MODELING COGENERATION POWER PLANTS USING NEURAL NETWORKS

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Abstract

As the energy cost is rising steadily and the environmental pollution is becoming an important issue, the roles of process plant boilers like that of the sugar plants boilers need better understanding as they can be made to operate in either energy conserving or bio-mass conserving modes. However, practical models of the plants need to be developed before any effort at optimization and cogeneration is carried out.

These boiler plants are difficult to model as they have non-linearities between input and output parameters and have large no. of parameters. Efforts have been reported in literature where techniques like that of Neural Networks have been used. A similar methodology has been evolved here successfully to model a 100 Ton water tube bagasse fired cogeneration boiler through back propagation trained Neural Networks.

Keywords: *Neural networks; Cogeneration; Process plant boilers.*

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1. INTRODUCTION

An over view of the sugar plant Power Generation : With the rising energy costs, the importance of the sugar plant boilers is increasing day by day as there is a possibility that they can be made more efficient and used for cogeneration (producing both power and heat) as well. Sugar prices are generally volatile. There is always a tough competition in pricing. Sugar industry is also a large energy user. Most sugar mills often produce their own electricity to meet on site needs by burning bagasse or other fuels. This however often has not been in cogeneration made until very recently. The energy and the environment concerns today provide an incentive to produce electricity efficiently and to feed it to the grid. Much of the potential for energy generation has so far been wasted as there was neither perception nor the technology for it.

The present work deals with the modeling of a power plant in a sugar factory to study its characteristics towards utilizing it more efficiently.

2. LITERATURE REVIEW

2.1 Efficiency of Process Power Plants

Premalatha et.al. [1] have studied the economics of sugar plants in India with advanced co-generation operations using high pressure boilers in place of conventional boilers. They have reported the need to switch to electrical drives as well towards increasing the efficiency further. Additional power generated may be considerably more than plants requirements. They also observed that an improved efficiency reduced the pollution for the same amount of power generated. Several studies of this type have been reported in literature

3. METHODOLOGY

3.1 Preamble

Emissions from boilers always need reduction, besides the need to model and run boiler in process plants in an optimum fashion. Sugar plants are generally connected to Power Grids and thus if they save any power they can feed it to the grid.

Due to complex relationships between in input and output parameters, building of models of process plants for understanding the operations is difficult. Neural Networks are general purpose modeling tools which are becoming popular for this type of applications.

3.2 Objective

The objective of the study is to model a high pressure bagasse fired, heat extracting and condensing power plant (of a sugar factory) through its input / output parameters using a forward neural network model, which can be used to study and improve its performance. The proposition is shown in Fig No. 3.1 .

3.3 Selection of the Variables (Parameters)

The boiler used for the studies was a 100 Ton per hour water tube boiler located at a sugar mill in UP. Permission was obtained from the management for exploration and modeling. All the data was taken from the log book of the plant and was interpreted with the help of plant personnel. It was decided to take seven days continuous data to model the plant to establish the feasibility. Considering the delay and reaction times in the plant four hourly averages were taken. A set of 164 four hourly observations were made available by the plant people. Out of this 146 observations were used for training the network and the rest were set aside for testing the network.

Operation of a cogeneration plant may differ somewhat from normal plants. The present work is however based on the way the plant was actually operating. A limited number of input and output parameters, that matter, like bagasse consumption, drum level, ID fan pressure, ID fan current, FD fan current, FD fan pressure, Economizer, Outlet draft, Air pre heater, Inlet pressure, Economizer outlet flue gas temperature were chosen from the input side and Steam flow , Superheated steam pressure and Superheated steam temperature were chosen from the output side .

3.4 The Neural Network Model Adopted

Operation of sugar plants and their power plant boilers is fairly similar in the country. In the light of discussions in the previous sections the open ended Back Propagation Algorithm was proposed to be used for modeling the Boiler Plant. After some trails and errors a regular network with two hidden layers was used with a total of 29 neurons in the hidden layers adopted as per common rules of thumb. Fig. 3.2 shows the conceptual flow chart of the activities carried out.

This modeling effort matches with some of the boiler modeling efforts shown in the references Ozel [2] and Michael etal. [3].

