Control of Air Conditioning Systems Using Neural Network

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***Abstract*—Nowadays air conditioning system is the necessity part of human life. The different controllers used for controlling air conditioning system like on-off controllers or PID controllers. But these controllers cannot give the sufficient response and consume high power. This paper aims to control the air conditioning system such that the output temperature of air conditioning systems are getting as required by the operator with fast response and low consuming power. For this purpose neural network controllers are designed which is feedback to the air conditioning system. We designed such neural network control system that speculates its own control law. The advantage of using neural networks are this controller is self-learning system and give the faster and better response with comparison to another controllers and give the zero overshoot output.**

***Index Terms*—air conditioning system, neural network controller, simulink model**

I. Introduction

From last few decades traditional ON-OFF controllers and conventional Proportional plus Integral plus Derivative controllers (PID) were used for controlling the Air Conditioning system. But these controllers don’t always produce desired and fast response due to dynamic characteristics of the systems. And tuning of conventional PID controllers was difficult. So in recent years intelligent control system are designed for controlling the air conditioning (AC) system. Neural network controllers are best option for controlling the system. By choosing suitable neural networks, learning method and input-output data the neural network can be learn the system states, to predict the future behavior of the system. Neural network controllers give the fast response and these controllers are reliable and robustness. The system which are linear or non-linear can be controlled by neural network because of neural networks have the ability to approximate arbitrator value through self-learning property. Due to this property of neural network the designed controllers make up the system uncertainties and system nonlinearities and make system response stable.

A numerous number of applications based on neural network controller are developed for temperature control. Generally temperature control systems are control by PID controllers. But decoupled temperature system can’t be controlled by conventional PID because of these system have large time constant with long delay time characteristics. Similar to this system, neural network with PID controllers are designed to control the system [1].

Controllers like on-off or PID controller were designed for ordinary AC system. With increasing uses of AC, the centralized heating ventilating and air conditioning (HVAC) system and air handling units (AHUs) are developed. For controlling these systems, neural networks based control systems are used. While by simple PID control system controlling of this system are difficult [2].

Application of neural network increases with time. The system which is uncertain and non-linear is control by adaptive neural network control to approximate and determine the characteristics of the uncertain nonlinear system with predictive compensation [3]. Some uncertain system has specified nonlinearities like non smooth nonlinearities. By taking certain well defined sign function and suitable neural network approximation to control the uncertain system with non-smooth nonlinearities [4]. Different temperature control system like Model Reference Control (MRC) and Non linear Auto Regressive Moving Average (NARMA) controllers used in industry for thermal treatment process. For better response nonlinear neural network controller were introduced in [5]. Some system has large inertia and pure lag compensation characteristics. This system can’t be controllable by simple PID controller. Similar to this system is variable frequency air conditioning system which has large inertia and lag compensation characteristics. Neural network PID controllers are introduced for controlling to this system [6].

Control system has suffering with problem of undesired response, overshoot, vibration and large settling time, if the system going from one state to another state. Although PID controllers are simple in structure intelligent control strategies have more advantages over different ordinary controllers. Optimal fuzzy logic controller using genetic algorithm remove the problem of overshoot, vibration and large settling time and give the desired response while system specification change [7].

With improvement of living standard of human life application and model of air conditioner developed like Variable Air Volume (VAV) air conditioning system. Controlling of AC for long time in a day require. Neural network using data mining with association [8] were used instead of simple neural network structure to remove the

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time factor problem and control the VAV air conditioning system.

For designing of controller for air conditioning system studied, modeling and simulink of DC motor with compressor [9] is necessary. Air conditioner comfort the human life but there is problem in using of air conditioning system one is performance and life of air conditioning system and second is power consumption. We design a controller using neural network for controlling Air Conditioning system and compare the result neural network controller with traditional PID controllers.

