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Modeling and Design of Automated Industrial Process System for Regulating Temperature by using Neuro-Fuzzy system

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ABSTRACT:In this paper it has been discussed about the improved impact of Neuro-Fuzzy controller over the temperature control process in an industrial process control (IPC), where the temperature can be maintained with more accuracy as per the system demand or certain reference value. The heat exchanger is usually done with the water or the liquid by the help of the heater and stirrer. Here the objective of this paper is to get the quick and less transient output. From the MATLAB simulation result analysis, it is found that the Neuro-Fuzzy technique is quite impressive regarding this case.

KEYWORDS*:*- Neuro Fuzzy Controller, Fuzzy Logic, sisotool, System Identification, Compensator, PID

I.INTRODUCTION

In today's scenario automatic control is more preferable then the manual operation for better performance in any means. Temperature management in an IPC is a very crucial factor, as it may lead directly or indirectly to the effect on the plant efficiency. For a Thermal power plant the temperature plays a major role which is quite expensive as well as small instability in maintaining this temperature (as previously decided) may lead to a serious damage or loss. Hence here the control of temperature or the heat exchanger is to be done with automatic controller for more accuracy of outcomes. In general a heat exchanger needs a heater to heat the subject (water or liquid) and a stirrer to fast cool down of the overheated subject.

Traditional controllers like Proportional-Integral-Derivative (PID) controllers are easy to understand and can be applicable to many control problems, but these controllers suffer with many deficiencies like they are quite uncomfortable with the plant nonlinearities and plant uncertainties. The Ziegler-Nichols II (ZN-II) method can be applied to tune the PID, but still here the close loop response has off-set and the responses are quite oscillatory and unstable [1].

The use of intelligent hybrid systems is growing rapidly with successful applications in many areas including process control, engineering design, financial trading, credit evaluation, medical diagnosis and cognitive simulation. Neural network and Fuzzy Logic mimic the functioning of human intelligence process, which is quite impressive after all a hybrid technique that can perform like human thinking and predictions is way better than the traditional and conventional techniques [10] .

In further sections we have discussed about the mathematical model, system identification, compensator and the controllers. Then finally in last section we have a conclusion based on the previous discussed controller performances.

II.TEMPERATURE CONTROL PROCESS OUTLNE

In an Industrial Temperature Process Control for automatic operation we need to connect a heater that will raise the temperature of the system (liquid tank) to the desired one and a stirrer to quick reduce the temperature if it is higher than the pre-set value. For this process we need at least two temperature sensors as per the range of the temperature we

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are dealing with. These are basically Resister Thermal Detectors (RTDs) and Thermocouples used in different areas with respect to different temperature ranges.

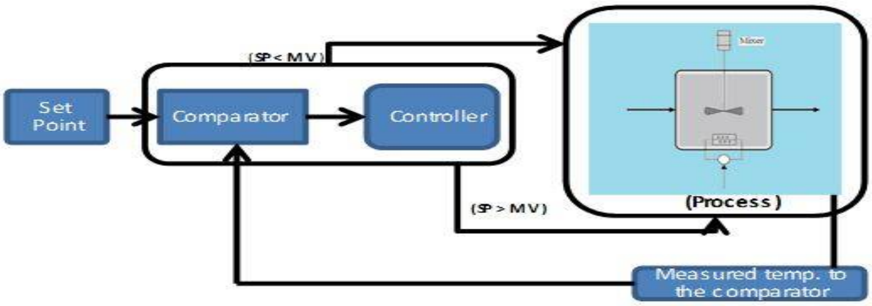

Fig 2.1 [Proposed Model of Automated Temperature Control]

First of all the temperature of the liquid tank is sensed and compared with the set-point. The result or the error is then manipulated by the controller and accordingly the heater or the stirrer runs to work as per need. When the setpoint is greater than the measured tank temperature, the heater will run to add temperature to thew system. Similarly, when the predesired value is less than the measured temperature, the heater effect starts decreasing and the stirrer comes to action. Addition of a stirrer to this process drives the controller faster to maintain the required temperature. The temperature process outline is given below.

