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Design and Implementation of Intelligent Controllers for Pressure Process Station

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Abstract*: *Pressure Measurement is very essential parameter and an important one in pressure station. Excessive Pressure needs to be controlled before it affects the pressure station in any immediate situation. Pressure is one the parameter which is a basic key requirement for many industrial as well as control system applications such as industrial HVAC, Coating (CVD/PVD), Food and beverage industries, water treatment and etc., There are three main types of pressure measuring devices which are framed using these three pressure types are absolute, gauge and differential. The pressure transmitter plays an instrumental part while dealing with the pressure measurement in the process station. In this application, an intelligent network controller has been developed to minimize the settling error which is enveloped during the process. And also a neural network predictive controller, Fuzzy logic controller was drawn up for the operation and compared with ZN tuning PID controller. And these controller results are compared the standard error measurement. The errors of ISE, IAE and IATE are used for the primary comparison of the results acquired in these controllers.

Keywords: Fuzzy Logic Controller (FLC), Integral Absolute Error (IAE), Integral Time Absolute Error (ITAE), Integral Square Error (ISE), Neural Network predictive Controller, Ziegler Nichols (Z-N).

I. INTRODUCTION

In most of the industries and power plants controlling the parameters like temperature, flow, level and pressure is one of the important tasks in the system process. Pressure is by the way of measuring a force which is acting on the perpendicular motion and it is used to change the field. Thus pressure is one of the key control variables for the control process which we are implemented. The Figure 1 shows the pressure process station utilized for this work. The open loop test was conducted by giving pressure as input to the pressure station and take pressure as output in terms of psi unit. Then the model was identified using the data gathered from the open loop test. After that two different controllers were designed. One is fuzzy logic controller which uses IF and THEN rules. Then the next one is neural network predictive controller which comes by inspiring the biological neurons in human brain.

Fig.1 Pressure process station.

Pressure is one of the primary variable to control and maintain because it is one such critical for any industry. The change in pressure behavior adamantly will result in system failure and even cause huge explosion in the plant. Maintaining and pressure management using Yokogawa DCS is discussed [1]. Measurement related Decentralized WAN Predictive Controller for damping and SVC Compensation has been developed and deliberated [2]. To solve a liquid level of control problems with the change in unknown flow dynamics and the change in time delay. They have proposed a conventional PID controller designed from fuzzy logic algorithm was debated [3]. For resolving lamping lag and other problems in couple tank reactor an application and controller has been designed for liquid level measurement in the process application [4]. The detailed explanation about the fuzzy controller and its design from toe end to head end including a well-known has been discussed [5].

For an unknown object model, a system has DRN network. The optimized algorithm for multi-criteria nonlinear control system and designed the controller. They have designed a control algorithm and identified nonlinear system model based on feed forward and direct recurrent network base [6]. The optimized the algorithm for multi-criteria nonlinear control system and designed the controller [7]. A generalized introduction to the fuzzy logics and its linguistics terms using MATLAB have been discussed [8]. An RFNN algorithm based predictive control has been developed for the integral action in the nonlinear process system. The generalized predictive controller has been used for the industrial process using recurrent fuzzy neural network. The real time control application algorithm is developed for both the RLS and the law learning for RFNN was discussed [9]. A clinical approach has been developed for the nonlinear discrete dynamic system using neural network predictive controller. A complete new approach has been used to control the non-linear discrete dynamic impulse system which completely relies on the neural network model; a first order linear model has been developed and was detailed [10].

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The paper is discussed in the below manner: Section 2 deliberates designing of fuzzy controller. Section 3 deals with Pattern Search.

Section 4 discusses the Genetic Algorithm. Section 5 shows the simulation results of ZN-PID, PS-PID and GA-PID and compared using the performance evaluation. Finally, Section 6 completes how the GA-PID is better than ZN-PID and PS-PID.

II. FUZZY LOGIC CONTROLLER

FLC is an Artificial Intelligence based Algorithm Technique which indeed interprets a human action and it is implemented using MATLAB. Fuzzy Controllers are widely regarded as one of the best controllers for the applications of Industrial and Control Systems where control logics place a vital role. The general idea about fuzzy logic is to get a finite input values from the sensor and it transforms into a membership function values ranging from 0 to1. Fuzzy logic controllers are knowledge based controllers resides on "IF-THEN" constraints.

