IEA ECBCS Annex 36: Retrofitting in Educational Buildings – Energy Concept Adviser for Technical Retrofit Measures

SUBTASK A

Overview of Retrofitting Measures

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December 2003

Chapter 3

Heating systems

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3.5. Control Strategies

3.5.1. General information

Control especially as part of more comprehensive energy management can be understood and defined as an energy saving technology itself. An efficient control system of building and HVAC plant is necessary for achieving energy efficient building. However the “optimal” control strategy for a specific building depends not only by technical parameters as building type and design, ventilation and climatization plants etc, but also on human behaviour i.e. parameters like dress code, user attitude and user expectations. In general in each building there is a strong interaction between the energy plant and the control system. In buildings with active components, this aspect is enlarged to the envelope also; it is therefore important that all these parts are designed together in one process and a strong co-operation between architects, HVAC engineers and control engineers is necessary.

One of the most challenging item in control systems is to allow user interaction without compromising the overall well working of building energy devices. The impossibility of influencing the local climate conditions is often one of the main reason of complaint by the occupants. Recent research indicates that users are more tolerant of deviations in indoor climate if it is controlled by themselves, this fact is of great importance even for energy related evaluations. Even if users should have a high possibility of controlling their own environment, automatic control is needed to support users in achieving a comfortable indoor climate and to take over during non occupied hours to reduce energy consumption and to precondition rooms for occupation. Simplicity and transparency of the user/system interface is of great importance, and one of the main request is that the control system responds to their needs and allows them to change indoor conditions with rapid feedback.

The control system should obviously follow external climate conditions, in order to allow a correct regulation of heating/cooling plants according to the real needs of the occupants. Building with active envelope or with natural or hybrid ventilation devices are in closer contact with external climate conditions, so special care have to be taken in studying this aspect. Control system should be in these cases self learning, in order to be ready to exploit the favourable conditions and to mitigate the unfavourable ones.

The main control tasks in an energy efficient and healthy building should be:

- Room temperature
- Room heating and cooling
- IAQ during occupied hours
- IAQ during non occupied hours
- Solar shading
- Night ventilation during summer
- Preheating of ventilation air during winter

Thermostats and TRVs (Thermostatic Regulation Valves) were the first control equipment to disseminate in the building sector owing to the first energy crisis. Building management systems developed in the ‘80s in the residential and services sectors, as simplified applications of systems and technologies already developed in the industrial sector in the ‘70s to automate production processes and to optimize plant performances.

3.5.2. Control methods

There are numerous methods by which heating and other building services within buildings can be controlled. Most systems seek to control either by:

- Time i.e. when a service like heating or lighting for instance is provided and when it should not be provided or
- A parameter representative of the service like temperature for space heating. This can also vary with time.

As an example some typical control methods are described hereafter:

Time Control Methods (for heating):
- Time switches turn on and off the heating (or water heating) system at pre-selected periods (of the day, of the week)
- Optimisers: these controls start the heating system in a building at a variable time to ensure that, whatever the conditions, the building reaches the desired temperature when occupancy starts.

Temperature control methods:
- Frost protection generally involves running heating system pumps and boilers when external temperature reaches a set level (0°C) or less in order to protect against freezing
- Compensated systems: which control flow temperature in the heating circuit relative to external temperature thus allowing a rise in the circuit flow temperature when outside temperature drops.
- Thermostatic radiator valves: these units sense space temperature in a room and throttle the flow accordingly through the emitter (radiator and convector) to which they are fitted
- Modulating control: can be applied to most types of heat emitters and is used to restrict the flow depending on the load demand and thus controlling the temperature.
- Proportioning control: involves switching equipment on and off automatically to regulate output

Other methods:
- Occupancy sensing: In areas which are occupied intermittently, occupancy sensors can be used to indicate whether or not somebody is present and switch the heating/cooling and ventilation on accordingly. Detection systems are based on ultrasonic movement or infrared sensing.
- Other methods can be thermostats and user interactive control

The basic control technologies have been in existence for some time. Systems available range in complexity, from the extreme case of the timer-controlled water heater or thermostatic radiator valves, to the so-called "intelligent houses" which manage everything from the security and safety systems to the air conditioning, lighting and ventilation system, to telematic services and to most appliances of a house according to efficiency criteria. The use of these technologies allows the optimisation of various services often with large energy savings. A well functioning BEMS can be expected to save 20%, and occasionally more, of the energy consumption of the plant being controlled. Savings can be expected to recur year after year which makes installation of modern control or BEMS even much more profitable.

