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Intelligent Air-conditioning Management System based on Fuzzy Control

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Abstract. A system combined with Local Operation Network Techniques for control and power management of air conditioning systems to enhance the integration of control information is proposed. Instead of using only one actuator in common control strategy for air conditioning control, we use now multiple actuators and variable speed operated pumps for the heat exchangers. The new system reduces electrical power consumption of the air conditioning pump. The control information exchange system provided by Local Operation Network ensures that only one of the actuators perform the control task within a specific scan time cycle, which is critical for robust fuzzy control.

Keywords: Local Operation Fuzzy Control, Power Management, temperature sensor

1. Introduction

Air-conditioning is a rapidly expanding technology throughout the world. It may be described as the control of the room conditions so that desired temperature, humidity, distribution and air movements are achieved. The growth of cheap energy sources are leading to an even more rapid expansion of air-conditioning particularly in developing countries (such as Vietnam, China). Typical application scenarios are homes, hospitals, public places, factories mines, shops and offices. Moreover, it is the fact that there are other numerous places that the human comfort is not the first consideration. These include textile and printing industries, computer labs, semi-conductor manufacturing, laboratories, photographic and pharmaceutical industries, manufacturing, storage of sensitive equipment, horticulture, animal husbandry, food storage, and many others.

The conventional control strategy in air-conditioning industry uses only one actuator for temperature control. Here in this research, we proposed an approach using two actuators for optimally control of a supply temperature of an air conditioning system. Our variable speed operated pumps for the heat exchangers decreases the the electrical power consumption of the pump during the control mode of the system. The control information exchange system provided by Local Operation Network Works ensures that only one of the actuators execute the control task within each scan time cycle. It is critical important for the robust control of the system. Figure1 is a typical work flow of the air-conditioning system; Figure 2 gives the system block diagram of an air-conditioning system we proposed in our work.

2. System Workflow

In the condition of the maximum energy demand, the air conditioning system should operate like a normal control system. The air conditioning pump has its maximum performance and the control valve has its "full width". In the reduced energy demand mode, the pump speed is first reduced to a relatively low level and also the dynamical behavior of the pump is very different from the dynamical behavior of the control valve. In the second stage of the performance, the control valve of the system takes over the control task

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until the process value is equal to the set point value. It needs to mention that the control valve should first start to close, when the real speed of the pump is at its smallest level. So it is obvious that a feedback of the pump and valve position are so very important for this kind of operation strategy. In our system, the valve and the control pump are now both the actuators in the supply loop. In order to achieve robust control behavior, we need to feed the controller with the information about which actuator is operating. The local operation network can help to gives the actual position of the actuators and provide the real-time feedback. One processor is assigned for each actuator to perform communications with other control units.

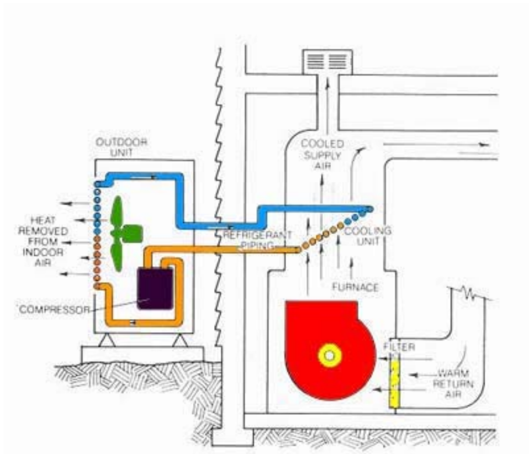

Fig 1. Work flow of a air-conditioning system

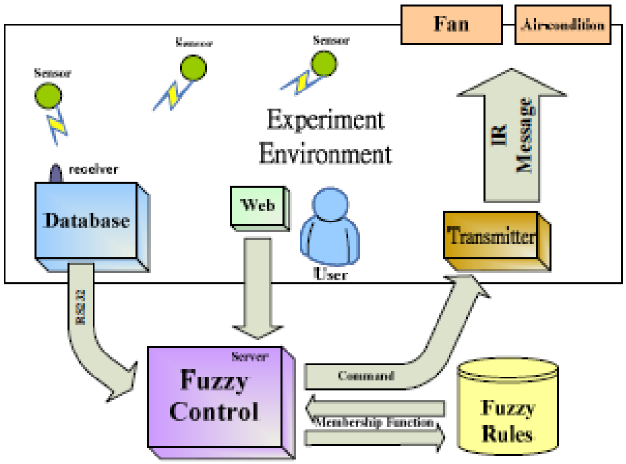

Fig.2: System structure in this project

3. The Contorl Loop Optimization

3.1. Operation Workflow

In our system, the requirements for optimal and robust performance include 1) the control pump should operate at speed as low as possible. 2) Each of the actuators has a separate fuzzy controller because of the characteristic of the system, and 3) the entire control loops should be categorized as a Fuzzy PID Control system.

