The Simulation of Boiler System for HADONG Fossil Power Plant

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Abstract – The Simulation of Boiler System for Hadong Fossil power plant has been made by Korea Electric Power Research Institute (KEPRI) in an attempt to develop Windows NT based full scope replica simulator for Hadong Fossil power plant, 500MWe once-through boiler.
In the project KEPRI developed Once Through, Super Critical type Boiler System, the core part of the Simulation and integrated the system with other process systems such as BOP System, and AUX System. This paper is to introduce the basic concept of the simulation for the Boiler System. It will also introduce PRO-TRAX System, for used as a modeling tool..

1. INTRODUCTION

From TMI(Three Mile Island) and Chernobyl accidents, power plant utilities all over the world recognized the importance of introducing operator training simulators for safe operation of power plants.
One major lesson learned from the accidents is that effective and systematic operator training using a full scope simulator is required to improve operation ability and to develop operation procedures to cope with and prevent accidents effectively.

To cope with these problems KEPRI(the sole research institute of KEPCO), in 1994, started an ambitious project of "3-pack Domestic Simulator project" to develop two nuclear power plant simulators for "Younggwang" and "Kori" respectively and one fossil power plant simulator for "Poryong". Through the successful completion of the project, KEPCO could train operators to cope with above problems.

However the 3-pack project was UNIX based system and required strenuous efforts to maintain.
In 1998 KEPRI started new simulator project for Hadong Fossil Power Plants. For this project Windows NT was adopted for OS, thus provided more user friendly environment.

In this project, unlike other projects, KEPRI took the major role in developing simulator. KEPRI not only designed the basic criteria but developed Boiler System, the core Part of the simulation, and such systems as Electrical system, Boiler Aux System. In addition KEPRI integrated all process systems and tested to prove the performance. In the following passages, We are going to describe in detail the key theoretical equations for Boiler System, the structure of the system, and other necessary concepts for the systems.

2. Introduction on the Hadong Fossil Power Plant and Boiler System

Hadong Fossil Power Plant is 500MW, Coal fired, Super Critical Once Through Type Plants. It is located 14km south east to Hadong, KyungNam. In normal operation the super heater outlet pressure and temperature are 246 kg/cm2 , 538 °C respectively. The heat efficiency can be improved by raising temperature and pressure. However the temperature is normally limited to 566, therefore by raising pressure hadong and other super critical plants improve the efficiency. The normal flow of Boiler System consists as follows;
The feedwater from #8 Feed Water Heater enters Economizer. The Economizer is composed of 450 tubes (counter flow heat exchange). By passing Economizer, the Water absorb heat form residual heat from Flue Gas. The water will gather at the outlet of the Economizer then goes to Bottom Ring Header. By passing Spiral wound tubes composed of 300 tubes, the water absorb most of the radiation heat from the combustion then passes vertical tubes. At the outlet of the tubes, the water is already in supercritical vapor state. That is a steam that does not have latent heat.
The steam then passes 3 super heaters – primary, platen, and final S/H- and heads to high pressure turbine.

The exhaust steam from the HP Turbine enters Primary Reheater and Final Reheater and heads to IP turbine.

Figure 1. below shows the structure of the Main Boiler System excluding Air/Gas system and others.

