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Evaluation and Improvement Performance of a Boiler in a Thermal Power Plant Using Artificial Neural Network

Abstract-*This research aims to avoid damage in power plant boiler steam generation by using Artificial Neural Network techniques (ANN) to improve the boiler performance. The training and testing using ANN by Back Propagation (BP) algorithm. The inputs to the neural network such factors which include air fuel ratio, water level, flame, gas, pressure and temperature. Control of the optimum input variables represent the output of the neural network. Experimental data is obtained by using an industrial boiler operating at AL-Dura power plant.the method of control by ANN is off – line ,the information of boiler taken from real plant and applied in matlab program for training ANN to taken right decision for control of boiler. ANN results were used in the control of thermal parameters based on the software program Matlab\simulink and showed that the maximum deviation between experimental data is less than 0.01 from the predicted results of the neural network in comparison to the results with modeling of the match at High Rate with actual power plant. It is recommend that Artificial Neural Network techniques (ANN) can be used to predicate and optimization the performance of a power plant and many problem can be solve in engineering applications.*

Keywords- *ANN (Artificial Neural Network, boiler model, power plant, training, prediction model.*

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1.Introduction

Most of the electricity produced from steam power plant and an important part of steam power plant is a steam generation (boiler),it is a closed container made of high quality steel in which steam is generated from water by the applied of thermal from combustion of fuel such as coal,oil or gas. When a fuel is burning a surface of the boiler is heating , hot gases generated in heating surface and exposed on one side and water or steam on the other side. The steam which is collected over the water surface is taken from the boiler through super heater and then suitable pipes for driving turbine for electric generation or for some purpose in industry alapplication .[1], The performance of steam power plant determine by performance of boiler. Many of experimental and numerical researches were discussed on the boiler characteristics in several decades. [2] which applied artificial neural network to predicted of amount of Total Dissolved Solid (TDS) of Shatt Al-Arab river basin in Basrah which is located in south of Iraq .the results showed approach very good agreement for predictions of the TDS

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concentrations between observed and simulated values.[3] which presented to improve power efficiency of steam power plant in various capacities in India .It is envisaged that thermal generation of 50,0000MW will be added to the total power generation capacity of India at the end of 2015.improving the power generation capacity by various steps in power plant. The areas which are mainly considered for the power plant performance maintenance loss, plant load factor, thermal efficiency factors, forced outage and plant availability factor. From analysis it the boiler efficiency notes between (83.66 - 83.5)%and in Maximum Continuous Rating (MCR) efficiency is 86.97%. when replacing axial and radial seals of the boiler ,the air in leakage from the air side to flue gas side can be reducing and the efficiency of the boiler improved. [4]offered to improves the boiler performance by recovering part of the heat which otherwise would have been let out of the stack in this case flue gases temperature is between (120 – 1300) C which is high enough which can be use for such purpose. Boiler is important from energy conservation to find out variation of boilerper formance related to its various running parameters. Hence, it is necessary to discover the current level of efficiency for evaluation performance of boiler, which is mandatory for power conservation action in industry. In Sugar industry, out of so many components. In any sugar industry, heart component is Boiler and tomaximize beneficiary output from sugar mill, it is necessary to maintain performance of Boiler with the design efficiency. So, in present work, an Energy analysis using direct heat loss is performed for a Bagasse Boiler of shree Mahuva Sahkari Khand Udyog Mandali. The evaluation of this power and steam producing plant is important for the proper functioning of the plant. And utilized heat loss method to find efficiency and losses in boiler house. All the necessary records for the calculation is taken from boiler house studying reading and plant data of shree Mahuva Sahkari Khand Udyog Mandali. Theimportant variable of boiler performance is sugarcane bagasse in sugar mill cogeneration systems and help calculation in its system. Many researcherhave proposed artificial neural network technique (ANN) modelingwithexperimental ortheoretical workfor more industrial and engineeringapplication. [5]proposed artificial neural network technique to control of the water level in the drum boilers in AL-Dura power plants.the input of neural network is pressure, feed water flow and steam flow,While the output of neural network is drum level.In this present used least number of hidden neurons and the leastvalue of mean square error. The neural network is simulated andits plottedthe output of the real data. And using feed forward neuralnetworks andrecurrent neural networks for testing . The results showed that the mean square error of feed forward neural networksis more than 1.0 E-04 but of recurrent neural networks is less than 1.0 E-06.this technique applied by Computer programs in MATLAB. [6]Presented using Artificial Neural Networks ato predict the water level in the drum of a boiler.In the present work applied ANN model of the boiler feed systemto increases the efficiency and reduce the tripping of the steam power plant,The variables of this model can beobtained from the characteristicsof the boiler and physical dimensions. The results showedthe frequency of deviations were reducedof the water level in the drum of the steam boiler and the degree of deviation also reduced. The model-based control algorithms is developed of boiler .The aim of this article to study the impact different parameter such as flame,air\fuel ratio, gas ,pressure , air fuel ratio, temperature on thermal power plant by using ANN. Evaluation the performance for this plants by using ANN.

