Smart Temperature Control Mechanisms for Industrial Units

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Abstract: 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. To control the temperature of outlet fluid of the warmth exchanger device a conventional PID controller can be used. The entire heat exchanger machine is modelled using experimental information and PID controller is used as the controlling unit. The designed controller regulates the temperature of the outgoing fluid to a desired set point within the shortest possible time no matter load and technique disturbances, system saturation, balance and nonlinearity. The advanced Fuzzy logic controller (FLC) has confirmed improvement inside the overshoot and development in settling time as compared to the classical controller. The PID controller is then replaced through a Fuzzy logic controller for a better control movement, which had established better manipulate accuracy and quicker reaction.

Keyword: FLC, Gas Plant, PID, PSO

1. Introduction:

Industrial process control has become the fastest growing field in industry. Over the years industry has made a transition from manual production techniques to automatic procedures that require less human efforts. This has resulted in reduced labour costs along with features like reduced wastes, better consistency of the product and improved tolerances. Almost all the process in the present day industry rely on process and instrumentation control however the precise control of production method is now possible due to the advancement in the field of computer control and associated softwares. Any industrial process can be controlled by finding a variable representing the desired result from a product and automatically adjusting that variable or variables of the process.

Process control refers to the methods that are used to control process variables when manufacturing a product. For example, factors such as the proportion of one ingredient to another, the temperature of the materials, how well the ingredients are mixed, and the pressure under which the materials are held can significantly impact the quality of an end product. Manufacturers control the production process for three reasons:

· Reduce variability
· Increase eff iciency
· Ensure safety

Temperature control is by far the most common form of control in all the industrial processes. It may be control of input feed material or control of temperature conditions at which the process is operating or indirectly the control of temperature of the steam/gas/fluid being used to drive the process. A primary condition for temperature control is that the system must generate heat and provide a path for its distribution. This energy may be utilized to do work. The energy source of any process changes energy from one form to the other, for instance when fuel is burned, a chemical change takes place. The carbon in the fuel unites with oxygen to produce carbon dioxide. Heat released by this action is the end result of the energy transformation process.

The control function of a thermal system is concerned with the flow of heat. Temperature control can be done manually by a human operator or automatically by a system temperature controller. Controllers of this type are used in industry to achieve automatic control. The temperature-sensing element is filled with a fluid that changes volume in response to variations in temperature. This change is used to physically alter the flow of heat to the system load. The temperature of an operating system may employ a temperature sensor as RTD to sense temperature at different locations. Temperature monitoring can also be accomplished with a noncontact infrared thermometer. This temperature can then be instantly observed on a liquid crystal display.

Some major application include food and chemical processing, aerospace, and electronic component manufacturing, plastics industry, metal and glass industry , in laser processes etc.

PID controllers are widely used in process industries. Most PID controllers in industry are implemented in programmable logic controllers, SCADA, remote terminal unit, etc. Because of high requirement of best tuning procedures which tune the plant in such a way that could provide optimized solution, many tuning methods have been developed so far in which some methods give better response for speed of the system and some show good response for stability. Thus, maximum methods are application oriented.

2. Related Work:

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 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.

3. Methodology:

The PSO algorithm is an algorithm based on population which is stochastic and resolves the complex optimization problem which is nonlinear. In the year 1995, Dr. Kennedy and Dr. Eberhart was first introduced the PSO algorithm. The fundamental idea of PSO algorithm was first developed from the social behaviour of animals. It was based on bird flocking or fish schooling etc. It is based on the concept that when a group of birds searching for food or location without knowing the best position for them irrespective the individual. If any member can find out a desirable path to go, the rest of the members will follow them according to the nature of the social behaviour. [10-11]