III.MATHEMATICAL MODELING

The plant process, which temperature is to be controlled, can be calculated from the energy balance equation. Here the process is taken as a First Order Time Delay (FOTD) transfer function [1]. The tank has two inlets through which the natural or the environmental water and the controlled heated liquid or water enters. Let the T_1 , T_2 be the temperatures and F_1, F_2 be the flow of water respectively and the tank inside temperature is as T_3. If V is the volume of the tank, then comparing the tank measured temperature with the two different input temperatures we will get,

$$\frac{dT_3}{dt} = \frac{F_1}{V} * (T_1 - T_3) + \frac{F_2}{V} * (T_2 - T_3)$$ ---------------------------equation 3.1

Though this is theoretically correct and based on flow controlled of one of the two inputs to the tank, but it is quite unstable and time consuming process. The error as compared to time is increasing as per the simulation result of the equation model.

IV.USE OF COMPENSATOR

A compensator is an additional component or circuit which is inserted into a control system to equalize or compensate for a deficient performance. With the alternation of the frequency response or the root locus of the system we can get the suitable system performance with the compensator. Generally three types of compensators are taken into considerations, such as Lead compensator, Lag compensator and Lead-Lag compensator. For an electrical system a compensator is a RC- network.

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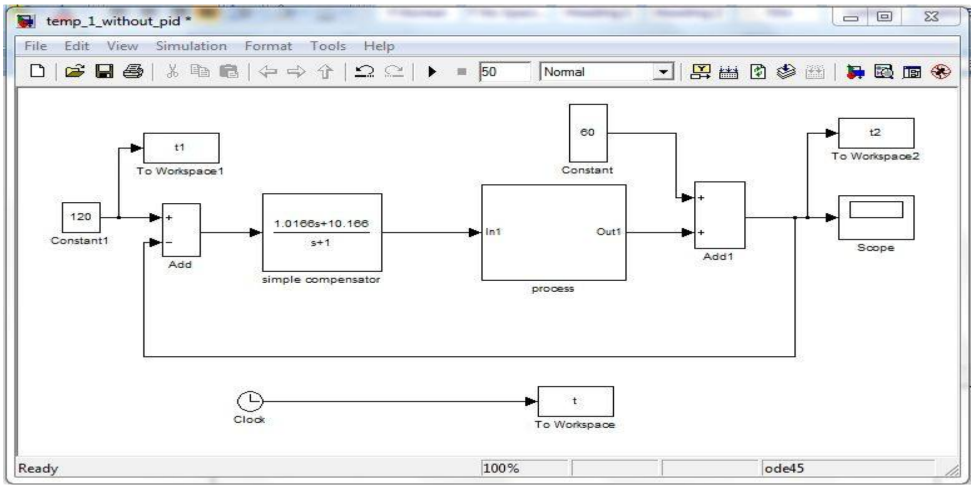

Fig 4.1 [Simulink model using a Compensator]

Here the process system is a first order equation and accordingly a compensator is designed using the sisotool in MATLAB. With this compensator the whole simulink model is redesigned, shown in fig 4.1. Here the set-point is a unit step function and the disturbance to the system is 60 degree Celsius. But the output is not impressive as it cannot meet the desired pre-set value.

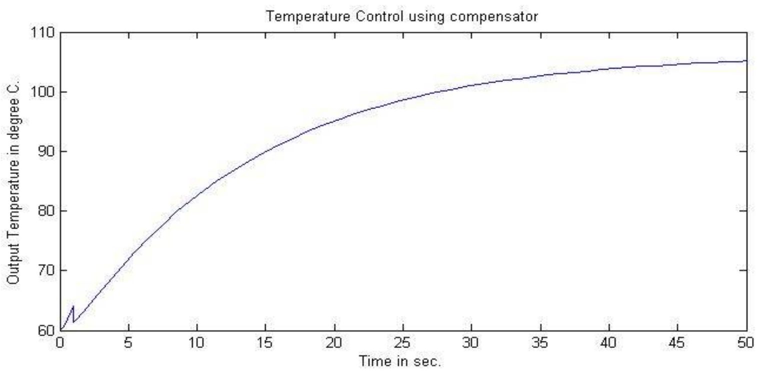

Fig 4.2 [Output graph with respect to time for the compensator]

The simulink result shown in Fig 4.2 of the simulink model (Fig 4.1) has a clear indication about the failure to achieve the required value, which is 120. That means the model or the compensator in this system has steady state problems. Again the compensator has some more issues like slow response and steady state errors for which it is not acceptable here.

