Modeling of Reheated Steam Temperature System using a Generalized Regression Neural Network

1Soonyoung Lee, 2Li Yun-Peng
1Department of Electrical Engineering, Engineering Research Institute, Gyeongsang National University, E-mail; leesy@gnu.kr
2Department of Electrical Engineering, Gyeongsang National University, Jinju, Gyeongnam 660-701 Korea, E-mail; liyunpeng2004@126.com

Abstract
In order to control the power plant accurately, exact models of the reheater and attemperator are needed. But sometimes due to a lack of needful information and complex internal structure of the system, it is unadvisable to establish the dynamics model based on energy mass balance, physical rules and thermodynamics principles. In this paper, a generalized regression neural network (GRNN) is developed to identify the thermodynamic system of reheater and attemperator. The models of the reheater and the attemperator are derived by using the GRNN and trained by using Matlab neural network toolbox. These models are developed for a once-through type boiler based on the real data obtained in 500[MW] power plant. The responses of the proposed models are well matched with the outputs of the real plant.

Keywords: reheater, attemperator, GRNN

1. Introduction

Reheater is used in big steam power plant to increase efficiency. It reheat the steam leaving high pressure turbine before it enters the intermediate turbine. Structure of the reheater and attemperator is shown in Figure 1. Reheater includes two heat exchangers, the primary reheater and the final reheater. Between the two reheaters there is one attemperator for decreasing the outlet temperature to protect the turbine. The inputs are pulverized coal mass flow, steam mass flow, inlet temperature, and output is outlet temperature in the reheater model. In the attemperator model, inputs are spray mass flow, injection spray temperature, inlet temperature, and output is outlet temperature.

![Figure 1. Structure of the reheater and attemperator.](image)

In power plants, accurate control of the steam temperature is getting more important because of increasing economic demand, energy saving, operational demand and pollution problems, etc. Proper power plant models are needed to design the suitable controllers.

In many cases, the power plant models are such simplified that they only describe the relation between input and output variables, where many intermediate variables are omitted[1,2]. It is difficult to get a satisfactory control results with these simplified models.

Power plant systems are highly nonlinear with numerous uncertainties. Thus, it will not provide good results to get the mathematical model based on the fundamental laws of physics such as energy
mass balance, thermodynamic principles[3-5].

In this paper, a generalized regression neural network (GRNN) will be used for establishing the reheater and the attemperator model. These models are developed for a once-through type boiler based on the real data obtained in 500[MW] power plant. The responses of the reheater models are compared with the responses of the real plant in order to show that GRNN is a good method to identify the reheater system.

2. Neural Network Modeling

The GRNN is a similar network with Radial Basis Function Neural Network. It has the same hidden layer in the architecture, but has a little different in the output layer. The GRNN has a special linear output layer. Architecture of the GRNN shows in Figure 2[6,7].

![Figure 2. Architecture of the GRNN.](image)

The number of neurons in each layer depends on the number of inputs, outputs and samples of the training dataset. In the Radial Basis Layer, the box $\|\text{dist}\|$ in this figure accepts the input vector $p$ and the input weight matrix $\text{IW}_{1,1}$, and produces a vector having $Q$ elements. The bias vector $b^1$ and the output $\|\text{dist}\|$ are combined with element by element multiplication.

MATLAB uses RADBAS as transfer function, which is a Gaussian function given by (1).

$$
\Psi_i = f(D_i) = \exp\left(-\frac{0.8326^2 D_i^2}{\sigma^2}\right)
$$

The parameter $\sigma$, called spread, set the open of this function. The parameter spread defines the neighborhood. Therefore, it is related to the number of patterns to be considered for the estimation of a variable. The higher the value, the greater the area of the neighborhood and more patterns will be considered. The lower this value, the smaller is the neighborhood and less patterns are taken into account[8]. $D_i^2$ is a scalar function.

In the special linear layer, nprod box produces the dot product of a row of $\text{LW}_{2,1}$ and the input vector $a^1$.

In the MATLAB, there is a neural network toolbox, it supports many methods to create neural network. The concrete method is as follows. In the command window of the MATLAB, type "ntool" to create a GRNN.
This is the trained neural network, shown in the Figure 3. In this neural network, there are two layers as shown Figure 4.

An internal structure of the layer 1 is shown in the Figure 5. The layer is the same as radial basis function (RBF) network.

An internal structure of the layer 2 is shown in Figure 6. This output layer is a special linear layer.
3. Simulation results

The models training process is performed by using Matlab neural network toolbox and is simulated by Matlab Simulink. The data for training and simulation are collected from the 500[MW] power plant. About 170,000 data, sampling time is 50 sec, are used in the simulation procedure. The experimental training data are recorded for 150,000, and 20,000 data are used for model validation.

Figures (7) to (9) are represented the simulation results for the primary reheater. Figure 7-9. show the training result, validation result, and validation error, separately.

From the simulation results, it shows that the error is less than 0.03 in the training and less than 1 in the validation.

Figures (10) to (12) are represented the simulation results for the final reheater. Figure 8-10. show
the training result, validation result, and validation error, separately.

![Figure 10](image1.png)  
**Figure 10.** Final reheater training result.

![Figure 11](image2.png)  
**Figure 11.** Final reheater validation.

![Figure 12](image3.png)  
**Figure 12.** Final reheater validation error.

From the simulation results, it shows that the error is less than 0.05 in the training and less than 1.5 in the validation.

Figure 13-15 show the simulation results for the attemperator.
From the simulation results, it shows that the error is less than 0.02 in the training and less than 1.4 in the validation. These simulation results show that the responses of presented models in this paper are significantly closer to the actual system responses.

4. Conclusions

In power plants, boiler modeling has a wide application in evaluating logic configurations, performing system tuning, applying any other control theory, etc. Furthermore, proper power plant models are needed to design the accurate controllers.

Sometimes, mathematical model can not accurately describe a power plant due to nonlinearity, uncertainties and complexity of the plant. In this case, a neural network system can be a useful method to estimate such a complicated systems.
In this paper, a generalized regression neural network is used for establishing the reheater and the attemperator models. Models are designed by using generalized regression neural network and the models are trained with the real data, by using Matlab neural network toolbox. These models are simulated for a once-through type boiler based on the real data obtained in 500[MW] power plant. The responses of the proposed models are compared with the responses of the real plant in order to show that GRNN is a good method to identify the boiler thermodynamic systems.

5. References