3.6 Improved Lighting Design

The 48 volt DC power available in the Smart House is advantageous for lighting, too. It is easily synthesized into any waveform for dimming control and for improved fluorescent lighting. Using a 400 Hz synthesized waveform to power fluorescent lights eliminates need for a separate ballast, increases efficiency, increases bulb life, and allows flicker-free light. And, of course, lighting fixtures benefit from the inherent personnel safety of 48 volt DC power.

3.7 Energy Management

The Smart House makes practical the use of time-of-day rate structures in the residential setting. So far time-of-day rate structures have not been widely used in the residential sector because of the complexity of metering and because homeowners do not understand how to reduce their costs in response to the rate structure. The Smart House can automatically defer discretionary appliance usage to low-rate periods. In general, the Smart House can greatly assist electric and gas meter reading by allowing remote meter reading and programmable meters.

3.8 Gas Distribution

Gas distribution in the Smart House operates on the same principles as electrical power distribution. As with electrical energy, gas is distributed from a supply controller. A gas appliance requests gas at a certain flow rate. The request is validated, gas is supplied, and the flow is cut off should the requested flow rate limits be exceeded or should incorrect operation be detected at the appliance.

4.0 CONCLUSION

The Smart House is a revolutionary approach to the problem of providing integrated, safer, more flexible power, and communication systems to residences.

"HVAC-DYNAMIC" - SIMULATOR AND EMULATOR SYSTEM

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KEYWORDS

Adaptive Controller, Dynamic Simulation, Emulator System, HVAC-Plant, Model Library, PID-Controller.

ABSTRACT

HVAC-DYNAMIC is a computer program designed for simulation of dynamic behaviour in HVAC plants. The program is based on a model library, which contains models for some standard components in HVAC systems. Available models today are: pipe, valve, shunt coupling, fan, duct, damper, heat coil, heat recovery wheel, temperature sensor, controller and actuator. The library is also containing a simplified model of the building itself and its outdoor climate. The program may be used for investigation of dynamic interactions between different components in the HVAC plant, or be utilized more as a tool for designing and testing of different control strategies and algorithms. Furthermore it is possible to connect real, external controllers to the computer through appropriate interface. In this emulation mode the program will simulate the HVAC system and respond to inputs from the external controller. Commercial controller can then be tested, compared and tuned in a matter of hours instead of spending several days doing the same job in the actual plant. This paper presents a brief review of the program system together with some test results.

"HVAC-DYNAMIQUE - SYSTÈME DE SIMULATION ET ÉMULATION

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Mots de clef.

Contrôleur Adaptateur, Simulation Dynamique, Système d'émulation, Plant-HVAC, Librairie modèle et Contrôleur-PID.

Abstrait.

HVAC-Dynamique est un programme d'ordinateur désigné pour la simulation du comportement dynamique dans les plants-HVAC. Le programmme est basé sur une librairie-modèle, qui contient des modèles pour quelques pièces standard dans les systèmes-HVAC. Des modèles èxistant aujourd'hui sont: tuyau, valve, couplement shunt, canal de ventilation, batterie de chaleur, roue pour èchangement de chaleur, élément de mesure pour température, controleur et actuateur. La librairie contient aussi un modèle simplifié de la construction lui-même, et son climat éxtérieur. Le programme peut ètre employé pour invèstigation d'intéraction dynamique entre differente pièces dans le plant-HVAC, ou peut plutot ètre employé comme instrument de travail pour désigner et tèster different contrôle stratégique et algorithmique. En plus il est possible de connecter de vrai contrôleur extèrne à l'ordinateur par une interférence appropriée. Dans ce mode d'émulation le programme simulera le système HVAC et répond aux ordres du contrôleur extèrne. Le contrôleur commerciale peut alors ètre tèsté, comparé et ajusté dans quelques heures, au lieu de dépenser plusieurs jours faisant le même travail dans le plant même. Cet article présente un bref apercu sur le système du programme et donne aussi quelques résultats.

1. INTRODUCTION

The last few years have shown a considerate growth in the development of advanced HVAC control systems. The most important reasons for this are more expensive energy and higher demands on indoor climate and air quality, together with general progress on computerized control.

A necessary condition for efficient development of new and better HVAC control systems is good knowledge of the dynamics in the plants. The best way to acquire such knowledge is through dynamic simulations. In order to increase the research efforts in this field and provide more useful informations to manufactorers, buyers and users of HVAC control equipment, The Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology (SINTEF) has developed a program for dynamic simulation of different HVAC systems.

HVAC-DYNAMIC is a simulation program based on a model library containing models for some standard components in HVAC processes. The program is capable of operating as an emulator system connected to a real, commercial controller.

