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Performance comparison between single & couple rectangular tank system using NNPID controller

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Abstract

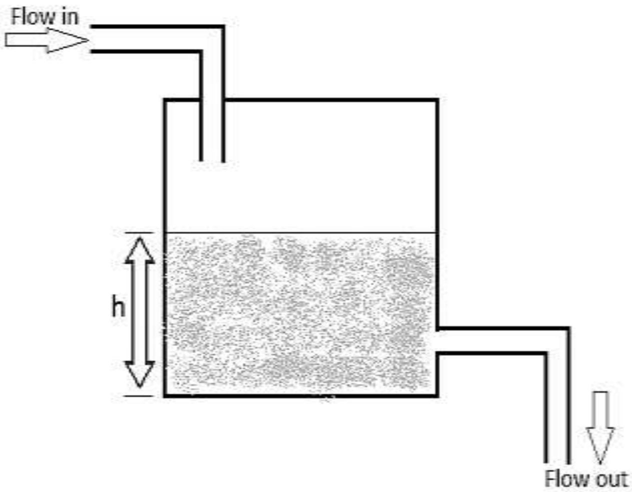
This thesis addresses Neural Network Based Predictive controller based control systems for coupled tank system. The first is a PID controller based control systems. PID controller tuning methods has been carried out. Neural Network based Predictive Controller and system Identification has been discussed where controllers are designed for single rectangular tank system, coupled rectangular tank system. Initially PID Controller is introduced for Single Rectangular Tank System. The controller is tuned by Manual Tuning Method and Ziegler-Nichols Tuning Method. For controlling these two systems Neural Network Based Predictive Controller is suggested. Block specification, system identification and Back propagation are also illuminated. The proposed technique shows the satisfactory result in terms of controlling the coupled tank system with fixed input and it is also executed in simulation and gives the satisfactory result. Finally process is reliable for nonlinear plant in simulation. At last, MATLAB coding produces different response curve for real time system which is also discussed in the paper.

Introduction

The control of liquid level in tanks and flow between tanks is a basic problem in the process industries. The process industries require liquids to be pumped, stored in tanks, and then pumped to another tank. Many times the liquids will be processed by chemical or mixing treatment in the tanks, but always the level of fluid in the tanks must be controlled, and the flow between tanks must be regulated. Often the tanks are so coupled together that the levels interact and this must also be controlled. Level and flow control in tanks are at the heart of all chemical engineering systems. But chemical engineering systems are also at the heart of our economics. Vital industries where liquid level and flow control are essential include; Petro-chemical industries, Paper making industries, Water treatment industries. The coupled tanks system can be extended in many ways. The next most interesting form is the multi-input coupled tanks. This is made with another pump supplying fluid to the second tank and the valve allowing fluid to leave the bottom of first tank. This makes a system with two interacting outputs and two inputs. The result is an interesting multivariable system with many control possibilities.

Mathematical Modelling & Derivation

- **Rectangular Single Tank System**



Flow out (f_{out}) depends upon the pressure in the tank depth (h) and density (ρ) of the fluid. ∴ $f_{out} = (R.\rho.g).h$

Where, $R = \frac{changeinleveldifference,\ ft}{changeinflowrate,\ ft^3/sec}$

$Steadystateliquidflowrate\ =\ Qft^3/sec$

$Steadystatehead = Hft$

$\therefore Q = k.H$

According to Coulomb's Law, for Laminar flow the resistance is,

$$R_l = \frac{dH}{dQ} = \frac{H}{Q}$$

And, for turbulent flow the steady state flow rate is, $Q = k\sqrt{H}$

$\therefore$ turbulent resistance$(R_t) = \frac{dH}{dQ} = \frac{2H}{Q}$

$\therefore Q = \frac{2H}{R_t}$;

$$ie.\quad capacitanceoftank(c) = \frac{changeinliquidstored,\ ft^3}{changeinhead\ ,\ ft}$$

$q_i = smalldeviationofinflowratefromitssteadystatevalue, \quad ft^3/min$

$q_o = smalldeviationofoutflowratefromitssteadystatevalue, \quad ft^3/min$

$h = smalldeviationofheadfromsteadystatevalue\ ,\quad ft$

$\therefore C.dh = (q_i - q_o).dt$ ……………………. (1)

From the definition of resistance, $q_0 = \frac{h}{R}$

By putting the value of q_0 in equation (1). We get;

$$C.dh = \left(q_i - \frac{h}{R}\right).dt$$

$$or,\qquad RC.dh + h = Rq_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots..(2)$$

