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Fuzzy Logic Based Temperature Controller For Industrial Furnace

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Abstract: 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. 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.

Keywords: 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.

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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.

The PID controller 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 implementation, robustness, and simplicity. The PID controller has ability to cope up with changes in surrounding environment, changes in input feed, changes in flow speed of working fluids 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 utilization 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-Nichols, Newton method, needs a complete set of information related to the plant behavior and pre-requisite 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 changes it may not provide suitable control. In this thesis, considerable advancements and improvements have been carried out to mitigate the requirements of the 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 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 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:

Process control can reduce variability in the end product, which ensures a consistently 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

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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.

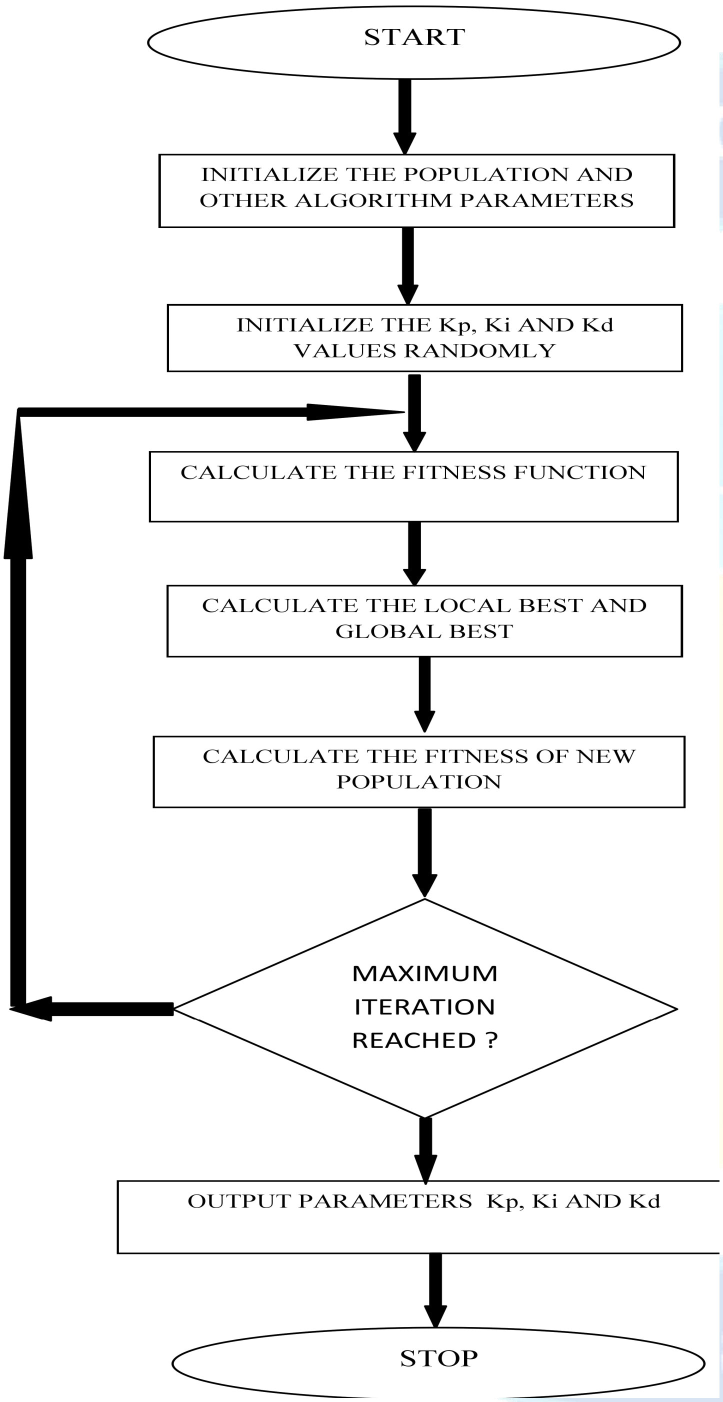

Fig 1: PSO Algorithm for PID Controller

Some processes need to be maintained at a specific point to maximize 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 minimizing 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 oftemperature of an industrial process.

3.1 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.

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 ofmany 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:

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

Where,

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

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

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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].

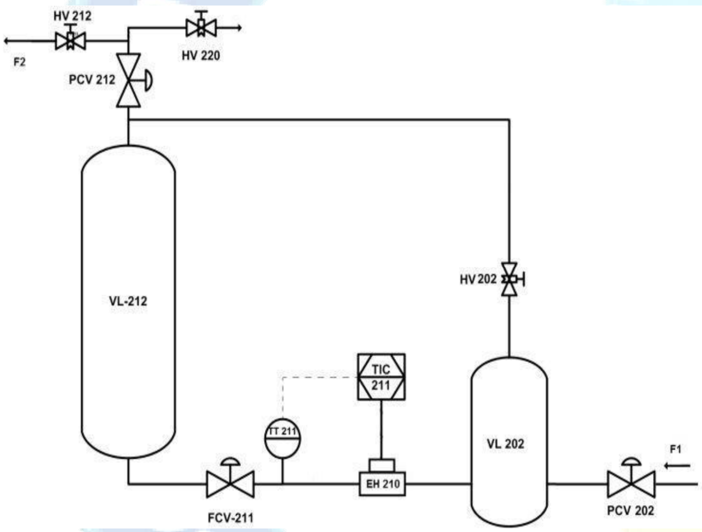

Fig 2: Gas pilot plant with a controller to control temperature of gas.

