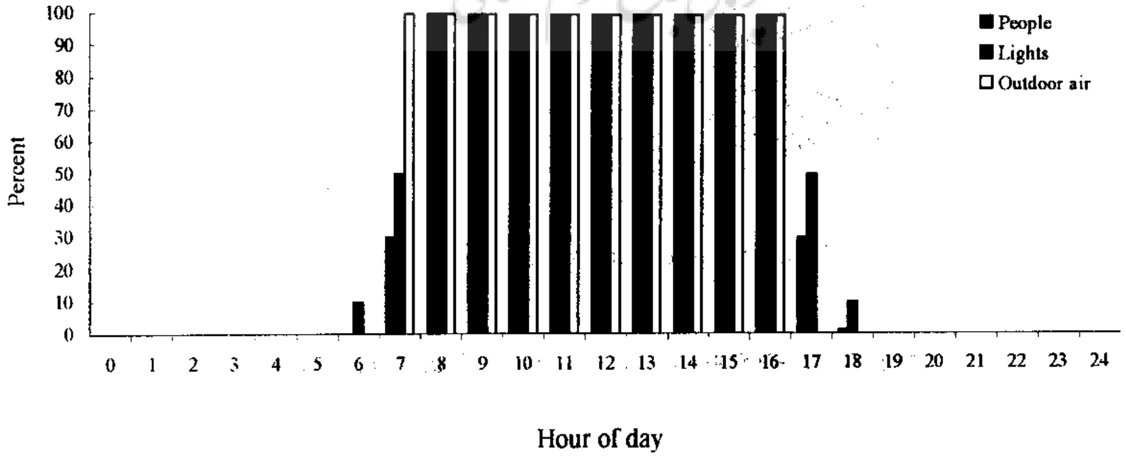


Figure 2.2 Building schedules.

operational strategies are presented in categories that describe the energy consumption index (Btu/ft^2-yr), first-year utility cost ($), and life-cycle cost ($). The interest and inflation rates are noted in Section 5. and the maintenance costs are described in Table 5.1. As noted, the operational strategies are simulated for the older building with CAV-RH and the newer building with VAV-RH. The results are reported in Figs. 6.1 and 6.2.

The simulation results for the older building (Fig. 6.1) indicates that OSS is the most energy-efficient strategy among all four strategies examined. However, if the three OSS, CWR, and CHWR (OCC) strategies are simultaneously applied, the least amount of energy is consumed. The NP is not a useful strategy, as the examined building with density of 100 lbm/ft^3 does not allow for reduction of peak cooling load by means of mass thermal storage. For all strategies except for NP, as shown in Fig. 6.1b, the first year operating costs remain within 3 percent from those of the CAV-RH system. The additional cost for a three-stage centrifugal chiller required for implementing the CWR, CHWR, and OCC strategies creates an unrecoverable offset in the life-cycle costs, Figs. 6.1c. Neglecting the cost for the new chiller, the life-cycle cost for application of these strategies are $755,013 for CWR, $753,110 for CHWR, and $751,266 for OCC.

For the newer building, the OSS is shown as the most effective strategy among all others examined, Figs. 6.2a., where the advantages are due to the modulation of VAV supply fan. The highest energy consumption occurs when the CWR strategy is employed because of the higher cooling-tower-fan operation rates. As compared to all others and similar to the older building results, the NP strategy results in the highest operational cost due to lack of sufficient building thermal mass storage. In comparing all strategies, Figs. 6.2b, the largest possible first-year-utility cost savings is $329 per yr and it is due to the utilization of the CHWR strategy. Because of the lower utility cost, therefore, the life-cycle cost of the VAV-RH system with the CHWR strategy remains the lowest, as shown in Fig. 6.2c. Also, because the cost of the VAV-RH system includes the cost of the three-stage centrifugal chiller, as opposed to the BES in the older building, the large offsets in the CWR and CHWR life-cycle costs do not exist.