II. Neural Network Controllers

Here we are using neural network for controlling air conditioner. ON-OFF controller and conventional PID controller is already design for this purpose. But due to change in temperature, external environmental conditional ON-OFF controller failed for controlling the system and the tuning of PID controllers are difficult for states change of system. So for the complex system we are using neural network structure for controlling air conditioning system. Controlling of temperature of system in industry, which have long delay time and large constant is controlled by [10]. A PID controller can be used for variable frequency air conditioning system but the richness of PID is weak whenever the parameters of model are changes [11]. The proposed control scheme for controlling air conditioning system gives the improve result. Result of proposed controller is compare with result of conventional PID controller.

Artificial neural network is an information processing system and it has some characteristics same as biological neural network. Intelligent control strategies can design a method that can estimate any signal for getting desired response without assuming signal behavior. A neural network control strategy is one of the intelligent control strategies.

Any neural network can be characterized by its three parts. Fist part is the architecture of neural network means the method for connection of neurons. Second part is the training, or learning or algorithm for determining the weights and last part is the activation function. The neural network architecture can be described in three parts:

- Input Layer – The input layer has input neurons which are the state of the system. The output of the system (air conditioner) at different time which is desired at that time is input to the neural network controllers.
- Hidden layer – The neuron in this layer is known as hidden neuron which performs different activation function. The activation function of hidden layer's neuron of proposed controller is tan sigmoid (tansig) function.
- Output layer – The output layer contains two output neurons. The activation function of the output layer's neurons is the hyperbolic tangent sigmoid function. A simple structure showing the different layers of neural network in Fig. 1. Equations of input and output for different layer are described below.

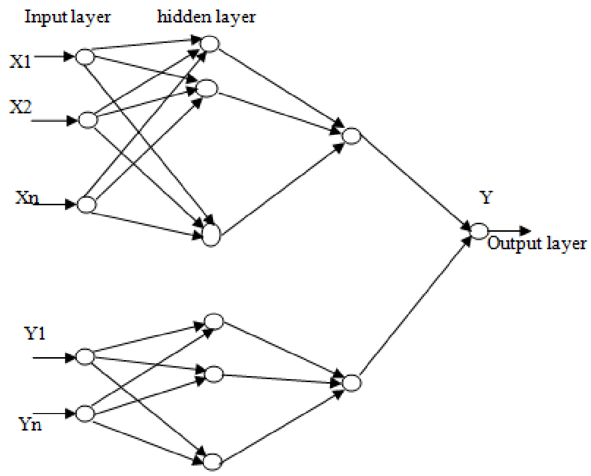

Figure 1. Structure of neural network.

In Fig. 1 output from the input neuron of input layer can be expressed by following (1).

$$I_j^1 = x_j \quad \text{where } j = 1,2,\ldots\ldots\ldots \tag{1.1}$$

$$I_k^1 = y_k \quad \text{where } k = 1,2,\ldots\ldots\ldots \tag{1.2}$$

where I_j^1 and I_k^1 is the output of the j^{th} and k^{th} input neuron of the input layer. The number of input layer's neurons are j and k. these neurons lies on the complex degree of controller used for air conditioning system.

The input apply to the hidden neurons of the hidden layer can be expressed by following (2).

$$\mathrm{net}_l^{(2)} = \sum_{j=0}^{X} W_{lj}^{(2)} * I_j^{(1)}$$

$$\mathrm{net}_m^{(2)} = \sum_{k=0}^{Y} W_{mk}^{(2)} * I_k^{(1)} \tag{2}$$

here $\mathrm{net}_l^{(2)}$ and $\mathrm{net}_m^{(2)}$ are the input to the hidden layer's neurons. Input for l^{th} neuron of hidden layer is $\mathrm{net}_l^{(2)}$ while for m^{th} neuron of hidden layer's input is $\mathrm{net}_m^{(2)}$. $W_{lj}^{(2)}$ and $W_{mk}^{(2)}$ are the weights of hidden layer.

