Simulation of energy in the building and design a new intelligent building with controllable and wise devices

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Abstract

Building energy simulation is important for the study of energy efficiency in buildings. An energy saving control system of lightning, heating and variable-air-volume air conditioner in intelligence building is simulated in this paper. It reaches good control effect and energy efficiency by making the best of the advantages of intelligence building. In the regulating period, the lightning lux, heating flux and air volume is decided by means of feed forward control. The previous turning off period is determined in the way of penalty function. It has been used in a sample building for developing building energy standards and analysing energy consumption and conservation measures of buildings.

Keywords: neural network, building, intelligent

1. Introduction

Intelligent building is a building with intelligence. The air condition (AC) system exhausts most energy in the building, so it is necessary to adopt a control method to get the optimum energy efficient by making the best of the resources in the intelligence building. The air system is a complex system with characters such as: too many factors, nonlinear, long delaying, strong inertia etc. And the accurate mathematics model is hard to make out, so the performance of classical control theory can hardly be satisfying. Thanks to the ability of intelligent building, such as measuring, recording and analyzing the data, some advanced methods can be used to achieve both good control effect and ideal efficiency.

Energy management and control system (EMCS) technology has evolved over the past three decades from pneumatic and mechanical devices to direct digital controls (DDC) or computer based controllers and systems. Today's EMCS systems consist of electronic devices with microprocessors and communication capabilities and utilize widespread use of powerful, low cost microprocessors and standard cabling communication protocols.

This paper discusses functions and capabilities of a typical building/facility EMCS and its simulation. Most basic functions and some intermediate and advanced functions described in this paper are generally required to operate buildings/facilities efficiently.

1.1. Intelligent buildings - control theory

The essence of Building Management Systems and Intelligent Buildings is in the control technologies, which allow integration, automation, and optimisation of all the services and equipment that provide services and manages the environment of the building concerned.

Programmable Logic Controllers (PLC's) formed the original basis of the control technologies.

Later developments, in commercial and residential applications, were based on 'distributed-intelligence microprocessors'.

The use of these technologies allows the optimisation of various site and building services, often yielding significant cost reductions and large energy savings. There are numerous methods by which building services within buildings can be controlled, falling broadly into two method types:

- Time based - providing heating or lighting services, etc., only when required, and
- Optimiser Parameter based - often utilising a representative aspect of the service, such as temperature for space heating or illuminance for lighting.

1.2. Heating - time-based control

Time-based controls can be used to turn on and off the heating system (and/or water heating) at pre-selected periods (of the day, of the week, etc). Optimiser Parameters: whatever the conditions, the controls make sure the building reaches the desired temperature when occupancy starts.

- Heating - optimizer parameter-based (temperature) control examples
- Temperature control: protection against freezing or frost protection generally involves running heating system pumps and boilers

when external temperature reaches a set level (0°C).

- Compensated systems: will control flow temperature in the heating circuit relative to external temperature. This will give a rise in the circuit flow temperature when outside temperature drops.
- Thermostatic radiator valves: these sense space temperature in a room and throttle the flow accordingly through the radiator or convector to which they are fitted.
- Proportional control: involves switching equipment on and off automatically to regulate output.
- Other methods can include thermostats, occupancy sensing PIR's (passive infra-red sensors), and manual user control.

1.3. lighting control methods

Different control systems exist, again time-based control and optimiser parameter-based where a level of illuminance or particular use of lighting is required.

- Zones: lights are switched on corresponding to the use and layout of the lit areas, in order to avoid lighting a large area if only a small part of it needs light.
- Time control: to switch on and off automatically in each zone to a preset schedule for light use.
- Passive Infra-Red (PIR) Occupancy sensing: In areas which are occupied intermittently, occupancy sensors can be used to indicate whether or not anybody is present and switch the light on or off accordingly.
- Light level monitoring: this consists of switching or dimming artificial lighting to maintain a light level measured by a photocell.

1.4. building management systems and intelligent buildings - energy savings

Until recent years, energy efficiency has been a relatively low priority and low perceived opportunity to building owners and investors. However, with the dramatic increase and awareness of energy use concerns, and the advances in cost-effective technologies, energy efficiency is fast becoming part of real estate management, facilities management and operations strategy. The concepts are also now making significant inroads into the domestic residential house building sectors.

For lighting, energy savings can be up to 75% of the original circuit load, which represents 5% of the total energy consumption of the residential and commercial sectors.

