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Effect of Operation Conditions on Exit Water Temperature of Condenser (Atmospheric) by Using Neural Network

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Abstract

The goal of this research is the determination exit water temperature of a condenser (atmospheric) use in steam power plant by artificial neural network with various operation conditions. Input of neural network include surface area, inlet water temperature, water flow rate, steam temperature, enthalpy difference and steam flow rate. Output of the neural network consists of the exit water temperature. For the subject of the neural network, training or learning algorithm are applied the most famous of which is back propagation algorithm. This algorithm is a systematic method for training multi layer artificial neural network. The real exit water temperature first using experimental work and is defined as a goal function for neural network (NN) , so that all outputs of the network can be compared to this function and the error can be calculated. Then another a set of input from experimental work was used to test the NN, the performance of the NN is optimum. Compared with a validated first model, the standard deviations of neural network models are less than 0.12%, and all errors fall into $\pm 1\%$**.**

Keywords: heat transfer, atmosphere condenser, neural network, Exit water temperature

الخلاصة

فائدة هذا البحث هو حساب درجة حرارة خروج ماء مكثف يعمل بالضغط الجوي في محطة توليد قدرة بواسطة الشبكة العصبية ولظروف عمل مختلفة. قيم الإدخال للشبكة العصبية هي المساحة السطحية لانتقال الحرارة، درجة حرارة دخول الماء، معدل تدفق ماء التبريد، درجة حرارة البخار ، فرق المحتوى الحراري ومعدل تدفق البخار. مخرجات الشبكة العصبية هي درجة حرارة خروج الماء . اعتمدنا اشهر طريقة للتدريب وتعليم الخوارزمية وهي Back propagation algorithm. هذه الخوارزمية لها طريقة منظمة لتدريب الشبكة العصبية الاصطناعية متعددة الطبقات.القيم الحقيقة لدرجة حرارة خروج الماء يتم الحصول عليها من الجانب العملي للبحث وتعرف كأنها هدف الشبكة العصبية لذلك كل نواتج الشبكة يمكن مقارنتها وحساب الخطأ. تم استخدام قيم عملية أخرى لاختبار الشبكة العصبية وطبقا للنتائج آن أداء الشبكة العصبية متكامل. ومن مقارنة نتائج الشبكة مع قيم الجانب العملي وجدنا انحراف معياري اقل من 0.12% وكل نسب الخطأ اقل من $\pm 1\%$.

1. Introduction

The main advantages of incorporating a condenser in a steam power plant increase expansion ratio of steam and thus increase efficiency of the plant, the reuse of condenser (condenser steam) as feed water for boilers reduces the cost of power generation and the temperature of condensate is higher than that of fresh water. [1] Therefore the amount of heat supplied per kg of steam is reduced. Study of thermal profile of condenser working need to find exit water temperature and water properties based on average water temperature. Since the traditional approaches are not always feasible to deal with complex heat transfer processes, neural network (NN) is an alternative approach which doesn't deal with the details of heat transfer process. In open literature, applications of NN to steady-state thermal problems can be classified into three types, including prediction of hest transfer coefficients, optimization of heat exchangers and prediction of heat exchangers performance. Qasim M.doos [2] presented a neural network model on a power station in al-doura refinery for the multi agent process as a classifying system to improve the process real time performance. The model is able to lean the rules and the parameters accurately with low cost, high performance and less effort. . K.Medjaher[3],presented a simulation model for a vertical U-tube steam condenser , The storage of hydraulic and thermal energies is represented using a coupled pseudo-bond graph model. The simulation results obtained from the bond graph model are validated with experimental data from a laboratory set-up. Kwangkook Jeong, [4] present an analytical model of heat and mass transfer processes in a flue gas condensing heat exchanger system. A pilot-scale heat exchanger was used to validate the analytical model. The experimental results show a very good agreement with analytical model results. S. Pourmohammad [5] is proposed a feed-forward neural network to extract Fuzzy Hyperbolic Model (FHM) of industrial plants.