In order to train a neural network, input data is normalized between 0 and one and given to the network. Each input set has a corresponding output set. Back Propagation (BP) method is adapted for learning in the neural network. In this algorithm the output of output-layer neuron is compared with teaching signal T as shown in Fig. 3.3 . To minimize the least square error margin, each connection weight and the threshold value of each neuron are changed in direction of straight line from output-layer to input-layer. The momentum and learning coefficients are the training parameters of the Back Propagation neural network. The momentum term promotes learning speed by rapidly changing connection weights of neurons. The learning coefficient controls the stability of the process. They have to be judiciously selected. Also optimum number of hidden layer and neurons in the layers determine the quality of the network.

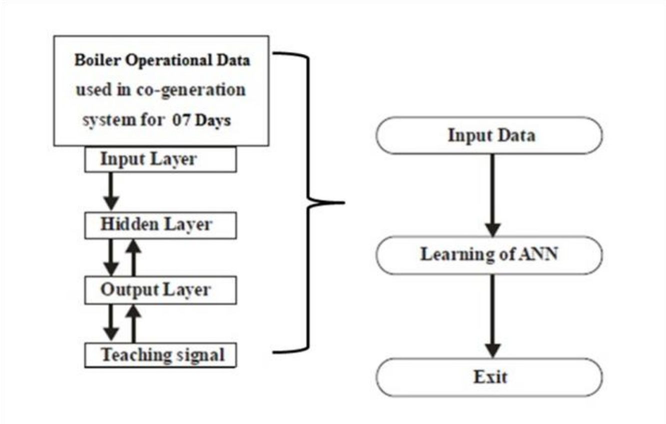

Fig 3.1: Learning Flow Chart for the Network

4. INPUT DATA AND TRAINING

Experimental data used in the study consists of a total of 161 sets taken from the working system. Out of these 146 data sets were used in training the network while 15 of these were used to test the system. Data sets were cleaned up and organized with the help of the persons from the plant.

The configuration of the network evolved is as follows:

Number of input first layer neurons	15
Number of hidden layers	2
Number of neurons in the first hidden layer	20
Number of neurons in the second hidden layer	9
Number of neurons in the output layer	3
Learning rate range	0 to 6
Momentum rate range	0 to 1
MSE for individual patterns	0.0005
MSE for the overall pattern	0.0005

The network was successfully trained and tested.

Results obtained after training of the network are shown in the next section for a few conditions.

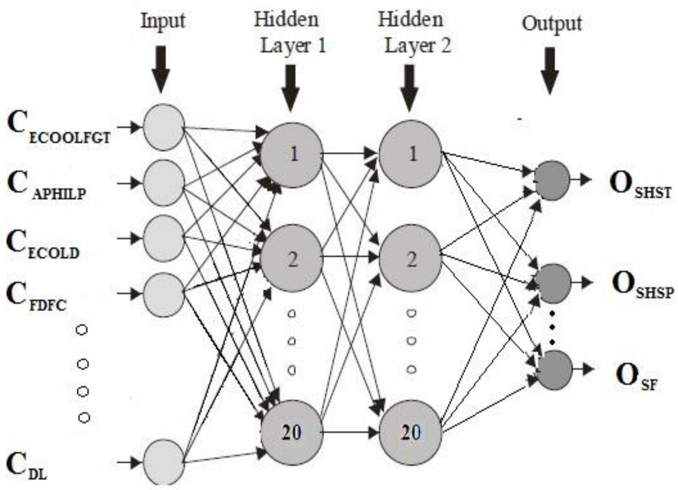

Fig 3.2: The configuration of the network trained through Back Propagation algorithm

5. RESULTS AND DISCUSSIONS

5.1 Summary

Input/ output model of a sugar factory Boiler Plant has been developed using Feed Forward Neural Networks. This kind of model is expected to help in understanding the plant characteristics and efficiency parameters.

5.2 Training the Network

As brought out in the earlier section the Neural Network selected had 15 inputs and 3 outputs, covering the common parameters. There are a total of 161 Data sets, out of this146 Nos. have been used for training and 15 Nos. have been used for testing. Each data is an average of four hours of variations.

