Fast Response Systems Using Feed Forward Loop for Fuzzy Tuned PID Controllers

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Abstract— The temperature during heating processes more essential in oil quantity. Many of the research effort they developed new control technique to control and regulate the steam temperature in industries. This seems to be because PID controllers is simple structure, assure acceptable performances for a wide range of industrial plants and their usage (the tuning of their parameters) is well known among industrial operators. PID with FLC with combination of this we neglected the steady state errors. PID controllers are particularly suited for pure first- or second-order processes, while industrial plants often present characteristics such as high order, time delays, nonlinearities and so on challenges during design the PID is to tune the PID parameters gain that suite to the plant. To overcome this problem, feed forward tuning PID using the fuzzy logic controller with self-tuning method is utilized to regulate the steam temperature. It gives good process dynamic characteristic which are process rise time, process settling time, percent overshoot and less steady state error. The ability to track any parameters changes and has fast recovery the output response during disturbance period.

Keywords— PID controller, feed forward loop for Fuzzy tuned PID Controllers.

I. INTRODUCTION

Feedback is a very powerful idea. BENNETT (1979, 1993) feedback control system is required to track set point changes and to suppress unmeasured disturbances that are always present in any real process. The feedback control system of each system can be designed independently. Feed forward control is used to rapidly suppress feed flow rate disturbances. PID tuned controller is to develop a new control technique to regulate steam temperature during the extraction process. Control Systems temperature is a major contributed to the process variable for good fruition and distillated oil. Self tuning by fuzzy PID is categorized by adaptive control is automatically tuned by the PID control gain. The fuzzy set output of error and derivative error may tune the appropriate PID values in Fig 1. Ziegler-Nichols are not used in higher order might fall to obtain best performance of the output. In industrial applications using higher order time delays with nonlinearities. The combination of fuzzy set and PID control, step response of transient analysis should improve. Output of fuzzy set from the error and derivative error used to tune the appropriate values of PID parameters. Fuzzy logic has mimic the human reasoning process to identify and control complicate systems with impossible and difficult to control by means. Fuzzy logic expert knowledge in human expect about the situation of the problem comes. It should be incorporate into fuzzy controller. For the operating conditions critical issues sort of intelligence may automatically control.

II. FUZZY LOGIC CONTROLLER

A. Self-tuning fuzzy PID.

Self tuning of PID controller has easily tuned the input step to the reference. Then error and derivative error to fuzzy inference it improves the
steady state analysis and automatically tunes appropriate values without any disturbances.

PID controllers are the most widely-used type of controller for industrial applications. The three main parameters involved are Proportional (P), Integral (I) and Derivative (D). The proportional part is responsible for set-point, while the integral and derivative part account for the accumulation of past errors and the rate of change of error in Fig 2. The basic requirements of the output will be the stability, desired rise time, peak time and overshoot. Online and tuning is achieved manually which requires very experienced personnel and there is always uncertainty due to human error. While this method is good for online calculations, it involves some trial-and-error which is not very desirable. PID controller is used single-loop controllers, as a software component in programmable logic controllers and distributed control systems, as a built in controller in robot.

RTD is used for temperature measurement. The analog signal is converted into digital by the converter. Pulse width modulation (PWM) is input to the switching unit. It represent by the duty cycle of the square wave varies from -100% to 100% ON period for induction heating should be varies with duty cycle for switching the output signal.

The parameters of Kp, Ki and Kd are tuned by using fuzzy logic controller. Two inputs of fuzzy logic controller which is the error and the derivation of error is set. Assume the variable ranges of the parameters Kp, Ki and Kd of PID controller in Fig 3.

The parameters Kp, Ki and Kd varies in between [Kpmin, Kpmax], [Kimin, Kimax],[Kdmin, Kdmax]. The ranges of value of Kp, Ki and Kd as shows in below Eq (1-3)

\[
K'p = \frac{Kp-Kp_{min}}{Kp_{max}-Kp_{min}} \quad (1)
\]

\[
K'i = \frac{Ki-Ki_{min}}{Ki_{max}-Ki_{min}} \quad (2)
\]

\[
K'd = \frac{Kd-Kd_{min}}{Kd_{max}-Kd_{min}} \quad (3)
\]

PID parameters will obtain from the simulation of PID controller to get the feasible and optimum performance.
The range for each parameter is, $K_p$ [0.1, 1], $K_i$ [0.0001, 0.001], $K_d$ [0.001, 0.01]. From the equation below, the appropriate values in Eq (4-6)

$$K_p = 0.9K'p + 0.1 \quad \text{(4)}$$

$$K_i = 0.0009K'I + 0.0001 \quad \text{(5)}$$

$$K_d = 0.009K'd + 0.001 \quad \text{(6)}$$

**B. Robust Test:**
Sensitive small output change the parameters are designed robust. To check the robustness of the controller design, two robustness test have been carried out which are set point tracking and load disturbance. These two tests are performing on simulation and real-time control for all controller design. First test is set point tracking. The step taken for simulation and real-time process is as below:

1. The step input on Simulink block is replaced with the block repeating sequences that found out on Simulink library browse
2. For set point tracking test, the $r(k)$ is set as follows.
   $$r(k) = 
   \begin{align*}
   &800\degree C; 1 < k < 3000 \\
   &900\degree C; 3001 < k < 6000 \\
   &850\degree C; 6001 < k < 9000
   \end{align*}$$

Three different parameter set point was set as a desired input. The entire step on set point tracking test above applicable for all controllers designed output response is shown in Fig 4. Second robustness test is load disturbance. This performed to see the ability on controller to maintain their performance either the disturbance is introduced to the system output to control the heat provided by the steam in Fig 5. For simulation, the input step wills replaced with input Gaussian noise generator that disturb the output process. For real-time control implementation, the heating process was disturbed by flow a cool air to steam distillation system during the process run. Start at 1900th sample, cool air was flow until 1920 sample.