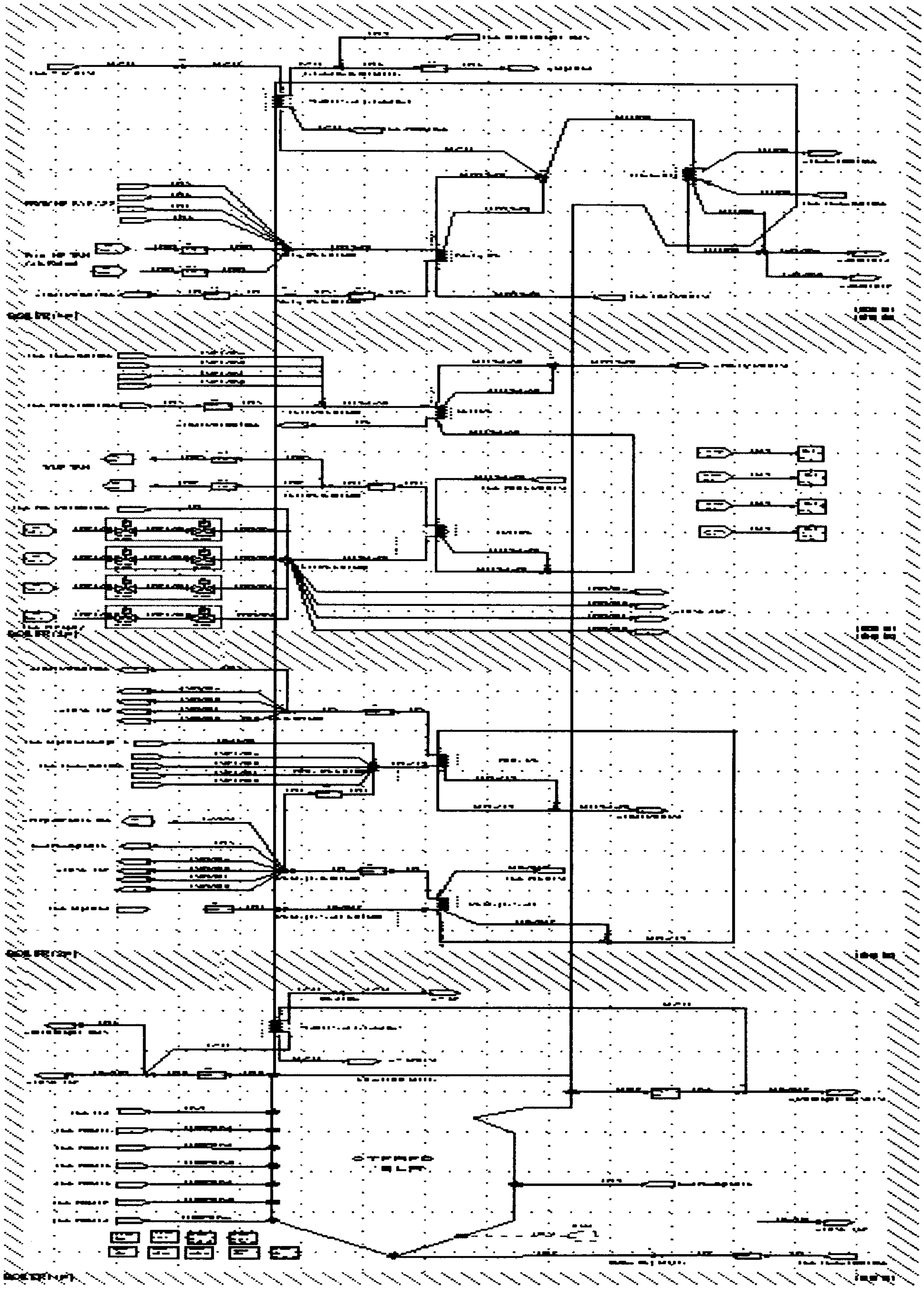

Figure 1. Over View of Boiler System

3. Theoretical description of Furnace model

3.1 The characteristic of module OTFRFD

To simulate Once-Through Furnace, we used OTRRFD module in trax system.
It simulates a universal pressure, fossil-fired boiler furnace. The fuel and air inputs are provided by Burner module. The OTFRFD has the following options to select the desired boiler configuration.

- 1~6 burner elevation
- Overfire air port
- Gas recirculation port
- Burner tilt
- Number of nodes for furnace temperature distribution

The following major phenomena can be simulated.

- Radiant heat transfer to furnace waterwalls
- Energy conservation in the gas, steam/water mixture in waterwalls.
- Burner tilt effect

3.2 Heat Release and Transfer

In Hadong there are 6 levels of elevation for coal firing. Therefore as shown in the figure there are 6 Burner inlets. For each node heat release and heat transfer was computed. Fuel burned in each node is computed based on the available air in that node as follows:

For complete combustion :

$$W_{fbrn} = W_{fuel}$$

For Partial combustion :

$$W_{fbrn} = W_{fuel} W_{air} / W_{thair}$$

where :

