CHAPTER 1

INTRODUCTION

A steam boiler is a covered container that furnishes a method for combustion heat to be transferred into water until the water becomes steam. The steam is then utilized for further energy conversion processes. The water wall tubes, superheater, evaporator, re-heater and economizer are the main parts of the steam boiler. These parts in the boiler are functioning in capturing the thermal energy in the combustion gases to evaporate the water into steam.

For the selected thermal power plant, large number of operational data is captured continuously by the on-line plant's simulating system for its proper operation. These are usually stored as database only. Using these data, ANN models can be modeled for the simulation of the plant operation as we have done in the present study. ANN models are useful as they can be trained occasionally with latest data and these models are easy to use, fast in response and suitable for off-line and on-line applications.

In the present work, the ANN model was trained and validated using real site data to investigate the tube leakage in the evaporators. The related variables were classified and the most influencing on were considered in the ANN model. The variable "Low Temperature Superheater Right Wall Outlet Before Supreheater Dryer" (V20) is assumed to be the main contributor to the shutdown.

1.1 Background of Thermal Power Plant

The primary function of a steam boiler is to produce steam at a given pressure and temperature. In order to accomplish this function, the boiler serves as a furnace where air is mixed with fuel in a controlled combustion process to release large quantities of heat. The pressure-tight construction of a boiler provides a means to absorb the heat from the combustion and transfer this heat to raise water to a temperature such that the steam produced is of sufficient temperature and quality (moisture content) for steam loads. The main components and systems of the thermal power plant boiler are shown below.

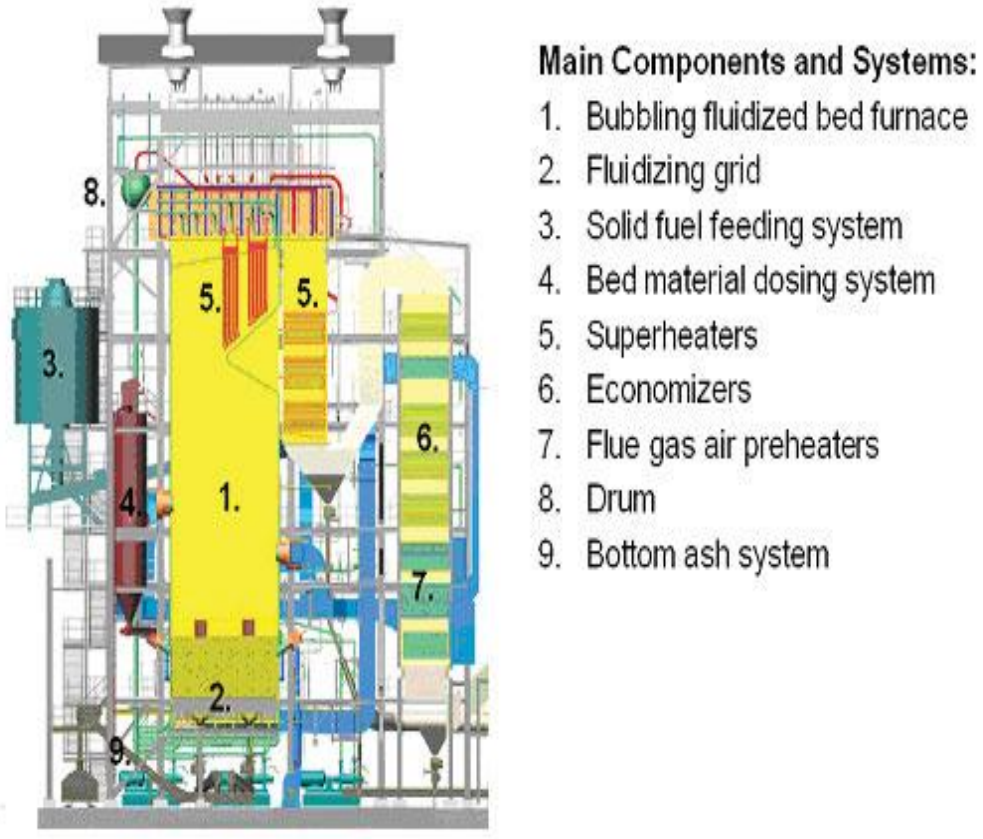

Figure 1.1 Schematic Diagram of Thermal Power Plant Boiler [3]