Boiler-Turbine system is considered as a case study to show how the proposed ANN can be used to extract the fuzzy model. The obtained model is validated by some input-output data provided from the reference model. Simulation results proved the effectiveness of the offered neural network in extracting the fuzzy model of the plant. Several investigators (A.Abbassi[6] ,H.Metin Ertunc[7] ,H.M.Ertunc[8]) have proposed artificial neural network modeling with experimental or theoretical work for evaporator condenser, Results obtained indicate that artificial neural network controller is suitable substitute for hardware controllers for thermal systems, Although it was observed that ANN model yielded a good statistical prediction performance in terms of correlation coefficient, mean relative error, root mean square error and absolute fraction of variance. The focus of this study is built neural network depended on experimental data and more accurate thermodynamics properties by using Engineering Equation Solver (EES) to testing and training model of atmospheric condenser operating in steam power plant to give more approach data with actual case.

2. Engineering Equation Solver (EES):

EES automatically identifies and groups equations that must be solved simultaneously. This feature simplifies the process for the user and ensures that the solver will always operate at higher efficiency.

EES provides many built-in mathematical and thermophysical property functions useful for engineering calculations. The large data bank of thermodynamic and transport properties built into EES is helpful in solving problems in many engineering applications. [9]

3. Neural network basics :

Neural networks have been applied in many fields (Aerospace Automotive Banking Defense Electronics Entertainment Financial Industrial Insurance Manufacturing Medical Oil and gas speech Securities Transportation). Neural network, as a non-parametric approximate is used to fit curves through given data without being provide a predetermined function. Many types of neural network have been invented and well-developed. Since neural networks are adaptable to an evolving environment and are able to take a quick decision once they have learned the proper control function. Artificial neural networks (ANN) because they are cost-effective, easy to understand and their ability to learn from examples, have found many engineering applications, to estimate variables that usually can be measured or calculated.

4. Condenser database modeling :

Sufficient data samples are necessary for NN model development. It is almost need to take more accuracy data from actually cases to represent any model. Condensers operating with little efficiency in local steam power plants because of the bad conditions and old life of work. Two units steam power plant was intended for training purpose of worker staff from G.U.N.T Company used to result sufficient data for NN training and testing. Experimental devices were carried out to validate the data for NN modeling. Fig. (1) Show the overall experimental set up of first unit steam power plant (ET 810). The experimental setup consisted of feed water tank, feed pump, gas-heated boiler (flam tube-flue tube) for generation of steam, a double-acting single cylinder piston steam engine with generator, Micro motor as engine load, Atmospheric condenser , Measurement of temperature – pressure - flow rate - speed , and safety equipment .Transfer heat area of condenser is (80 cm^2), the maximum cooling water consumption is (100 L/h) .

Fig. (1) Single cylinder steam engine from G.U.N.T.

Fig. (2) Show the overall experimental set up of second steam power plant (ET 813.01). The experimental setup consisted of electrically heated steam generator , The steam engine is an enclosed two – cylinder machine with 180□ crank offset with dynamometer , Atmospheric condenser , The condensate tank is designed as a cascaded tank and separates oil from the steam engine , condensate pump , Measurement of temperature – pressure - flow rate - voltage – current , and safety equipment . Transfer heat area of condenser is ($380\ cm^2$), the maximum cooling water consumption is ($1000\ L/h$). [10]

Fig. (2) Two – cylinder steam engine from G.U.N.T. Comp.

The two units are used in this paper to cover a wide range of water flow rate and result the data from multi devices at different specifications. After the system has reached the steady state following measurements has been taken: temperature of outlet Steam engine, condensate temperature, cooling water inlet and outlet temperature, cooling water flow rate, amount of steam condensate and period of time using watch to calculate steam flow rate based on following equation:

$$m^{\bullet}_s = \frac{\rho_w * V_w}{\Delta t} \quad \ldots\ldots (1)$$

Where: $m^{\bullet}_s =$ Water flow rate kg/s

$\rho_w =$ Water density kg/m^3

$V_w =$ Volume of condensate m^3

$\Delta T =$ Period of time S

After a few minutes the pressure of boiler is adjusted using the steam valve and repeat reading more than ones for the same measuring points. The data ranges used for neural network training and testing are listed in table (1).

