Chapter 4

Introduction

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Chapter 4

Active Design Measures

4.1 Introduction

A combined approach adopting passive design measures – to optimise daylighting and thermal comfort by minimising solar heat gain – before adopting active design measures would be a holistic and sustainable approach to designing an energy-efficient building. Many active design measures can be considered. However, these guidelines focus on SEUs and EEC measures discussed in Chapter 2, namely, ACMV systems and energy management systems (EMSs). In general, the selection of efficient equipment and systems should be prioritised. However, economic evaluation will justify any additional investment for the selection. The appropriate EMS that enables real-time monitoring and controlling with optimisation capabilities can achieve energy savings.

4.2 Efficient Lighting

Using efficient lighting has an added advantage besides saving lighting energy. The added benefit is the reduced heat emission from lights due to the lower wattage of efficient lighting. The first law of thermodynamics says that energy cannot be created or destroyed. Therefore, 100% of the electricity used by light fittings will become heat energy when lights are switched on in a building. Given this reduced heat emission from efficient lighting, the cooling load for ACMV systems will be reduced. Hence, the ACMV equipment capacity can be downsized, which can be translated into savings in equipment and subsequent operating energy costs.

For efficient lighting design, refer to DOE's Guidelines on Energy Conserving Designs of Buildings (DOE, 2008). In addition to complying with the requirements and selection of electric lights with high efficacy as stated in the said guidelines, five basic recommendations will lead to efficient lighting in a building, namely:

1) Use natural daylighting as much as possible.
2) Ensure the installed lighting power density (W/m^2) is as low as possible while providing the required amount of light and quality according to the DOE Guidelines, 2008.
3) Select lights with high luminous efficacy, an indicator of the efficiency of the lamps, and is defined by equation 2 below. Higher efficacy values indicate higher lamp efficiency, producing more light for the same energy used.

$$Efficacy = \frac{Lumen}{Watt} \qquad (2)$$

4) Use light-emitting diode (LED) lights for general lighting, with additional task lights to provide the required lighting lux level, hence, resulting in energy savings.

5) Ensure that electrical lights are switched off when not required or partially switched off when basic lighting is required in unoccupied areas through sensors. When daylight is harvested in an office space, 'auto-off and manual-on' control is recommended. This means that electrical lights are automatically switched off whenever the measured daylight is adequate. Still, the building occupants need to manually switch on the lights when daylight drops below the preset lux levels. However, it is advisable to switch on the lights automatically when the measured daylight drops below the desired lux level in public or common areas.
6) Appropriate light zoning provides a quick and easy way to reduce energy consumption in a building. Appropriately designed light zoning allows switching off when the space is unused or when daylight is available, such as in areas adjacent to windows. In addition, segregation of areas according to their respective functions and operating schedules for emergency, night lighting, and security lighting will help further reduce lighting energy due to the difference in operating requirements.

As a general rule, it is advisable to make early plans for various operating requirements such as night lighting, security lighting, fire safety lighting, and other building functional requirements. Energy efficiency considerations during the operation stage will be incorporated during the design stage. The lighting system should be properly commissioned and fine-tuned. For example, the position of motion and photosensors, timing devices, and others may need to be adjusted to optimise lighting performance.

4.3 Air-conditioning and Mechanical Ventilation (ACMV) System

As discussed in Chapter 2, space cooling requirements are the most significant energy user in a building in hot and humid climates. The cooling load calculation of a building determines the air-conditioning capacity of the ACMV system to be installed in a building. The correct sizing of the ACMV equipment depends on this cooling load calculation, which largely impacts capital costs during the building construction phase, and later the operating cost during building occupancy and operation. On the other hand, if the ACMV system is undersized, the building will not be provided with adequate cooling and cannot function properly to meet the requirements of its occupants.

The cooling system design loads for the ACMV system and equipment sizing should be determined following the DOE Guidelines 2008 and the ASHRAE *Handbook of Fundamentals* (ASHRAE, 2017).

The cooling load of space is a simple summation of all the heat generated internally and heat gains from external sources. The heat generated internally is commonly known as the internal cooling load, while the heat gains from external sources are known as the external cooling load, as outlined below.

1) Internal cooling loads or heat gains comprise the following:
    a) occupants (may be either sensible or latent heat)
    b) electrical lights (sensible heat)
    c) equipment and appliances (sensible heat)
2) External cooling loads or heat gains comprise the following:
    a) heat transmission through building structure as a result of conduction, convection, and radiation (sensible heat)
    b) solar radiation through fenestrations (sensible heat)
    c) conductive heat gain transmitted through fenestrations (sensible heat)
    d) outdoor ventilation and infiltration air (sensible and latent)

Based on the above list of internal and external heat gains, cooling loads of ACMV systems' sizing and selection can be reduced if some internal and external heat gains can be minimised. In designing energy-efficient ACMV systems, the following measures should be considered:

1) Reduce lighting and equipment loads.
2) Minimise heat gains through building envelope as much as possible through strategic fenestration and shading devices.
3) Specify building functions according to the owner's project requirements and determine cooling loads without overloading with safety factors to ensure that the ACMV system is not oversized. Judicious application of diversity factors is important to the tight control in the sizing of equipment for optimum efficiency and operation of the ACMV system.
4) Zone perimeter areas separately and design local air distribution system with increased cooling capacity for spaces with the significant glazed area.
5) Use energy recovery wheels to precool outdoor ventilation air.
6) Use a demand-controlled ventilation strategy to minimise intake of outdoor air based on demand, with carbon dioxide (CO_2) sensors.
7) Minimise infiltration of outdoor air through entrance doors by designing vestibules or sensor-controlled doors to avoid entrance doors frequently left wide open.
8) Inform the design of schedules of occupancy and use in a building early during the planning stage so that designers can efficiently select equipment and configuration and ancillary control systems.
9) Consider using variable speed drives to efficiently control fans and pumps to match airflow and water flow according to the load requirements. Consider controls using pressure reset based on measured feedback on systems with variable flow.
10) System selection and configuration should consider the extent of redundancy. Redundancy allows a spare capacity such that a single piece of equipment can be down for maintenance, and the rest of the system can still operate at some level. If incorporated into the sizing of the duty equipment, redundancy in equipment capacity should include efficiency devices, such as variable speed drive, high efficiency motor, efficient unloading devices, multi-compressors, water-cooled magnetic bearing chillers, etc. This is to achieve optimised equipment or system efficiency when operating at varying loads. For instance, a chiller configuration may comprise 3 x 50% capacity. This would be a two-run or one-standby operation or a one-run or two standby operation giving flexibility in matching varying cooling load requirements while maintaining high equipment or system efficiency as much as possible. Compared to a 2 x 100% chiller configuration, a 3 x 50% chiller configuration would provide a greater opportunity to achieve higher system efficiency.

4.4 Energy Management System (EMS)

The EMS is a subset of the building automation system (BAS) function. It is a computer-based automated system that monitors and controls all energy-related systems in building services. With the advancement in BAS technology and the advent of the Internet of Things, an integrated building management system can provide more options and scopes in energy management. However, a basic EMS should be able to

1) gather and analyse data from every energy user in a building;
2) identify problems and trend tracking by analysing both single-variable and multi-variable data;

3) provide monitoring and initiate alerts if the building's energy consumption or building energy performance parameters, such as EEI or BEI (refer to Chapter 5), exceed the preset benchmark parameters;

4) integrate equipment and other subsystems with control systems to perform optimisation, such as:

a) scheduling and manual overriding
b) controlling set points for key operating parameters
c) optimising the system and equipment
d) reporting and recording operational alarms
e) ensuring the correct and safe sequence of operation, including maximum demand limiting functions

5) identify energy wastage and perform optimisation;

6) analyse and benchmark the building's energy performance against national benchmarks when they are available.

EMS implementation is already starting to be a common system in new buildings because of the following EMS benefits:

1) It provides real-time remote monitoring and integrated control of a wide range of connected systems, modes of operation, energy use, environmental conditions, and others to be monitored. It also allows hours of operation, set points, etc. to be adjusted to optimise performance and comfort.
2) An EMS informs and enables the building staff to predict problems and provide a schedule for maintenance programmes.
3) It allows facilities to power equipment only when needed, eliminating the waste of lighting, heating, and cooling portions of the building that are unused around the clock. The US Green Building Council claims that the scale of savings that EMS can achieve ranges from 10% to 25%. If the EMS is operated properly, it should optimise energy use without compromising comfort or performance.
4) An EMS allows records of historical performance to be kept, enables the benchmarking of performance against other buildings or records of the same building, and may help automate report writing.
5) It can perform its functions completely automatically, day in, day out, year after year, without the need for much interaction. However, a 'system downtime' is not acceptable for many users or owners, such as in data centres or healthcare facilities. Therefore, systems need to be robust, reliable, and able to adapt or expand with the need of the customers.
6) An EMS can provide educational dashboard information at a suitable public access area of a building, showing the status of building energy performance and carbon emission reduction. This will help generate greater EEC awareness amongst building occupants and the general public while meeting corporate social responsibility and expectations.

For building management, options are now available to monitor the EMS online and from a web-based information system. The system can be applied and developed to monitor and analyse the real-time energy performance of multiple buildings offsite. The data processed and analysed by EMS can be used for in-house energy management reporting and updating purposes. In addition, options are available to develop the administration of external reporting to a dedicated agency or body with the authorities, such as the DOE, to collect energy building information and energy consumption data. Designated establishments can upload such building information and data to a web-based energy management information system administered by the DOE. An example of such web-based energy management information system is the Building Control Information System (BCIS). The BCIS can facilitate the data collection, analysis, and tracking of building energy performance by the DOE. However, the implementation of such a system is subject to many considerations, such as security, information disclosure regulations, industry acceptance, investments, development of skilled workforce resources, etc.