The boiler has an enclosed space where the fuel combustion takes place, usually referred to as the furnace or combustion chamber. Air is supplied to combine with the fuel resulting in combustion. The heat of combustion is absorbed by the water in the risers or circulating tubes. The density difference between hot and cold water is the driving force to circulate the water back to the steam drum. Eventually the water will absorb sufficient heat to produce steam.

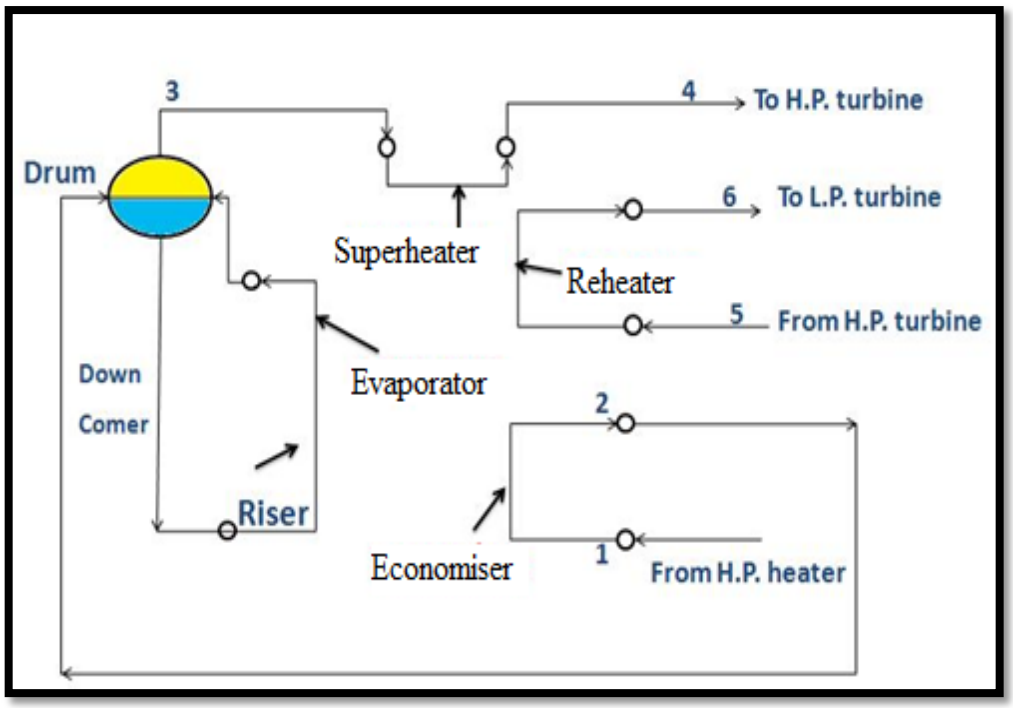

Figure 1.2 Typical Boilers [4]

In the boiler, feedwater is heated in three kinds of heat exchanger (economizer, evaporator and superheater). Feedwater from high pressure (h.p) heater enters the economizer where it is heated by outgoing flue gasses then it is fed into the drum. The water enters the drum as saturated water and the saturated water falls through the downcomer into the bottom header and moves up the riser then boiled back to the drum. The saturated water that passes through the downcomer and riser is boiled in the evaporator to become saturated steam before entering the drum once again. Saturated steam goes to the superheaters for being heated to desire temperature before enters the turbine.