The initial phase in the fuzzy logic procedure is to characterize and introduce an input and output variable of the respective fuzzy controller. There is no general definitions or rules to select those variables but the variables are belongs to the states of controlled system. The fuzzy controller rules are usually in programmable ideal terms. The linguistic variables and the fuzzy sets implement the fuzzy theory and their procedures. The figure 2 shows design of fuzzy logic system.

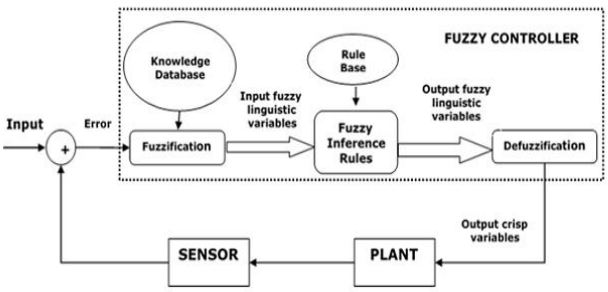

Fig 2.Architecture of Fuzzy Logic System

Fuzzy logic provides an alternative approach to other controller techniques like Ziegler-Nichols and it also outcomes the superior results. Ziegler-Nichols tuning method provides the control theory for controllers like PID with aid in the systems of controls. Fuzzy logic is a simple way of approach to control engineering application problems. Fuzzy logic mimics like how a single person or even a group of peoples would take a decision in such faster way.

A. Fuzzification interface:

The inputs are modified by the process and it will be analysed and interpreted with the Fuzzy rule-base.

B. Fuzzy Rule-base:

It contains a group of rules for controlling the overall application and process.

C. Inference mechanism:

It is like processing unit because it only decides which input is relevant to the current time and it has to take the decision that which input must go with the system.

D. De-Fuzzification interface:

It only switches the fuzzy result get through an inference mechanism in design process and sends the input into the plant.

Inference system classified into two categories, one is Mamdani then the other one is Sugeno system. There are some notable differences between the two is that Sugeno doesn't have membership function and no defuzzification process. The Figure 3 displays the Mamdani type fuzzy controller which is utilized for this work.

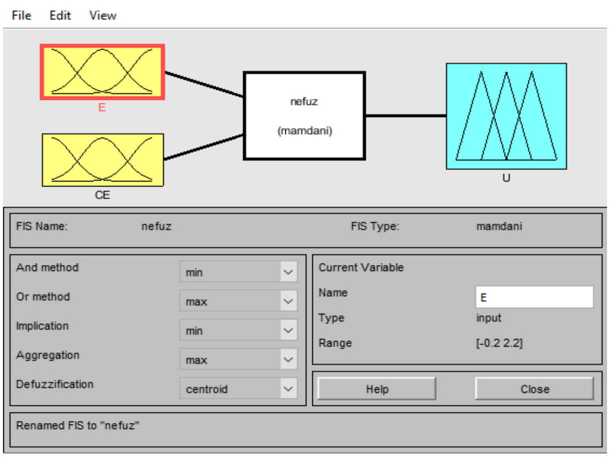

Fig.3.Mamdani type fuzzy controller

The surface viewer is output screen which is used to view the fuzzy logic system design output. Before viewing the output, it is important to define the device input, response, membership function and fuzzy rules etc. The Figure 4 displays the surface view of fuzzy logic controller.

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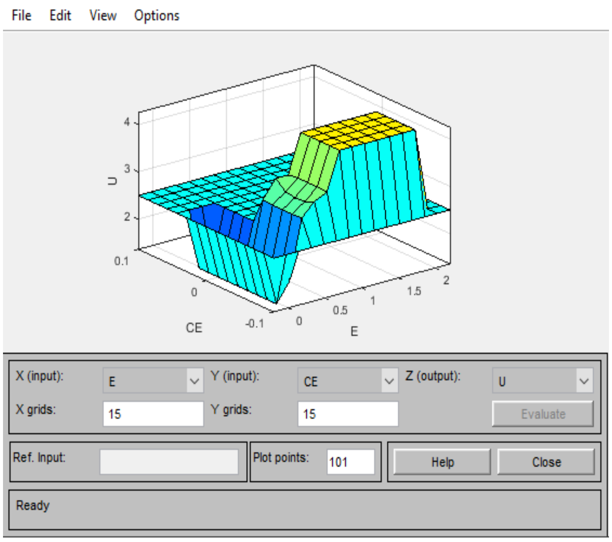

Fig.4.Surface Viewer of FLC

III. NEURAL NETWORK PREDICTIVE CONTROLLER

For the nonlinear process plant, the neural network predictive approach uses the system's network model to predict future output and its behavior.