Taking Laplace on both side of equation (2), we get;

$$(RCs+1).H(s)=R.Q_i(s)$$

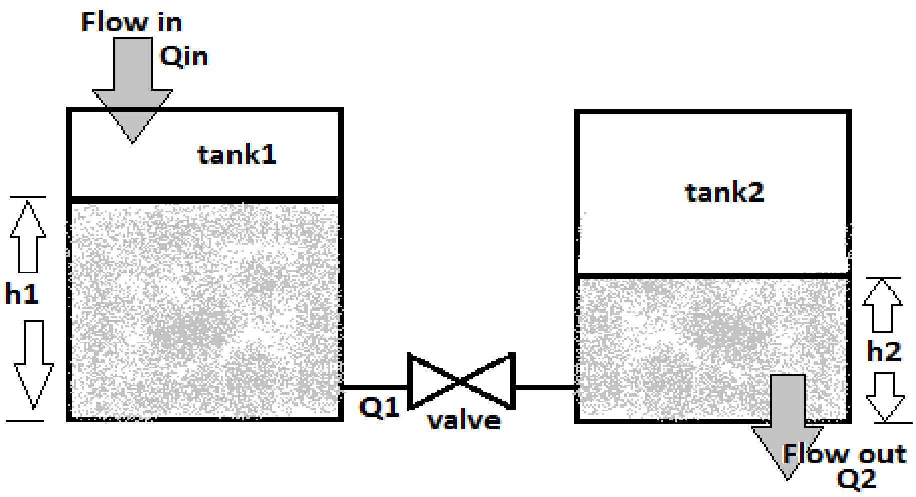
$$or, \quad \frac{H(s)}{Q_i(s)}=\frac{R}{RCs+1}$$

$$or, \quad Q_o(s)=\frac{1}{R}.H(s) \quad ;$$

$$\Rightarrow H(s)=R.Q_o(s)$$

$$\therefore \frac{Q_o(s)}{Q_i(s)}=\frac{1}{RCs+1}$$

- **Rectangular coupled tank system**



Mass-balance equation of tank 1 & tank 2;

$$A_1\frac{dh_1}{dt}=Q_{in}-Q_1 \dots\dots\dots\dots\dots\dots\dots\dots (1)$$

$$A_2\frac{dh_2}{dt}=Q_1-Q_2 \dots\dots\dots\dots\dots\dots\dots\dots (2)$$

Out flow of tank 1 & tank 2;

$$Q_1=K_1\sqrt{h_1-h_2} \dots\dots\dots\dots\dots\dots\dots\dots (3)$$

$$Q_2=K_2\sqrt{h_2} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (4)$$

By putting the value of $Q1$ & $Q2$ in equation 1 & equation 2, we get;

$$A_1\frac{dh_1}{dt}=Q_{in}-K_1\sqrt{h_1-h_2}$$

$$or, \quad \frac{dh_1}{dt}=\frac{Q_{in}-K_1\sqrt{h_1-h_2}}{A_1}$$

$$or, \quad \frac{dh_1}{dt}=\frac{Q_{in}}{A_1}-\frac{K_1\sqrt{h_1-h_2}}{A_1}$$

$$\therefore \quad \frac{dh_1}{dt}=\frac{Q_{in}}{A_1}-\left(\frac{K_1}{A_1}\sqrt{h_1-h_2}\right)$$

And, for tank 2;

$$A_2 \frac{dh_2}{dt} = K_1\sqrt{h_1 - h_2} - K_2\sqrt{h_2}$$

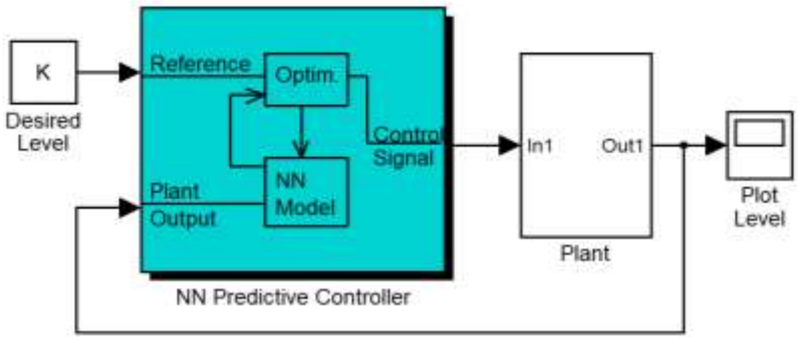
$$or, \quad \frac{dh_2}{dt} = \frac{K_1\sqrt{h_1 - h_2} - K_2\sqrt{h_2}}{A_2}$$

$$or, \quad \frac{dh_2}{dt} = \frac{K_1\sqrt{h_1 - h_2}}{A_2} - \frac{K_2\sqrt{h_2}}{A_2}$$

$$\therefore \quad \frac{dh_2}{dt} = \frac{K_1}{A_2}\left(\sqrt{h_1 - h_2}\right) - \frac{K_2}{A_2}\sqrt{h_2}$$