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V.SYSTEM IDENTIFICATION

For system identification we need to consider the factors affecting the process controller. Time delay is one of the important factors as the heating process needs some time. This delay factor can be taken as a first order transfer function for the simulation testing. The heater constant, the input disturbance or the environmental water temperature and the controller are also considered together as open loop transfer function for the simulation stability testing in MATLAB with the help of SISOTOOL command.

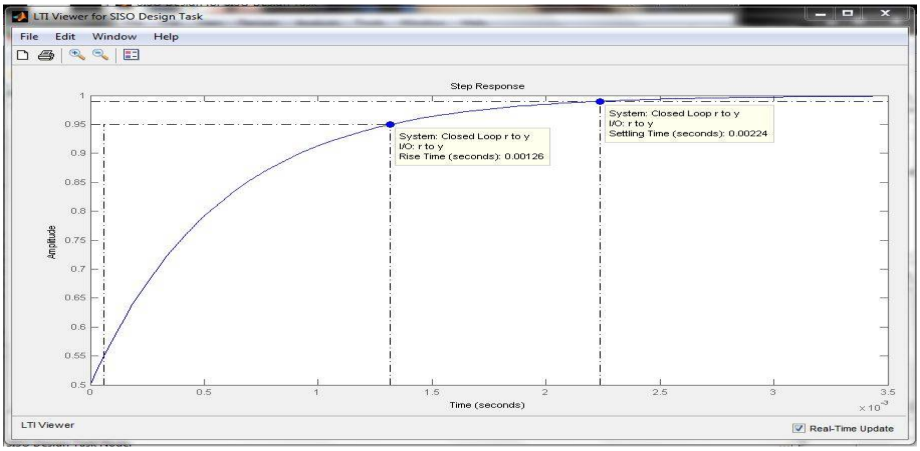

Fig 5.1 [LTI viewer of the open loop transfer function]

Figure explains the best possible output characteristics like raise time and settling time.

With proper root locus manipulation by placing poles and zeros, we derived the transfer function of controller for the required model. The MATLAB sisotool trial followed by the Linear Time Interval (LTI viewer) gives an idea about the effective stability of the transfer function. The best optimized transfer function with proper parameters produces the result as shown in fig 5.1.

Now extracting the delays, the heater constant and the disturbance we have the mathematical expression for the PID controller and the tank first order transfer function. Now from the controller expression the PID values can be found out.

VI.USING PROPORTIONAL INTEGRAL DERIVATIVE (PID) CONTROLLER

PID controller is widely used in industrial processes. The three constants proportional, integral and derivative constants simultaneously act on the error to get the controlled output. From the system identification we got the mathematical expression for the process model.

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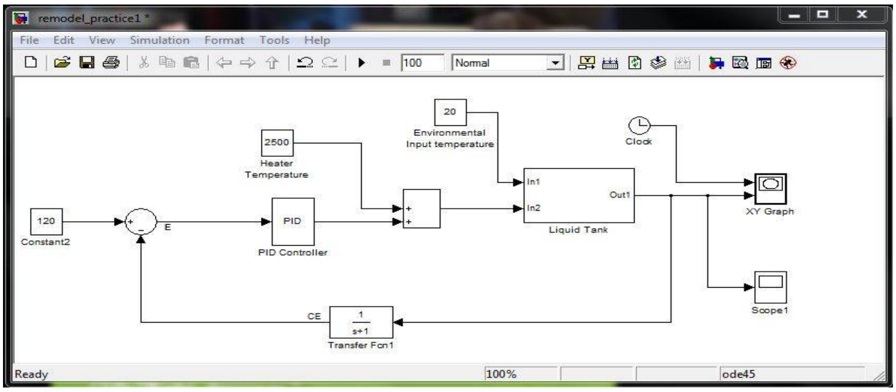

Fig 6.1 [MATLAB simulink model using PID controller]

By solving the expression we can have the three constant values for the PID controller. Using this PID controller, the discussed temperature process simulink model can be redesigned as shown in the fig 6.1. The output of this model execution is shown in fig 6.2. Here it can be clearly seen the overshoot problem, which may cause a fatal issue for the process.

