Peltier based Novel Heat Pump for Flow Cell in Automated Analyzer using PWM Techniques

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Abstract: ***Temperature control is an important parameter in analyzing the blood samples in bio-chemistry analyzers. Besides temperature control at certain accuracy in analyzer, it is more important to achieve the set point temperature (SPT) in a very short interval of time, normally within 5-6 seconds. This fast thermal response is achieved by using peltier element. Peltier element works on the principal of Peltier Effect. In the presented work, a PID based heat pump is designed in order to achieve the required set point temperature at the possible fastest rate. The proposed system works using two power transistors in tandem with combination of N-P-N and P-N-P power transistors that source and sink the current through the peltier device attached with the system body.***

Keywords: Peltier element, PID → Proportional Integral Differential, SPT→Set point temperature

1. Introduction

Temperature is a physical property of matter that quantitatively expresses the common notions of hot and cold. Temperature effects the concentration of the liquid sample such as human blood, glucose. With increasing the storage temperature the concentration of blood sample, Glucose and phosphorus clinically changed. Bio-chemistry analyzer is a pathological instrument intended for bio-chemistry tests of blood sample. Besides temperature control at certain accuracy in analyzer, it is more important to achieve the set point temperature (SPT) in a very short interval of time. This fast thermal response is achieved by using peltier element. Peltier element works on the principal of Peltier effect. When an electric current flows through a circuit composed of two different conductors, heat will be liberated at one junction and absorbed at the other; depending on the direction in which the current is flowing (Peltier effect). The quantity of heat Q liberated per unit time is proportional to the current I. $Q/T = \pi$, Where π is the Peltier coefficient and T the absolute temperature. A proportional-integral-derivative algorithm is proposed for controlling the temperature. Set Point Temperature is achieved by using the PWM output of micro-controller followed by low pass filter. $Q/T = \pi$, Where π is the Peltier coefficient and T the absolute temperature. The Peltier effect is inverse of the see beck effect.

2. Related works

The heat energy loss of methane liquid is the most important reason for low temperature of methane biochemical reaction in cold area by energy-flow analysis. The heat energy recovery of methane liquid can build a self-energizing system. Vegetable greenhouses and birdhouse or livestock barn in cold area need heating in winter, in order to supply the most heat energy, invented the methane-
Electricity-heat pump system model introduced and evaluated the running characteristic and effect. [1]

This system uses 8bit AT89C51 CPU as a core for building an electronic oven temperature control system with High precision, the temperature was changed to voltage signals by the thermal resistor PT1000 and amplified by LM358, then the analogue voltage signal is converted to digital data by the AD0809. The PID algorithm was adopted as the software for power and temperature control of the furnace, the control accuracy is up to 0.2ºC. At the same time, with a temperature Display and can upload the data to PC for the data curve being printed. The experiment shows that it's very useful in the practical system of agriculture and industry or household. [2]

Peltier device is considered as a suitable instrument to produce heat transfer, and many methods which present thermal sensation have been proposed in the field of hap tics. The bandwidth of thermal control may help a performance

Investigation of presenting thermal sensation. However, conventional research mainly conducts discrimination experiments of materials, and focuses relatively little on the characteristic analysis of the thermal system. In addition, when the device is driven, nonlinear terms of the device characteristic such as Joule heat is generated, and those make the bandwidth analysis difficult. On the other hand, the author has proposed observer-based temperature and heat inflow control system in the past, in which the nonlinear terms are compensated. This research uses the control systems and measures those frequency responses. The responses are compared with theoretical transfer functions which are derived by block diagrams of control systems. Experimental results show some correspondence with theoretical models, which are expected to be used for analysis of presenting thermal sensation in the future. [3]

In this paper, an operator based robust fault tolerant method for fault signal to the output part of an Aluminium plate thermal process with nonlinear Peltier device in the presence of input constraints is proposed by using robust right co prime factorization approach. In details, after describing a mathematical model of the thermal process, an operator based robust fault tolerant control system is designed for this process with input constraints; the fault signal to the output part is analyzed using two sorts of operators. The effectiveness of the proposed design scheme is confirmed by simulation and experimental results on temperature control for the aluminium plate with nonlinear Peltier device. [4]

PID controller is widely used for main steam temperature control of boiler unit in thermal power plant. To avoid the drawback of current PID design methods, this paper presents a new design method for multi-objective PID controller to synthetically consider system requirement in speediness, reliability and robustness. NSGA- algorithm with the elite strategy is applied to the parameter optimization design. The simulation results on an actual main steam temperature control system indicate that, the multi-objective PID controller designed by presented method, can improve the dynamic performance of main steam temperature control system, with good robustness and anti-interference ability. **[5]**