The network selected has 2 hidden layers of 20 and 9 nodes each. The training was carried out using the Back Propagation algorithm till the Mean Square Error of the Network in predicting the known outcomes was reduced to around 0.0005, which occurred in around 3000 iterations. This level is generally satisfactory for simple models as per the literature.

Some of the results obtained from testing are shown through the Fig Nos. 5.1 and Fig. No. 5.2

These figures show the comparison of Super Heated Steam outputs and also the Super Heated Steam Pressure Outputs of the NN model with actual values. Figures also demarcate the results for both the training and testing phases.

It can be seen that for most instances the predicted values are within the operating range and predict the correct direction of change. The N N model also predicts the values of steam pressure changes correctly at the time of sudden changes

It may be appreciated that though Steam Temperature, Pressure and Flow rates have been modeled as independent parameters, they are thermodynamically related. As per conventions of Neural Network modeling it generally does not require a separate treatment.

Results when compared to models available in literature e.g. Ozel [2] .show that the current effort is close to the results of the published performances. Such models have been used for control of boilers and also for optimization and emission control.

The modeling techniques employed can thus be used in understanding and developing cogeneration applications. The model developed can be further improved by using data from a larger period of time with greater variations in the parameters. It may be noted that there may be some variability in bagasse properties itself which has not been taken in consideration.

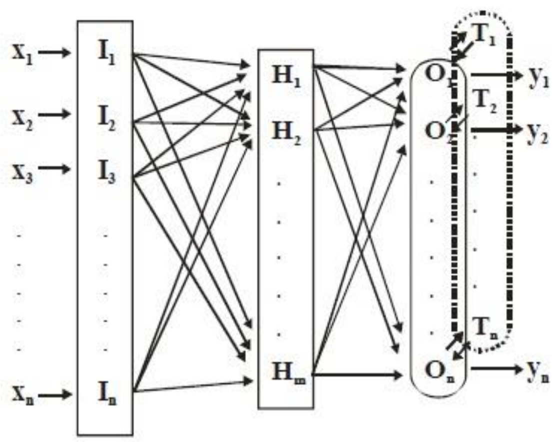

Fig 3.3: The training paradigm

6. CONCLUSIONS

This work focuses on the study of modeling of a process plant (of a sugar factory) through its input and output parameters using a feed-forward neural network. The conditions and the environment for modeling were selected based on perceived utility.

A process plant like the sugar factory boiler operates on a continuous basis while the neural network needs periodic inputs. It thus requires that time interval for sampling should be selected. After studying the data which was logged at hourly intervals a four hour averaged interval for observations was selected. It was observed that most changed inputs produce changed outputs in less than this time. The number of variables in the plant is rather large. To be able to focus on basic working of the boiler it was reduced to 15 inputs and 3 outputs. The neural network model was thus made with 15 input modes and 3 output parameters. Only two hidden layers were selected as is a common practice. The no. of nodes in the hidden layers were selected empirically as 20 and 9. A total of 161 data sets were collected. Out of these 146 were used for training he Neural Network Model and 15 were for testing the network.

The Back Propagation algorithm was deployed for training using a set of codes available. The learning rate parameters and the momentum values were varied during the training and testing.

The following conclusions were drawn from the studies:

1. Feed forward Neural Network can be successfully used for modeling a continuous process plant like a boiler, with 4 hours of averaging of the data.
2. The values of Steam Flow, Super Heated Steam Pressure and Super Heated Steam Temperature could be predicted with less than 3 percent, around one percent and less than one percent errors respectively.
3. Comparison of the results with literature shows that modeling results are comparable and the method can be used for optimization and control etc.