Nomenclature

Variable	Description
bj	The bias
f j	Transfer function
k	Constant =0.9 for gas,0.94 for oil and 0.97 for coal
Pi	Input of the system
Wij	The weight in the connection
X	Input of neural network
Yj	The output for the computation unit

2-Artificial neural network:

Artificial Neural Network (ANN) is one of an important artificial intelligent field which obtained development to simulink brain human or similar to the behavior of biological neural systems.NeuralNetworks are powerful tool that have the abilities to identify underlying highly complex relationships from input–output data only.In ANN can be built a model of a

complexsystem that difficult solved analysis numerical methods. Back Propagation algorithm used for learning and multi – layered feed – forward networks applied of the applications in power systems.The basic structure of a neuron shows in Fig. (1). ANN consist ofinput layer, hidden layer and output layer each layer have number of neurons, each neuron connected to another by weighted .neuron allow pass signal from input layer to output layer. Neurons connected by links, each link has a numerical weights associated with it. the basic means of long-term memory in ANNs is weights [7].
This equations show the function of the neuron:

$$yj = fj(x) \quad (1)$$

x

$$= \sum_{i}^{n} \text{Pi Wij} + \text{bj} \quad (2)$$

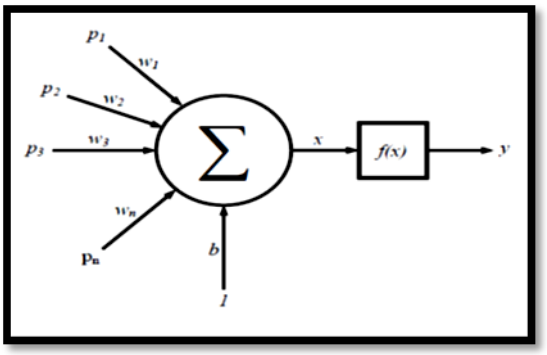


Figure 1: Structure of a Neuron

3-Activation Functions of Artificial Neural Network:

Many activation functions of Artificial Neural Network (the step, sign, linear and sigmoid) have been tested, but only few have found practical applications. Activation functions are illustrated in Fig.(2). When output equal to the neuron weighted input its called linear activation function. The weights represent a data being used by the net to solve a problem.[8] . Neurons with the linear function are often used for linear approximation .in function of classification and pattern recognition can be used The step activation functions and sign activation functions in decision-making neurons. but sigmoid activation function used in the back-propagation networks to transforms the input, which can have any value between plus and minus infinity, into a reasonable value in the range between 0 and 1 [9].

4-learningAlgorithm of Artificial Neural Network:

ANN mean Learning rules and training algorithm .The purpose of learning rule is to train the network by modifying the weights and biases to perform special function.Thelearning of Artificial Neural Network consist of two types:

I.Supervised learning

The training set of the neural network learningby externalteacher andinputs and outputs are knownin this type of learning the output of neural network compare with target to reduces the error by changes its weight and estimates the negative error [10].