In general, the results confirm that utilization of these operational strategies is not recommended for operation of commercial buildings in the midwest region of the country. These operational strategies are motivated and devised to be used for thermal storage BES in larger cities where on-peak demand charges are high and maintaining the lowest possible on-peak demand remains as an important factor in operating such systems.

7. Conclusions and Recommendations

The assessment of the current BES technology as related to various operational strategies is made for the newer-type building with VAV-RH system and older-type building with CAV-RH system. The advantages and disadvantages of various BES are presented in terms of yearly energy consumption per unit area, first-year utility costs, and life-cycle costs, which could be important factors in selection, design, and owning these systems. It is expected that life-cycle costs due to employing these operational strategies vary for different locations because of the dependency on location-specific utility cost factors. Also, because the climates and outdoor conditions influence the operational efficiencies, every operational strategy must be examined for each locale on individual basis. The results show that for midwestern states such as Iowa, where utility cost factors are heavily-based on usage and motivation for operation during off-peak hours of the day is limited, these operational strategies are not effective. Of the strategies considered, the OSS for the older-type buildings and the CHWR for the newer-type buildings are the most effective operational strategies. From an energy-efficiency point of view, the most operationally efficient strategy is the OCC for the older-type building and OSS for the newer-type building. For the life of the system, economically, the most effective is the OSS strategy for the older-type building and the CHWR strategy for the newer-type building. In case of the need for replacement of chillers with environmentally-unsafe refrigerants in older-type buildings, the application of OCC strategy is considered to be the most effective.

Actual tests of these operational strategies are recommended as part of the future extension of this work, so that the findings may be verified. Also, the future work may include examination of various forms of economizer cycle, fan cycling, demand limiting, and super-cold air distribution. Further, it would be of interest to examine the effects of variations in the building design parameters, such as daylighting, envelope insulation, glazing, and mass, on the BES performance.

REFERENCES

Andrews, J. W., Piraino, M., and Strasser, J., 1993, "Laboratory Testing of Control Strategies to Reduce Peak Air Conditioning Loads," ASHRAE Transactions Vol. 99, Pt. 1., pp. 518-529.

Ardehali, M. M., and Smith, T. F., 2000, "Energy and Economic Numerical Simulation of Control and Operational Strategies for Building Energy Systems," The Fourth International Symposium on

strategies are simulated by the simulation code for the older- and newer-type buildings. The program requires certain financial parameters as input, namely, system installed cost, maintenance cost, monthly building energy consumption, utility rate structures, interest rate, and inflation rate. The interest and inflation rates are assumed as 10 and 3 percent. The monthly building energy consumption figures are taken from the corresponding files generated by the simulation program. The mortgage life and life-cycle periods are taken as 20 years. The installed cost or the system construction cost as well as the utility cost are outlined below.

5.1 System construction

For the BES construction costs and related analyses, the $\$/ft^2$ method is used (Ottaviano, 1993). The BES cost is inclusive of the cost for heating, ventilation, and cooling equipment, as well as the necessary cost for system controls and power wiring. The capital cost for each installed system and the associated maintenance cost are shown in Table 5.1. The first column displays the simulated system. In the next column, the cooling load capacity of each system is tabulated. The term 'peak', abbreviated as P following the capacity in tons of refrigeration, is used for the load computations of systems where the building load is equal to the sum of the peak loads of all zones. If the design-day building peak load is used, then the term 'block' is used, abbreviated as B, in describing the type of load modeling for the particular system.

The available figures from the noted reference are given in terms of $/ton for each system, as they are used to compute the $\$/ft^2$ for the corresponding system. The basic maintenance cost for all systems is taken as $\$0.26/ft^2$.

Table 5.1 System construction and maintenance costs.

System	Load (Tons)	System Cost ($\$/ft^2$)	Maintenance Cost ($\$/ft^2$-yr)
CAV-RH	80/P	8.83	0.26
VAV-RH	73/B	8.10	0.26

Because the existing older-type buildings operate with chillers without unloading capabilities, the implementation of the CWR and CHWR strategies in an older building requires accounting for the additional cost of a new 80 ton 3-stage chiller with an installed cost of $55,000. Because older chillers operating with environmentally-unsafe refrigerants need to be replaced, the replacement cost is further justified.