Then the controller measures the control input and optimizes the output of the plant over a given predefined time span. There are several steps to be taken to build this specific type of controller. The principal step in predictive control of the controller is to establish a configuration for a network plant. And, for the controller, the plant model helps to estimate device output.

A. System Identification

The primary step is training the network to reflect the plant's forward dynamics. The estimated error is the variance between the response of the network and the output of the plant, which is used as a training signal for the neural network. The Figure 5 shows the process of system identification imitate the exact process of the controller by how it identifies the system model by giving an input to both the plant and to the neural network model. Then by comparing the values obtained from both the system, it tunes the neural network model.

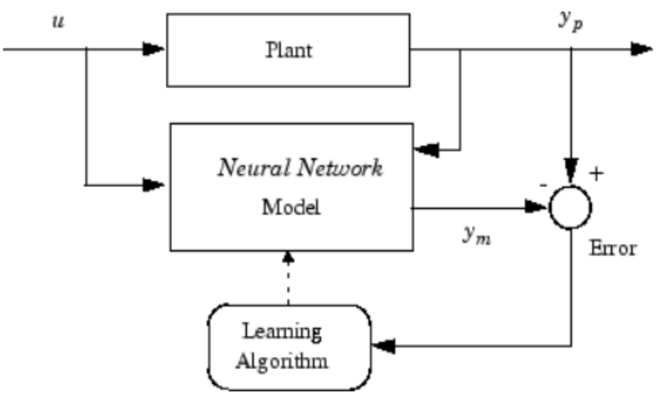

Fig. 5. Process of System Identification

The network model uses the previous input and output to estimate the values of plant output. And the following network is equipped in batch mode to be offline. By using the data obtained from the plant operation. Figure 6 shows an architecture of multilayer network model.

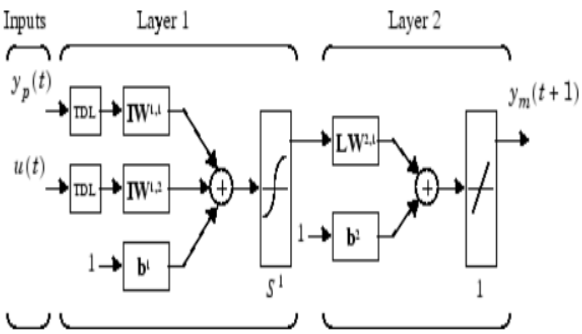

Fig 6.Multilayer network model

The Nonlinear dynamic system has an input and output will be prescribed by some neural model:

$$Y_m(k) = f_m(\varphi(k),\theta) \quad (1)$$

Where,

$Y_m(k)$ – Model output.

$\Phi(k)$ – Regression vector.

θ – Vector parameter.

B. Predictive Control

Predictive controller is purely based on the horizon technique which is an algorithm and control technique. There are various types of predictive controllers are used. But the most commonly used general predictive controller has the cost function is mentioned below,

$$J(k)=\sum_{l=1}^{N_R}[r(k+l) - y_m(k+l)] + \alpha \sum_{l=1}^{N_c} \Delta u^2(k+1-1) \quad (2)$$

Where,

$$\Delta u^2 = u(k+l-1)-u(k+L-2) \quad (3)$$

α = control signal weight factor.

It predicts plant dynamics for a predefined time period. The dynamics are used as optimized numerical program and to identify the control signal that minimize the performance of the predefined period of time.

$$J=\sum_{j=N_1}^{N_2}(y_r(t+j) - y_m(t+j))^2 + \rho \sum_{j=1}^{N_u}(u'(t+j-2))^2 \quad (4)$$

Where,

J - Objective function

N_1, N_2 - Min and max prediction horizon of the output

N_u - Control horizon

ρ - Control signal weight

u' - Control signal which is a tentative.

y_r - Systems desired response.

y_m - Neural network model's response

When the plant is designed and specified the inputs like no of samples, control horizon and cost horizon and when about to run the model.

The figure 7 shows a randomly generated plant output.