The input variables will be used by both Fuzzy controllers for the control valve and for the pump. Each actuator will be controlled by its own controller as shown in Figure 3. In order to have a robust control loop, this task as illustrated below will ensure that only one of the actuators will be in operation during the variable energy demand. In the beginning of a new scan cycle the task will decide which Fuzzy controller should overtake the control task. After the initialization of the system, the pump control will be in the operation mode. For this case the control valve is fully open. As long as the controller output value for the pump is larger than the smallest pump speed, the system will switch at the next cycle to the Fuzzy Pump Block. When the pump calculated control output value is less than the smallest pump speed, the system starts additional evaluation of the real pump speed. When the pump's speed feedback from local operation network is also the smallest speed, the system switches the control task to the Fuzzy Block Valve and the system can reach its optimal operation.

3.2. The Control Tasks for the Valves and Pumps

If the set point error still exists, the valve control system closes the valve position by the operation of the pump at minimum speed. If the valve width is less than 5%, the pump will be turned off by the controller. If the sign of set point error changes, the valve width will increase by the valve control until it reaches its maximum value. The system will switch to the pump control with the minimum pumping speed and at the maximum width of the control valve. This workflow help to make sure that the pump will not be in the variable speed range until the valve position has reached its maximum width.

3.3. Implementing the System into the Network

Figure 4 shows the system and network integration for the pumps and valves. All the process variables have been provided as the Standard Network Variables. Based on this approach, the Networked Systems enables the user to have access to different automation systems from the network management system, if all automation systems use the local operation networks.

4. Design Of The System For Supply Temperatur Loop

4.1. Fuzzy-Control System for the Operating of the Control valve and Pump

As soon as the system switches to the “Fuzzy Block Pump” as shown in Figure 3, the FC-Pump calculates an output value for the pump speed and the same for the FC Valve for the control valve position by a PID-characteristic. The fuzzy PID controller contains the following three input variables as shown in Figure 4. The set point error (e) is defined as the difference between the set point ref. and the process value according to a maximum range of e(max) = 40K with seven sets. If the actual set point error (e) is on a larger scale, the set point error (e) will be determined by e = e(max) and the controller generates a maximum output.

The Fuzzy controller utilizes the following two outputs:

- The variation of the controller output PD,
- The change of the reference output.

The integral characteristic is implemented in the calculation of the reference point y0. The reference output is calculated by addition of u0 in cycle (k-1) and y0 in the k^{th} scan time according to equation (3.4). And y0 is once calculated per scan time cycle which corresponds to the scan time Tc and the integral acting time Tn. The addition of the Fuzzy-PD-output to the “reference output y0” gives the complete output of the controller of the system.

4.2. Variable Pump Control vs. Constant Pump Control

To testify the system’s dynamics behavior, we first did the experiment with a control valve and a pump with constant speed. To compare the control loop’s behavior, the method of control time (Tc) measurement and the value of the overshooting of the process value are chosen here. We can see that both control systems have similar control loop quality with a very short control time Tc and little overshooting. We can also see that the the pump of the control system can work under a lower speed for the negative noise step. .