II.Unsupervised learning

The neural network learning by Self-Organized .the input is known but not desired outputs known.The weights and biases are adjust to only inputs .That training and learning depended on input data. neural network which it predictive of the output [11].

5-Boiler data base modeling:

Boilerin local steam power plants work with little efficiency becauseof old lifeofwork.for developmentto represent any model of Neural Networkmust be available set of data.Itisalmostneedto takemoreaccuracy datafromactualcases.Experimental datawere carried out to support the set of data for Neural Network modeling.aboiler(steam generation) in Al – Durapower plant shown in Fig.(3)) .
The experimental data consisted of (temperature, pressure,air fuel ratio, gas and flam):

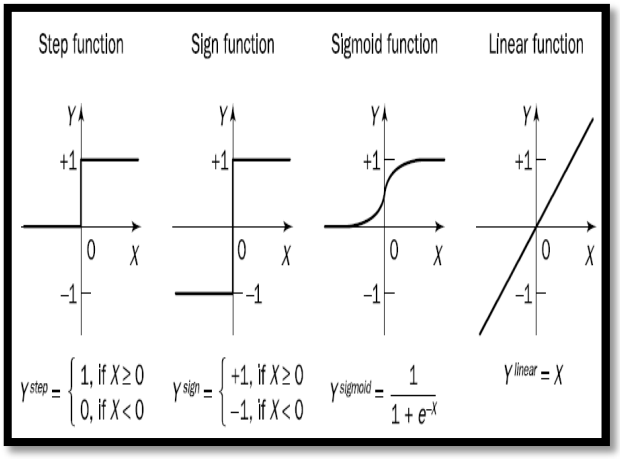


Figure 2: Neuron activation functions

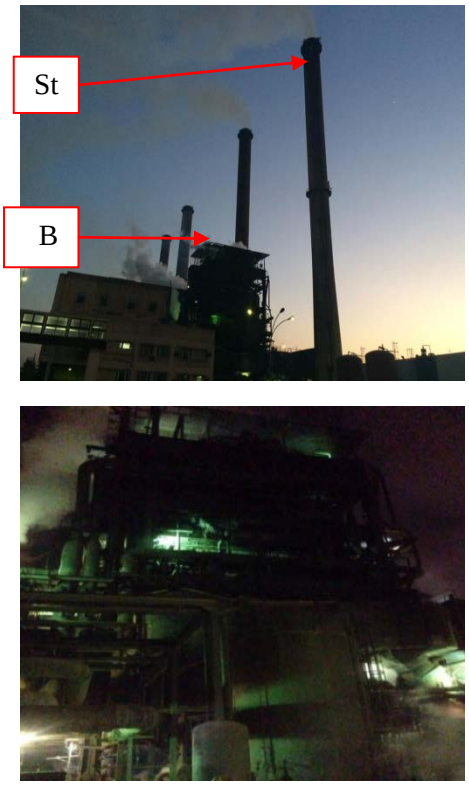


Figure 3:Steam generation in Al – Dura power plant

I.Temperature input variable:

A safety operation of boiler should be temperature generated from the boiler should be less than 550℃.Therefore ANNs applied in this limitasto avoid damageof the steam temperature before reaching the maximum peak.

II.Pres sure input variable:

Theemploying ANNs of the boiler to found that the proper pressure to boiler and steam turbine is less than 140Mpa.

III.Air fuel ratio inputvariable:

Air fuel ratio it is an important variable of combustion whenamount of air reacts with the amount of fuel. if the combustion products contain CO2 then mixture is called a rich but if the combustion products contain CO the mixture is called a poor and this causes losses in the heat, this.Excess air very necessary to complete reaction and get free from of heat loss. the formula to calculate the percentage of excess air as follows:

$$\text{Excess Air} = \text{K}\left[\frac{21}{21 - \%\text{Oxygen}}\right] \times 100 \qquad (3)$$

The table(1) illustrate the excess air for various fuels used in these reactions at full capacity as follows [10]. The appropriate values of air fuel ratio (E) in the combustion reactions which controlled by ANNs controller approximately 14 to provide a right heat for heating water with a required value.