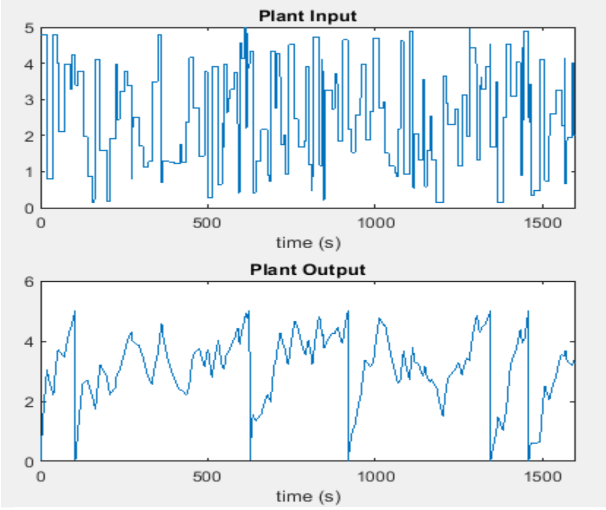

Fig.7 Random generated Input and plant model output

The randomly generated input will be feed to the system and based on the input, a response is generated and the error also generated which is as less than the -1 and not beyond. The Figure 8 gives the comparison of the response of the NN model and the response generated by the model.

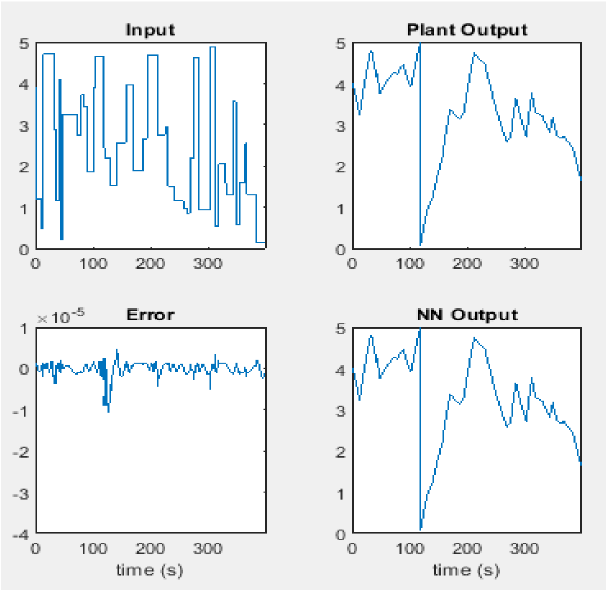

Fig.7.Comparison for output of the plant and neural network predictive output

IV. RESULTS AND DISCUSSION

The set point (40 psi) is given as input to the system. And the response obtained was evaluated using performance evaluation. The Figure 8 displays the response of the various controllers used for pressure process station. The orange color wave shows the response which is obtained from z-n network model. It shows that it has high overshoot and its peak response is also high. So there arise a help from another controller to minimize these errors. So the Violet color wave indicates the Fuzzy logic controller interface response. In that response, the rise time is high and does settle in sunmanned manner. So there comes a need for another controller. The yellow colour wave indicates the response of the neural network predictive controller model has better settling time, rise time than the other controllers.

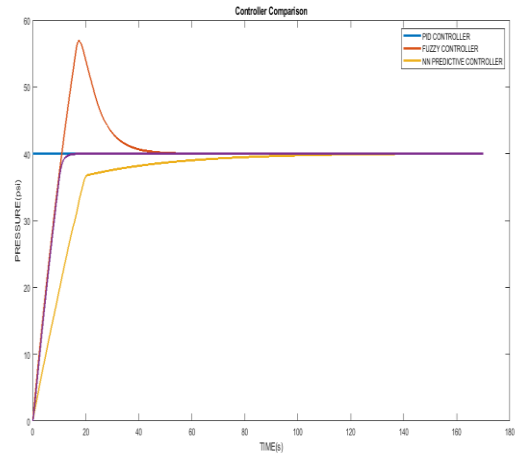

Fig.8.Simulation result of PID and Intelligent controllers

Table- I: Performance Comparison of Controllers

Controller	ZN	Fuzzy	Neural Network Predictive
IATE	397.2	246.6	45.81
IAE	25.91	20.19	10.97
ISE	27.64	18.68	14.29

This table I clearly show the values for each standard error like IAE, IATE, ISE pointed towards the Z-N, FL, NN controllers. Using these values, we can clearly understand that the NN predictive controller is superior than the other controllers.

V. CONCLUSION

The model has been identified and developed by using open loop test data. Then for controlling the pressure process station two intelligent controllers like Fuzzy logic and neural network predictive controller has been developed and the comparison is made with the conventional PID controller. The comparison was done by using standard error measurement methods. From the evaluation table of errors and simulated results, it is evident that the intelligent controller provides a superior performance than the conventional one. The main advantage of using the intelligent controller is it eliminates the overshoot and undershoot problem.

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