5.2 Utility

5.2.1 Electric utility rate

Because the building is simulated for the weather conditions in Des Moines, Iowa, the electric and gas utility rates of the Midwest Power and Midwest Gas companies are used to perform the economic and life-cycle cost analysis. The building application type and the demand for the peak electrical usage determines the class of service and the rate that is available from utility companies. For the building, the applied class of service is "Electric Small General Service". The electric rates are described below:

Monthly Rate:

Service Charge: $9.80 per month for low voltage delivery
$363.00 per month for 13 kV delivery

Energy Charge:	Summer rate	Winter rate	
for the first 4400 kW-h	$0.0868	$0.0868	per kWh
for all additional kW-h	$0.0597	$0.0538	per kWh

The Summer rate applies to service supplied from May 16 through September 15 of each year. Winter rates are applicable to service supplied during all other days.

5.2.2. Gas utility rate

The type of application and total number of therms used identifies the class of service for natural gas utility service from the Midwest Gas Company. The applicable rate for the building is identified as Small Volume Firm (SF-1) for class of service noted as Residential, Commercial, and Industrial having a peak day requirement of less than 500 therms. The gas rates are:

Monthly rate:
Service charge per meter Commodity charge: $8.75
First 250 therms per term: $0.41589
Balance per term: $0.37915
Includes cost of gas per therm $0.28695
Gas factor$0.00639 (to be added to above commodity charges)

The electric and gas utility cost structures are entered into the simulation code and the results are reported in Section 6.

6. Results and Discussion

The results of the simulations for the purposes of evaluating the requirements must be met during the occupied time. Similar to NP strategy, it is possible to constraint the OSS strategy by means of an offset between the BRAD and the setpoint temperatures, as shown in Fig. 4.2(b). The actual fan operation is reduced, Fig. 4.2 (c), as a result of applying the OSS strategy so that better energy efficiency is achieved.

Light buildings (30-70 lbm/ft3) cool down quickly and heavier buildings (130-200 lbm/ft3) require longer time for cool down at the start-up, hence, shorter and longer cool down time periods are needed for optimum start. At the end of day, a light building warms up quickly and heavier buildings take longer to warm up resulting in shorter and longer time periods for optimum stop of equipment. Therefore, the optimum equipment start-up varies for building function and occupancy type.

4.3 Condenser Water Reset

The CWR operational strategy enhances chiller operational efficiency as it reduces overall energy consumption by the BES. The source of energy consumption in a chiller is the work required by the compressor where the refrigerant gas is elevated from a lower pressure (evaporator) to a higher pressure (condenser). The effects of increase in the refrigerant- pressure-differential between condenser and evaporator increases the work of the compressor. Because the capacity of a cooling tower is a function of ambient conditions, lower ambient temperatures allow for additional cooling of the condenser water. The condenser water temperature decreased is a means to lower the pressure differential, thereby, reducing the compressor work. Reducing the condenser entering water (or the cooling-tower leaving water) temperature by means of resetting increases the operational efficiency (kW per ton) of a chiller. Prerequisites for this operational strategy are a chiller with multi-stage unloading characteristics and a controller with monitoring and regulating capabilities. As a constraint to CWR strategy, a minimum pressure differential must be maintained between the condenser and evaporator for proper oil movement (ASHRAE, 1992). The chiller efficiency may suffer if the cooling tower temperature is lowered to the extent that the return of refrigerant to the evaporator is impeded. Further, the cooler condenser water temperature is obtained at the higher cost of fan energy consumed by the cooling tower fan.

In the simulation code, the cooling tower controls are originally set so that 85°F condenser entering water is produced. Depending on the type of the chiller specified and the CWR range specified by the user, the program continuously monitors the ambient wet-bulb temperature for opportunities to unload compressors. The condenser entering water temperature is allowed to be reset downward by as much as 30°F (i.e., 55°F cooling-tower leaving water) depending on the chiller type and operating conditions.