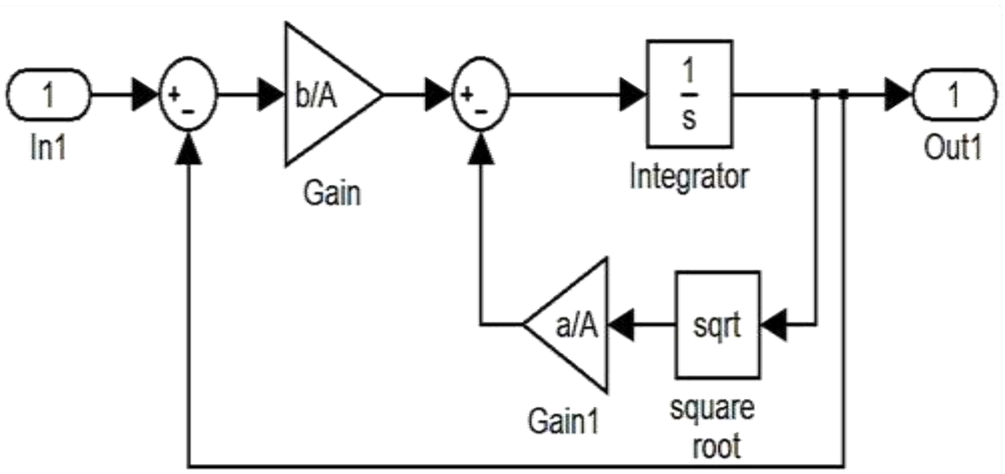
Matlab Block Diagram

This diagram is related with the project I have discussed here. In this diagram have given the variable real time input to the predictive controller and then controller output goes to the plant input and then the final plant output has given a feedback to the controller and then the controller controls the system with respect to some dataset.

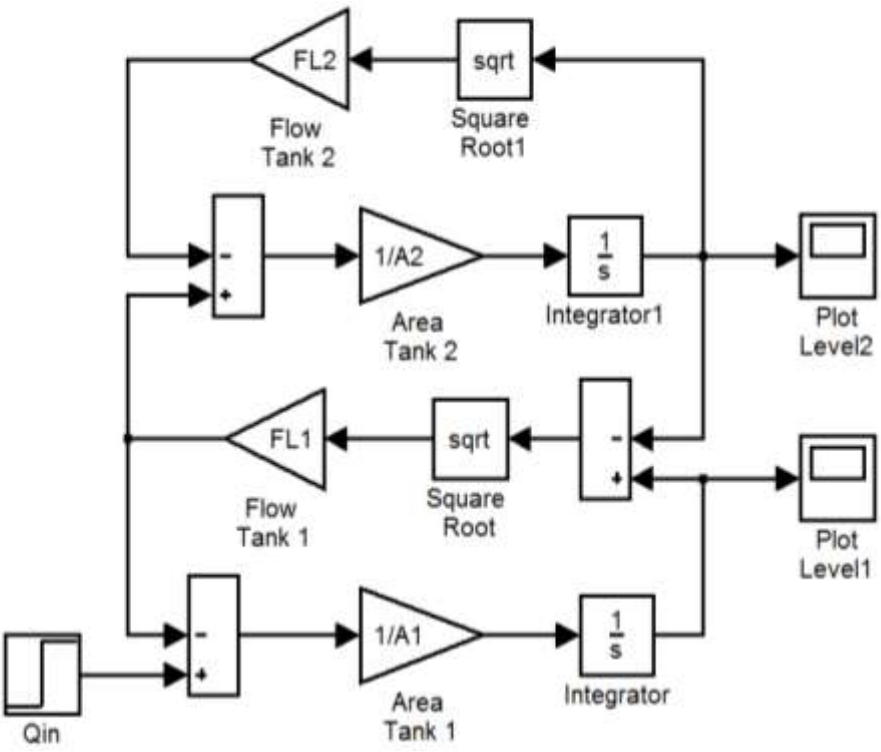


Using previous mathematical analysis of Rectangular tank system and rectangular coupled tank system I have designed this block diagram for this device.