The following (3) can be expressed as the output of the hidden layer's neuron.

$$H_p^2 = f_1[\mathrm{net}_l^{(2)}]$$

$$H_q^2 = f_2[\mathrm{net}_m^{(2)}] \tag{3}$$

where $f_1[..]$ and $f_2[..]$ are the activation function for hidden layer's neurons. Here tan sigmoid is used as the activation function in hidden layer. Here $f_1[..]$ activation function means $f_1[..]$ = tansig(x) while $f_2[..]$ = tansig(y).

The input (4) applies to the output neurons of the output layer.

$$\mathrm{net}_n^{(3)} = \sum_{p=0}^{X} W_{np}^{(3)} * H_p^{(2)}$$

$$\mathrm{net}_o^{(3)} = \sum_{q=0}^{Y} W_{oq}^{(3)} * H_q^{(2)} \tag{4}$$

The (5) for output of the output layer's neuron can be given.

$$H_r^{(3)} = g_1[net_n^{(3)}]$$
$$H_s^{(3)} = g_2[net_o^{(3)}] \quad (5)$$

here g_1 and g_2 both are tan sigmoid activation function of output layer's neuron. $W_{np}^{(3)}$ and $W_{oq}^{(3)}$ are weights for output neurons. Here used neural network are self-learning system so these weights are adjusted by themselves as required response.

A simple block diagram of neural network controller with air conditioning system is shown in Fig. 2. Neural network is directly used here to controlling the air conditioning system. The neural network controller has two inputs, first input is measured compressor's temperature and second input is the output of controller which feedback to control system. The control signal apply to the air conditioning system is optimized signal of controlled signal by neural network controller and desired reference temperature by operator.

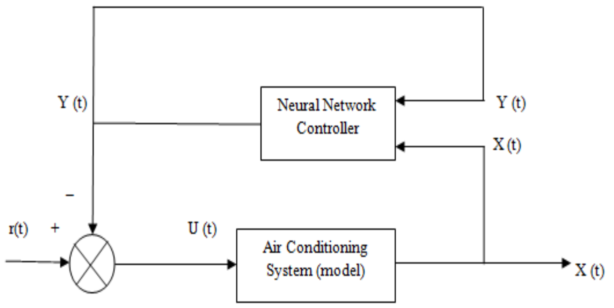

Figure 2. Block diagram of proposed controller.

The mathematical equation for the neural network model is given by (1). The output of neural network model can be defined as

$$Y(t) = f\{y(1), y(2) \dots\dots\dots. y(n), x(1), x(2) \dots\dots\dots. x(m)\} \quad (6)$$

The output value of neural network model Y(t) is feedback to neural network model and output of the air conditioning system x(t) inputs apply to the neural network model.

The output of neural network Y(t) compare with the reference input given by the operator and optimizing the control input. This control input signal applies to the air conditioning model.

III. Modeling of Air Conditioner

Cooling of a room, whole house, or entire business room is done by Air-Conditioner. Air Conditioner uses chemicals like Freon, or R-410A. These chemicals can be converting easily from a gas to liquid and vice versa. Transformation of heat from the air inside of home to the outside air is done by these chemicals.

Air Conditioner has three main parts first is compressor, second is condenser and last is evaporator. Compressor and condenser are placed outside to the air portion of the air conditioner. The evaporator is placed inner side of the house. Compressor is used for compressing the cool and low pressure gas. Condenser is used for cooling the hot gas from compressor and converts high pressure gas into liquid under high pressure. Evaporator evaporates and liquid change into gas.

Controller of air conditioner means controlling of speed of DC motor used for compressor. Temperature of air conditioning system depends upon the speed of compressor. So by controlling the speed of air conditioning system we can control temperature and can get desired temperature set by operator.

Generally brushless DC motor drive is used for Air Conditioning compressor. Electrical equivalent circuit of DC motor is shown in Fig. 3.