Energy savings potential from water heating, cooling, or hot water production, can be up to 10%, which represents up to 7% of the total energy consumption of the domestic residential and commercial sectors.

Experiences from studies in Austria suggest potential heating and cooling energy savings are up to 30% in public buildings. Even allowing for the fact that buildings used in the study may have been those with particularly high energy usage, the figure is an impressive one. (Source: EU2 Analysis and Market Survey for European Building Technologies in Central & Eastern European Countries - GOPA)

Intelligent Buildings and Building Management Systems technologies contribute directly to the reduction in energy use, in commercial, industrial, institutional and domestic residential sectors.

In short, Intelligent Buildings and suitably applied Building Management Systems are good for the environment.

Careful interpretation is required. In the UK, adoption of controls technologies into the new build and major refurbishment sectors is relatively high: Estimates a few years ago of the UK market for Building Management Control Systems for new build and major refurbishment, all sectors, suggest market adoption of (as at 1994 - Source UK1 An Appraisal of UK Energy RTD, ETSU -1994):

- Heating controls 70%.
- Hot water system controls 90%.
- Air conditioning controls 80%.

However according to European Commission as many as 90% of all existing buildings have inapplicable or ineffective controls, many of which require complete refurbishment of control systems.

Moreover conventional control systems stop short of automated Intelligent Buildings full capabilities. A significant human element is required for optimal effective operation even if control systems correctly specified and installed.

Given typical installations and equipment there is often a difficulty for building occupants (residential) or managers (commercial) to operate them correctly. Usage and correct operation are vital for effective results.

Education of users; improved systems-design user-friendliness, and the provision of relevant instructions and information are all critical to enable theory to translate into practice, and for potential effectiveness and savings to be realised.

1.5. Practical benefits

Energy-effective systems balance a building's electric light, daylight and mechanical systems for maximum benefit.

Enhanced lighting design is more than an electrical layout. It must consider the needs and schedules of occupants, seasonal and climatic daylight changes, and its impact on the building's mechanical systems.

1.6. Lighting systems

Adding daylight to a building is one way to achieve an energy-effective design. Natural daylight 'harvesting' can make people happier, healthier, and more productive. And with the reduced need for electric light, a great deal of money can be saved on energy. Nearly every commercial building is a potential energy saving project, where the electric lighting systems can be designed to be dimmed with the availability of daylight. Up to 75% of lighting energy consumption can be saved. In addition, by reducing electric lighting and minimizing solar heat gain, controlled lighting can also reduce a building's air conditioning load.

1.7. Mechanical systems

The HVAC system and controls, including the distribution system of air into the workspaces, are the mechanical parts of buildings that affect thermal comfort. These systems must work together to provide building comfort. While not usually a part of the aesthetics of a building, they are critical to its operations and occupant satisfaction.

The number one office complaint is that the workplace is too hot. Number two is that it's too cold.

Many people cope by adding fans, space heaters, covering up vents, complaining, conducting 'thermostat wars' with their co-workers, or simply leaving the office. Occupants can be driven to distraction trying to adjust the comfort in their space. Improper temperature, humidity, ventilation, and indoor air quality can also have significant impacts on productivity and health. When we are thermally comfortable we work better, shop longer, relax, breathe easier, focus our attention better.
In order to provide a comfortable and healthy indoor environment the building mechanical system must:

- Provide an acceptable level of temperature and humidity and safe guard against odours and indoor air pollutants.
- Create a sense of habitability through air movement, ventilation and slight temperature variation.
- Allow the occupant to control and modify conditions to suit individual preferences.

2. Simulations:

Thermal problem detection a model for integrating a rigorous thermal simulation with computational reasoning is discussed. This model is used to build an intelligent computer-aided system that assists designers throughout the design process. The model uses rigorous hierarchical thermal simulation modules linked to several databases. In addition, Artificial Intelligence Techniques are used to build a multilevel reasoníng structure for both the initial and the final design. Neural networks are utilized for the initial design stage problem detection where problems are incomplete. The neural networks are integrated with a multi-knowledge reasoning structure that utilizes the blackboard framework. This structure is used for problem detection in the intermediate to final design stages and for advice throughout the design process.