- **Rectangular single tank system:**



- **Rectangular coupled tank system**



Result Analysis:-

- **Rectangular single tank system**

The single rectangular tank is totally a linear system. So, it can be controlled by the PID controller and as well as by Neural Network Predictive controller. By controlling the rectangular tank system we can get the following result

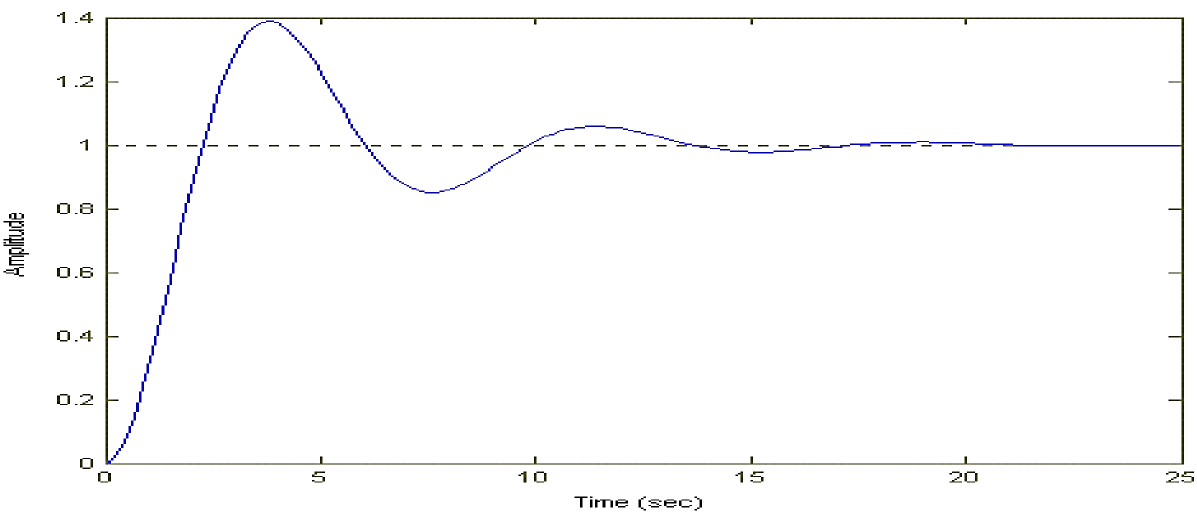


Fig. Response of single rectangular tank system tuned by PID controller

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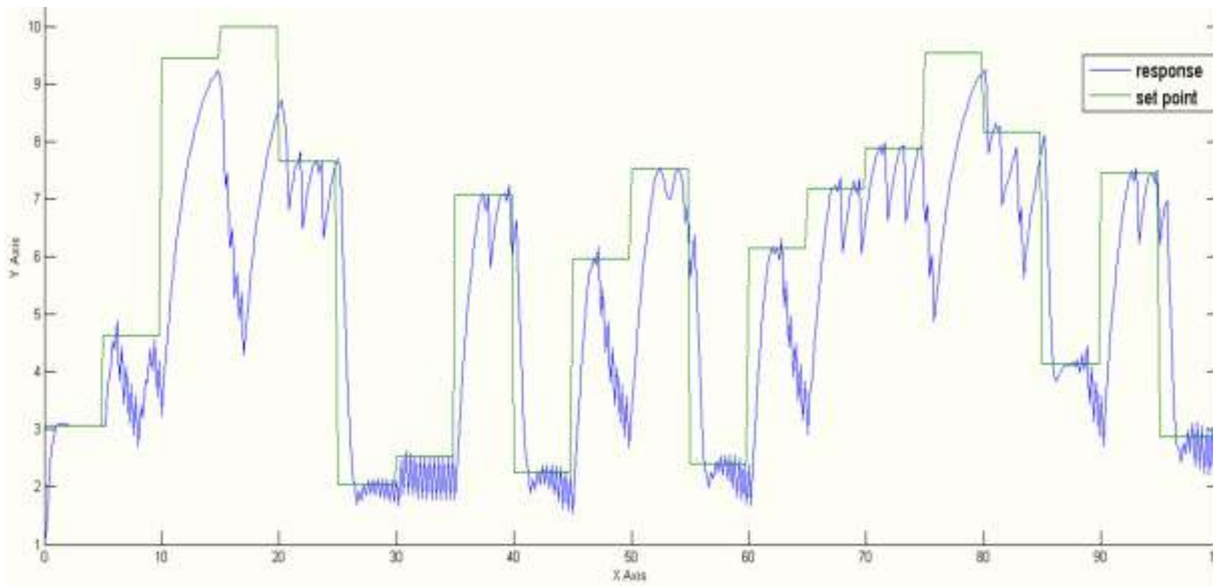

Fig. Response of single rectangular tank system tuned by NNPID controller

- **Rectangular coupled tank system**

The coupled rectangular tank is not totally a linear system. Because, the two tanks are connected with a valve. Initially, the valve is working as linear but, it becomes gradually nonlinear. So, it can be controlled by the normal PID controller. But, it can be tuned by Neural Network Predictive Controller. By controlling the rectangular coupled tank system we can get the following result