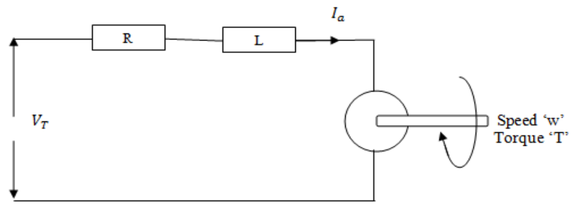

Figure 3. Equivalent circuit of DC motor.

Applying Kirchhoff voltage law (KVL) to equivalent circuit.

$$V_T - E_b = R * I_a + L * \frac{dI_a}{dt} \quad (7)$$

Torque of the motor can be written as

$$T = K * I_a \quad (8)$$

where K is torque constant.

The generated voltage

$$E_b = K * \omega \quad (9)$$

By using (7) and (9)

$$V_T - K * \omega = R * I_a + L * \frac{dI_a}{dt} \quad (10)$$

$$J * \frac{d\omega}{dt} + b * \omega = K * I_a \quad (11)$$

Using these equation block diagram of DC motor is shown in Fig. 4. Here we used direct neural network controllers. Whenever compressor temperature increase or decrease then neural network set the value of temperature to a limit such that the output of air conditioning system means output temperature of compressor will be same as the desired or reference temperature given by the operator.

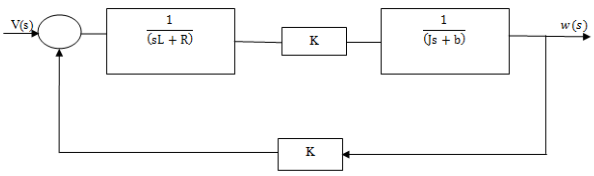

Figure 4. Block diagram of DC motor

IV. Simulink Model of Controller

Assigned values for our desired air conditioning DC motor model are following

J = 0.2; b = 1;

K1 = 0.23; K2 = 0.5;

K = 1;

L = 0.01; R = 1;

