An Intelligent Energy-Saving Bathing System Based on WSNs

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Abstract

To accelerate low-carbon economical development, an intelligent energy-saving bathing system for residential area based on sensor network is presented for the reason that sensor network has the advantage of low-power transmission. It is provided by a number of experiments that this bathing system has successfully achieved the energy-saving goal by rotational solar energy heater, reasonable temperature hint, fuzzy temperature control, waste heat recycling techniques and intelligent management of the entire system. The overall design of the energy-saving system, together with detailed architecture for electrical control and mechanical control are introduced in order to describe energy-saving principles of the bathing system. Finally, some test beds are presented to support the usefulness, practicability and advances of this system.

Keywords: Energy-Saving, Emission-Reduction, Intelligent Bathing System, Wireless Sensor Networks

1. Introduction

Based on low-carbon concepts advocated by the society, we have found the shortcomings of bathing systems after conducting through research. Firstly, users often set unreasonable temperature for lacking of pre-heating temperature range hint, resulting in a great deal of energy waste. Secondly, a large amount of heating energy of these gases produced automatically is losing to the air during the shower process. The heat energy contained in waste water is also losing in the process of flowing into the sewer. Thirdly, the ordinary solar heater has a very low solar energy utilization ratio. What's more, there is no unified management of water and heat resources in the entire residential area. Therefore, an intelligent bathing system Based on WSNs is presented to make up for the disadvantages mentioned above. We have adopted advanced rotational solar energy heater, reasonable temperature hints, waste gases condensation and waste heat recycling in energy-saving management.

2. Structure of the system

This system consists of terminal server equipment, ZigBee cluster nodes, the existing residential LAN(local area network), exhausting fan and exhausting gas recycle pipeline, terminal efficiency condensation machine, GSM module and metal superconducting pipes. The whole structure of the system is shown in Fig. 1.

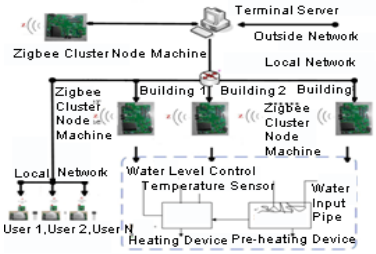

Fig.1. Structure of bathing system.

Considering the actual situation of residential regions and lower power dissipation of the overall control system, the existing LAN is used as a main communication channel and ZigBee cluster nodes[1] is fixed at users' location so that all users can be connected to the whole system control network. The environmental indexes[2] collected from temperature sensors can be analyzed according to the general relationship between heat losing speed under different environments and appropriate temperature of human body. Then the reasonable temperature hint can be sent to all users as text messages automatically via GSM module. Furthermore, users can control the PID (Proportional-Integral- Derivative) temperature heater through text messages to heat up automatically. Rotational solar energy heater is used to provide energy in heating process. Exhausting fan controlled by temperature sensor works automatically to separate poisonous gas from water vapor on the condition of the level water vapor stored reach to a specific level in the environment. The buzzer of the control system[3] rings when there is enough water in the heater. Waste water is collected through metal superconducting pipe and at the same time the heating energy contained is recycled to heat cold water in the input pipe. What's more, all the information collected by WSN will be managed uniformly by the terminal servers so that the human resources can be optimized.

3. Machinery control part

Mechanical control system is mainly used for level control of the fan exhausting waste collection and waste heat recovery section. Firstly, the machinery control part makes the exhausting fan work automatically when the heating begins to provide power to the water with the help of temperature transmitters. Meanwhile, the water vapor collected is analyzed initially. After this process, the poisonous gases are separated from the pure gases, whose wasted heat can be recycled by condensation technique. This part is composed of the exhausting gas collecting pipe and the condensing heat exchanger and other hardware.

Secondly, water level indicator can automatically control the level of input water with the help of a water level control device, rectifier, voltage regulator diode, electrode and musical integrated circuits. Besides, the rapid unidirectional heat transfer properties of metal superconducting are made the most of in collecting the waste water into the input pipe of the heater. This part consists of metal superconducting pipes, waste heat utilization device and other hardware. What’s more, the wasted water collected can be recycled for reusing after its temperature going down.