Table (1) Data value of input and output parameters of training model

A cm^2	$T_w)_{in}$ $^\circ C$	$m^\bullet_w$ kg/s	T_s $^\circ C$	$m^\bullet_s$ kg/s	$h_1 - h_2$ kJ/kg	$T_w)_e$ $^\circ C$
80	25	0.0153	47	1.7*10^-4	2150.2	29
80	25	0.0153	57	2.5*10^-4	2128.4	31
80	25	0.0153	71	3.2*10^-4	2097.8	34
80	25	0.0153	84	4.4*10^-4	2068.3	36
80	25	0.0153	88	5.4*10^-4	2059.5	39
80	25	0.0153	94	5.1*10^-4	2045.2	40
80	25	0.0153	102	6*10^-4	2026.5	44
80	25	0.0153	106	6.2*10^-4	2011.6	46
80	25	0.0181	47	1.8*10^-4	2150.2	28
80	25	0.0181	57	2.7*10^-4	2128.4	29
80	25	0.0181	71	4*10^-4	2097.8	33
80	25	0.0181	84	5.1*10^-4	2068.3	35
80	25	0.0181	88	5.9*10^-4	2059.5	38
80	25	0.0181	94	6.2*10^-4	2045.2	39
80	25	0.0181	102	7.15*10^-4	2026.5	42
80	25	0.0181	106	7.6*10^-4	2011.6	44
80	25	0.021	47	2.5*10^-4	2150.2	26
80	25	0.021	57	3.1*10^-4	2128.4	28
80	25	0.021	71	4.6*10^-4	2097.8	29
80	25	0.021	84	6*10^-4	2068.3	33
80	25	0.021	88	6.5*10^-4	2059.5	35
80	25	0.021	94	7.1*10^-4	2045.2	36
80	25	0.021	102	8*10^-4	2026.5	40
80	25	0.021	106	8.7*10^-4	2011.6	42

380	25	0.0833	47	12.1*10^-4	2150.2	33
380	25	0.0833	57	17.9*10^-4	2128.4	35
380	25	0.0833	71	27.21*10^-4	2097.8	38
380	25	0.0833	84	34.88*10^-4	2068.3	42
380	25	0.0833	88	37.75*10^-4	2059.5	45
380	25	0.0833	94	41.5*10^-4	2045.2	48
380	25	0.0833	102	49.12*10^-4	2026.5	53
380	25	0.0833	106	51.9*10^-4	2011.6	55
380	25	0.1389	47	19.1*10^-4	2150.2	32
380	25	0.1389	57	25.2*10^-4	2128.4	34
380	25	0.1389	71	30.8*10^-4	2097.8	36
380	25	0.1389	84	50.1*10^-4	2068.3	41
380	25	0.1389	88	58.4*10^-4	2059.5	43
380	25	0.1389	94	61.35*10^-4	2045.2	45
380	25	0.1389	102	76.4*10^-4	2026.5	50
380	25	0.1389	106	80.2*10^-4	2011.6	52
380	25	0.1944	47	25.5*10^-4	2150.2	31
380	25	0.1944	57	38.6*10^-4	2128.4	32
380	25	0.1944	71	46.7*10^-4	2097.8	35
380	25	0.1944	84	69.9*10^-4	2068.3	40
380	25	0.1944	88	81*10^-4	2059.5	42
380	25	0.1944	94	89.1*10^-4	2045.2	44
380	25	0.1944	102	98.3*10^-4	2026.5	49
380	25	0.1944	106	105*10^-4	2011.6	50

5. Condenser Neural network modeling:

The type of neural network used in this approach is the multilayer neural network (MLNN). This type of network consists of an input layer, an output layer, and one or more hidden layers (Fig.3). The choice of MLNN is based on the fact that this type of network is a supervised neural network that learns through a process called back propagation. [11]