IV.Gas input variable:

The gas variable is an important to control it and must be checking available gas before operation boiler to prevent explosion of boiler andafter boiler operation to ensure the continuation of flame. ANNs used due to the need for control of gas.

V.Water level input variable:

ANNs used to control on the level water because it causes sediment and salt and corrosion. The control of the water level inside the boiler drum by gauge glass is responsible for the. it gives a warning if the level is few to take the right decision[12].

VI.Flame input variable:

The air fuel ratio effected of flame to happen combustion in furnace to steam generation. The data range from experimental data used for neural network training is listed in Table(2).

Table 1: Excess air for various fuels

Fuel	Natural gas	Fuel oil	Coal
Oxygen in flue gas	(1.5– 3)%	(0.6 – 3)%	(4.0 – 6.5)%
Excess air minimum	(7 – 5)%	(3 – 15)%	(25 – 40)%

Table 2: Experimental data of input and output variables

Boiler model being developed in this study based on data from experimental setup to train and test neural network NN model based on software program built by Matlab language.

6-Results and Discussion:

I.Simulink model of Boiler using Artificial Neural Network

The model of steam generation is built in the Malab/Simulink code, by using NARMA artificial neural networks Toolbox to represent input-output behaviourof nonlinear systemsby selection of input variables . Input variables for boiler neural network modeling include (temperature, pressure, air fuel ratio,water level, gas and flame).Fig.(4) illustrated simulink model of boiler in AL-Dura power plant.the method of control by ANN is off – line ,the information of boiler taken from real plant and applied in matlab program for training ANN to taken right decision for control of boiler.

A\F	FL	WL	GAS	P	T	output
7	0.7	0.5	0.7	40	270	0
10	0.72	0.53	0.72	45	285	0
11	0.74	0.56	0.74	50	300	0
12	0.76	0.59	0.76	55	315	0
12.1	0.78	0.62	0.78	60	330	0
12.2	0.8	0.65	0.8	65	345	0
12.3	0.82	0.68	0.82	70	360	0
12.4	0.84	0.71	0.84	75	375	0
12.5	0.86	0.74	0.86	80	390	0
12.6	0.88	0.77	0.88		405	0
12.7	0.9	0.8	0.9	90	420	0
12.8	0.92	0.83	0.92	95	435	1
12.9	0.94	0.86	0.94	100	450	1
13	0.96	0.89	0.96	105	465	1
13.1	0.98	0.92	0.98	110	480	1
13.2	1	0.95	1	115	495	1
13.3	1	0.98	1	120	510	1
13.4	1	1	1	125	525	1
13.5	1	1	1	130	540	1
13.6	1	1	1	135	555	1