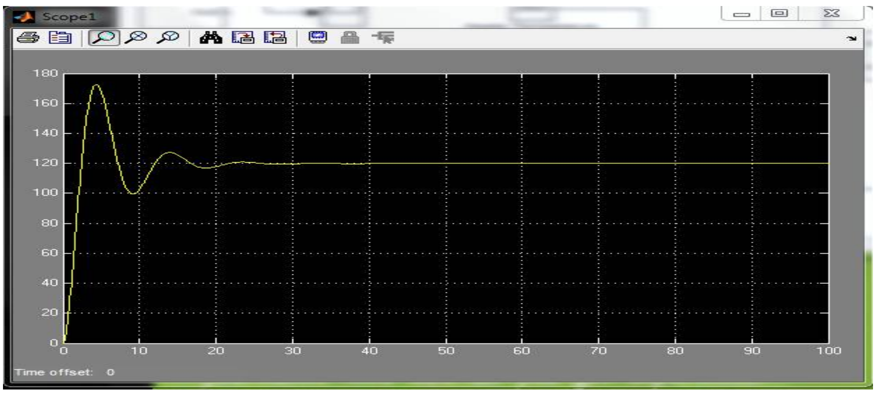

Fig 6.2 [Output curve with respective to number of iterations for PID controlled process]

Figure shows the best possible result for the PID controller to the respective model. The overshoot, and instability of the result is clearly visible in the Figure 6.2.

VII.NEURO-FUZZY SYSTEM

Neural network and Fuzzy Logic, mimic the functioning of the human intelligence process. In other words, Neuro-Fuzzy technique is an intelligent technique, which adopts with the system or process and derives it effectively. Neuro-fuzzy hybridization results in a hybrid intelligent system that energizes these two techniques by combining the human intuition style of fuzzy systems with the learning and connectionist structure of neural networks [4].

Fuzzy logic is an approach to computing the appropriate value instead of the usual “true false” (1 or 0) Boolean logic, on which the modern computer is based. A Fuzzy Logic system follows a syntax shown in fig 7.1. The input to this system is the error (or the difference between the set-point and the measured value) and the change in the error. These inputs then follow some steps to be fuzzyfied.

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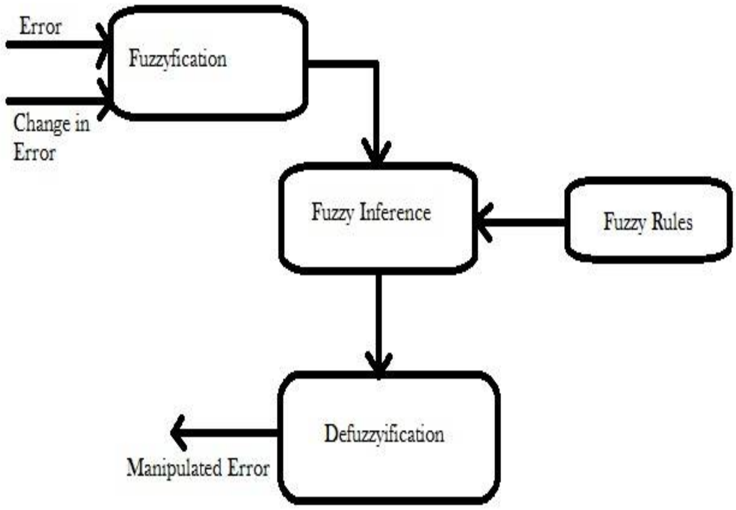

Fig 7.1 [Syntax of Fuzzy Logic system]

The very important part of the Fuzzy logic system is the Fuzzy Inference System (FIS). The fuzzy rules are evaluated with the fuzzy inputs and give the fuzzy outputs by the inference kernel. For the knowledge based engine, the membership functions helps in fuzzification and defuzzification. The Neural networks are used to tune the membership functions of the Fuzzy systems those are employed as decision making systems for the controlling subject.