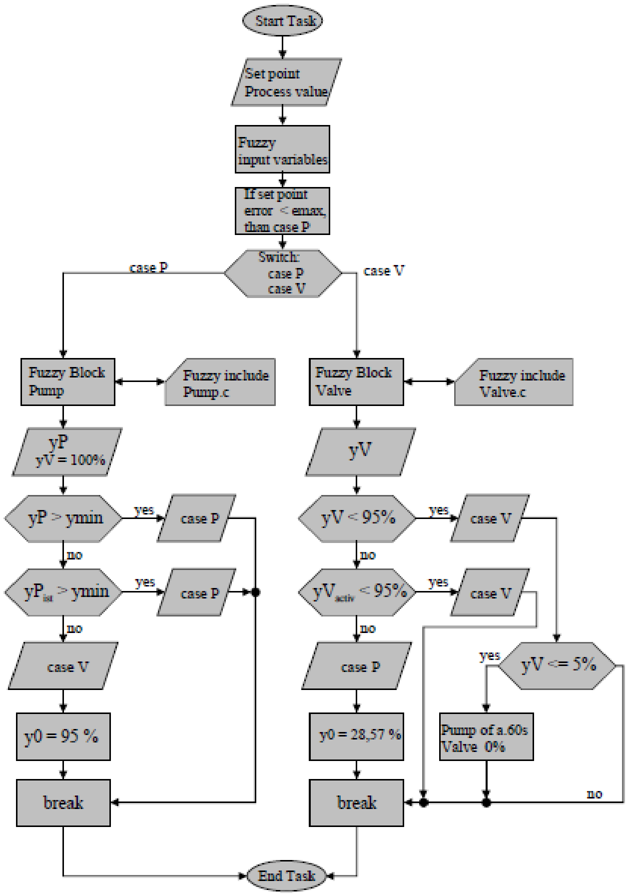

Fig. 3: Control Task for the Valve and the Pump

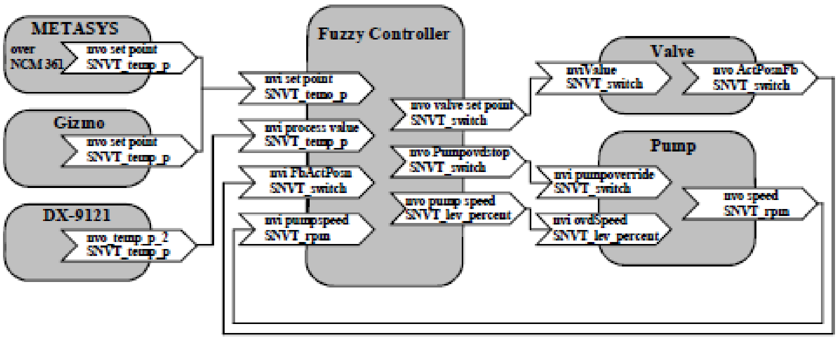

Fig. 4: Integration of the individual system into the network

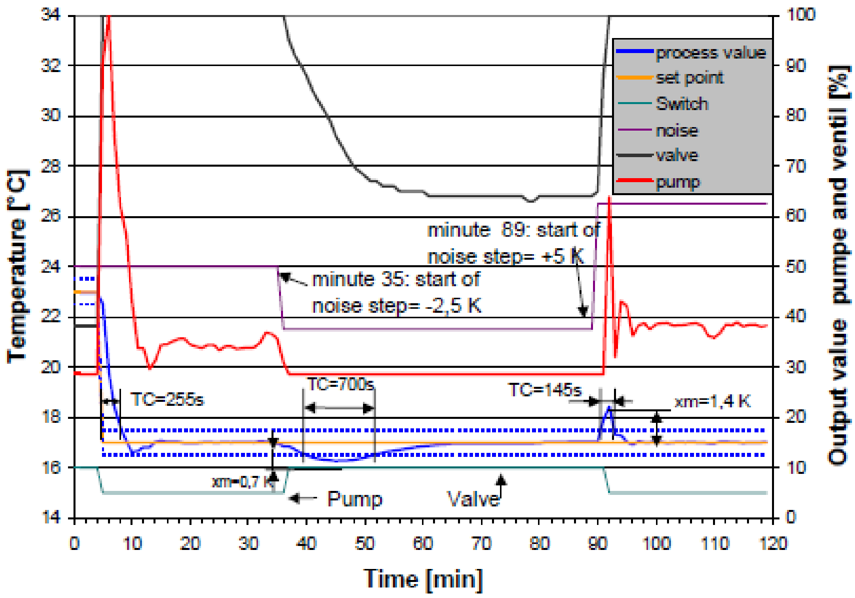

Fig. 5: Step response of the control Loop with two Actuators

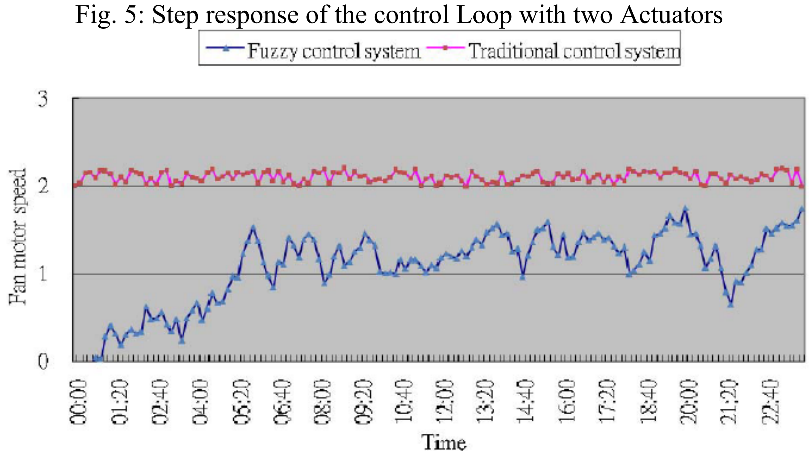

Fig. 6.The Fuzzy system performance with two actuators versus the traditional air-conditioning system

5. Case Study and Result Analysis

Figure 5 and Figure 6 give the results of a real case study. We can also see that the control range is limited between 95% flow capacity and 30% flow capacity. The maximum rate of saving of electrical power is 85%. From Figure 6, we can observer that the energy consumption various in different period of the experiment. However, it is obvious that the Fuzzy approach with two actuators can genuinely save more energy. It is worth mention that the energy saving potential depends on the energy demand of the system, which varies along the time. The case study verified the validness of the proposed two-actuator system and control strategy.

6. Conclution

We implemented an air-conditioning system with two actuator based on Fuzzy techniques. The system can reduce enormously in the energy consumption. The control task will be performed by the valve control only when the air pump is at its lowest speed range. In this case the electrical power consumption of the pump has its smallest value. Using the fuzzy control ensures best control result by considering a different dynamical behavior of the system. Since each actuator has its own processor and it helps to set up the value of the control valve. Thus, our system can be also regarded as an intelligent valve system.

The future research directions include the implementation of a large scale system for a specific building and bringing in new sensor and actuators for sensing and control.

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