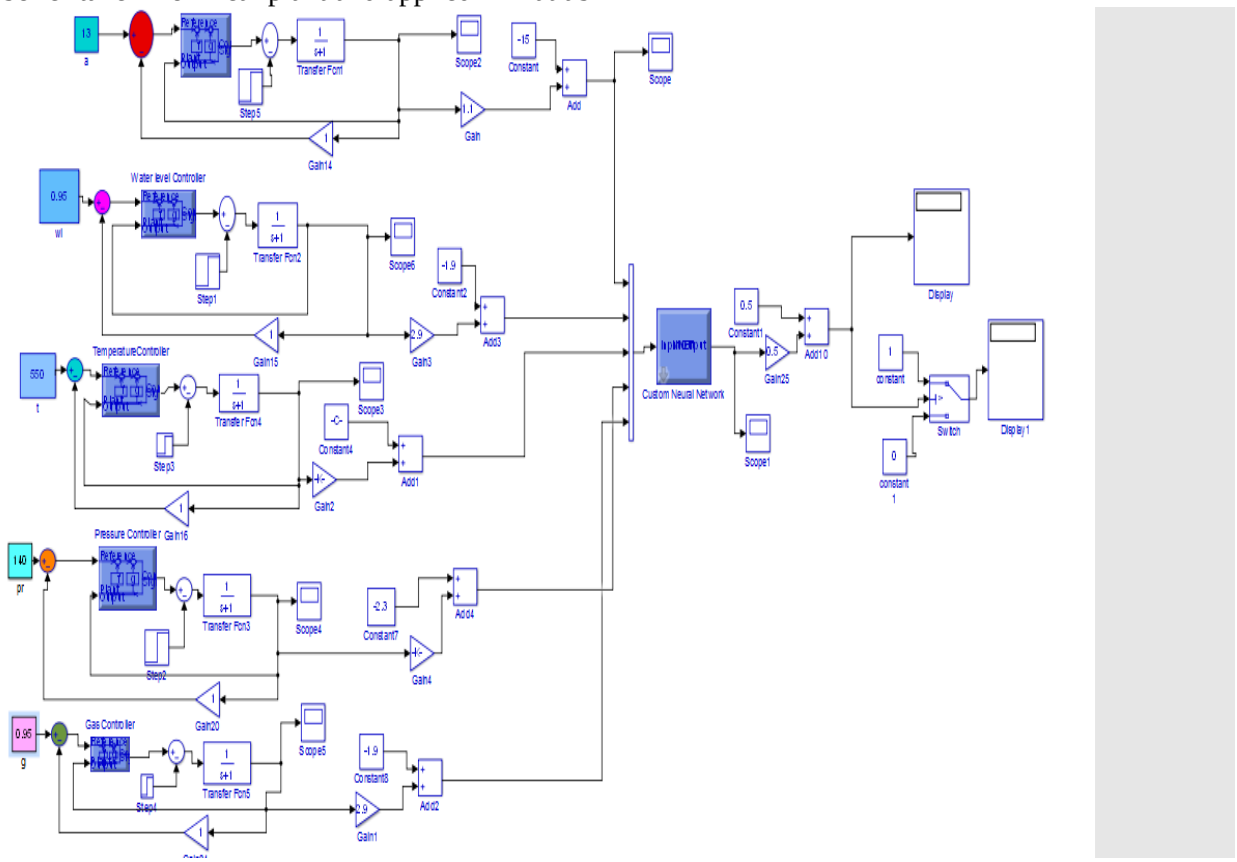


Figure 4: simulink model of boiler in AL-Dura power plant

II.Neural Network Training

The multilayer neural network with learning process called back propagation used in this approach. Input variables and the desired output are used to train a network until it can approximate function. the network is supplied with series of input and desired output. .The size of training data sets must be determined through a trial and error. Number of neurons in the hidden layer and number of layer is when increase are give good perfor mancein network but if the number of layer is low, neural network can't reflect on liner mapping for input and output. neural network training process to balance the training efficiency.In this work the neural

Number of Nodes	Train MSE	Number of Nodes	Train MSE	Test Regression
3	2.18e-06	3– 3	0.41	0.612
5	9.96e – 06	3–5	7.25e– 06	1
7	8.18e– 06	3–7	4.431e– 06	1
9	9.32e– 06	3–9	6.29e– 06	1
11	9.99e– 06	3–11	3.277e– 06	1

network training with two layers (hidden layer),3-11neuronsisstudiedand results error are provided in Table(3).

The aim of training neural network is to find an optimum answer of network. The best training of network with 2 layers and 11 neurons illustrated in Fig.(5), Fig.(6) show the predictions of neural network and the data used for training. Fig.(5) best training. Fig.(6)Desired and predicated output data for training neural network