The PSO algorithm is based on to solve optimization problems. In PSO, particle is defined as each member of the population whereas the population is called a swarm. In a swarm that is population initialized randomly and move randomly in chosen direction, each particle remains busy in the searching space and reminisces the best previous positions of itself and for its neighbours. The exact position and velocity of particle is decided by the swarm. As long as all particles have not moved, the next step will not start. As the swarm gets closer to the optimum value, all other particles move towards superior and better positions in the searching process. Due to its simpler implementation and easy convergence to a good solution the PSO method is becoming very popular In comparison with other optimization methods, it is faster, cheaper and additional efficient, except a few parameters to adjust be in PSO. For which, PSO is considered as an ideal optimization problem solver in optimization problems. PSO can be used to solve the non-linear, non- convex, continuous, discrete and integer variable type problems. [12-13]

PSO has some advantages over other similar optimization techniques such as GA, namely the following.

· PSO is easier to implement and there are fewer parameters to adjust.

· In PSO, every particle remembers its own previous best value as well as the neighborhood best; therefore, it has a more effective memory capability than the GA.

· PSO is more eff icient in maintaining the diversity of the swarm (more similar to the ideal social interaction in a community), since all the particles use the information related to the most successful particle in order to improve themselves, whereas in GA, the worse solutions are discarded and only the good ones are saved.

Given below are the two main equations of PSO algorithm. Velocity modification equation, the velocity of particle i is calculated by:

$$v_{ij^{t+1}} = wv_{ij^t} + C_1 r_{1j^t}[p_{best} - x_{ij^t}] + C_2 r_{2j^t}[G_{best} - x_{ij^t}] \quad (1)$$

first term second term third term

Where

· w is the weighing function and has a vital impact on speed if its value is less then it speeds up the convergence otherwise encourage exploration;

· v_{ij^t} is the velocity vector ofparticle i in dimension j at time;

· x_{ij^t} is the position vector ofparticle i in dimensionj at time;

· pbest is the personal best position of particle i in dimension j found from initialization through time;

· G_{best} is the global best position ofparticle i in dimension j found from initialization in the course of time t;

· C_1 *and* C_2 are positive speeding up constants which are used to level the contribution of the cognitive and social apparatus respectively;

· r_{1j^t} and r_{2j^t} are random numbers from uniform allocation at time t.

First term is inertia component responsible for movement of particle in the direction it was previously heading. 'w' has a vital impact on speed if its value is less then it speed up the convergence otherwise encourage exploration. Second term is the cognitive component acts as particles memory. Third term is the social component which is the reason why the particle move to best region found so far by the swarm.

Once the calculation for velocity of each particle is done then position can be updated using the position modification equation.

$$s_{i^{k+1}} = s_{i^k} + v_i^{k+1} \quad (2)$$

Where,

· $s_{i^{k+1}}$ and s_{i^k} are modified and current search points respectively
· $v_{i^{k+1}}$ is modified velocity

This process is repeated unless and until some stopping criteria is fulfilled.
Swarm size: The meaning of Swarm size is the size of population which is the number of n particles resides in the swarm. The larger parts of the search space is generated by big swarm which is covered per alternation. If the number of particles decreases the number alternation, then a good optimization output is obtained. On the other hand massive amounts of particles accelerate the computational convolution. Hence more time consuming.
· Iteration numbers: For obtaining a good result, the number of iterations depends on several problems. For small number of iterations the search process may end too early, but for large iterations, it is diff icult to compute the result. Also more time is required for computation.
· Velocity Components: They are very important for updating the velocity of particle. The particles velocity has three terms.
1. The term wv_{ij^t} refers to inertia component which gives a memory ofthe previous aeronautical direction. This component prevents from altering the direction of the particles and makes easy to get the current direction.
2. The term $C_1 r_{lj^t}$ [pbest $-x_{ij^t}$] refers to cognitive component which measures the particles performance comparative performances of past. The best positions of the particle can be achieved by this component. The cognitive component referred to as the longing of the particle.
3. The term $C_2 r_{2j^t}[G_{best} - x_{ij^t}]$ refers to social component that determines particles performance compared to a group of particles or neighbours. By the result of this component each particle moves towards the best location which is found by the help of its neighbourhood particle.
· Acceleration coefficients: The term C_1 decides the assurance of a particle of its own while C_2 decides assurance of a particle according to its neighbours.
3.5.3 Advantages and Disadvantages of PSO
Advantages ofthe PSO algorithm
· It is a derivative-free algorithm.
· The concept of PSO algorithm is very simple
· Very simple calculation is required for PSO algorithm
· Easy to implement.
· Less number ofparameters.
· less reliant of a set of primary points
Disadvantages ofthe PSO algorithm
· Due to the partial optimism, it degrades the regulation of its speed and direction. · Problems with non-coordinate system (for instance, in the energy field) exit.

