International Journal of Research and Development in Applied Science and Engineering (IJRDASE)
ISSN: 2454-6844

Smart Temperature Control Mechanisms for Industrial Units- A Review

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Abstract: Heat exchanger device is extensively utilized in chemical manner industries, which include petroleum refining and petrochemical processing; within the meals industry due to the fact it could preserve huge range of temperature and pressure. The principal goal of the warmth exchanger device is to govern the temperature of outgoing fluid to a preferred set factor regardless of various disturbances like deviation in input fluid go with the flow and deviation in input fluid temperature. The major cause of a heat exchanger machine is to transfer heat energy from a warm fluid material to a cooler fluid fabric, so temperature control of outlet fluid is of top importance. Due to inherent negative aspects of traditional manipulate strategies so version primarily based manipulate approach is hired and an internal model based PID controller is developed to govern the temperature of outlet fluid of the heat exchanger machine.

Keyword: FLC, Gas Plant, PID, PSO

1. Introduction:

The temperature monitoring and control is becoming more and more important in a lot of industries, like food industry, the laboratory, pharmaceutical industry or even in environmental monitoring, temperature control is vital. Many people still underestimate the importance of having an adequate temperature monitor in place, but failing to have one could mean that the company is breaking the law.

According to food safety law, all food products have to be kept at designated temperatures if they are going to be safe to eat. Having them too cold renders them inedible and too warm and it could encourage bacteria growth, so keeping a close eye on temperatures is vital. This applies to the storage areas, such as the fridges or freezers, but it also applies to the preparation and cooking areas and even on the shop floor itself, so it's essential to have a temperature monitor at every step of the way.

The temperature monitoring is also important in the laboratory and pharmaceutical industry. A lot of storage and testing environments, including fridges and freezers and even the lab, need to be kept at set temperatures if the work is going to be carried out effectively. Let's not forget the importance of keeping certain medications at the right temperature as well, so it's essential to have adequate temperature control in place at all times.

2. Related Work:

Zhiqiang Gao, Thomas A. Trautzsch, and James G. Dawson published a paper titled, "A Stable Self-Tuning Fuzzy Logic Control System for Industrial Temperature Regulation" in IEEE Transactions on Industry Applications, Vol. 38, No. 2, March April 2002. A control system incorporating fuzzy logic has been developed for a class of industrial temperature control problems. The FLC structure with an efficient realization had a small rule base that could be easily implemented in existing industrial controllers. It was tested on two different temperature processes. The PID response had more oscillation and overshoot as compared to the FLC response which was much smoother.

Nordin Saad, Mohd Syahrul Ridhwan Zailani presented the implementation of industrial PC control of a process in a pilot plant in their paper entitled "Industrial PC Control Implementation on PID controllers: Application to Pressure Control System" at International Conference on Intelligent and Advanced Systems. The evaluation of different tuning methods like Ziegler-Nichols, Tyreus-Luyben and Ziegler-Nichols closed-loop Bode plot, and the comparisons oftheir responses were done.

Mohammad Adnan Baloch, Nordin Saad I.Ismail, Taj.M.Baloch proposed a fuzzy controller for temperature control of a gas pilot plant in the paper "Design And Analysis of Pi-Fuzzy Controller For Temperature Control System". The overall model was built in MATLAB/Simulink- technical computing software that has adjustable structures where variables for the model and control strategies could be modified. The PID controller response using Ziegler Nichols open loop, Ziegler Nichols closed loop and Cohen Coon method are presented and evaluated against the response of 3, 5, 7 and 9 membership functions of the PI-fuzzy Controller. The peak overshoot reduced slightly but due to a number of rules the settling time increased for the FLC.

Nithya Venkatesan, N.Sivakumaran and P.Sivashanmuguham in their paper "Experimental Study

International Journal of Research and Development in Applied Science and Engineering (IJRDASE)
ISSN: 2454-6844

of Temperature Control using Soft Computing", investigated the control of an industry based shell and tube heat exchanger. The Fuzzy Logic based Controller (FLC) has been implemented in a MATLAB environment. The performance of the controller has been investigated for multiple changes in set points and load changes. The fuzzy logic based controller has higher speed of response and the steady state error for the fuzzy logic control has a small average value than that of the PI control. There is less oscillatory behaviour with the fuzzy logic controller, which allows a system to reach steady-state operating conditions faster.