A novel free-flow isoelectric focusing (IEF) implementation method has been developed, called IEF, as part of a larger effort to design micro fluidic sample preconditioning techniques. The IEF method consists of a novel device in which the electrodes are in intimate contact with the bulk fluid and pH gradient formation is driven by the products of electrolysis generated at the electrodes. The IEF flow cell is fabricated using rapid prototyping techniques. IEF has been used successfully to 'concentrate vegetative bacteria and proteins. The thickness and position of the focused hand can be adjusted by varying the buffer composition and the initial PN [6]

In this paper, we consider automatic temperature control system which is the most important part in blast furnace operation. In general, automatic temperature control for blast furnace is very difficult and sensitive because it is affected by a number of factors. So firstly, this paper describes temperature control model for blast furnace by using Takagi-Sugeno (TS) fuzzy model based on input-output data. Secondly, this paper describes automatic temperature control techniques based on model predictive control (MPC) techniques that are widely used in industrial process control practice. We propose the framework to build numerical model describing blast furnace based on TS-fuzzy inference system and to control automatic temperature control system using MPC. [7]

3. System Description

The presented work comprises of the followings:

- Designing of Heat Pump Circuit to drive the Peltier Device.
- Designing and Tuning of the PID algorithm
- PWM output using microcontroller AT89C51RD2 for setting the temperature set point.

The basic block diagram of the proposed system is shown in the figure1. A Pulse Width Modulation (PWM) module in addition with a low pass filter circuit (combination of R and C components) can produce different analogue voltages. In the proposed work, this analogue voltage is used to give set point temperature voltage. A PWM of frequency 1 KHz is generated using a microcontroller Input/output port pin. A low pass filter circuit of frequency F_{LP} = 5 KHz, using R = 1K and C = 1µF, gives a good quality set point temperature voltage. The set point temperature voltage so obtained as above compared with the current temperature (CT) and an error signal is generated in comparator. This is achieved by using an operational amplifier circuit. Temperature at flow cell is measured using LM-35 temperature sensor. It gives 10 mv per degree centigrade change of temperature. The output of the sensor is given to 12 bits ADC (ICL-7109) for displaying on LCD. The analogue output of LM-35 is also given to Operational Amplifier to compare the same with SPT. The error signal is generated thereafter and sends to PID algorithm to take up the necessary action.

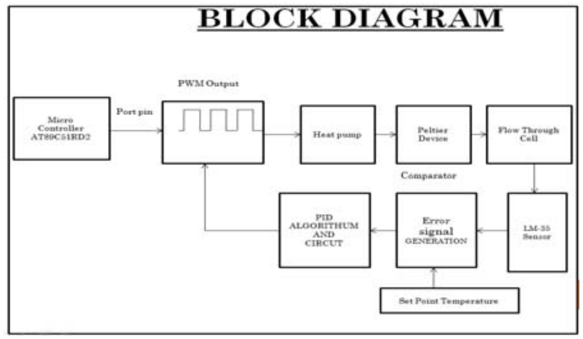

Figure 1: Block diagram of the system

4. Error Correction: PID Control

A proportional–integral–derivative controller also known as a PID controller is a basic control loop response mechanism that is extensively used in industrial control systems. A PID controller is used for calculating "error" values as the difference between a measured process variable and a desired set point. By adjusting the process control inputs, the controller attempts to reduce the error. Parameters of a PID controller used in the calculations must be tuned according to the nature of the system.

Three separate parameters are involved with PID controller calculations which are; the proportional, integral and derivative values. Proportional values determine the reaction to the current error, while integral values determine the reaction based on the sum of recent errors, and derivative values determine the reaction based on the rate at which the error has been changing. The following definitions may be needed:

1) Cycle time - Also known as duty cycle; the total length of time for the controller to complete one on/off cycle. Example: with a 20 second cycle time, an on time of 10 seconds and an off time of 10 seconds represent a 50 percent power output. The controller will cycle on and off while within the proportional band.
2) Proportional band - A temperature band expressed in % of full scale or degrees within which the controller's proportioning action takes place. The wider the proportional band, the greater the area around the set point in which the proportional action takes place. This is sometimes referred to as gain, which is the reciprocal of proportional band.
3) Integral, also known as reset, is a function which adjusts the proportional bandwidth with respect to the set point to compensate for offset (droop) from set point; that is, it adjusts the controlled temperature to set point after the system stabilizes.

4) Derivative, also known as rate, senses the rate of rise or fall of system temperature and automatically adjusts the proportional band to minimize overshoot or undershoot.