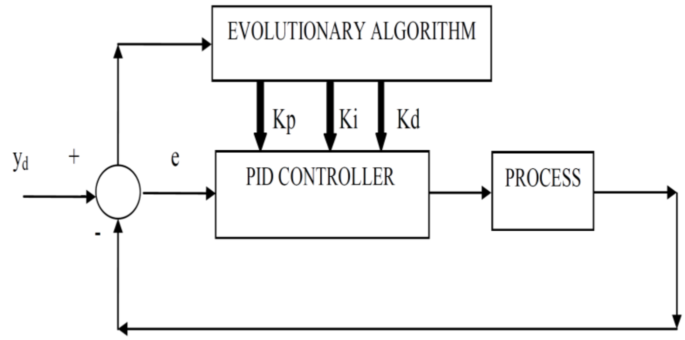

Fig 1: PID Control System with Evolutionary Algorithm

4. Result and Discussion:
4.1 Gas Pilot Plant
Figure 2 shows the process of regulating the temperature in vessel VL-212. F1 is the feed, i.e. gas that is to be adjusted to achieve a desired temperature in VL-212. The temperature transmitter (TT211) sends the measured temperature to the temperature controller, TIC211. The controller TIC 211 compares the measured temperature with the desired temperature set-point and produces the controller output (in mA) as a signal heater (EH210. This heater will respond to any change of the temperature that affects the temperature in vessel VL-212. F2 is the outflow of gas from the main vessel. The other parameters available in the plant are kept at constant values for model simplification. For example, the control valve at the inlet main vessel, FCV 211 is configured to open at 30% valve opening. The input and the output control valves HV202, HV220 and HV212 are manually controlled for the experiment to be conducted [14].

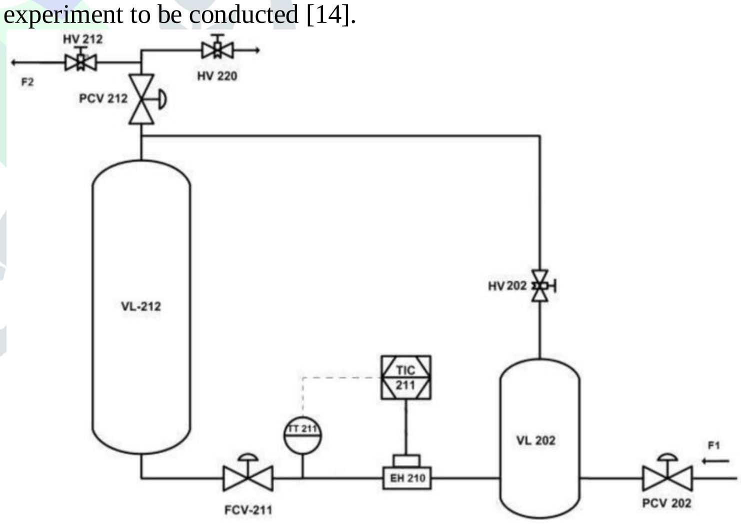

Fig 2: Gas pilot plant with a controller to control temperature of gas.