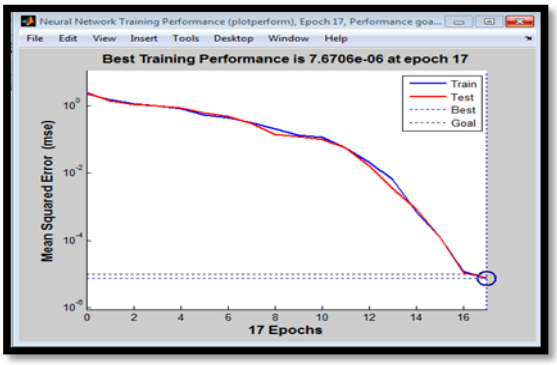
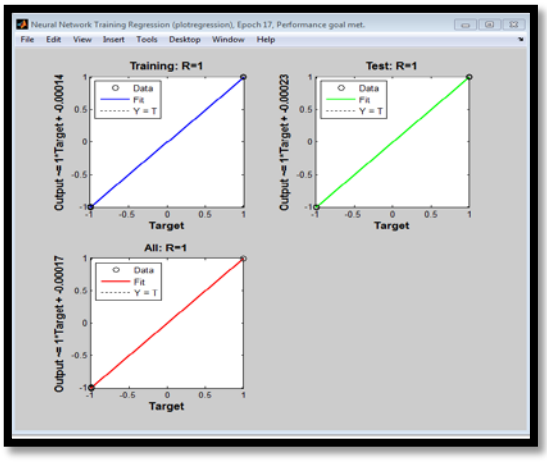


Figure 5: best training

Figure 6: Desired and predicated output data for training neural network

Table 3: result of one hidden layer and two hidden layer of neural network



7-Results of model

I.Water level :

Fig.(7) shown the upper water level is 0.95 and lower water level is 0.85 this rated of limited which alow boiler to operation.when water level is less than 0.85 this causeof cousumed of fuel but water level more than this range this mean the boiler is operating in stable.

II. gas available:

Fig.(8)shown the limited of gas from 0.75 to 0.95 that alowed to operation boiler. To prevent happen explosion in boiler.when gas available befor operation this limit of gas is effected of ignition of flame after operation .

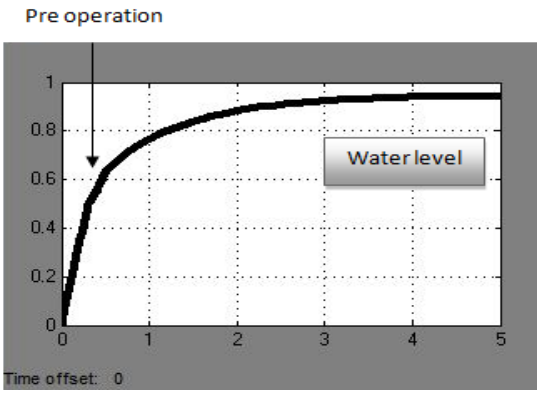


Figure 7: The water level

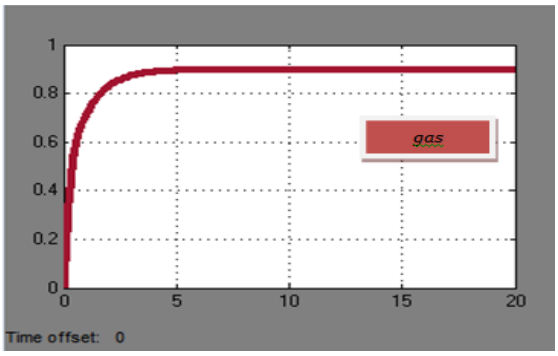


Figure 8: The gas of boiler

III.Air \Fuel Ratio:

the limited to complet combstion of boiler from 12.8 to 13.8that shown in Fig.(9). The propagation of flame depended of fuel and in begin of operation the increase in this ratio is slowly and after time increase with time .

IV.Flame:

when temperature and presure increase the propagation of flame increase Fig.(10) shows the propagation of flame.the combustion appeare after take a time. The flame occure after open the gas and spark ignition is appear.

V. Temperature:

Fig.(11) illustrated the temperature increase with time and pressure of the boiler in AL-Dura power plant .