4.4 Chilled Water Reset

The operational efficiency realized to the CHWR strategy is by means of increasing the chilled water supply temperature to the cooling coil according to a preset plan. The increase in the evaporator discharge (or the cooling-coil inlet) temperature due to the decrease in the building load causes a decrease in the pressure difference between the condenser and evaporator. Similar to the case of the CWR strategy, this reduction in the pressure difference results in reduced compressor work, and lower overall system energy consumption is achieved. The procedure is implemented as described by the following example. A chilled water system with 44°F and 54°F supply and return chilled water is considered. It is desirable to make the operation of the system more energy efficient by means of CHWR operation strategy with reset range of 8°F. The operation of the chiller at 60 percent cooling load implies that the supply chilled water leaving the evaporator is

$$T_{evap,2,new} = (T_{evap,2,old}) + [(\text{percent coolingload}) * (\text{reset range})] \qquad (4.1)$$

where the new reset temperature for chilled water leaving the evaporator is $T_{evap,2,new}$ and the old reset temperature for chilled water leaving the evaporator is $T_{evap,2,new} = 44°F$. Then, $T_{evap,2,new} = 48.8°F$. The program allows for the maximum chilled water reset value as input by the user. Also, the selection of the chiller must be such that the part-loading can be accomplished by unloading compressors as necessary. For this study, a maximum range of 10°F and a 3-stage centrifugal chiller is selected which allows for 33 and 66 percent part-load operation. There are other strategies that could accomplish the energy-efficient operation task at part-load, namely, variable speed pumping. Utilization of CHWR conflicts with variable speed pumping and is avoided in practice.

5. Cost Factors

The assessment of the current technology is concerned with the equipment cost, operation cost, and other related cost factors. The cost for the construction of the building is not considered because it is the same for all strategies examined in this investigation. The economic evaluation and life-cycle cost analysis of the BES operated with the NP, OSS, CWR, and CHWR schedules, such as people, lighting, and outdoor air, which must be defined. During the hours of 10 p.m. to 5 a.m., there are no people, lights, or outdoor air scheduled for the office occupancy of the building.

3. Building Energy Systems

It is desirable to improve the inefficient energy consumption of CAV-RH systems in existing older-type buildings by means of NP, OSS, CWR, and CHWR operational strategies. It is also of interest to explore the possibilities to further enhance the energy-efficient performance of VAV-RH systems in newer buildings by means of operational strategies. In the next section, the operational strategies as EEMs and method to simulate them are discussed.

4. Numerical Simulation of Operational Strategies

4.1 Night purge

The NP operational strategy is designed to reduce the utility costs by means of exploiting the thermal capacity of the building mass and to improve the indoor air quality in buildings by removing odors and other air-borne pollutants caused by the daytime building usage. During the unoccupied periods at night, when maintaining the thermal comfort is not required, the outdoor air is brought into the building to cool down the building mass for offsetting the cooling load at the beginning of the occupied hours. As a prerequisite for applying this EEM, therefore, the controller must be capable of monitoring the ambient and indoor air temperatures as well as controlling the supply fan. Furthermore, the outdoor air schedule must allow for NP operation. In other words, the outdoor air damper must be capable of opening fully, when the controller activates NP strategy. When the outdoor air reaches a pre-defined temperature, the control system activates the main supply fan to introduce the air to the building. The supply of cool air continues until space temperature falls to a specified temperature say 3°F above building return air dry bulb (BRAD) temperature, as depicted in Fig. 4.1. In simulation code, first the NP schedule is defined (Fig. 4.1a) and as the BRAD is tracked (Fig. 4.2b), the effective damper opening schedule is determined. Also, as another constraint to regulate the operation of NP in humid climates, the zone relative humidity may not exceed a specified value to avoid introducing a large latent load by bringing moisture-laden air directly into the building.

The application of NP in climates where it may cool the building far below an acceptable temperature thereby requiring heating in the following morning must be identified. Thus, a computer simulation of this operational strategy is necessary to avoid consuming additional heating energy while attempting to provide more energy-efficient cooling.