The model is determined by making small changes in the input variable about a nominal operating condition. The resulting dynamic response is used to determine the model. This procedure ensures that proper data is generated through careful experimental design and execution [15]. The empirical modeling was performed over the gas pilot plant and process reaction curve obtained is shown in Figure 3. A step input of 20% was given to the system due to which the output change result in approximately 7. 25^oC of increment.

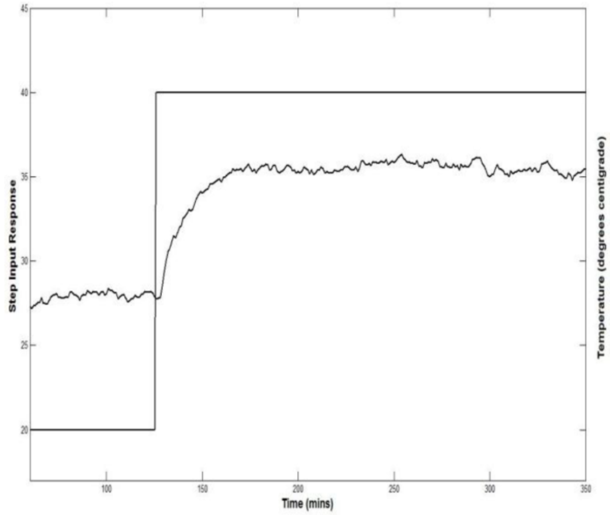

Fig 3: Process reaction curve

4.2 Model of Gas pilot plant using PID Controller

The figure below is modeled using simulink MATLAB. Here a step input is taken with a 20 minutes step time and this signal is given as input to the PID controller which is controlling the specified process (approximated to first order type) with a unity feedback system. The three levels shown below represent three different tuning techniques namely; Ziegler Nichols closed loop, Ziegler Nichols open loop and Cohen Coon Method. The tuning is done using SISO Tool of MATLAB for the first two methods and manual for the third method.

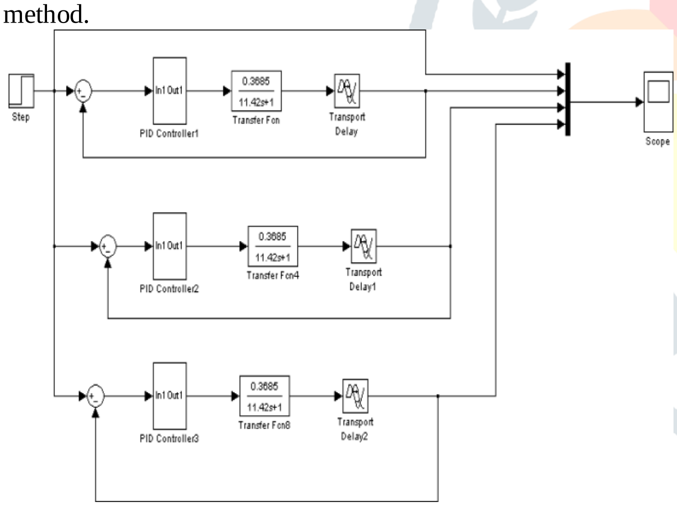

Fig 4: Simulink model for temperature controller using PID controller.

The controller results in figure 4.4 show that the conventional tuning method of Ziegler Nichols closed loop offers the best response having minimum overshot, settling time as compared to the other two methods [17].