1.2 Background of Artificial Neural Network

An artificial intelligence (AI) system is a term that in its broadest sense would indicate the ability of a machine or artifact to perform the same kinds of functions that characterize human thought. AI consists of five major branches, i.e. expert systems, artificial neural networks (ANNs), genetic algorithms (GA), fuzzy logic and various

hybrid systems, which are combinations of two or more of the branches mentioned previously.

ANNs are massively parallel distributed processor that has a natural propensity for storing experiential knowledge and making it available for use. It resembles the human brain in two respects: the knowledge is required by the network through a learning process, and inter-neuron connection strengths, known as synaptic weights, are used to store knowledge.

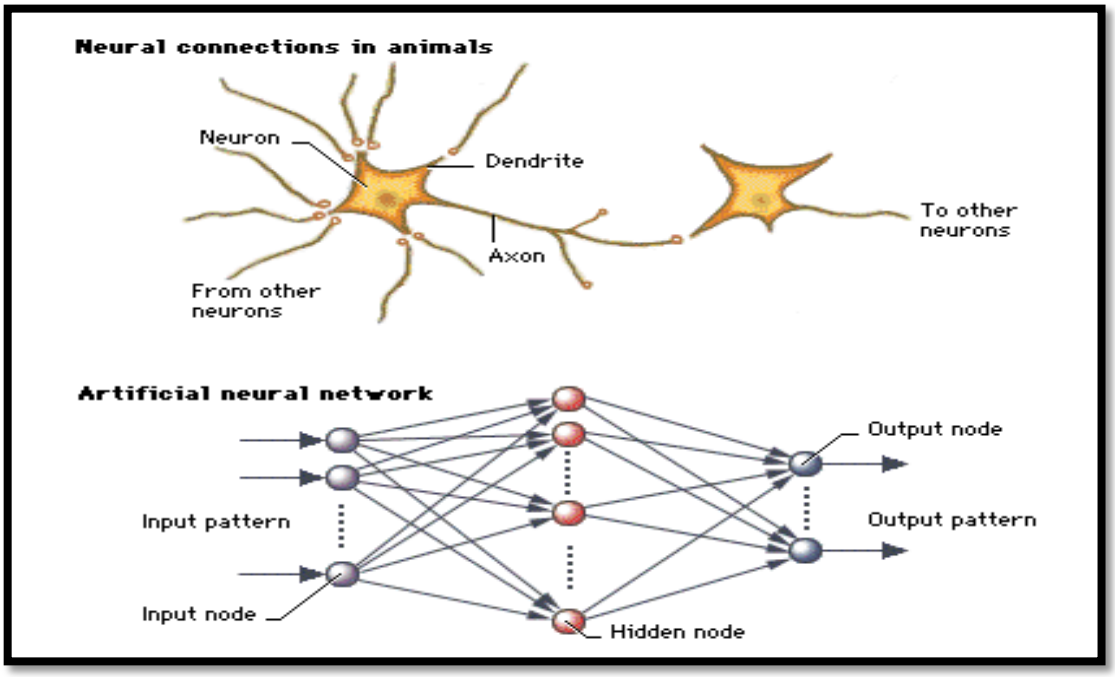

Figure 1.3 A Simplified model of an artificial neuron [15]

ANNs mimic somewhat the learning process of a human brain where they operate like a ``black box" model, requiring no detailed information about the system. Instead, they learn the relationship between the input parameters and the controlled and uncontrolled variables by studying previously recorded data, similar to the way a non-linear regression might perform. [6]

The multilayer feed-forward neural network usually consists of an input layer, some hidden layers and an output layer and each single neuron is connected to other neurons of a previous layer through adaptable synaptic weights.