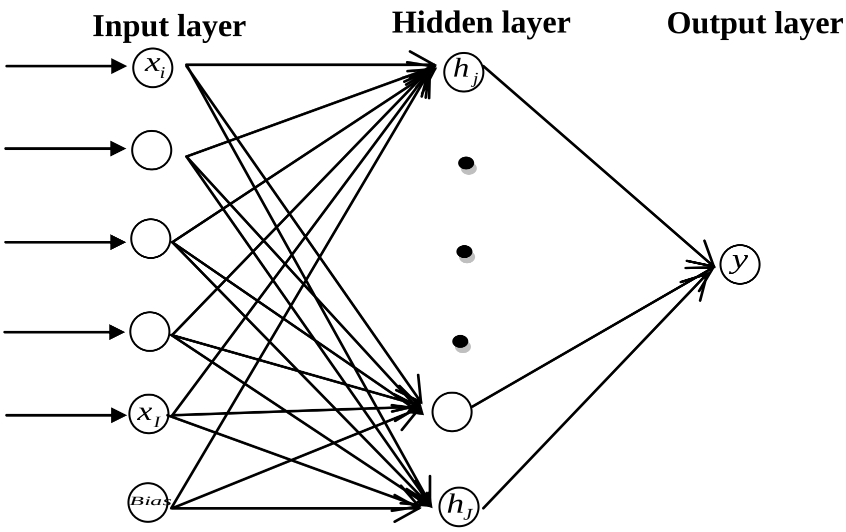


Fig. (3): The BP Neural Network

Standard back propagation is a gradient descent algorithm, as is the learning rule to multiple-layer networks and nonlinear differentiable transfer functions. Input vectors and the corresponding target vectors are used to train a network until it can approximate a function. Here the network is supplied with series of input and corresponding correct (desired) output. The network then tries to set its own parameter until it can approximate an unknown function that can associate input data with corresponding desired output.

Proper selection of input and output parameters is the first step of NN model development, which should reflect the condenser performance without missing necessary parameters. For atmospheric condenser performance, all stat parameters (shown in table (1)) and flow rates on steam and cooling water sides should be chosen as input parameters, which include inlet water temperature $T_w)_{in}$ (inside the pipe), surface area A, steam temperature enter to condenser T_s (outside the pipe), water flow rate $m^{\bullet}{}_w$, Steam enthalpy difference between inlet and outlet condenser $h_1 - h_2$, and steam flow rate $m^{\bullet}{}_s$. Usually, tube material is constant.

Surface area takes from specification of device. Inlet water temperature, steam temperature, and water flow rate were measured from measurement on front panel of device. The determination of the amount of steam is performed via measurement of the condensate using a measuring plastic container with period of time. h_1, h_2 are calculated from (EES) based on steam condition at condenser inlet and outlet. Once steam and cooling water entering states are given, the condenser performance indexes including the exit water temperature can be figured out by laboratory tests or numerical modeling. $T_w)_e$ Refer to amount of heat transfer and condenser work efficiency.

5 -1.Back propagation Program-Training Process:

Step 1: Design the structure of neural network and input parameters of the network.

Step2: Get initial weights W and initial θ (threshold values) from randomizing.

Step 3: Input training data matrix X and output matrix T.

Step 4: Compute the output vector of each neural units. [12]

(a) Compute the output vector H of the hidden layer.

$$net_K = \sum w_{ik} x_i - \theta_k \quad (2)$$

$$H_k = f(net_k) \quad (3)$$

(b) Compute the output vector Y of the output layer

$$net_j = \sum w_{kj} H_i - \theta_j \quad (4)$$

$$Y_j = f(net_j) \quad (5)$$

(c) Compute the root of mean square RMS

$$RMS = \sqrt{\frac{\sum (y_i - T_j)^2}{n}} \quad (6)$$

Step 5: Compute the distance δ

(a) Compute the distance δ of the output layer

$$\delta_j = (T_j - Y_j) f'(net_j) \quad (7)$$

(b) Compute the distance δ of the hidden layer

$$\delta_k = (\sum_j \delta_j w_{kj}) f'(net_j) \quad (8)$$

Step 6: Compute the modification of W and θ (η is the learning rate, α is the momentum coefficient)