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 $7.25^{o}C$ of increment.

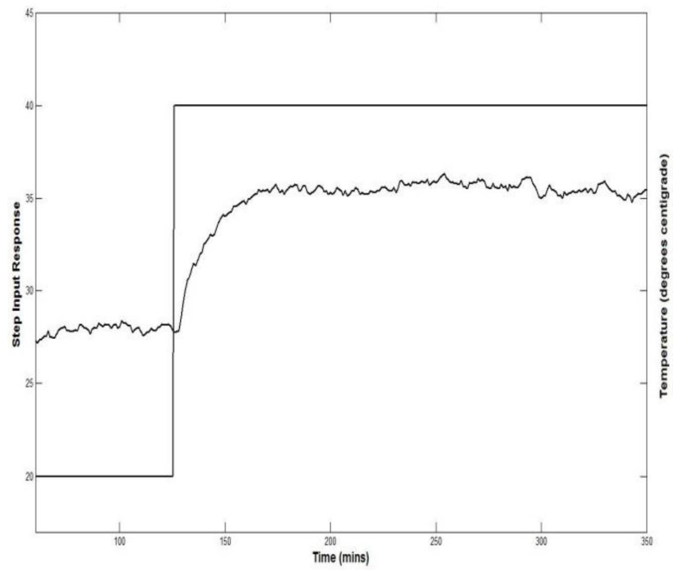

Fig 3: Process reaction curve

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.

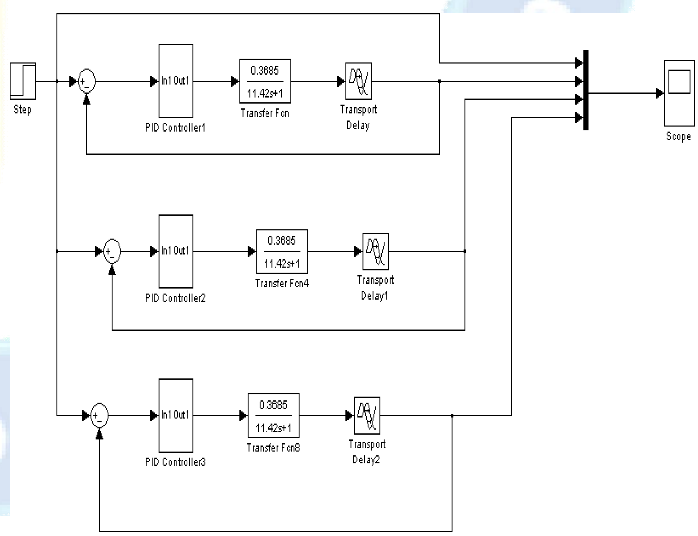

Fig 4: Simulink model for temperature controller using PID controller.

The controller results in figure 5 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 [11].

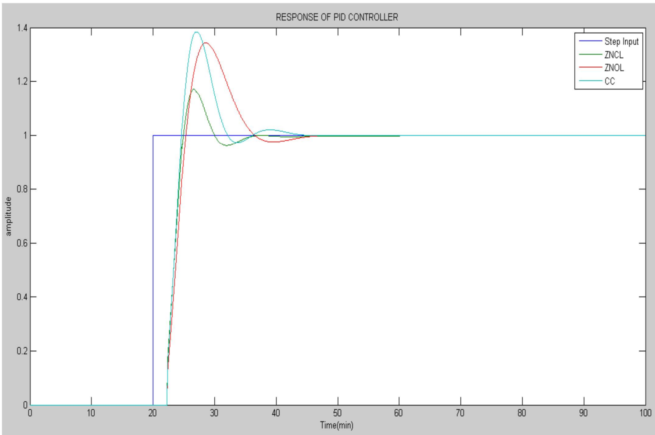

Fig 5: Step response of PID controller using conventional tuning methods

The results show that 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 FLC response is shown in dashed part in figure 6 while the PSO tuned PID controller response is shown in full lines.

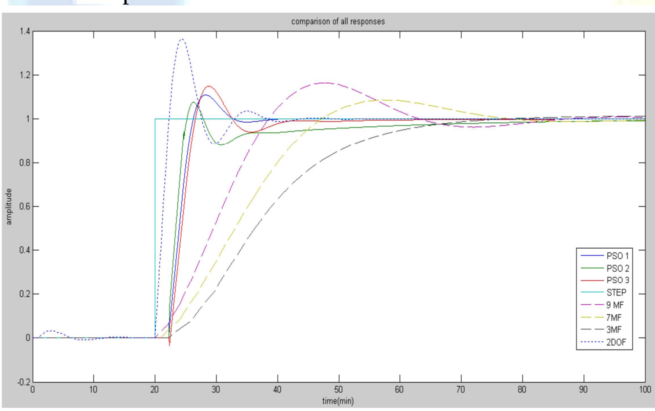

Fig 6: Combined Step Response of all types of Controllers

5. Conclusion:

The proposed PSO algorithm has better searching speed than the conventional G.A. method. The algorithms find the best solution with fewer numbers of iterations and there is a marginal difference in time taken to converge to the best solution. For higher values of iterations and swarm size, the computational efficiency and the program execution time is found to be increased. Furthermore, EA uses a parallel search through the search space; this increases the computational efficiency of the algorithms. Since, the basic PSO method does not perform the selection and crossover operation in the evolutionary process; it can save computation time compared with the GA method, thus proving that the PSO Based PID controller is more superior. It can be concluded that the proposed EA (PSO) based PID controllers can be extensively used for control of temperature in industrial processes.

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