N.NithyaRani, Dr.S.M.Giriraj Kumar, Dr.N.Anantharaman implemented an evolutionary algorithm genetic algorithm as an optimization technique in their paper "Modelling and Control of Temperature Process Using Genetic Algorithm". It was used to tune the PI controller and then the response of the system was compared to IMC (Internal Model Control). The simulation responses for the process models validated reflect the effectiveness of the GA based controller in terms of time domain specifications. The performance index under the various error criterions for the proposed controller is always less than the PID Zeigler Nichols and IMC tuned controller. The simulated responses confirm the validity of the proposed GA based tuning for the temperature process. The closed-loop responses for Ziegler-Nichols based PID tuning for an ideal PID controller has offset and the responses are quite oscillatory.

Ebrahim Najimi and Mohammad Hossein Ramezani designed a robust controller in their paper, "Robust control of speed and temperature in a power plant gas turbine". Simulation results of applying the designed robust controller on the nonlinear model of the system indicated that the controller could maintain turbine speed and exhaust gas temperature within the desired interval, under nonlinear uncertainties and load demand disturbances. This robust controller, as implies from its nature, had decreased maximum amplitude of the speed deviation considerably comparing to MPC and PID controllers.

Kim Dong Hwa in the paper, "Application of multivariable 2-DOF PID controller with neural network tuning method to the heat exchange", published in Fuzzy Systems Conference Proceedings, IEEE International Volume 1 applied a 2-DOF PID controller with neural network tuning method to the heat exchanger control e.g. in boiler of a power plant, gas turbine, and radiator which require a high rate heat eff iciency.

A. Vasickaninova proposed the control of a heat exchanger using Takagi- Sugeno fuzzy model in his paper "Control of a heat exchanger using Takagi-Sugeno fuzzy model". Comparison with classical PID control demonstrates the superiority of the proposed control especially in the case, when the controlled process is affected by disturbances.

Subhransu Padhee in his paper, "Controller Design for Temperature Control of Heat Exchanger System: Simulation Studies" analyzed the performance of different controllers such as feedback, feedback plus feed-forward and internal model controller to regulate the temperature of outlet fluid of a shell and tube heat exchanger to a certain reference value. From the simulation results, it was found that the internal model control has a superior performance than feedback and feedback plus feed-forward controller. The feedback controller implemented using classical PID controller shows a higher degree of overshoot and settling time whereas the internal model control negates the overshoot and has a manageable settling time

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The basic idea of PSO is based on food searching of a swarm of animals, such as fish flocking or birds swarm. PSO is a computational intelligence-based technique that is not largely affected by the size and nonlinearity of the problem, and can converge to the optimal solution in problems where most analytical methods fail to converge. The PSO algorithm incorporates both individual and social experiences in the search since the group members share information about the best positions found during their search for food. Much research is still in progress for proving the potential of the PSO which was developed through simulation of a simplified social system and has been found to be robust in solving continuous nonlinear optimization problems.

Zwe-Lee Gaing (2004) in his paper, "A particle swarm optimization approach for optimum design of PID controller in AVR system" has presented PSO for optimum design of PID controller in AVR system. The simulation results showed that the proposed method was indeed more efficient and robust in improving the step response of an AVR system. Miranda and Fonseca developed new Evolutionary PSO for voltage control. The simulation results indicated that it could obtain high quality solutions with shorter calculation time.

N. NithyaRani Dr. S. M. Giriraj Kumar in their paper titled, "Particle Swarm Optimization Technique for Temperature Process" designed a controller to maintain the temperature of water in the liquid tank in a desired value. The advanced control system, IMC-PID and Particle Swarm Optimization (PSO) is designed for this FOPDT process model. PSO algorithm is implemented and the performance is compared with the conventional PID and IMC algorithm in terms of performances indices. It is observed that PSO for the system provides optimum values ofperformance indices.

D.H. Kim, A. Abraham, and K. Hirota in their paper, "Hybrid Genetic: Particle Swarm Optimization Algorithm" compared the performance of a hybrid GA based PSO technique using four test functions. The GA-PSO system proposed in this paper could be easily extended to model other complex problems involving local optimal and global optimal solutions.