W_{fbrn} = Fuel burned

W_{fuel} = Fuel entering the node

W_{air} = Total air available in the node

W_{thair} = Theoretical air required for complete combustion

Any unburned fuel or excess is passed on to the node above. Since the ultimate analysis of the fuel entering each node can be different, a weighted average of air/fuel ratio and lower heating value is computed for each node as follows

$$h(N) = \frac{W_{fb} h_b + W_f(N-1)\, h(n-1)}{W_{fb} + W_f(N-1)}$$

$$X(N) = \frac{W_{fb} X_b + W_f(N-1)\, h(n-1)}{W_{fb} + W_f(N-1)}$$

where :

h(N) = Fuel lower heating value in Nth node

W_{fb} = Fuel flow from burners

h_b = LHV of the fuel coming from burner

W_f(N-1) = Fuel flow from previous node

h(N-1) = LHV of fuel from previous node

X = Air/Fuel ratio for complete combustion

Only radiation heat transfer to water walls is considered in each node,which is as follows:

$$Q_{gw} = K_{hx} K_{area} (1-S_t \theta) (T_g^4 - T_w^4)$$

where :

Q_{gw} = Heat Transfer to water wall

K_{hx} = Heat transfer parameter

K_{area} = Node area

S_t = Burner tilt sensitivity factor

θ = Burner tilt

K_{area} = Node area

T_g = Gas temperature in the node

T_w = Wall temperature in the node

4. Design and Data for Boiler System

To generate simulation model using such OOP module as ProTRAX, it is critical to previously calculate heat & mass balance.

The beginning of this step is to gather all necessary information from Plant operation data, Design Data, and other drawings. Once all necessary data are gathered, then modeler begins to draw simulation diagram which can properly represent and simulate the system. Figure 1 shown above is part of simulation diagram. Once the development of diagram is finished, modeler solve mass, momentum, and energy balance equations for each node. For example, once the inlet LHV and other physical properties - such as pressure, flow rate, moisture contents and etc. - for coal and the properties of inlet feed water are determined from Burner system, and Feedwater system respectively, modeler determine what should be those of outlet for gas and steam in the furnace. In this process, the balances for mass and energy are of critical and the results should be within reasonable range. From this calculation what we call operation data can be generated and used in the Operation data screen. In addition to this Operation data, the modeler determines such physical data as the elevation of each burner, the location of super heaters and reheaters from relevant drawings. This will generate Physical Data.

Once both Operation data and physical data are determined, then they are entered in the System. From the data, all necessary parameters are calculated. For example, heat transfer parameter from gas to wall can be coefficient can be calculated from Log-Mean Temperature Distribution equation.

Once all parameters are calculated then they will generate Fortran model.
By compiling and Linking Fortran model, one can generate executable file.

Figure 2&3 below are physical data screen and operating data screen for furnace module.