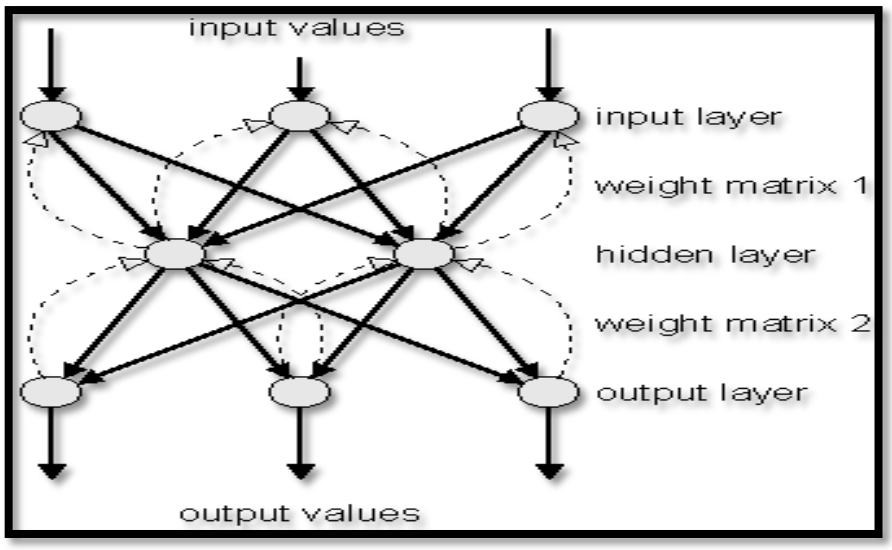

Figure 1.4 The Multilayer Feedforward NN Model [10]

Knowledge is usually stored as a set of connection weights. Training is the process of modifying the connection weights in some orderly fashion using a suitable learning method. The network uses a learning mode, in which an input is presented to the network along with the desired output and the weights are adjusted so that the network attempts to produce the desired output. The weights after training contain meaningful information whereas before training they are random and have no meaning. The node receives weighted activation of other nodes through its incoming connections. The training algorithms cannot undergo any training without any activation functions. The activation function is to calculate the weightage of each node introduced into the hidden layer. There are three types of activation functions used; linear transfer function (purelin), log-sigmoid and tan-sigmoid activation functions. Combination of these activation functions will produced different value of output.

First, these input nodes that enters the hidden layers are added up then passed through an activation function; the outcome is the activation of the node. For each of the outgoing connections, this activation value is multiplied with the specific weight and transferred to the next node. When each pattern is read, the network uses the input data to produce an output, which is then compared to the training pattern. If there is a difference, the connection weights are altered in such a direction that the error is decreased. After the network has run through all the input patterns, if the error is still greater than the

maximum desired tolerance, the ANN runs again through all the input patterns repeatedly until all the errors are within the required tolerance. When the training reaches a satisfactory level, the network holds the weights constant and the trained network. The functions RMSE is to calculate error between actual output and predicted output. The equation of RMSE used is:

$$\bar{}$$

K = number of iterations

Q = total number of iterations (epochs)

t = target output

a = actual output

1.3 Problem Statement

Risers are installed all around the four walls of the furnace act as cooling tubes or a water wall and carry away the heat from the furnace at the same rate at which heat is released in it by burning of fuel. Adequate circulation of water must be provided in the circuit as shown in Figure 1.5. If the circulation is not adequate, then rate at which heat from the furnace is carried away from the risers will be less than the rate of heat transferred to the risers and the difference will be stored in the metal of the riser tubes

leading to their overheating and ultimately rupturing when the tube temperature exceeds the melting point of the metal.

Usually the riser tubes have more thermal loading and generate more steam because they are located opposite to the burners. Too much steaming in a riser tube is not preferable. On the heated surface, the bubbles are originated and the formation of the bubbles will be higher if there is a high rate of heat transfer to the riser. The bubbles may coalesce and first form an unstable vapor film which continually collapses and reforms.