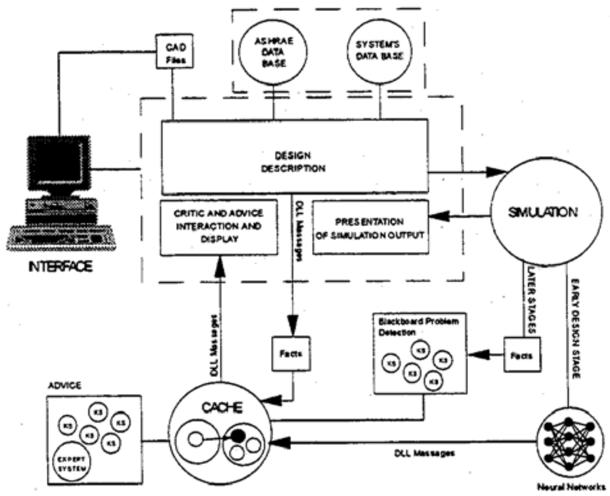

Figure 1: the system model

The system consists of four major components that are organized in an integrated framework. These components are: 1. the graphical user interface 2. The simulation program 3. The data base 4. The intelligent agents; figure (1).

The interface in this system is built to provide flexible tools to propose the design problem and to navigate and interact with the system's output and intelligent agents. This way accomplished by providing a graphical user interface that performs all necessary criteria in one environment. The interface allows the user to define the thermal design problem, start a detailed simulation, navigate the outcome, interact with the intelligent agents and based on this, allow alterations to the design. The interface is designed to allow integration with other CAD software.

The simulation in this system uses Transfer Function Method algorithm (TFM) for analysis.

The intelligent structure in the system consists of the problem detection and advise agents. The agents in the system use the blackboard model supported by a multi-knowladge statistical reasoning framework. The statistical reasoning supports modelling the uncertainty that is present within the reasoning. The control in the intelligent agent is based on a combination of a backward and forward reasoning and backtracking. Currently the problem detection agent is being revised to include an additional model that uses the neural network as its reasoning structure to support problem detection in incomplete designs. Both models are being connected to the multi-knowledge intelligent advisory structure.

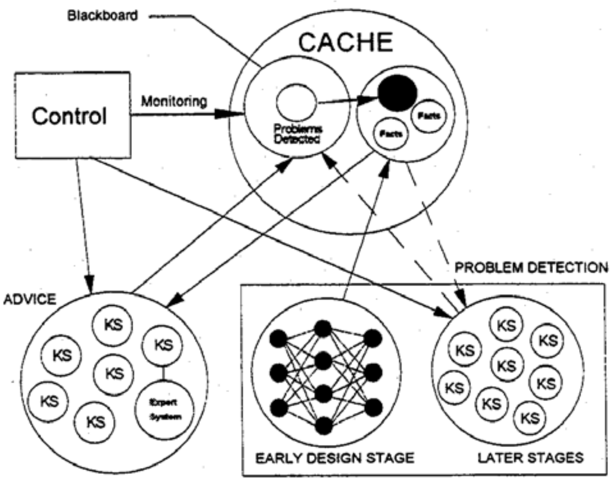

figure2: intelligent agent's structure

2.1. Control of Air Condition System

An energy saving control system of variable-air-volume air conditioner in intelligence building is formulated in this section. It reaches good control effect and energy efficiency by making the best of the advantages of intelligence building. During the cooling preparation period, neutral works is used. In the regulating period, the air volume is decided by means of feed forward control. The previous turning off period is determined in the way of penalty function.

In this paper, the predictive control of cooling preparation period of AC system in intelligence building by means of neutral network is expressed. BP network has the strong ability of adapting and self-studying. It suits to the control of those nonlinear or indefinite systems. The arithmetic could approach any nonlinear mapping relation and has strong deducing ability. So it suits to the cooling preparation predictive control. The preparation period Top is mainly determined by the outdoor temperature x I , initial indoor temperature x2, volume of rooms x3 and the power capability of the air conditioner x4.

$$T_{op} = f(x_1, x_2, x_3, x_4) \quad (1)$$

For a given building, as x3 and x4 are constant, so only x1 and x2 are considered. This object is a typical MIS0 nonlinear system. The precious mathematics model can scarcely be worked out in traditional way.