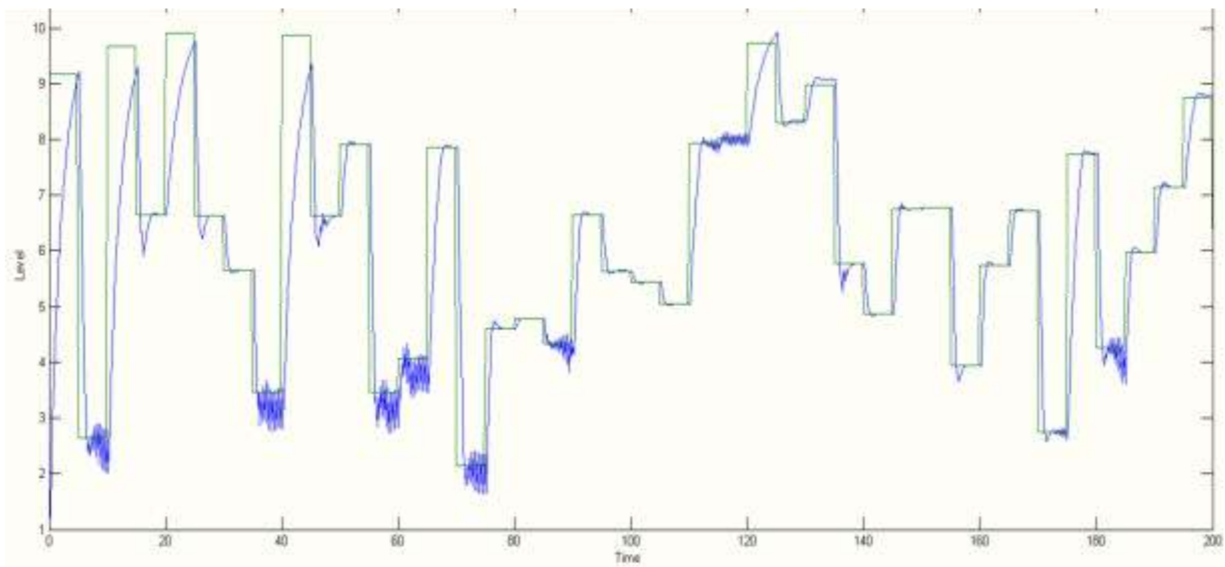

Fig. Response of rectangular coupled tank system tuned by NNPID controller

By controlling the system I also get the following response

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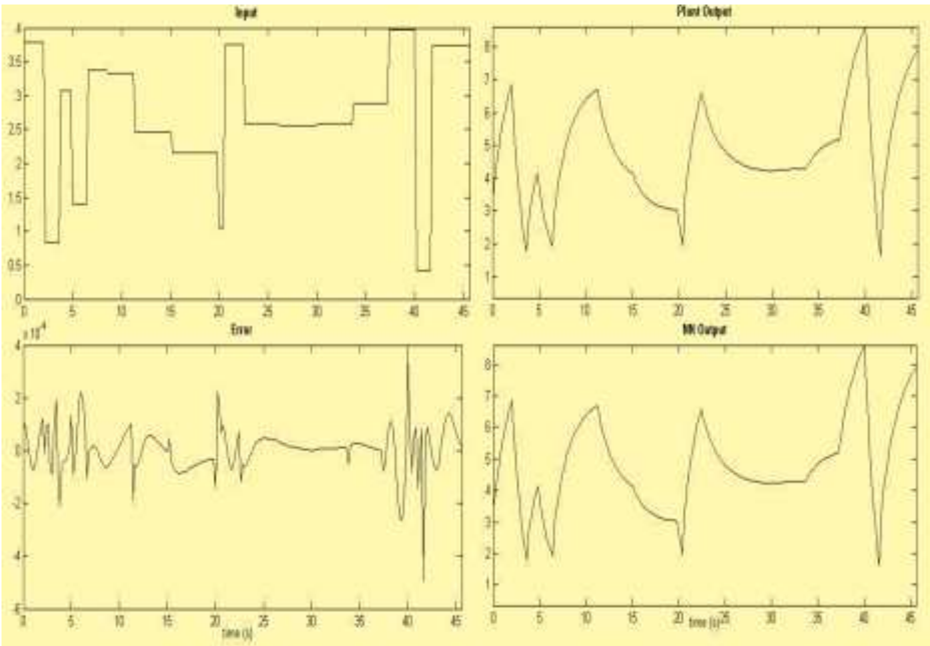