4.2 Optimum start/stop

The OSS operational strategy is devised to achieve higher energy efficiency and to reduce utility costs by decreasing time duration of operation of the BES supply fan. Conceptually, without sacrificing thermal comfort, a delay in start-up and an early shut-down of the equipment can potentially increase energy efficiency. The thermal capacity of the building mass allows for reduction in supply fan operation, therefore, it is expected that more massive buildings have higher potential for benefiting from this strategy. The control system could have the capability to record the ambient conditions and equipment settings for future use. The recorded data would provide an array of options, or a "look-up" table, so that the equipment can be started and stopped without causing discomfort for the building occupants. In this manner, the optimum start/stop strategy minimizes the supply-fan run time.

In the simulation code, the user specifies the desired OSS operation schedule that must be in accord with a previously-defined building operation schedule. The standard time of operation for the supply fan is from 5 a.m. to 7 p.m., Fig. 4.2 (a). The OSS schedule controls the supply fan operation and determines how much later the fan can be started than 6 a.m. and how much earlier than 6 p.m. the fan can be stopped. Because the supply fan can only be shut off and not turned on by the OSS controller, the main supply fan time of operation must span the time required by the OSS operation. For the hourly calculation, the number of minutes needed for the supply fan to bring the BRAD temperature up or down to the setpoint temperature is estimated by the OSS controller based on the recorded performances from the previous days. If this value is greater or equal than the number of minutes remaining in the optimum start period the fan is turned on. If the number of minutes is less than one hour, the fan is turned on for a fraction of the hour to maintain setpoint temperature. Because the optimum start controls estimate the time needed for startup, the accuracy of the estimates decreases if longer optimum start periods are specified by the user. Therefore, it is recommended that the optimum start periods not exceed 3 hours.

For the optimum stop, the supply fan is shut off if the BRAD temperature does not fall below the heating setpoint or rise above the cooling setpoint. The optimum stop period is usually less than an hour because the minimum IAQ control for various building and equipment components requires controllers that have multi-input and multi-output capabilities. The direct-digital controllers (DDC) are on-line controllers that apply pre-programmed strategies and do not perform any optimization of the control variables (Coffin, 1992). The pre-programmed instructions consist of an array of choices and conditional loops for addressing a particular event with a proper response. This feature enables DDC controllers to operate in real time. Thus, the operational strategies must be defined in advance of the future events and categorizing these events is a necessity.

For this study, various operational strategies are examined so that their applicability and features can be identified. The objectives of this study are to examine the effects of NP, OSS, CWR, and CHWR operational strategies on the energy consumption and life-cycle cost of BES in older and newer-type buildings.

Energy simulation and life-cycle cost analysis of operational strategies for commercial buildings can assist in identifying the advantages and disadvantages and the cost effects can be quantified. Realistic modeling and simulation of a building require the application of indoor air quality (IAQ) requirements (ASHRAE IAQ, 1989) and related utility rates, such as electricity and gas costs, from the local service companies. The latest energy rates from utility companies are used for

and 7, results, and conclusions and recommendations are discussed.

2. Building Description

The building type and utilization schedules selected for evaluation of the operational strategies is based on the commercial building studied by Ardehali and Smith (1997). However, in this study, some of the older-type building envelope features are modified to reflect the latest efficiency measures taken in design of newer buildings. Therefore, the two building types are referred to as the older and newer buildings. The older building is an office building with 30,000 ft^2 of conditioned area, located in Des Moines, Iowa, and with features of three floors; 12 ft floor-to-floor height; glazing with an area equal to 15 percent of the total exterior wall area, a thermal resistance of R-2.04, and a shading coefficient of 0.51; wall insulation of R-5; and roof insulation of R-11. The ceiling space is chosen as 2 ft to allow for needed clearance for recessed type light fixtures, a fire suppression system, communications conduit and wiring, sanitary piping, and the necessary BES. The occupancy-type is office without the need for any special exhaust or make-up requirements. There are no shading devices associated with the building envelope, nor are there any adjacent tall buildings that would result in daytime shading. There are no roof glazing or skylights in the building. The color of the building walls and roof is assumed dark to account for an envelope solar absorptivity of 0.9. interior zone of each floor has 6400 ft^2 of conditioned area. The geographical and weather data, orientation, infiltration, and other parameters related to building load calculations are fixed, and are the same for all the BES simulated.