A. Implementation of Neuro-Fuzzy technique

Here the error signal is not directly fed to the PID controller to deal with, rather the error is first manipulate by the Neuro-Fuzzy technique and then fed to the controller. The error and the change in error are fuzzyfied with the FIS which is designed with a number of rules or conditions.

B. Designed of FIS for the proposed system

Based on the data set, Neuro Fuzzy inference system (NFIS) simulation program, we have chosen the Sugeno-style inference, based on Takagi-Sugeno-kang method of fuzzy inference. Here the properties of the FIS system are given below.

Name='FIS'

Type='sugeno'
NumInputs=2
NumOutputs=1
NumRules=4
AndMethod='prod'
ImpMethod='prod'
DefuzzMethod='wtaver'

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C. The simulink models of the proposed system

We have various conditions to keep in mind. Some of them are, while the input temperature is constant or variable, the performance of the model while heater temperature is fix or dynamic. And the important thing, that can approve the validity of this model, i.e. effectiveness of the stirrer and heater to maintain the tank or process temperature.

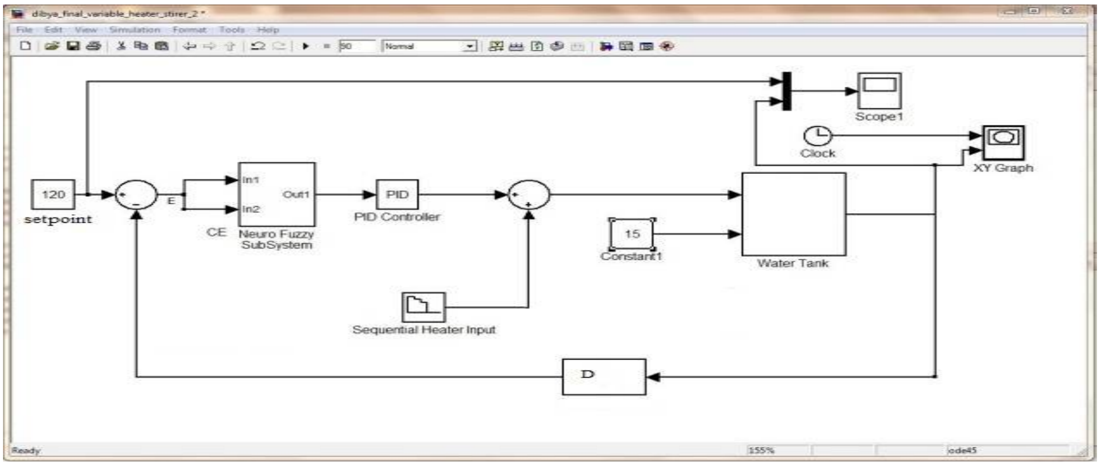

Fig 7.2 [Model tank output temp at 120 set point fixed input disturbance with heater operation]

Here the proposed model is driven by the Neuro-Fuzzy technique. The disturbance added to the tank or the process is the environmental temperature. In fig 7.2 the input disturbance is the environmental temperature which is kept constant as 15 degree Celsius. Following the temperature in the tank and the set-point we have taken, the heater is set to be operational as a part of automated control service and maintain the tank temperature. The simulation result of the model is shown in fig 7.4.