2. SIMULATION PROGRAM

The development of the computer program HVAC-DYNAMIC has been going on for a long period of time. It all started with a dynamic room model for temperature control studies made by Børresen (1973), but the intensions that time did not include development of a dynamic simulation program. Further advancement on dynamic modelling and computer simulation of HVAC plants was made by Novakovic (1982). On this basis the joint activities of two SINTEF divisions, The HVAC group at The Division of Energy and Fluid Dynamics and The Division of Automatic Control, has brought about real progress in the program development during the last few years. Work in this field has been done by Børresen and Thunem (1984), Øgård (1985), Brustad (1985) and Novakovic et al. (1986).

The result today is the program system HVAC-DYNAMIC. It is fully operative and has been used in a SINTEF project for testing and comparing certain commercial HVAC controllers on the market. The development of HVAC DYNAMIC may now be considered finished, but further experience with the program system together with more research on HVAC plants will definitely cause improvements on certain aspects.

2.1. Program structure

The simulation program has a hierarchical modular structure. There are mainly three different modules:

1. An Administration Program :
   controls the simulation and takes care of the interactive communication with the user (input/output of data).

2. The Model Library :
   contains several independent models for single HVAC components.

3. The User Routine :
   the user himself has to write a subroutine where he builds up his own complete HVAC plant by picking out different models for single HVAC components from the model library and connecting them with each other, using outputs from one model as inputs to the next.

Before HVAC-DYNAMIC is ready for execution the user written routine has to be compiled and linked to the rest of the program code. The entire simulation program is written in FORTRAN 77.

In run modes before the simulation starts the administration program allows the user to :

- specify/change process parameters and initial values for the state variables,
- store/fetch process parameters and initial values on/from data files,
- choose simulation interval and timestep,
- specify storage of one or more state variables on a time series file during simulation.

After a successful run the stored results for the state variables may be presented graphically by using separate program facilities available on the computer.

2.2. Model library

The model library includes a number of subroutines containing state space models for some standard HVAC components. The present version of HVAC-DYNAMIC has models for pipe, valve, shunt coupling, fan, duct, damper, heat coil, heat recovery wheel, temperature sensor, controller and actuator. The model library is also containing a simplified model of the building its occupancy pattern and the outdoore climate. All parameters in the models are based on physical data for real components.

Most of the models in the library are linear and of first order. Some of them has to deal with time delay and nonlinear effects as hysteresis and saturation. The model of the building is linear and of second order.

The state equations in the models are locally solved by a transition matrix in each routine. Each of the discrete models is numeric stable, but in case of strong feedback couplings between the models numerical instability may occur. Instability problems can however be avoided by reducing the integration time step.

2.3. Emulator system

HVAC-DYNAMIC is able to operate as an emulator system. The system is then containing the earlier mentioned simulation program, computer-process interface and a real external controller unit. The computer process interface

contains digital-to-analog and analog-to-digital converters which are used to connect and synchronize the real controller and the simulated plant.

So far the emulator system has only been used to perform direct digital control of simulated plant by a real, commercial available controller. Emulation of supervisory control in sense of energy management such as optimal points of time for start/stop of the plant can also be carried out, but work concerning simulation of supervisory control has just started at the two SINTEF divisions.

3. EMULATOR TESTING OF DDC-CONTROLLERS

In this paper we present some results from SINTEF's emulator testing of two different types of digital HVAC controllers. One of the controllers used in the test was adaptive and the other one was a PID controller, but both are available on the commercial market today.

Evaluation of the controllers was done by means of certain test procedures specially developed for this occasion. Important factors in that consideration were control quality and energy consumption. The quality of the temperature control was evaluated on the basis of visual interpretation of obtained results together with calculated mean vales and variance for the measurements. In addition we considered the control action of the actuators in the plant because intense control activities are bound to wear out both actuators and control organs in the long run.

The controllers were tested on two different types of buildings and HVAC plants. Plant one is an office buidling with approximately 5000 m^2 floor area. Total rate of ventilation air for the building is 6.52 m^3/s, and the supply air is to be kept at a constant temperature. The control activity is performed by mixing dampers and a heating coil in sequence. Plant two is a hospital with approximately 6000 m^2 floor area and a ventilation rate of 36.1 m^3/s. The temperature of the supply air is here to be controlled by a heat recovery wheel in the sequence with the heating coil. The temperature control inside the buildings is taken care of by local heaters. Both plants do exist in real life, and the computer simulations are performed with great accuracy to those. All parameters in the simulation models are based on actual conditions in the real buildings and HVAC plants.

In order to get realistic disturbances on the temperature control systems in the plant both the outdoor climate and the occupancy pattern for the building are modeled in the simulation program. The modelling of the outdoor climate is based on variations in outdoor air temperature, cloud cover and solar radiation for some typical days in autumn, winter and spring. Simulated energy cosumption for the heating period of the year with different controllers installed may then be calculated from a few simulations.