![Fig 4 Output response of FTPID 7mf for set point tracking.](image1)

III. DESIGN OF TUNING FUZZY PID CONTROLLER.
The aggregation and defuzzification method are used respectively max-min and centroid method. Regarding to the fuzzy structure, there are two inputs to fuzzy inference: error $e(t)$ and derivative of error $de(t)$, and three outputs for each PID controller parameters respectively $K'p$, $K'i$ and $K'd$. Mamdani model is applied as structure of fuzzy inference with some modification to obtain the best value for $Kp$, $Ki$ and $Kd$. Fuzzy inference block of the controller design is shown in Fig 6.

![Fig 6 Fuzzy Interface Block](image2)
Suppose the variable ranges of the parameters $K_p$, $K_i$ and $K_p$ of PID controller are respectively $[K_{p\text{min}},K_{p\text{max}}]$, $[K_{i\text{min}},K_{i\text{max}}]$ and $[K_{d\text{min}},K_{d\text{max}}]$. The range of each parameter was determined based on the simulation on PID controller to obtain a feasible rule bases with high inference efficiency.

### IV. ARCHITECTURE OF FUZZY LOGIC CONTROLLER.

![Fig 7 Block Diagram of Fuzzy Logic Controls.](image)

Architecture of fuzzy logic control system is given by inputs are error and error rate, which are combined by block $M$ to input to the fuzzy inference system. The lookup table.1 Fig 8 is derived based on the membership function of inputs, the output and the fuzzy control rules. A control gain factor $G$ is used to tune the output of the lookup table to obtain different output values. A feedback signal is obtained from the output of the system.

- NB  Negative Big
- NM  Negative medium
- NS  Negative small
- Z   Zero
- PS  Positive Small
- PM  Positive medium
- PB  Positive Big

#### A. Establishment of Fuzzy Control Rules.

<table>
<thead>
<tr>
<th>Dev</th>
<th>NB</th>
<th>NS</th>
<th>ZE</th>
<th>PS</th>
<th>PB</th>
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<tbody>
<tr>
<td>NB</td>
<td>S</td>
<td>S</td>
<td>MS</td>
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<td>NS</td>
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<td>PS</td>
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<td>PB</td>
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In Online tuning of PID controller we included addition to feed-forward, PID controllers are often enhanced through methods such as PID gain scheduling (changing parameters in different operating conditions), fuzzy logic in Fig 9.

![Fig 9 Simulink block diagram for Fast response systems using feed forward loop for Fuzzy tuned PID Controller.](image)
A high enough sampling rate, measurement precision, and measurement accuracy are required to achieve adequate degree of freedom by using fractional order. The order of the integrator and differentiator add increased flexibility to the controller. Rule based fuzzy system. The analysis of rise time, settling time and percentage overshoot the ability to curbing the temperature response is desired. Suppose using 7mf the output response is acceptable in process control.

V. SIMULATION RESULTS.

Before apply to the controller apply real process and simulation work carried out at initial conditions based on the dynamic process of the system shown in Fig. 10 (Integral Input) and Fig.11 (Derivative Input). The controller has ability to curbing the output temperature response at desired. Fast response of feed forward controller lowest settling time 6.0s, rise time 5.0s and percentage overshoot 1.16% is shown in Fig.15.
Fig 15 Simulink output response for feed forward loop for fuzzy tuned PID Controller.

Output Controller performance of 7mf

<table>
<thead>
<tr>
<th>Controller</th>
<th>Rise time (s)</th>
<th>Settling time (s)</th>
<th>Overshoot (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTPID (7mf)</td>
<td>0.5</td>
<td>6.0</td>
<td>1.16</td>
</tr>
</tbody>
</table>

VI. CONCLUSION

FTPID have the capability to control the plant steam temperature at the desired point. In terms of process combination of Fuzzy and PID controller have neglecting the steady state and overshoot. FTPID is able to provide Shortest rise time and settling time, small overshoot and robustness forward tests track any parameters changes and have fast recovery to the desired temperature during load disturbance test. Fuzzy tuned controller was applied to tune the value of $K_p$, $K_i$ and $K_d$ of the PID controller. The system responses indicate the performance of the Feed system was improved and satisfied.

VII. REFERENCE

[14] N. B. Kha and A. Kyoung-Kwan, “Position Control of Shape Memory Alloy Actuators by Using Self Tuning Fuzzy PID Controller,” in