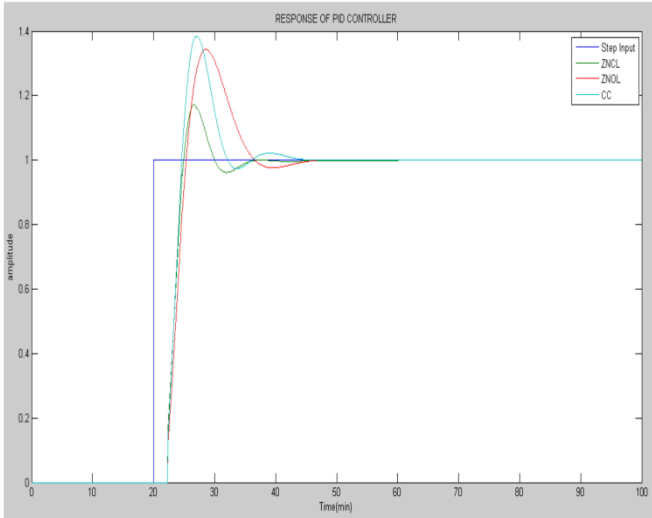

Fig 5: Step response of PID controller using conventional tuning methods

Figure 6 shows the Simulink diagram of PID Controller having two degrees of freedom using ZNCL tuning.

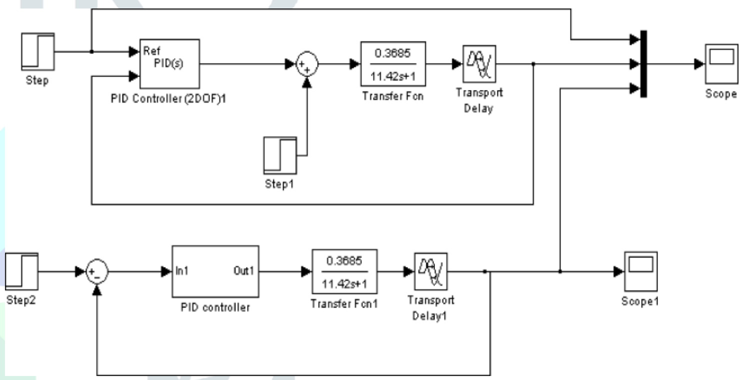

Fig 6: Model for temperature controller using 2-D.O. *F* based PID parameters.

2-D.O.F PID controller gives good performance for both reference tracking and disturbance rejection. It contains a standard PID controller in the feedback loop and adds a pre-filter to the reference signal. The pre-filter helps produce a smoother transient response to set-point changes. In this case, we are using a Simulink PID Controller (2 D.O.F) block to control a temperature of gas in a gas pilot plant. The modelling was done using the Two D.O. *F* block in control toolbox of simulink MATLAB. The model shows comparison between the 2- D.O.F PID Controller and the conventional ZNCL tuned PID Controller. The results are shown in figure 7.

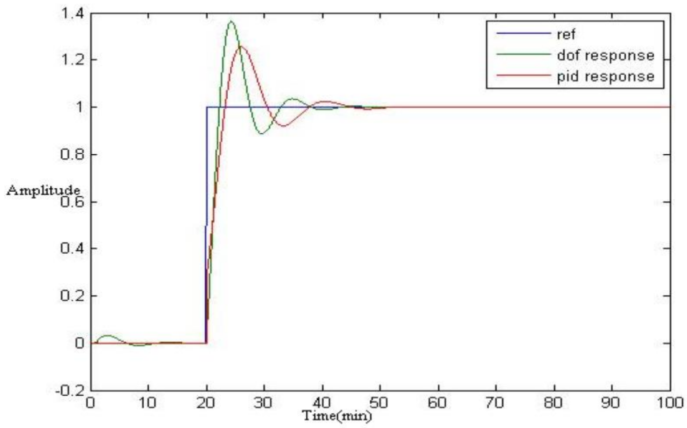

Figure 7: Step response of system using 2D.O.F control

5. Conclusion:

The main aim of this paper was to analyse the best controlling method for the controlling of process temperature in a process industry. A comparison was done between the conventionally tuned PID Controller and Fuzzy Logic Controller with different membership functions. PSO algorithm was developed and was used to tune the PID Controller and hence find the best possible optimized results. Various results were generated at different times the best results were saved and the best one was chosen from each algorithm for comparing it with the old traditional method of tuning the PID controller.

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