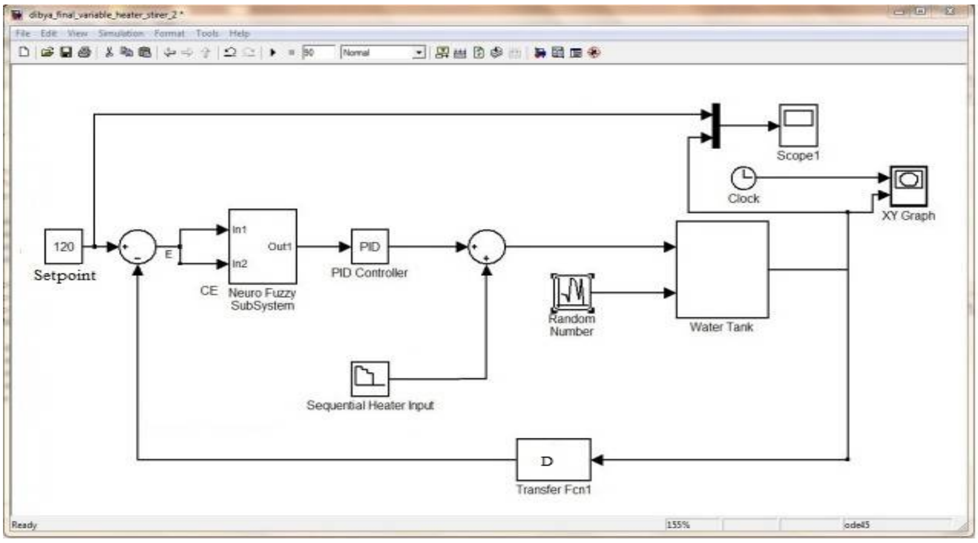

Fig 7.3 [Model tank op temp at 120 set point variable environmental temp with heater operation]

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In Fig 7.3 it has been shown that the simulink model is being tested with variable input, that is due to environment or climate changes the temperature of the natural water input to the condenser or the heat exchanger deviates. The following output temperature graph has been shown in fig 7.4 forming a comparison view between the model 7.2 and 7.3.

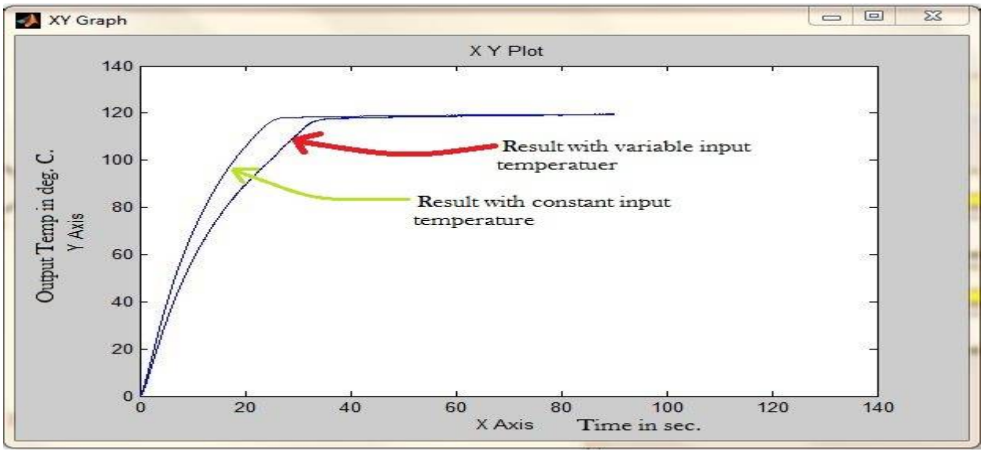

Fig 7.4 [Tank output temp at 120 set point with heater operation]

From the above output curves (shown in fig 7.4) we can notice the two curves indicating the temperature process control following two different conditions, one is fixed input temperature and the other one is a variable input. Here the tank temperature is lower than the set-point hence the heater operates to increase the tank temperature to the desired value.

VIII.CONCLUSION

In this paper it has been studied about the operation of the compensator to the temperature process control, the PID control and the process control using Neuro-Fuzzy PID system. Though the compensator compensates for a deficient performance but it has many issues like slow response, improving steady state error is difficult. To avoid such issues if we are using the Lead-Lag compensator, then the system will be more bulky and expensive. As we can notice from the above, for ZN-II tuned PID, the closed loop response has off-set and the responses are quite oscillatory and unstable. If the process condition changes, then the control system may become oscillatory and unstable. The overshoot indicate on the graph refers to poor response towards the stability of the system. In many processes, they cannot afford a overshoot beyond its permissible range. The stability factor is as much important as the error correction, which the PID fails to satisfy. Form this paper we have found that the Neuro-Fuzzy system gives a better result in almost all cases as compare to other methods of techniques. The continue error minimization and stability criteria is very impressive. The ability to maintain the temperature of the tank automatically by additional use of some devices like sensors, FPGA kit etc, a nonlinear system, which is difficult to model mathematically can be implored on the control system. This technique is very simple as a programmer just need to set the rules as per the operation of the process needs.

In future, we have planned to work on its practical implementation with more precision and better performance index.

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