(a) Compute the modification of W and θ of the output layer

$$\Delta w_{kj}(n) = \eta \delta_j H_k + \alpha \Delta w_{kj}(n-1) \quad (9)$$

$$\Delta \theta_j(n) = -\eta \delta_j + \alpha \Delta \theta_j(n-1) \quad (10)$$

(b) Compute the modification of W and θ of the hidden layer

$$\Delta w_{ik}(n) = \eta \delta_k X_i + \alpha \Delta w_{ik}(n-1) \quad (11)$$

$$\Delta \theta_k(n) = -\eta \delta_k + \alpha \Delta \theta_k(n-1) \quad (12)$$

Step 7: Renew W and θ

(a) Renew W and θ of the output layer

$$w_{kj}(p) = w_{kj}(p-1) + \Delta w_{kj} \quad \text{(13)}$$

$$\theta_j(p) = \theta_j(p-1) + \Delta\theta_j \quad \text{(14)}$$

(b) Renew W and θ of the hidden layer

$$w_{ik}(p) = w_{ik}(p-1) + \Delta w_{ik} \quad \text{(15)}$$

$$\theta_k(p) = \theta_k(p-1) + \Delta\theta_k \quad \text{(16)}$$

Step 8: Repeat step 3 to step 7 until converge.

5 -2. Back propagation Program-Testing Process:

Step 1: Input the parameters of the network

Step 2: Input the W and θ

Step 3: Input the unknown data matrix X

Step 4: Compute the output vector

(a) Compute the output vector H of the hidden layer (according to equation (1) and equation (2))

$$net_K = \sum w_{ik} x_i - \theta_k \quad \text{(16)}$$

$$H_k = f(net_k) \quad \text{(17)}$$

(c) Compute the output vector Y of the output layer (according to equation (3) and equation (4))

$$net_j = \sum w_{kj} H_i - \theta_j \quad \text{(18)}$$

$$Y_j = f(net_j) \quad \text{(19)}$$

5 -3. Neural network training:

The entire database is used to training NN. The proper size of training data base, best-fit transfer functions and appropriate number of neurons in the hidden layer should be determined through a trial and error NN training process to balance the training efficiency, accuracy and possible over- fitting risk. sually increase number of layer and neuron is used to give good precision in network, but complex mathematical relation for regulation of interplay , we can't anticipated that .

Relation between layer and neuron is important, so if the number of layer is low, neural network can't reflected non liner mapping for input and output. On the other hand, if they are more than required, the network produces nonlinear mapping with unsatisfactory performance. [13] Here, the neural network with 1-3 layers (hidden layer), 1-14 neurons is studied and results error are provided in table (2). It 'is clear that 3 layers with 6 neuron in input layer , 14 neurons in hidden layers ,and 1 neuron in output layer have less error approach to zero.

Table (2) Results of neural networks

No. of layer / No. Of neuron	1	2	3
1	**3.68*10^-4**	**1.7*10^-6**	**1.7*10^-9**
2	**5.1*10^-4**	**4.14*10^-6**	**5.4*10^-10**
4	**5.9*10^-4**	**3.14*10^-7**	**3.8*10^-12**
6	**2.3*10^-5**	**2.25*10^-9**	**1*10^-13**
8	**2.51*10^-5**	**1.86*10^-10**	**3.7*10^-15**
10	**3.1*10^-5**	**1.48*10^-11**	**4.8*10^-17**
12	**1*10^-6**	**3.82*10^-12**	**3.6*10^-24**
14	**2.02*10^-6**	**1.82*10^-15**	**1.1*10^-32**

The goal of training is finding an optimum answer of network, Fig.(4) show the training graph of developed network with 3 layers and 14 neurons. Fig.(5) illustrate the good agreement between NN predictions and the data used for training.

