

Fuzzy Logic Based Temperature Controller

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Abstract: The considerable fact 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, a 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 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 the 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 lode and technique disturbance, 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 classical controllers. The PID controller is then replaced through a Fuzzy logic controller for a better control movement, which has established better manipulate accuracy and quicker reaction.

Keywords: Fuzzy Logic Controller, Gas Plants, Proportional integral derivative, PSO

1.Introduction:

Industrial process control has become the fastest growing field in industry. Over the years the industry has made a transition from manual production techniques to auto procedures that require less human efforts. This has resulted in reduced labour cost along with features like reduced wastes, better consistency of the product and improved tolerance. Almost all the processes 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 variable 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, temperature of the material, how well the ingredients are mixed, and the pressure under which the materials are held can significantly impact the quality of an end product. Manufactures control the production process for three reasons:

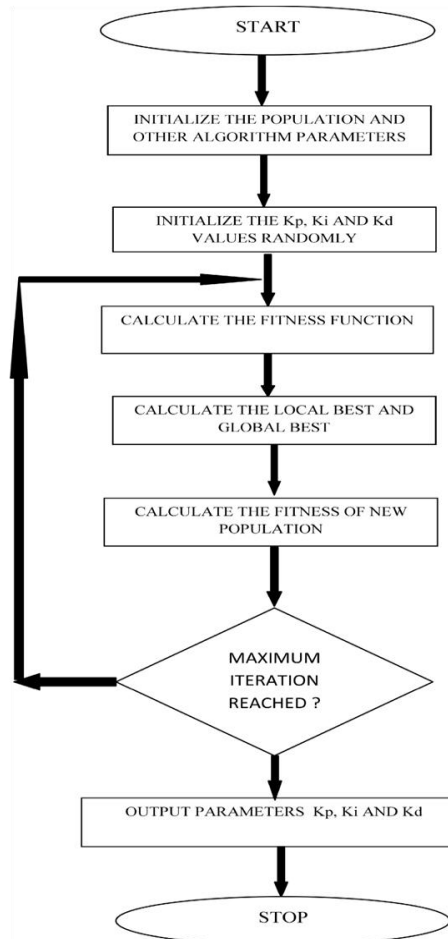
- Reduce variability
- Increase efficiency
- Ensure safety

Temperature control is far the common form of control in all the industrial processes. It may be control of input in feed material or control of temperature conditions at which the process is operating or indirectly the control of temperature of steam/gas/fluid being used to derive 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 utilised 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 process 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. Controls 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 applications include food and chemical processing, aerospace, and electronic component manufacturing, plastic industry, metal and glass industry, in laser processes etc.



PID controllers are widely used in process industries. Most PID controllers, SCADA, remote terminal units, etc. Because of the high requirement of best tuning procedures which tune the plant in such a way that could provide an optimised solution, many tuning methods give better response for stability thus, maximum methods are application oriented.

The PID control contributes to this satisfactory operation of the process by upholding the required parameters within the acceptable. Conventional PID controllers are employed in most engineering applications because of its easy implantation, robustness, and simplicity. The PID controller has the ability to cope with changes in the surrounding environment, changes in input feed, changes in flow speed of working fluid which may occur due to blockage of valves etc. The gains of PID controllers must be properly tuned to guarantee security, dynamic performance and sustainable utilisation of the plants. The conventional methods for improving the performance in tuning k_p , k_i and k_d gain parameters viz., simplex method, Ziegler-Nicholas, Newton method, need a complete set of information related to the plant behaviour and prerequisite knowledge of the problem. The conventional controllers are designed for particular operating condition and the gain values are manually tuned. Therefore, they fail to provide better results and when the operating conditions change it may not provide suitable control. In this thesis, considerable advancements and improvements have been carried out to mitigate the requirements of industry.

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 Application, Vol. 38, No. 2, march april 2022. A control system incorporating fuzzy logic has been developed for a class of industrial temperature control problems. The FLC structure with an efficient realisation 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 of their responses were done.