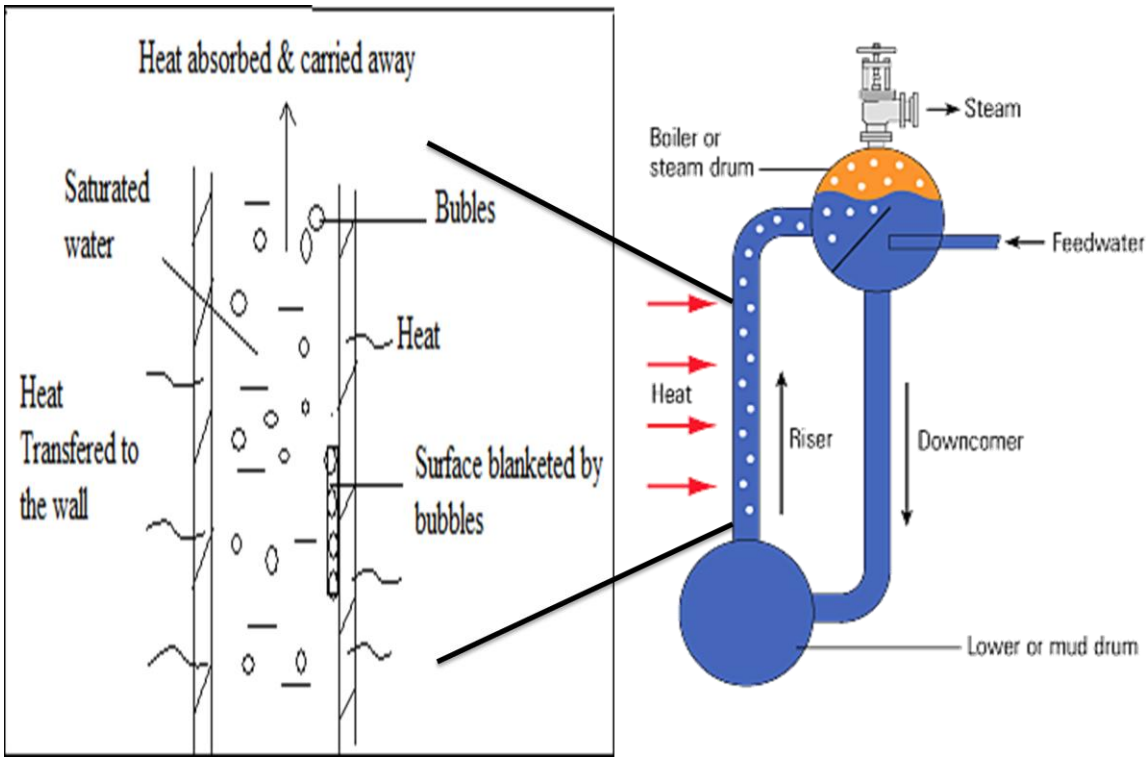

Figure 1.5 Nucleate and Film Boiling in a Riser Tube [2]

Since the vapor film as shown in the figure 1.5 above has much lower thermal conductivity than a liquid film, it will offer a large thermal resistance, almost blanketing the surface where it forms. The difference between the heat absorbed and heat transferred to the wall will be stored in the metal of the tube with the increase in its internal energy. Hence, consequently the temperature of the metal may exceed the melting point and the tube may rupture allowing tube leakage [2].

Leakage of risers will produce the mixture of steam and water to escape out from the risers into the furnace. The mixture of steam and water will decrease the heat of the furnace and slowly reduce the temperature of the superheater which situated at the upper part of the furnace.

1.4 Objectives and Scope Of Study

Objectives have been structured and strongly needed to be achieved at the end of this project in order to analyze the importance of the variables of the steam boiler for prevention of the unit trip.

i. To study the behavior of the boiler operation variables of the steam boiler.

ii. To design an ANN model for detection and diagnoses of the boiler tube leakage trip.

The scope of this research is to develop ANN modeling using different NN Topologies and locate the best ANN topology combination for fault diagnosis and detection (FDD).