The newer building has the same features as the older building with the exception of applying (1) low-E glazing with R-2.6 and shading coefficient of 0.58, (2) wall insulation of R-11, and (3) roof insulation of R-30.

The ventilation rate for the office occupancy varies from 15 to 20 CFM/person, as suggested by the standards (ASHRAE IAQ, 1989). The minimum ventilation air is 20 CFM/person. For both building types, the occupancy is from 7 a.m. to 5 p.m. on weekdays. The floors are carpeted and the indoor design condition is 75°F dry bulb with relative humidity of 50 percent. The cooling thermostat driftpoint is 95°F and the heating thermostat driftpoint is 60°F for the unoccupied periods during the weekdays and weekends. The building is thermally zoned with sufficient core area such that one or several tenants may occupy the space; however, for multiple occupancy, the central system serves the entire building and the cost of BES is applied to individual tenants on the basis of $\$/ft^2$ for conditioned space. The occupancy of the building is considered to be for a typical office use at the rate of 100 ft^2 per person, and 2.5 W/ft^2 for standard lighting and office automation electrical load.

بسم‌الله الرحمن الرحیم

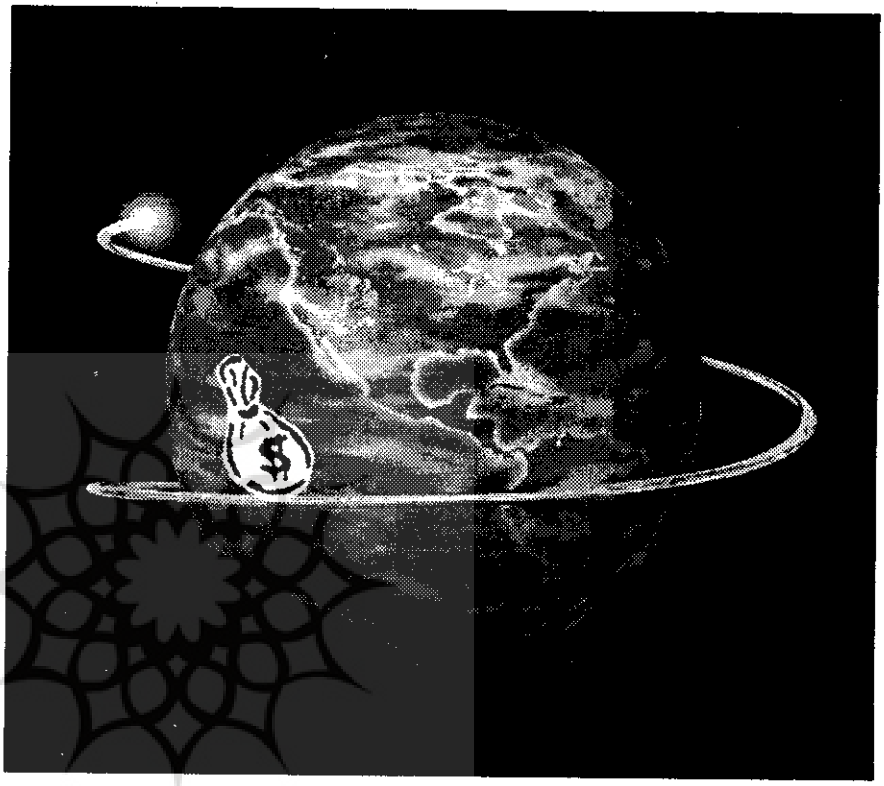
اقتصاد انرژی

خرداد ۱۳۷۹
شماره ۱۳

در این شماره

Energy and Economic Numerical Simulation of Control and Operational Strategies for Building Energy systems