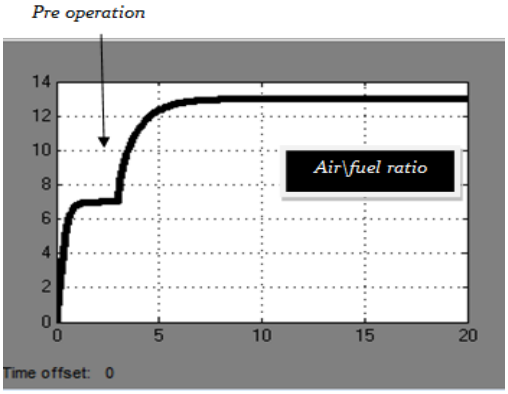


Figure 9: Air fuel ratio of AL-Dura power plant

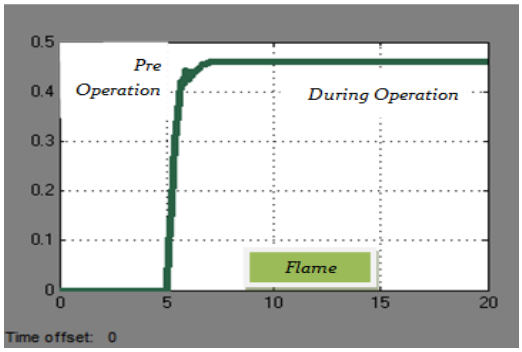


Figure 10: The propagation of flame

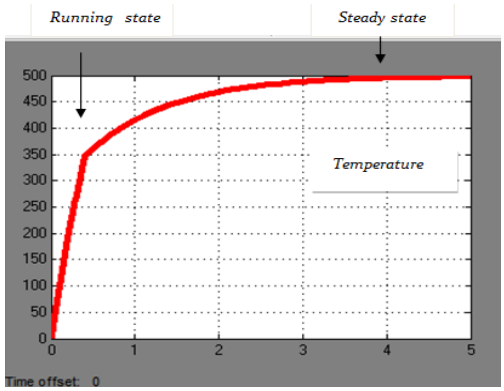


Figure 11: The temperature of boiler

VI. pressure:

the pressure increase with time of the boiler and reach to 140 bar or leas than to 135 bar.Fig.(12) shown the pressure of boiler in AL-Dura power plant**.**this limit of pressure is suitable with design of boiler .

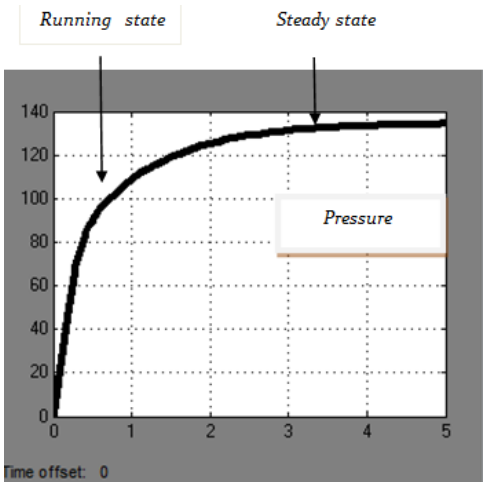


Figure 12: The pressure of boiler in AL-Dura power plant.

8-Conclusion

Thispaperproposeevaluation performance of boiler in Al-Dura power plant using Artificial Neural Network (ANN) modeling. ANN model deals withexperimental data from this plant. Ithas been proved that the ANN model is more efficient and accurate. The accuracy and precision of the Neural Network modeling presented is an impactsfactor of safety of the Boiler.back propagation algorithmused intheconstructionofthe neural network.the output of neural network is created by thetrainingandtestingThe number of neurons for determing the results of ANN.In each run of ANNand fixed number of neurons It might have give different results but when increasing the number of neurons in hidden layer will decrease the number of calculation steps and decrease in sum squared error.inthis paper twolayerswith3-11neurons which has give the best solution. The results were used in Matlab program built in this paper to Comparison between the model that built in Matlab with experimental results which show a very good agreement. Matlab modeling can be use to find any parametersneededtostudy the boilerperformance**.**

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