Fig. Response of training data

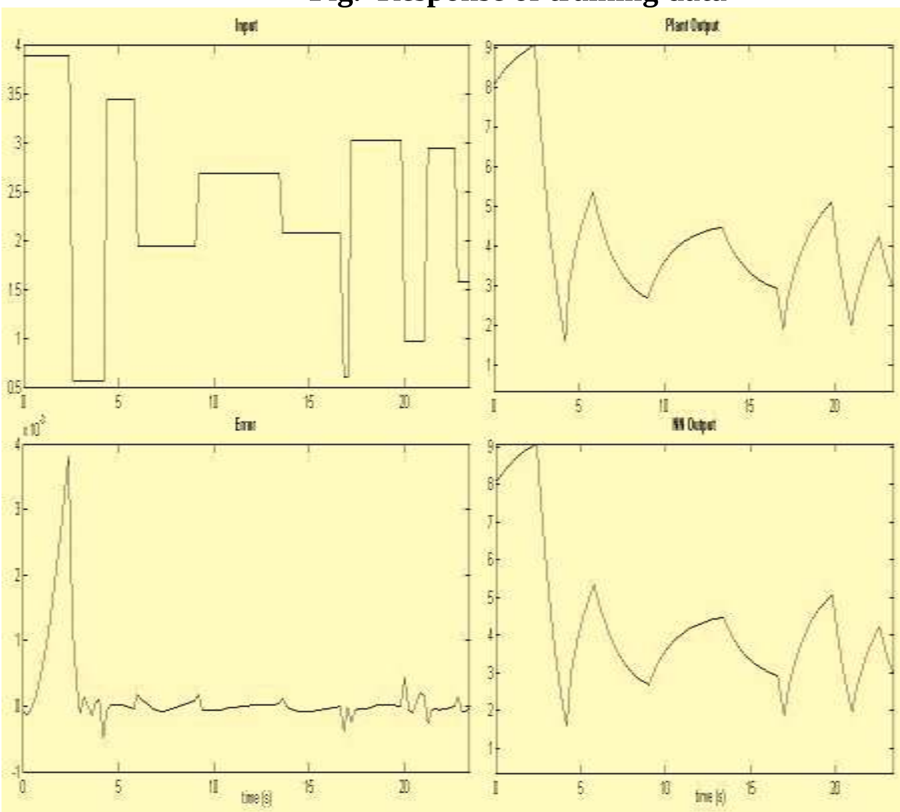

Fig. Response of validation data

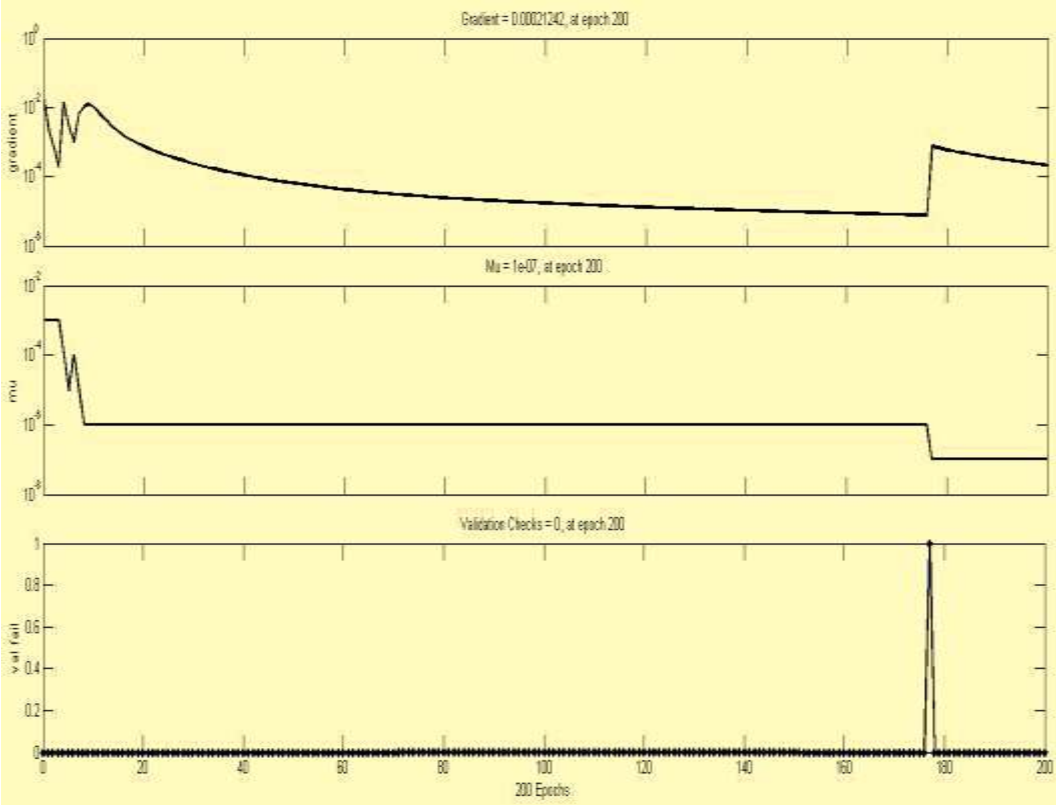

Fig. Response of training state

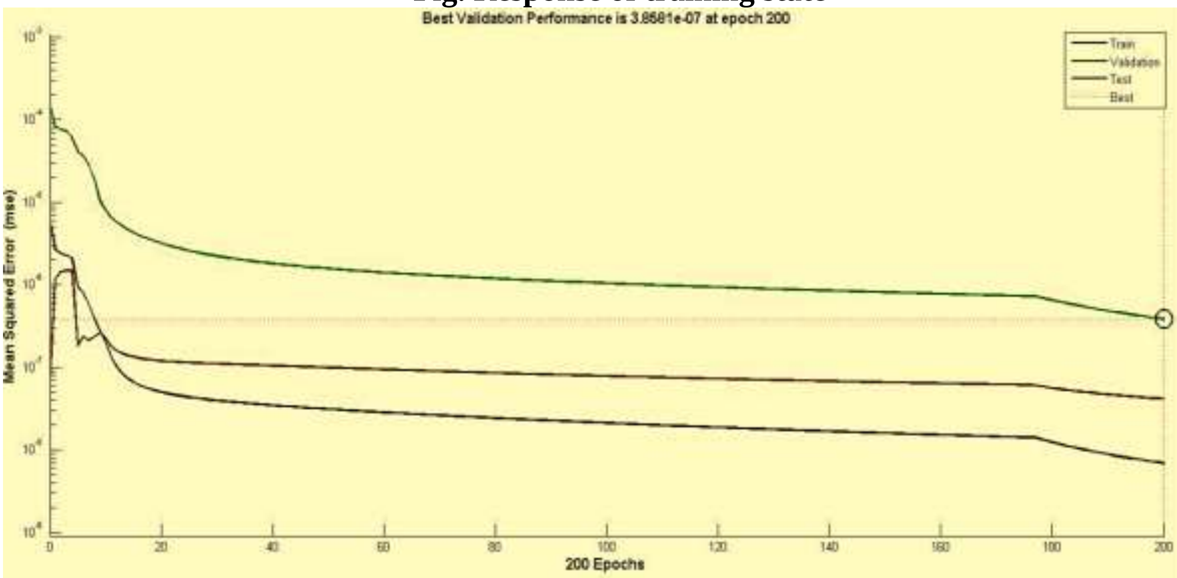

Fig. Response of training performance

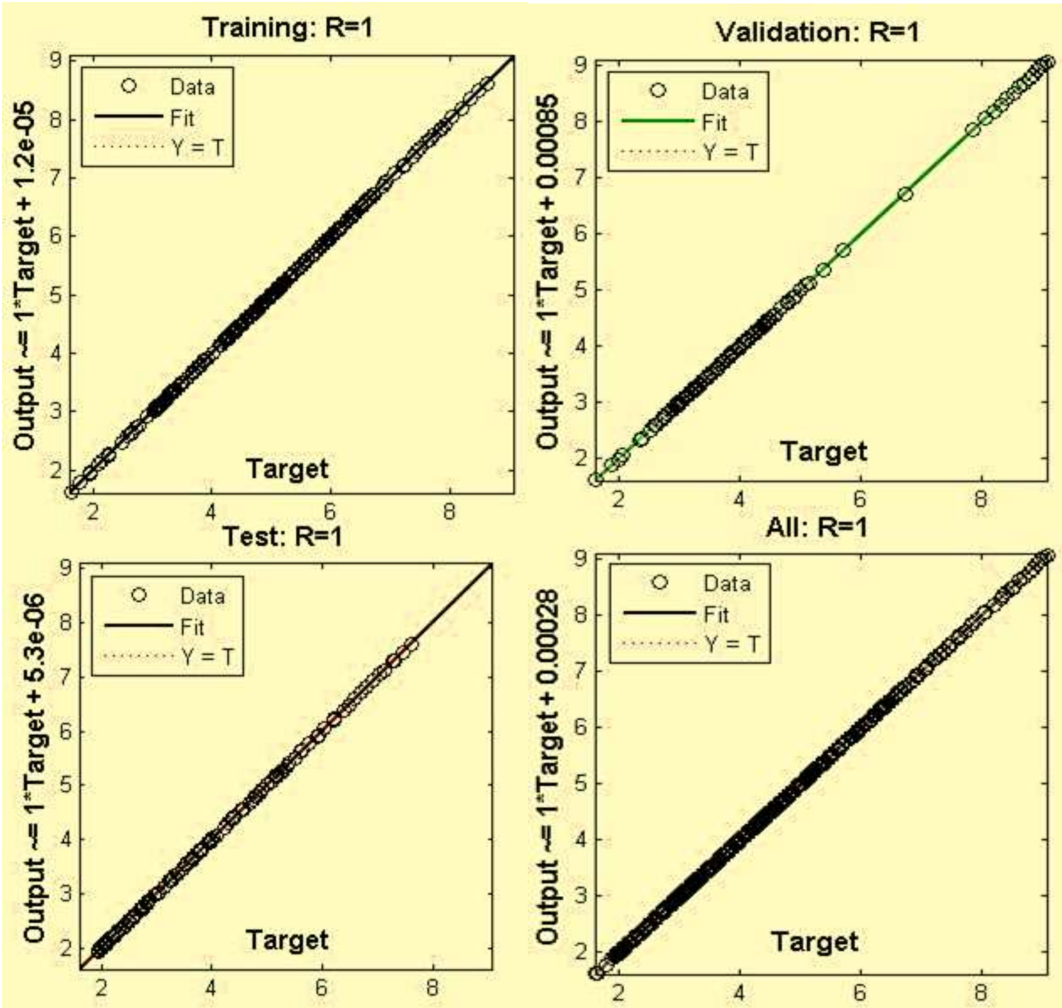

Fig. Response of training regression

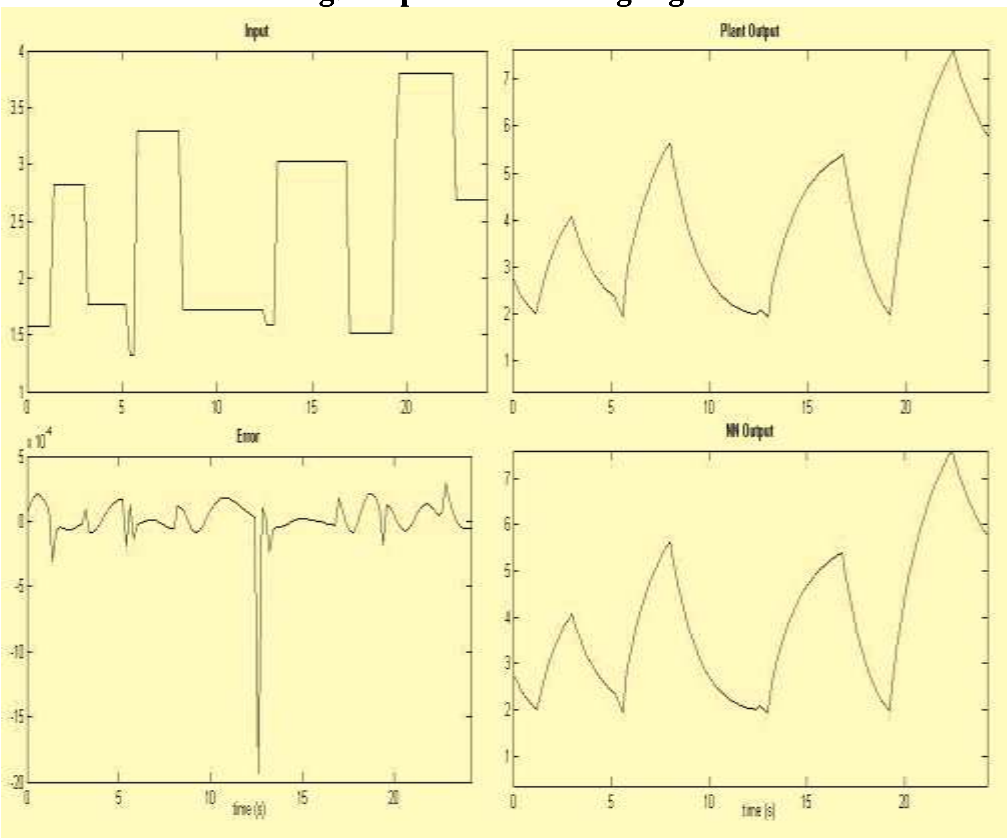

Fig. Response of testing data

Conclusion

The generalized predictive control algorithm is extended to non-linear plants by using a neural network based model for prediction. This concept was then applied to the plants. Methods for system identification were extended to ensure good excitation of the plant during training data generation for plants where standard methods such as level change-at-random-instances are done. A combination of random and controlled excitation yielded good results. The plant that the controller was tested on is a coupled tank system. It is a non-linear plant with constraints on both the plant states and on the control signal. The process of creating a neural network based model of the plant – also known as system identification.

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