4. Electrical control part

The computer terminal server is linked with all users’ WSN. In terms of general control of the entire system, the LAN in the regions is regarded as a main communication channel, which minimizes the cost of the intelligent system and saves the material lost without redesigning a network channel. When it comes to the electrical control within every user's terminal, the environmental variables such as temperature and human activity can be collected by Zigbee cluster node and transmitted to terminal service device through WSN. After detailed data analysis, a variety of proper temperature range can be provided to the users and the bathing system can adjust its working situation.

4.1. Rotational solar energy heater

We adopt rotational solar energy heater and electricity to power the system. The

information collected by photo resistance is transmitted to the Single Chip Microcomputer and it is converted to digital signal by the A/D converter. Then the digital signal is analyzed by Single Chip Microcomputer. The solar energy battery can rotate with change of sunlight based on the adjustment of PWM (Pulse-width modulation) single received, which achieves the goal of absorbing the maximum amount of solar energy compared with those static solar energy batteries. In addition, based on the storing and releasing electrical energy theory, the battery charged by the solar energy can power the entire system so that it is helpful to make full use of the solar energy.

4.2. Reasonable temperature hint

Reasonable temperature hint is appropriate temperature information at which users are suggested setting before heating cold water, since the improper heating temperature results in energy waste.

The objects radiate emitted energy because of the thermal motion of microscopic particles inside the objects and temperature difference. Once there is a temperature difference among objects, energy exchange happens in the way of thermal radiation. Then the objects with higher temperature lose heat and the lower ones gain energy. This is what we called radiation transfer thermal. Generally speaking, we can calculate heat transfer according to the radiation transfer thermal equation below[4]:

$$hr = 2.3\times10^{-11}\times\varepsilon\left(\Delta T/2+237\right)^{3}\left(W/cm^{3}\square^{\circ}C\right) \quad (1)$$

Where ε is the surface emissive which changes according to surface conditions of the water heater and the wall material. In common case, we selected ε of the shower products to be 0.05-0.1.

According to actual analysis, heat flow phenomenon is inevitable in bathing system. Heat loss caused by the phenomenon of heat flow can be calculated by the following formula:

$$hc = 4.3\times10^{-4}\times\varepsilon\left(\Delta T/H\right)^{1.4}\left(W/cm^{2}\square^{\circ}C\right) \quad (2)$$

Where H is the vertical height of the heater.

After adopting radiation transfer thermal to the bathing system, we can get the following equation with the help of model creating conclusion and actual situation analysis.

$$T_w = T_h - (\delta_1\times q_1/\lambda_1) \quad (3)$$

$$q_1 = \left(T_w - T_f\right)\times\left(\varepsilon s\times5.67\times\left(\frac{T_w}{100}\right)^{4} - \frac{\left(\frac{T_f}{100}\right)^{4}}{\sqrt[4]{\left(T_w - T_f\right)+k\left(T_w - T_f\right)}}\right) \quad (4)$$

Where ε_s is the coefficient of the wall of the heater, it is usually 0.8. Besides, k is the direction coefficient of the outer wall of heater, it is defined as 2.56. The upper surface is 3.26 and the bottom one is 1.63. T_w represents the current temperature of the water, T_k is expecting temperature of the waste heat,δ_1 equals the size of the material of the heater, q_1 is the outer heat flux density, λ_1 represents the thermal conductivity of wall material and T_f is the ambient temperature[5].

Combined equations (3) with (4) , we use terminal service machine to analyze and calculate a series of data collected and provide a reasonable temperature range to all users.

Since reasonable temperature hint can be got from the calculation above, users can get the information from GSM model. The entire service machine transmits its reasonable hint to users through GSM so that a text message containing the temperature information can be received soon.