Mohammad Adan 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

3. Methodology:

Process control can reduce variability in the end product, which ensures a consistent high-quality product . Manufacturers can also save money by reducing variability. For example , in a gasoline blending process , as many as 12 or more different components may be blended to make a specific grade of gasoline . If the refinery does not have precise control over the flow of the separate components, the gasoline may get too much of the high-octane components. As a result, customers would receive a higher grade and more expensive gasoline than they paid for, and the refinery would lose money. The opposite situation would be customers receiving a lower grade at a higher price.

Fig 1: POS Algorithm for PID Controller

Some processes need to be maintained at a specific point to maximise efficiency . For example, a control point might be the temperature at which a chemical reaction takes place. Accurate control of temperature ensures process efficiency. Manufacturers save money by minimising the resources required to produce the end product. A run -away process, such as an out-of-control nuclear or chemical reaction, may result if manufacturers do not maintain precise control of all of the processing variables. The consequences of a run-away process can be catastrophic.

Precise process control may also be required to ensure safety. For example, maintaining proper boiler pressure and temperature by controlling the inflow of air used in combustion and the outflow of exhaust gases is crucial in preventing boiler explosions that can clearly threaten the safety of workers. In this thesis two advanced controllers namely fuzzy logic controller and PSO (artificial intelligence) PID Controllers have been proposed for the controlling of temperature of an industrial process.

4. PID controller conventional controlling method:

A PID was widely used in feedback control of industrial processes on the market in 1939 and has remained the most widely used controller in process control units today. The PID controller can be understood as a controller that takes the present ,the past and the future of the error into concentration. PID controller used three basic behaviour type or models: P-Proportional ,I- Integral andD- Derivative while proportional and integral method are also used as single control model.A derivative mode is rarely used on its own in control system combinational such as PI and PD controller are used very often in practical system.

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 varitiest of operating system. The main parametre concerned are proportional, integral and derivative . The proportional part is liable for following the required set point whereas the integral and derivative part counts for the build up of past error 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 T which in turn increases the speed o f 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 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:

$$c(t) = K_c \left(e(t) + \frac{1}{T_i} \int e(t)dt + T_d \frac{de}{dt} \right) + C$$

$e(t)$ = Set point - Plant output
 K_p = proportional gain,
 K_i = integral gain,
 K_d = derivative gain

5. Result and discussion:

5.1 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 desired temperature in VL-212. The temperature transmitter (TT211) sends the measured temperature to the temperature controller, TIC 211. The controller TIC 211 compares the measured temperature with the desired temperature set-point and produces the controller output (in mA) as a single heated (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].

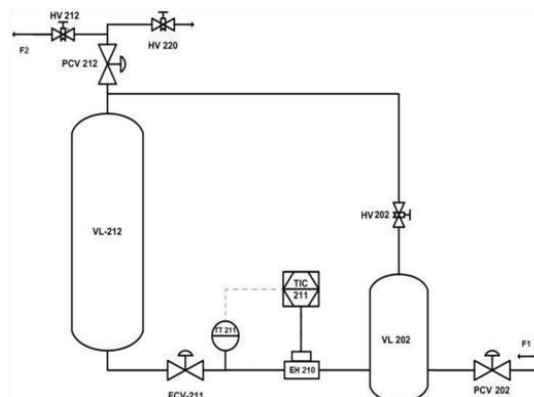


Fig. 2: Gas pilot plant with a controller to control temperature of gas

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 modelling was performed over the gas pilot plant and the 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 resulted in approximately 7.25°C of increment.

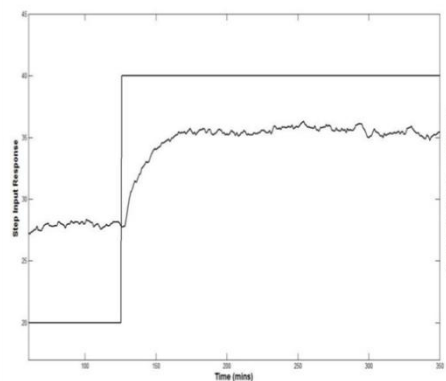


Fig. 3: Process reaction curve

5.2 Modol and Gas pilot plant using PID controller:

The figure below is modelled 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 Nicholas 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.