However, it can be solved by neutral BP algorithm. The Network is made up of 3 layers, the input layer, the hidden layer, and the output layer. The node number n1 of input layer is 2, and n3 of out layer is 1. n2 of the hidden layer is 7, which is determined by experience equation:

$$n_2 = \sqrt{n_1 + n_3 + a} \qquad a \in N(1,10) \quad (2)$$

As the BP algorithm has the shortcoming of slow convergence speed, so a variable studying step amendment is adopted:

$$\omega(k+1) = \omega(k) + \alpha(k) \cdot D(k) \quad (3)$$

$$\alpha(k) = 2^{\lambda} \cdot \alpha(k-1) \quad (4)$$

$$\lambda = \mathrm{sgn}[D(k)D(k-1)] \quad (5)$$

$$D(k) = -\partial E(k) / \partial \omega(k) \quad (6)$$

Where ω is the weight; α is the studying step; D is the minus grade of k time; E is the error, defined as the function of input and output sample x and d:

$$E = \frac{1}{2} \sum_{i=1}^{4} (d_i - x_i)^2 \quad (7)$$

The program is written in VC, and is trained by the data from a physical simulation system. The simulation system consists of a control subsystem, a given room and air conditioner. The studying data come from different conditions in this system, which meet the requirement of BP network. 70 sets of date are used to train the weight and valve of network. And 20 sets of date are used to detect it.

The result is proved to be good, shown in Fig.3 In practice, all the training date required can be got from the data sampling and storing system of intelligent building for the self-studying of BP network. And the predicted cooling preparation period can be figured out by it, and then air conditioner would turn on according to it.

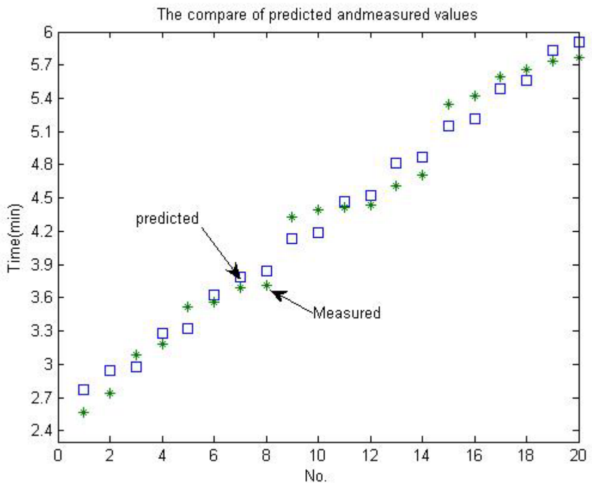

Figure3: The compare of predicted and Measured values

2.2. Feed-forward

Control in Regulating Period The main aim of AC control during regulating period is the temperature. The comfortable temperature scope is 18-28 degree, and the temperature in the buildings should be kept in it. The energy exhausted W by AC is approximately in proportion to the temperature deviation:

$$W = \int k(T_0 - T(t)).dt = (T_0 - T_{AV})\Delta t \quad (8)$$

Where To is the initial temperature, T(t) is inner temperature, TAv is the average temperature.

According to the statistics data, compared with 25 degree, if the inner average temperature is kept at 20 degree in summer, the electricity energy could be saved about 35%.

So, if the intelligence of the building is fully utilized, such as all kinds of sensors and controllers, the temperature can be regulated below the high limit, which can achieve ideal energy efficiency.

Feedback control can only reduce the error after it occurred. However, due to the time lag of the AC system and the delay of the control, the temperature would wave up and down like curve 11. So, an energy-saving method by means of feed forward control is presented, the main idea of which is to predetermine the lead time of control actions to reduce the overshoot and fluctuation of the controlled temperature.

Feed forward control is different from feedback control.

It makes decision according to the disturbance. When the disturbance occurs in a system, the forward control outputs the control value according to it and in the end to removing it.

If the arithmetic and the parameters are correct, the high control resolution and little fluctuation could be got easily, shown in Fig4. It can make an intelligent building "know" the trend of heat changing through the gate management system and energy statistic system, just like a man. In practical system, both feedback control and feed forward control is used to get good quality in the regulation of temperature in air conditioning system.

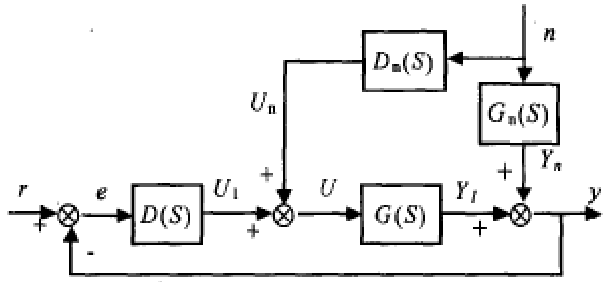

Fig4: Feed-forward Control

If disturbance N(S) could be measured, so the error Y,(S)caused by it would be eliminated by the feed-forward loop DII(S).