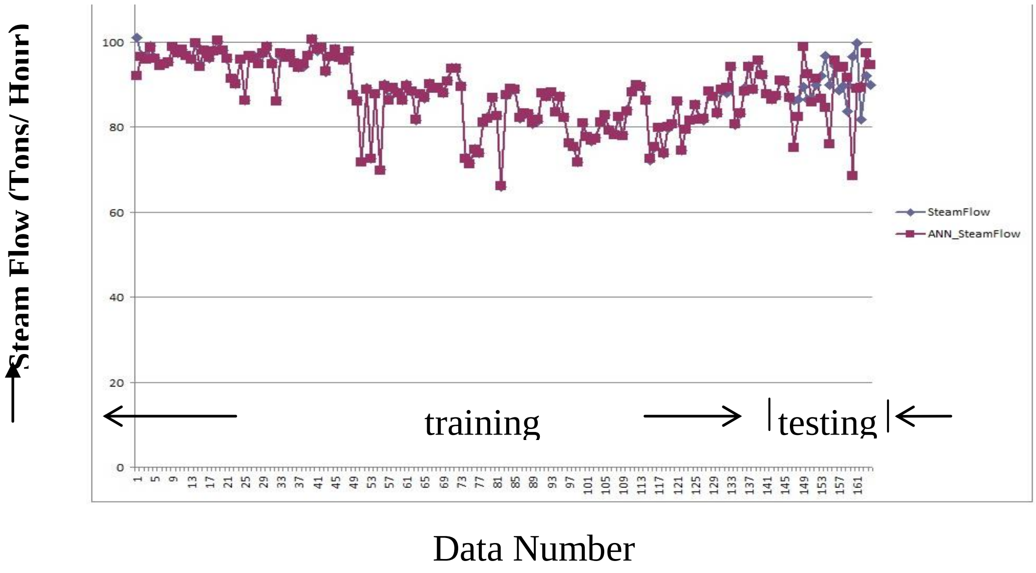

Fig 5.1: Training and testing results for Steam Flow Rates obtained from the Network compared with real values

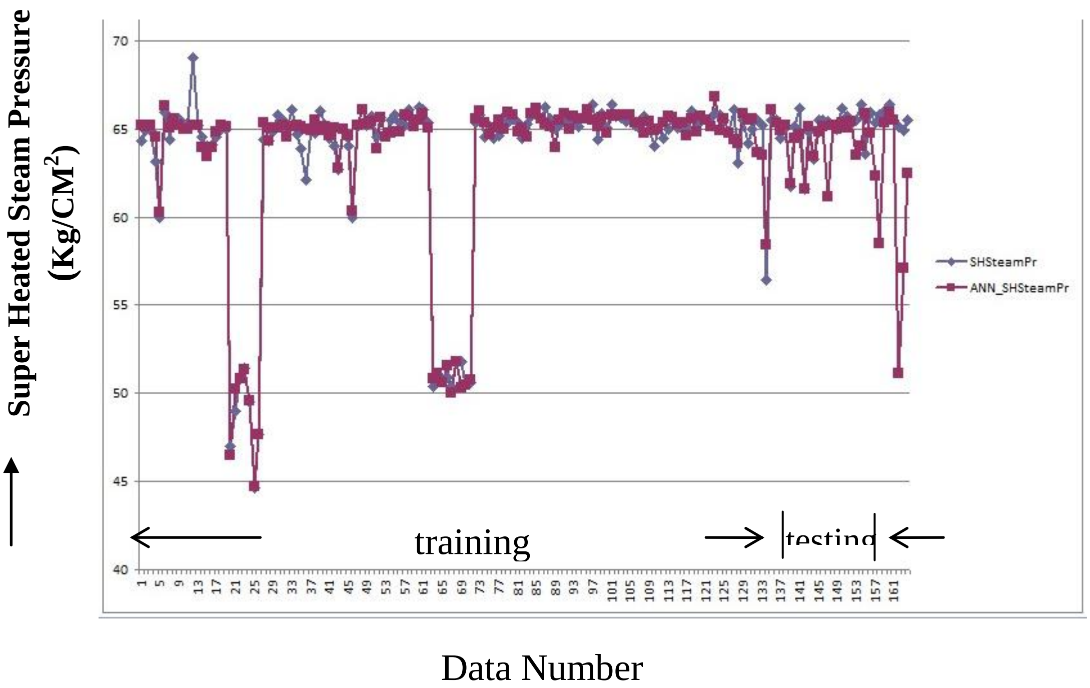

Fig 5.2: Training and testing results for Super Heated Steam Pressure obtained from the Network compared with real values

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