Morteza M. Ardehali, Ph.D., P.E.
Department of Energy Systems Engineering
K.N. Toosi University of Technology
Tehran, Iran
e-mail: mma@apadana.com



Theodore F. Smith, Ph.D.
Department of Mechanical Engineering
University of Iowa
Iowa City, Iowa USA

ABSTRACT

The inherent limitation in performance of building envelope components and energy consuming equipment necessitates the examination of operational strategies for improvements in energy-efficient operation of buildings. Due to the ease of installation and increasing availability of electronic controllers, operational strategies that could be programmed are of particular interest. The Iowa Energy Center has taken the initiative to conduct the necessary assessment of current technologies and the commonly-used operational strategies for commercial and industrial buildings, as applied to the midwestern part of the country, with weather and energy cost data for Des Moines, Iowa. The first part of this study focused on the energy consumption and cost effectiveness of Building Energy Systems (BES). The objectives of the second part of the study is concerned with examination of various operational strategies, namely, night purge (NP), fan optimum start and stop (OSS), condenser water reset (CWR), and chilled water reset (CHWR) applied to older- and newer-type commercial office buildings. The indoor air quality requirements are met and the latest applicable energy rates from local utility companies are used. The results show that, in general, NP is not an effective strategy in buildings with low thermal mass storage, OSS reduces fan energy, and CWR and CHWR could be effective and require chillers with multi-stage unloading characteristics. The most operationally efficient strategies are the combination of OSS, CWR, and CHWR for the older-type building, and OSS for the newer-type building. Economically, the most effective is the OSS strategy for the older-type building and the CHWR strategy for the newer-type building.

● THe equipment that you send into the wells are to be kept there?

- Well, we use the measurement equipments and we pull it out after taking the measures, but the completion equipments will remain in the well and. The completion is really the string pipe and valves that are used to produce the well will remain as long as the well is in production.

● In your work, do you have difficult and easy things to do? Are there any differences in cost, operation, etc?

- Every type of well has its own difficulties and has got its techniques. Yes, cost will be different, depending on the depth of the wells, depending on the geology, some wells are more difficult to drill and then there will be well control issues that have to be considered. It takes longer to drill some wells than some others, and so on.

● So the difference is in the composition of the wells.

- Every well is a new experience even in the same field.

● So it's a wonderful job.

- It's full of challenge.

● Would you please explain about your career experience with Schlumberger and you personnel in Iran?

- I am a petroleum engineer. I started with Schlumberger as a testing engineer and continued with Schlumberger in well logging. I am the general manager of Tehran office. In Iran, we have 228 people working for Schlumberger. More than ten percent of the company's technical staff in Iran are Iranian people. We have Iranian managers, engineers and technicians.

● Are there other offices in other parts of Iran?

- We also have operational bases and offices in Bushehr and Ahwaz.

● Where is your headquarters?

- Our headquarters for the Middle East is in Dubai and worldwide is in Paris.

● Schlumberger is originally from which country?

- The two Schlumberger brothers, Marcel and Conard were French. But today SCHLUMBERGER is a multinatinal company, truly an international company. 100 different nationalities are working in Schlumberger.

● What is the market value of Schlumberger?

- The market capitalization of Schlumberger is $40 billion worldwide. Of course, it depends on how shares go up and down.

● Can you have any kind of cooperation with IIES for instance for setting up conferences and training courses?

- In fact, I have had talks with IIES management back in November last year. we have sent also some progran of training which we can do together with IIES. Here in Iran we can provide the people and experts with training courses. In aditton, we are looking at making a new technology forum or confernce which will be exclusively Schlumberger and we will be talking to IIES about this in near future. We would like to organize it but we would like also to get assistance of IIES to help us in organizing it. It will be held in Tehran and it will be mainly aimed at exhibiting new technology that has been used in Iran by Schlumberger.

● We appreciate your efforts and thanks for the interview.

■