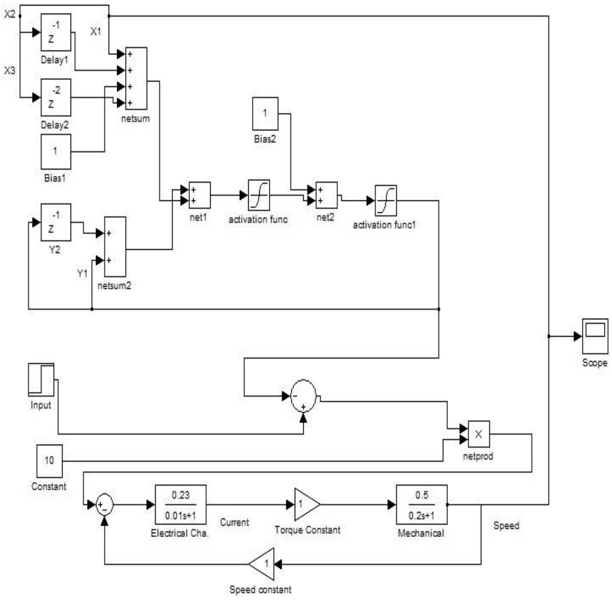

Figure 5. Simulink model of NN controller

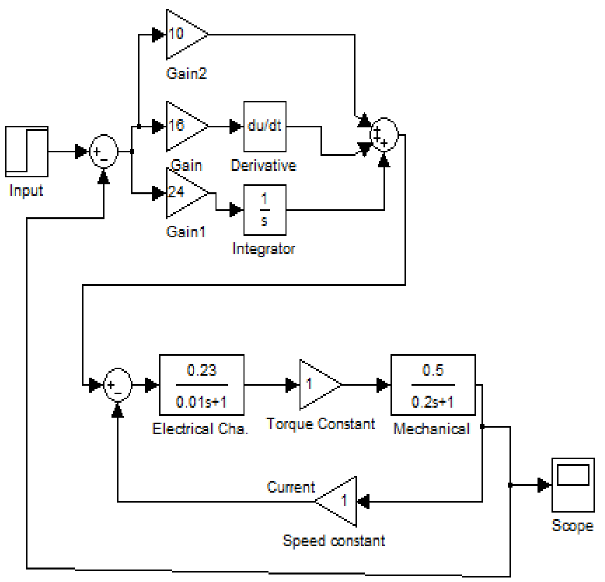

Figure 6. Simulink model of PID controller

A. *Simulink of NN Controller*

Fig. 5 shows the simulink model of controller with air conditioning system. Here neural network is self-learning system. There is no need in modification or changing in neural block or activation function if there is change in reference speed (denote the temperature of air conditioning system) by the operators. The neural network controller receives data from output of air conditioning system and output of self-block as input to controller. The output of controller is such that the output of air conditioning system is very close to desired response.

In any case if the output of the air conditioning system is not close to desired response by operator, then output of self-learning neural network controller adjust themselves in such a way that the output response of the air conditioning system becomes very close to the desired output response set by the operator. Here the activation function of both layer hidden layer and output layer is tan sigmoid function. General form of tan sigmoid function is defined as

$$S(x) = \tanh(nx) = \frac{e^{nx} - e^{-nx}}{e^{nx} + e^{-nx}} \qquad (12)$$

B. *Simulink of PID Controller*

PID model for air conditioning system is shown in Fig. 6. Here proportional gain $K_P = 10$; derivative gain $K_D = 16$; and integrated gain $K_I = 24$; are chosen for speed control of DC motor model. Input speed 27.64 is applied to PID controller specified by operator's speed. The output of this controller is compared with result of proposed Neural Network Controller.

V. Result and Discussion

The output response of both PID and Neural Network controller is shown in Fig. 7. Transient response of Neural Network controller and conventional PID controllers are compared with each other as shown in Table I. Neural Network controller gives the better performance for controlling the speed of compressor compared to conventional PID controller. Fig. 7 and Table I shows the response of Neural Network controller is fast and smooth with compared to conventional PID controller. Overshoot of NN controller is zero. Hence energy consumption is less and compressor's life increase.

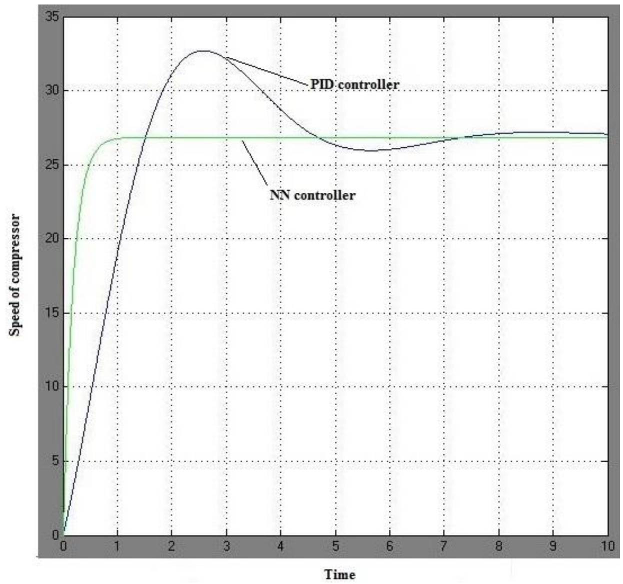

Figure 7. Simulation result of NN and PID controller

TABLE I. Transient Response of NN and PID Controller

Type of controller	Rise time	Overshoot
Conventional PID controller	1.15	5.57
NN controller	0.39	0

VI. Conclusion

PID controllers have simple structure but for large operating range tuning of PID controllers are difficult and can't give desired response. To remove these difficulties neural network controller is designed which is gives the fast and desired response.

In this paper neural network control strategy for air conditioning system is introduced. The neural network structure is simple and self learning system. The temperature control response of air conditioning system is getting better and improved as compared with conventional PID control system. We get fast and desired response of air conditioning system as set by operator.

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