D,(s)G(s) + G,(s) = 0 (9)

So the feed-forward control unit should be:

If both forward and backward feedback control are used, the controller can eliminate the fluctuation caused by the measurable disturbance, and can reduce the interference immeasurable. Also the feedback can provide the function to detect the result of control. The forward and backward feedback controller can improve the control resolution greatly, and get the satisfactory control effect and energy efficiency. A digital simulation system by MATLAB is adopted to test the control of variable air volume condition system. As shown in Fig5, curve 2 has the accurate feed-forward function, where there is no error; curve 3's feed-forward function is not accurate to the disturbance, where there is little error; and curve 1 is the pure feedback function, where there is great error.

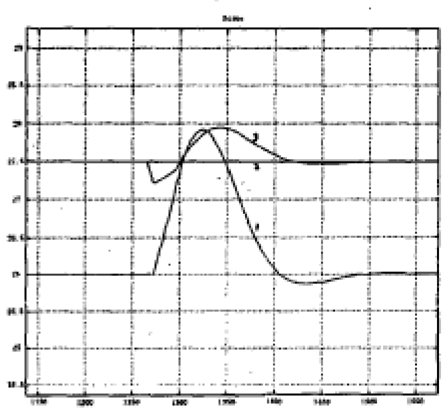

Fig.5 Simulation Results

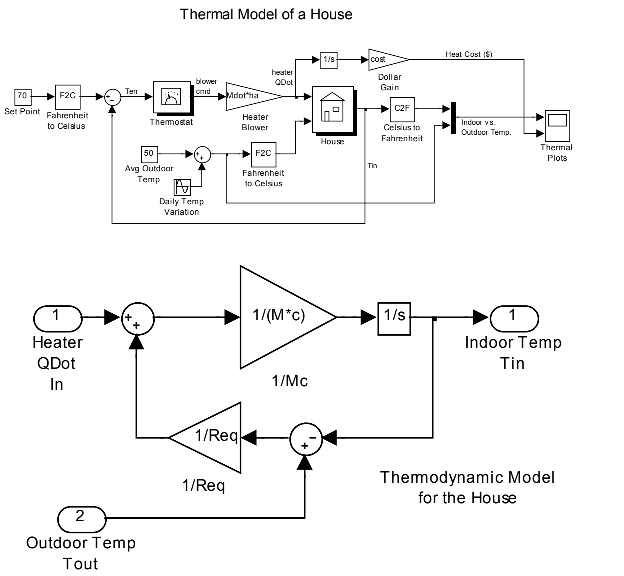

Figure6: thermal model of intelligent building for heat cost calculation.

Figure 6 is run in MATLAB software, SIMULINK environment. It can monitor the temperature of building by online mode.

3. Conclusion

Ultimately, the tools developed in this research will go beyond saving energy — they could also help building operators respond to electricity grid emergencies and to money-saving opportunities when energy costs are high. Thermal design contains many variables and constrains that must be taken into construction. These variables and constrains increase as the design evolves and make it more difficult to detect potential problems in the design.

In this paper we found a new method for thermal simulation and problem detection in the building and so have suggested a intelligent building for energy saving.

The prediction data has had a good fit with measured data's.

Finally, for network controlling we suggest a internet-based control systems to improve the energy efficiency of buildings (IBEC). IBECS is a practical networking system that takes advantage of a building's existing IT infrastructure to control off-the-shelf lighting components and other building equipment through the internet.

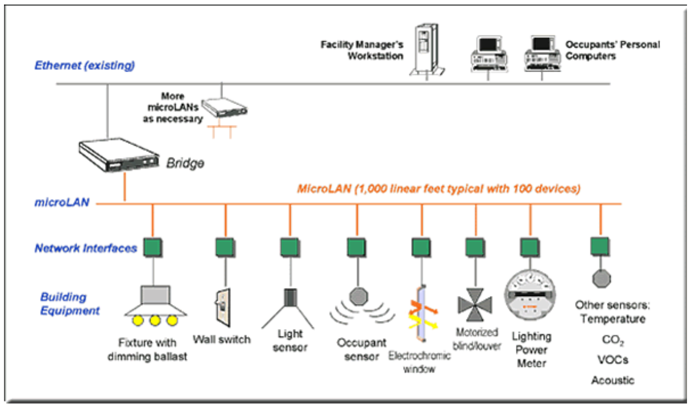

Figure7: IBECS is a practical networking system that takes advantage of a building's existing IT infrastructure to control off-the-shelf lighting components and other building equipment through the internet.

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