PID Controller-Conventional Controlling Method

A PID is widely used in feedback control of industrial processes on the market in 1939 and has remained the most widely used controller in process control until today. The PID controller can be understood as a controller that takes the present, the past, and the future of the error into consideration. PID controllers use 3 basic behavior types or modes: P- proportional, I- integral and D- derivative. While proportional and integral modes are also used as single control modes, a derivative mode is rarely used on its own in control systems. Combinations such as PI and PD control are used very often in practical systems.

3. Proportional (P) Controller

P controller cannot stabilize higher order processes. For the 1st order processes, meaning i.e. processes with one energy storage element, a large increase in gain can be tolerated. Proportional controller can stabilize only 1st order unstable process. Changing the controller gain K, can change closed loop dynamics.

- A large controller gain will result in control system with:
- smaller steady state error, i.e. better reference following
- Faster dynamics, i.e. broader signal frequency band of the closed loop system · Larger sensitivity with respect to measuring noise
- Smaller amplitude and phase margin

When P controller is used, large gain is needed to improve steady state error. Stable systems do not have problems when large gain is used. These are the systems with single energy storage (1st order capacitive systems). If constant steady state error can be accepted with such processes, then P controller can be used. Small steady state errors can be accepted if sensor will give measured value with error or if importance of measured value is not too high.

3.1 PD Controller

D mode is used when prediction of the error can improve control or when it is necessary to stabilize the system. From the frequency characteristic of D element it can be seen that it has a phase lead of 90

Often derivative is not taken from the error signal but from the system output variable. This is done to avoid effects of the sudden change of the reference input that in turn will cause sudden change in the value of error signal. Sudden change in error signal will cause sudden change in control output. To avoid such situation, it is suitable to design D mode to be proportional to the change of the output variable. PD controller is often used in control ofmoving objects such as flying and underwater vehicles, ships, rockets etc.

3.2 PI Controller

PI controller will eliminate forced oscillations and steady state error resulting in operation of on-off controller and P controller respectively. However, introducing integral mode has a negative effect on the speed ofthe response and overall stability ofthe system. Thus, PI controller will not increase the speed of response. This is so because the PI controller does not have the means to predict what will happen with the error in near future. This problem can be solved by introducing derivative mode which has the ability to predict what will happen with the error in near future, thereby decreasing the reaction time ofthe controller [6].

PI controllers are very often used when speed of the response is not an issue. A control without D mode is used when:

- fast response ofthe system is not required
- large disturbances and noises are present during operation ofthe process
- there is only one energy storage (capacitive or inductive)
- there are large transport delays in the system

3.3 PID Controller

PID controllers are the most widely-used controllers. They are conjointly referred to as "Three-term controllers". They are structurally easy and exhibit strong performance over large varieties of operating conditions. The three main parameters concerned are Proportional (P), Integral (I) and Derivative (D. The proportional part is liable for following the required set-point, whereas the integral and derivative parts accounts for the build up of past errors and therefore the rate of modification of error within the method severally. Derivative mode improves stability of the system and enables increase in gain K and decrease in integral time constant Ti, which in turn increases the speed of the controller response.

PID controllers are used when dealing with higher order capacitive processes (processes with more than one energy storage) when their dynamics are not similar to the dynamics of an integrator as is the case of many thermal processes). PID controllers are but also used in the control of mobile objects (course and trajectory following included) when stability and precise reference following are required. The output of PID Controller is represented by the equation:

$$U(t) = K_p e(t) + K_i \int_0^t e(\tau)d\tau + K_d \frac{de}{dt} \quad (1)$$

Where,

Error, $e(t)$ = Set point- Plant output

K_p = proportional gain, K_i = integral gain, K_d = derivative gain

4. Conclusion:

The trend in present research of PID controller is to focus on the fast and reliable methods in order obtain the best performance of existing PID control. Hence intelligent optimization techniques will be developed to decrease the computational time with increased reliability and efficiency of the controller. The inclusion of evolutionary algorithms in PID gain tuning helps to automate the entire design process to a useful degree.

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