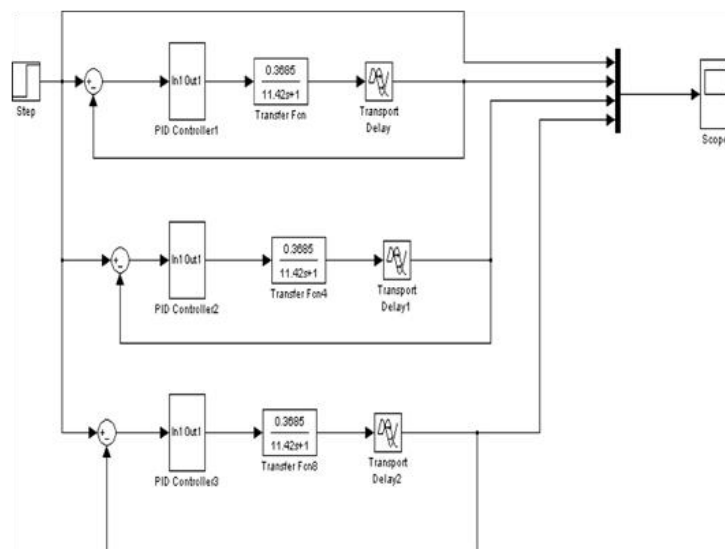


Fig. 4: Simulink model for temperature controller using PID controller.

The controller result in figure 5 shows that the conventional tuning method of Ziegler Nichols closed loop offers the best response having minimum overshoot, settling time as compared to the other two methods [11].

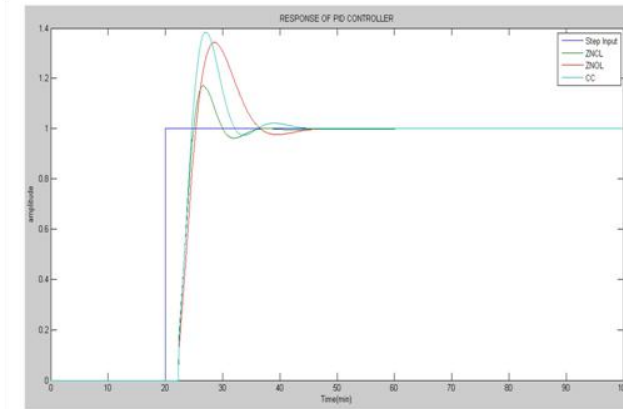


Fig. 5: Step response of PID controller using conventional tuning methods

The results show that the Fuzzy Logic Controller has more response time as compared to PSO tuned PID controller. This is due to the presence of a long rule table. The PSO tuned PID controller response is shown in full lines

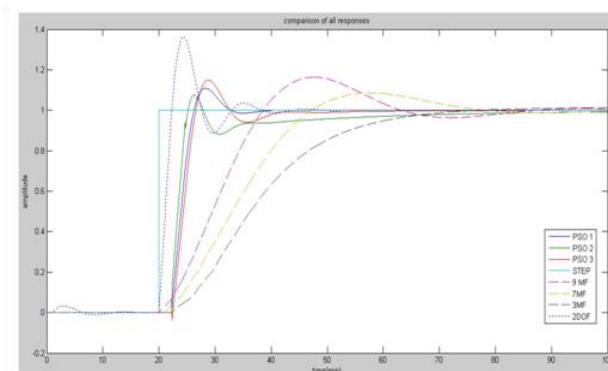


Fig. 6: Combined Step Response of all types of controller

6. Conclusion:

The Purpose PSO algorithm has better searching speed than the conventional GA method. The algorithm find the best solution with fewer number of iteration and there is a marginal difference in time taken to converge to the best solution for higher value of iteration and swarm size , the computational efficiency and the program execution time is found to be increased further more EA use a parallel search through the speed search: this increases the computational efficiency of the algorithms since the basic PSO method does not perform the selection and cross over operation in the evaluation process it can save computational time compared with the GA method , thus proving that the PSO based PID controller is more superior it can be conclude that the proposed EA (PSO) based PID controller can be extensively used for control of temperature in industrial process.

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