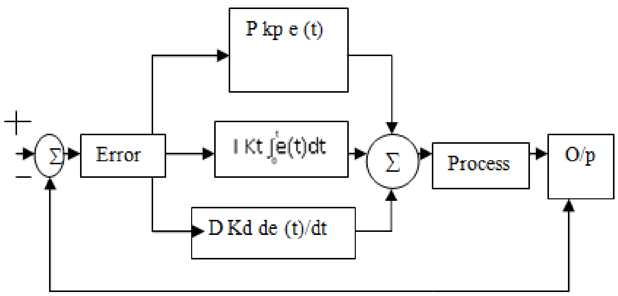

Figure 2: A block diagram of a PID controller

A basic explanation of a control loop is the simple act of adjusting hot and cold faucet valves to preserve the faucet water at the preferred temperature. Usually by mixing of the two streams, the hot and cold water, the desired temperature can be obtained. When the person touches the water to measure its temperature the sense of feel tells them if the stream of water has met the desired temperature. From this point the person will either adjust the hot and cold water valves until the preferred temperature is met and stabilized or do nothing because the desired temperature has already been met. Sensing the water temperature is equivalent to taking a measurement of the process value or process variable (PV). The desired set point (SP) is the temperature in which the person is trying to obtain. Additionally, the water valve position which can be called the input to the process is known as the manipulated variable (MV), which basically means that one can change the values of this variable. Moreover, in this example the difference between the desired set point and the temperature measurement is known to be the error (e). The error will quantify if the water is too hot or cold and by how much.

After measuring the process variable (PV) or in this case the temperature, then calculating the error, the controller determines when to change the manipulated variable (MV) or tap position and by how much. Once the controller turns on the water, they might turn the hot valve slightly if warm water is preferred, or they may turn it all the way. This is an example of the proportional control. To speed up the process so that the water becomes hot faster, the controller may open the valve more and more as the time elapse, this is a simple example of an integral control. By using both the proportional and integral control methods, the water temperature has the potential to oscillate between hot and cold. This is due to the fact that the controller is over-compensating and overshooting the desired set point at a rapid rate. If the controller wanted to achieve the desired temperature on a more gradual convergence, the controller can damp the anticipated future oscillations. In other words the controller may elect to temper their adjustments this can be referred as a derivative control method.

5. Heat Pump

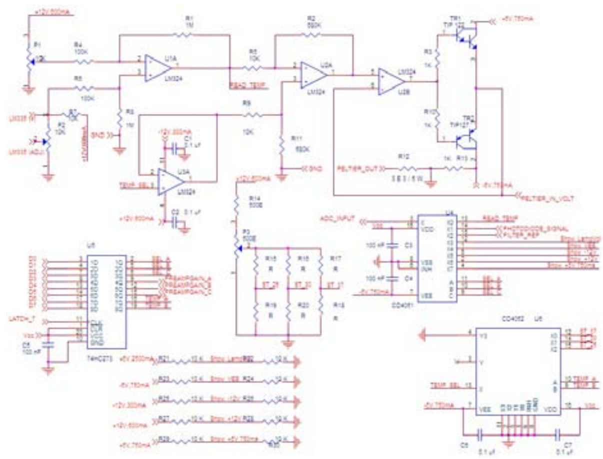

Figure 3. The schematic diagram of proposed heat pump

Say, the set point temperature is Ts, and current temperature is Tc, then the error is given by: Erro, e = Tc ~ Ts

Depending upon the error either positive or negative, the power transistors TIP-122 and TIP-127 are triggered by giving their respective base voltages. It is to note here that at one only one transistor is on and other is off.

6. Pulse width modulation

A Pulse Width Modulation (PWM) module in addition with a low pass filter circuit (combination of R and C components) can produce different analogue voltages. In the proposed work, this analogue voltage is used to give set point temperature voltage. A PWM of frequency, FPWM = 1 KHz is generated using a microcontroller C Input/output port pin. A low pass filter circuit of frequency FLP = 5 KHz, using R = 1K and C = 1µF, gives a good quality set point temperature voltage. The SPT voltage so obtained as above is compared with the current temperature (CT) and an error signal is generated. This is achieved by using an Operational amplifier.

7. Results and Conclusion

The proposed heat pump in combination with peltier device and PWM technique has shown a fine control of temperature within ± .5^{0}C at the flow cell in automated analyzer. Also, more importantly, the time taken from 25 to 37^{0}C or from 37 to 25^{0}C found to be within 10 seconds which is quite appreciable and fulfil the requirement of the process. The accuracy of control can be further refined if the process demands by simply adjusting the algorithm parameters. And the time can be further optimized by increasing the current capacity at the power source and adjusting the load resistances.

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