4.3. Unified management of the residential region

The main control of the entire system is via the use of a set of management software that is properly adopted in the neighborhood region, which works as the control center of the intelligent system. Based on the existing LAN used as a main communication channel and ZigBee

cluster node fixed at users' location, the entire system is connected to ZigBee WSN. The lower power dissipation of ZigBee has guaranteed the energy-saving and emission reduction features of the system. The administrator can query the amount of water, electricity and heat resources by his mobile phone. In addition, the system gives out a necessary warning and control after comparing with the information set in the database beforehand. What's more, reasonable temperature parameters can be set automatically to control the heat resources. Therefore, the amount of the water and energy can be controlled by the software in the service center of the entire region.

5. Fuzzy temperature control

Fuzzy control has become the most intelligent control technique for the advantage of effectiveness and validity. PID control technology is adopted in fuzzy temperature control of electric water heaters system[6]. After the users get the reasonable temperature hint, they can set a heating temperature in form of a text message so that the heater will work automatically. PID control technology concentrates on the adjustment of improper heating power. Based on fuzzy control theory, the problem to be solved has been divided according to a common problem-saving approach, which makes the control domain more complicated.

5.1. Design of control scheme

The electrical water heater is regarded as the controlling object of the system. It adjusts the water temperature by changing the voltage of the resistance. The control from the control signal *u(t)* to the water temperature *c(t)*[7] can be viewed as the generalized controlling object. When the control signal *u(t)* equals to 4V, the highest water temperature can reach to 100 OC. Since the controlled object has inertia characteristics, it's appropriate to adopt PID controlling into the system. Therefore, the control scheme of the controlled object has been designed to control the water heater combining the fuzzy control regulation with PID control. Based on the theory mentioned above, the simulation structure of the fuzzy control system has been designed in Fig. 2.

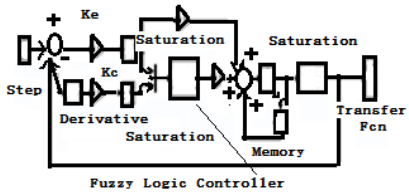

Fig. 2. Structure of the fuzzy system

5.2. Settings of Variables and Membership Function

Let temperature deviation[8] and temperature deviation changing rate *ec* be the amount of input of fuzzy control and *u* be the amount of output control for the amount. Let *T* be the current temperature of the water heater and T_s be the set temperature. Therefore, the temperature deviation *e* equals to the difference between *T* and T_s.

Table 1. Settings of fuzzy control system

fuzzy variable subset in the domain region	fuzzy variable subset parameter of inflection point
NL(negative large)	[-6 -6 -4]
NM(negative middle)	[-6 -4 -2]
NS(negative small)	[-4 -2 0]
ZO(zero)	[-2 0 2]
PS(positive small)	[0 2 4]
PM(positive middle)	[2 4 6]
PL(positive large)	[4 6 6]

We set the fuzzy domain of the variable *e*, *ec* and u [-6, 6], that is the amplitude of the input signal ranging from +6 to -6V, then the control signal *u(t)* ranging form 0V to 5V. The membership functions of

linguistic values are the triangular function. The other names of fuzzy variable subset[9], the membership function type and the parameters of an inflection point are shown in Tab. 1.

5.3. Simulation results

When the input temperature is 80 ^{O}C, the simulation curve of the response of fuzzy temperature control system is shown in Fig. 3. It's obvious to figure out that the responding output of the system can reach a stable situation within the permitted time, which proves that the fuzzy temperature control system has an effective control.

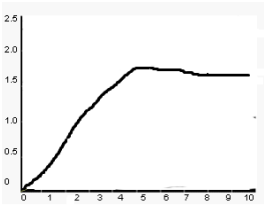

Fig. 3. experimental simulation curve

6. Conclusions

The intelligent bathing system has successfully achieved the goal of energy-saving to a certain degree. In reality, the number of bathing system is increasing year by year. Therefore, it's promising in adopting the energy saving system in bathing market, which will be a significant measure in energy saving and emission reduction. In short, the intelligent bathing system meets the need of energy saving and emission reduction in modern society.

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