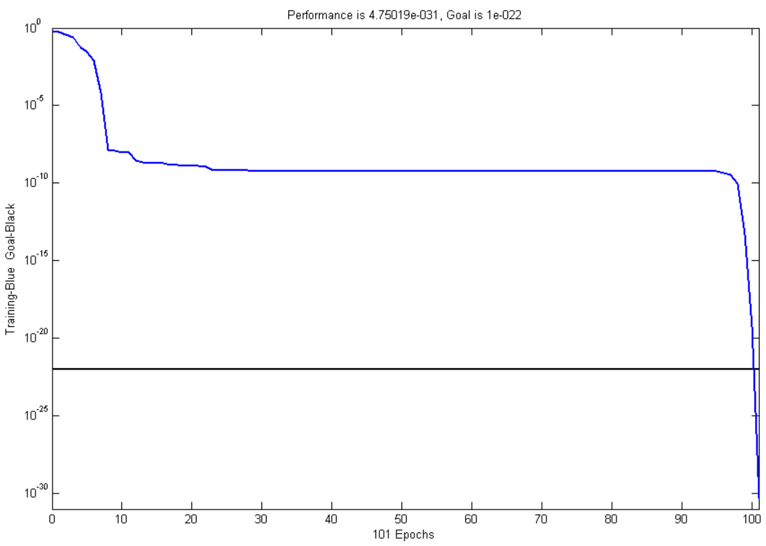


Fig. (4) Best training results

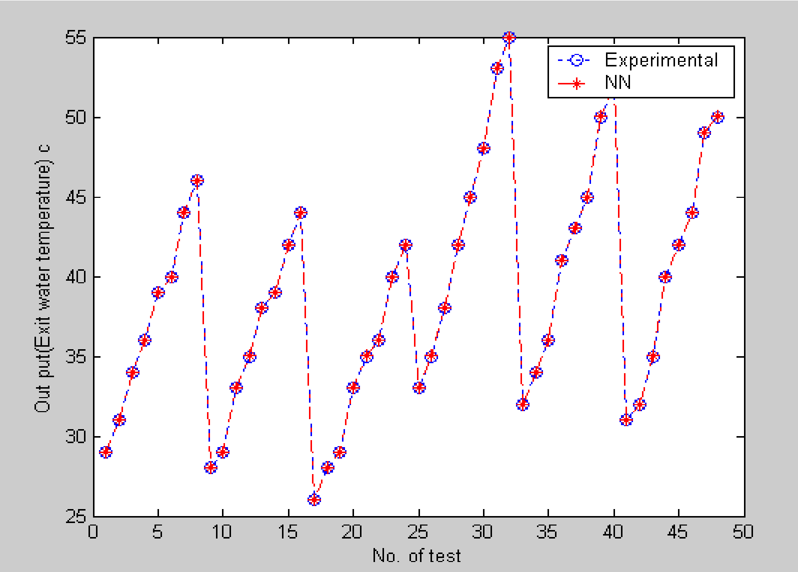


Fig. (5) Desired output and actual neural network for training

5-4 Neural network testing

A good performance results was observed when NN training based on variation data shown in table (1). To check the reliability of NN should be tested NN based on another data that used in training. This paper used another experimental data shown in table (3) from the same devices used in training network to tested NN and the results shown in fig (6) illustrate the good agreement.

Table (3) Data value of input and output parameters

A cm^2	$T_w)_{in}$ $^\circ C$	$m^\bullet{}_w$ kg/s	T_s $^\circ C$	$m^\bullet{}_s$ kg/s	$h_1 - h_2$ kJ/kg	$T_w)_e$ $^\circ C$
80	**25**	**0.0153**	**78**	**3.7*10^-4**	**2081.5**	**35**
80	**25**	**0.0153**	**98**	**5.7*10^-4**	**2035.4**	**42**
80	**25**	**0.0153**	**112**	**7*10^-4**	**2002.2**	**49**
80	**25**	**0.0181**	**78**	**4.5*10^-4**	**2081.5**	**34**
80	**25**	**0.0181**	**98**	**6.7*10^-4**	**2035.4**	**41**
80	**25**	**0.0181**	**112**	**7.8*10^-4**	**2002.2**	**47**
80	**25**	**0.021**	**78**	**5.5*10^-4**	**2081.5**	**32**
80	**25**	**0.021**	**98**	**7.7*10^-4**	**2035.4**	**38**
80	**25**	**0.021**	**112**	**9.7*10^-4**	**2002.2**	**45**
380	**25**	**0.0833**	**78**	**31.11*10^-4**	**2081.5**	**40**
380	**25**	**0.0833**	**98**	**44.6*10^-4**	**2035.4**	**50**