Some results from SINTEF's emulator test of the two different digital HVAC controllers are shown in Figure 1. These results are obtained for the hospital building on a nice day with cloudless sky in spring/autumn. Diagram 1 shows the temperature of the supply air which is to be kept at 16^{0}C day and night. Diagram 2 shows the position of the valve actuator and the control valve itself. Diagram 3 shows the control signal and the resulting rotational speed of the heat recovery wheel. The disturbances in air temperature at noon are caused by changes in buildings occupancy together with nonlinear effects in the heat recovery wheel. The result of this particular simulation is clearly in favour of the adaptive controller since the PID controller has considerate stability problems. In other simulations the difference was not as obvious as here, but the tendency has however been clear enough.

Evaluation of the control quality obtained with the two tested controllers was made by comparing mean values and variances in the temperature measurements. Besides we considered the control quality visually and compared the energy consumption. The main conclusion is that the adaptive controller do perfor better control if we focus on control quality. The energy consumption however is almost the same for the two controllers. Another result that came out of our emulator test is that controller ability to compensate for hysteresis and saturation in the actuators is of great importance for the control quality.

4. CONCLUSIONS

Considering the great development on digital control systems for HVAC plants it is important to have some kind of test facilities for evaluation of new products.

HVAC-DYNAMIC seems to be one program system of this kind. It may be used both for simulation and emulation purposes and functions as a tool for improving control algorithms, configurating new and better control systems and testing already existing controllers.

5. ACKNOWLEDGEMENT

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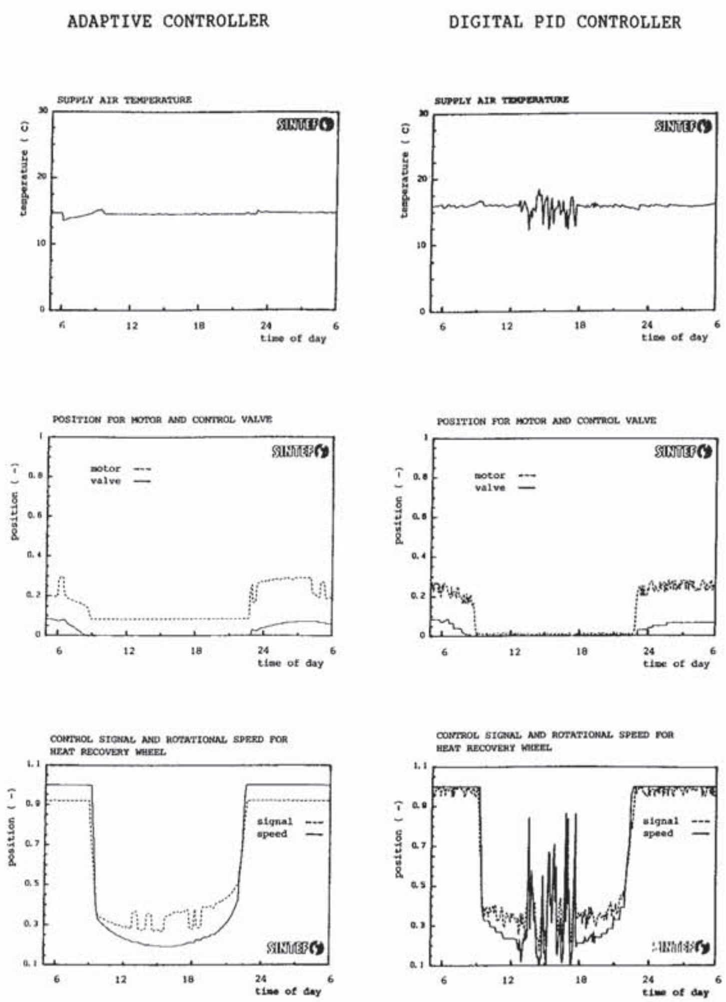

Figure 1 :
Results for emulator test of two different digital HVAC controllers

Information System for Housing Equipments Control

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KEYWORDS

Automatization, Equipments Control, Informations Transmission

ABSTRACT

The development of informatics and micro processor technics and the advent in the house of many automatisms (heat control, alarm systems, household appliances) lead the CSTB to study a solution for the control of all the equipmentsby a central device. Unlike industrial telemonitoring and remote control, such a system has to comply with some constraints like design, low cost, operational reliability, ease of using and especially to be more than the addition of all the existing appliances. The main stated problems for the realization of such a system are : it's required to dispose of a great number of sensors to have a good knowledge of the state of the equipments and of the functions to assume and the transmission of the informations to the central unit shall be done with a medium which can be incorporated to the house. Different solutions can be considered (data bus around the house, transmission by current carrier, infra red ...). Finally, the communication system with the user (command, display) is realized by a MINITEL which is a terminal placed at user's disposal by PTT (Posts and Telecommunications) for a telematics applications.