3.5.3. Building Energy Management Systems

The term Building Energy Management Systems (BEMS) encompasses a wide variety of technologies which includes also energy management systems and building controls. Their function is to control, monitor and optimise various functions and services provided in a building, including heating and cooling, ventilation, lighting and often the management of electric appliances. Building Energy Management Systems are also referred to by various other names alike Energy Management System (EMS), Building Management System (BMS) or Building Automation System (BAS).

A Building Energy Management System (BEMS) consists normally of one or more self-contained computer based 'outstations' which use software to control energy consuming plant and equipment, and which can monitor and report on the plant's performance. These outstations have the ability to be linked together in a modular fashion by a network, and can communicate with each other and with an optional central operator's terminal, which is often a conventional Personal Computer (PC). BEMS provide control by using software logic and are re-programmable, whereas older controllers of the electrical or electro-mechanical type relied on purpose built hardware which required hardware changes to change their characteristics or abilities.

Typically BEMS consist of both hardware and software and systems are divided to subsystems of three different levels: field level, automation/control level, and management level. In addition, remote monitoring and servicing is a feature utilized in some special application areas when supervised systems are geographically scattered.

The hardware is usually represented by one (or more) control and processing units and by a number of other peripheral devices (which control the operation of say, heating or cooling systems, artificial light-sources or other appliances and which can also be represented by sensors, thermostats, etc.) connected to the control units. The control unit, based on the information supplied by some of the peripherals or based on pre-set instructions, runs the system. The control unit can be as simple as a relay or a timer switching on or off an electric water heater or as sophisticated as a microprocessor operating on «fuzzy logic». Commands can be sent from the central unit to the peripheral units through Ethernet cable, power-lines or telephone lines, or

fibre-optic cables. The material "medium" through which commands and messages between the various parts of the system are exchanged, is often called (Field)BUS.
The software is simply the program and the instructions that allow the control unit to manage the operations of the peripheral devices and of the appliances..

Integration of all controls into one Building Energy Management System has some advantages: it makes it easy for operators, it co-ordinates the control of different systems, it reduces the number of sensors. New standards for data interface at field level like LON (Local Operating Network) for instance, can result in easier integration of components from different suppliers into one system without the need for protocols to translate between suppliers. A local operating network consists of intelligent devices, or nodes programmed to send messages to one another in response to changes in various conditions and to take action in response to messages they receive. The nodes on a LON may be thought of objects that respond to various inputs and produce desired outputs. Linking the inputs and outputs of network objects enables the network to perform applications. While the function of any particular node may be quite simple, the interaction among nodes enables a local operating network to perform complex tasks. A benefit of local operating networks is that a small number of common node types may be configured to perform a broad spectrum of different functions depending how they are linked in a network.
The ongoing fast development of information and communication technologies is rapidly changing the technology basis of BEMS too. The development is going to towards more open systems and standards from the proprietary and therefore expensive systems of today. In the future the BEMS technology will evolve from vertical into horizontal where big companies perhasp no longer control the whole chain. Open interfaces at every level of system enable open competition throughout the life cycle of systems. In the future internet, mobiles and wireless technologies will be widely popular also in the controlling of buildings

3.5.4. Advanced control strategies

Nevertheless an energy efficient and coherent management of controls can hardly fulfilled by means of traditionally rule-based control strategies, because the different systems can get to different (sometimes contradictory) requirements: optimisation in these cases, at the end, can result in an overwhelming task. On the other hand advanced control techniques can find natural application in this technological context of sensors network, allowing to control several parameters through an optimised strategy.

Advanced control strategies require, besides a number of sensors, a number of actuators and require to be tuned to get optimum results. Advanced control strategies can be distinguished in:

- Optimum and predictive
- Simulation assisted
- Neural networks
- Fuzzy logic
- Adaptive artific ial life based techniques

The most advanced techniques, like those based on artificial life, can be self learning, providing a great improvement in control systems potentials. In spite of all these advantages, and though they have been known for many years and have been commonly applied in industrial processes, advanced control strategies are not widely used in the building industry. The reason for this is mainly implementation difficulties, especially with regard to the need for a very complex and time consuming tuning process for the systems. The application of building and plant dynamic simulation techniques, more and more reliable, can now be helpful in a wider use of these techniques of building control management. The adoption of advanced control strategies needs an amount of sensors to measure:

- Temperature
- Relative Humidity
- Indoor Air Quality
- Occupancy

Some of these sensors, like temperature ones, are reliable and not expensive, and further improvement are not necessary, some other, like those for IAQ, still present some problems. One of the purpose of the control system is to establish the desired air flow rate and airflow pattern at the lowest energy consumption possible.
During past years It has been proven that an energy efficient healthy building needs a Demand Controlled Ventilation (DCV) system. A DCV system needs to be managed by a reliable control system and for this purpose the adoption of IAQ sensors is necessary. CO_2 is at now the most suitable parameter for measuring the indoor air quality in places where humans are the most dominating pollutant. Unfortunately IAQ sensors (either CO_2 or VOC – Volatile Organic Compounds sensors) are still quite expensive, of uncertain reliability (VOC sensors) and needs periodical recalibration. For these reasons some alternative way for reaching the same information about IAQ level, have been tested. The main alternative methods is to try to correlate occupancy and IAQ levels with the adoption of Passive Infra Red (PIR) sensors and/or with the adoption of people counting systems even by means of image recognition techniques.

PIR techniques were adopted successfully in some building with cellular offices studied in Annex 35 HybVent project of International Energy Agency. IR sensors can detect movements in the room; the major advantage of this system is its relative low cost (compared to CO_2 sensors) and its autonomy (the inlet with the IR sensor works on a long-life battery, no wiring is required). The major disadvantage is that the airflow is only indirectly correlated to the demand. Sometimes, the airflow can be too low, or too high. Anyway, presence detection has proved to be a good way to control the ventilation demand in rooms with low variation of occupancy. It could be successfully applied, in some cases, in school classrooms. For conference rooms, simple people meter techniques (usually adopted in commercial building even for security reasons) or more sophisticated image recognition and processing techniques could be more suitable because it should better estimate the real needs.
One of the most interesting and promising task of control system is the possibility of intervention in cooling peak loads reduction. For this purpose, different strategies can be studied, according to different climate conditions, here a list of possibilities, some of them are well known, some other are new and promising. Both of types need a good control strategy.

Night time ventilation: this strategy can help in pre cooling occupied space in building with a sufficiently heavy thermal structure. The effect of this strategy is the possibility of reducing the use of mechanical cooling during first daily building working hours, in this way the peak of energy demand (always observed at starting of cooling machines) can be delayed. A differentiation of plant starting time between different zones of the building, can result in a substantial peaks reduction.

Solar shading: an optimal solar shading is often the most logical solution for reducing summer cooling loads. The task of control system is in these case the optimisation between the reducing of solar gain and the necessity of a good luminance level without the use of artificial light that vanished the benefit of solar shading.

Local removal of heat and contaminant loads: an optimisation of the local removal of heat and contaminant loads near to the zones of heat and contaminant production, before their diffusion in the indoor environment, can help substantially in reducing thermal and ventilation loads. In this way, actually, it is possible to reduce the amount of overall renewal airflow rate.

Desiccant devices and personalised local thermal comfort island.
The use of sorption air dehumidification - whether with the help of sorption regenerators or liquid systems – offers new possibilities on air conditioning technology. This can mean the general of classic compression refrigeration equipment by means of the incorporation of evaporation cooling, or the increase of evaporation temperatures in refrigerating plants by means of the of air dehumidification by cooling below the dew-point. The desiccant technology thereby represents a new quality in air conditioning technology. The terms desiccant cooling or DEC are synonyms for the procedural combination of "air drying, evaporation cooling and heat recovery“ In contradiction to production of chilled water the desiccant system is a system to directly produce conditioned fresh air. The main purpose of it therefore ventilation of air and thereby to condition this air in order to achieve comfortable indoor conditions. Economic advantages arise for DEC equipment when coupled with district heat or with waste heat from a cogeneration plant. Of particular interest is coupling with thermal solar energy. According to the design conditions, regeneration temperatures of the air of up to 80°C may be necessary; however under part load conditions the system provides air conditioning also with lower driving temperatures down to 50°C.

The use of DEC technology is specially convenient in coupling with local thermal comfort island, achieved by mean of radiant panels system. In this case the possibility of ventilation with pretreated and de-humidified air prevents the risk of undesired condensation over the surface of radiant panels, especially in warm and humid climate.

This strategy can allow a strong reduction of cooling loads in partially occupied open plan buildings. In this way only the actually occupied zone can be cooled, at the desired level, obtaining a double positive effect of energy saving and users satisfaction. Of course in this case also it is important, once again, the role of control system.

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