380	25	0.0833	112	56.72*10^-4	2002.2	57
380	25	0.1389	78	39.8*10^-4	2081.5	39
380	25	0.1389	98	71*10^-4	2035.4	48
380	25	0.1389	112	83.1*10^-4	2002.2	55
380	25	0.1944	78	60.8*10^-4	2081.5	37
380	25	0.1944	98	92.2*10^-4	2035.4	46
380	25	0.1944	112	111*10^-4	2002.2	53

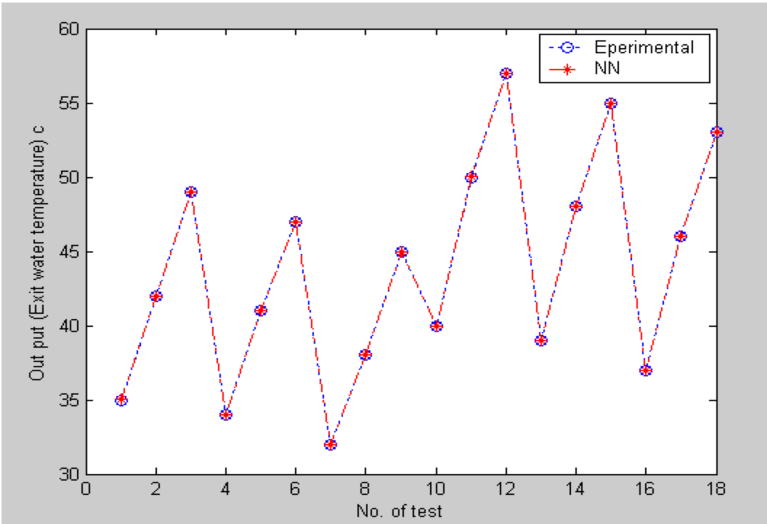
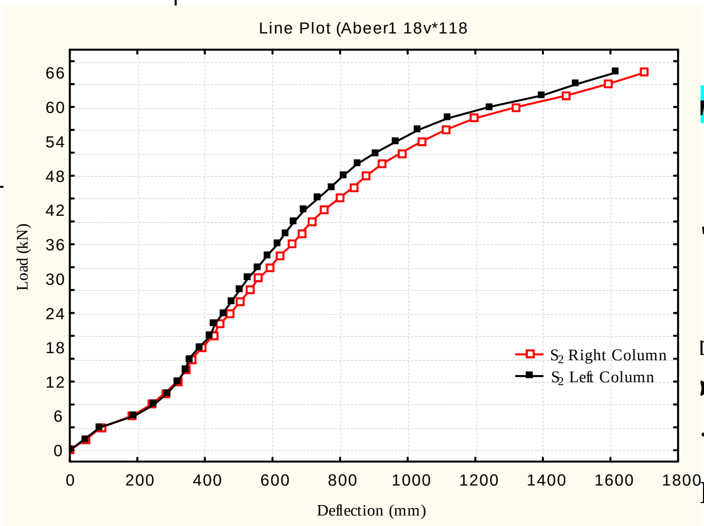


Fig. (6) Desired output and actual neural network for testing

6. Conclusions:

This paper described a new method for condenser performance evaluation based on neural network. Experimental were carried out to validate the neural network model. Measurements were made and experimental results with EES results were used as a set of input. After the determination of algorithm and quantification of the network, the phases of training and testing of the results are carried out and the output of network is created. After study 1-3 layers with 1-14 neuron, three layers with 14 neurons has the best answer and used in this paper. Regarded to complex mathematical relations for regulation of weights in neural network output optimization, we can't anticipate that increasing of layers. During network training network weights converge so with regard to input vector, the output vector produced and network output convergence with goal function obtained by training function. The study shows the change of exit water temperature with the change of input parameters. The trained NN model can approach desired values with height accuracy. Compared with an experiment results the exit water temperature drops predicted by the trained NN is 0.1% of training data and 0.12% of testing data. All deviation falls into±1%. With artificial NN exit water temperature is estimated rapidly and exactly .So, after network training, we don't need condenser analysis.



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