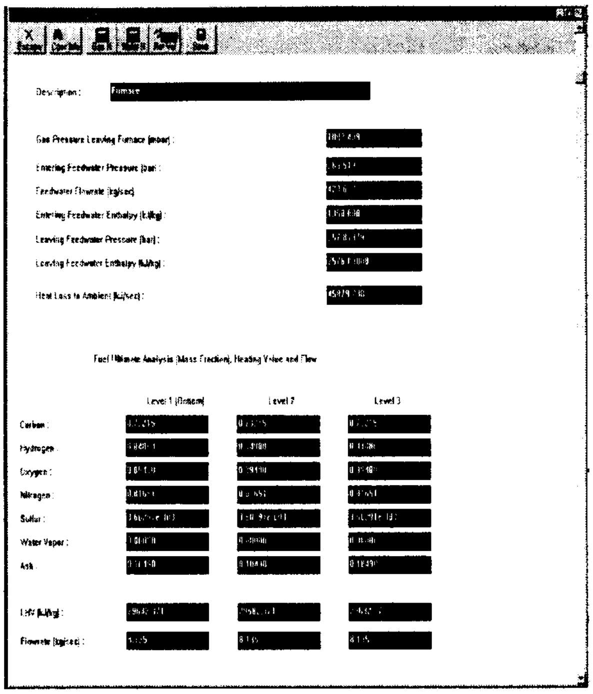

Figure 2. Physical Data Screen

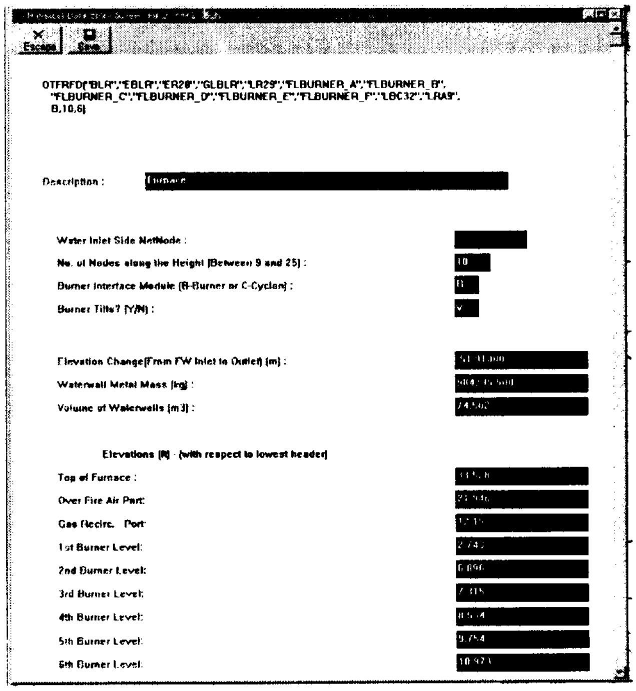

Figure 3. Operating Data Screen

5. Performance Test Results of Hadong Simulator

There are many steps to verify and validate the performance of the simulator. The first step is to test each model independently. There are four process models – Boiler, BOP, AUX, and Electrical model.
The first and the most important step to test each system is to run the model alone at 100% steady state. In this stage many errors can be identified. Typical of them are unstable fluctuation and wrong output.

When, after tuning, all parameters are stable and match well with plant data, one can move to the next step of Cold shutdown test. In this step, the modeler turn all system variables into off – that is turn off pump, close valve and etc. – state and check they are stable and have the same property as that of plant.
Once they are finished all process system are integrated together and tested again. In this step there are not many errors occur.

When tests for process system are completed, the systems are linked with Control System, then modeler can start the simulator like actual power plant. From this step every efforts are made to make them response as actual plant does. We call this step FAT-Factory acceptance test.

Figure 4 to 7 below show test results of Boiler System at 100%. KEPRI tested the simulator in accordance with the criteria of ISA. ISA (International Simulation Association) recommends that values of key parameters should not deviate more than 2%. To prove the system is stable we provided four key variables of Boiler Outlet Steam Pressure, Boiler Outlet Steam Temperature, - both of them are key parameter for Power of plant – Furnace Outlet Gas temperature before entering Super Heaters, and finally Economizer Outlet Gas temperature – which will be used to heat Air and then leave the plant.

As you can see all variables are stable and within reasonable range.

Figure 4. Boiler Outlet Steam Pressure

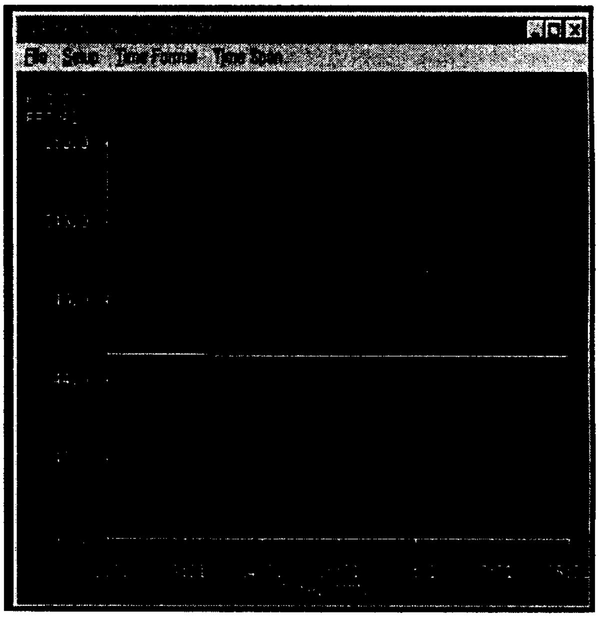

Figure 5. Boiler Outlet Steam Temperature.

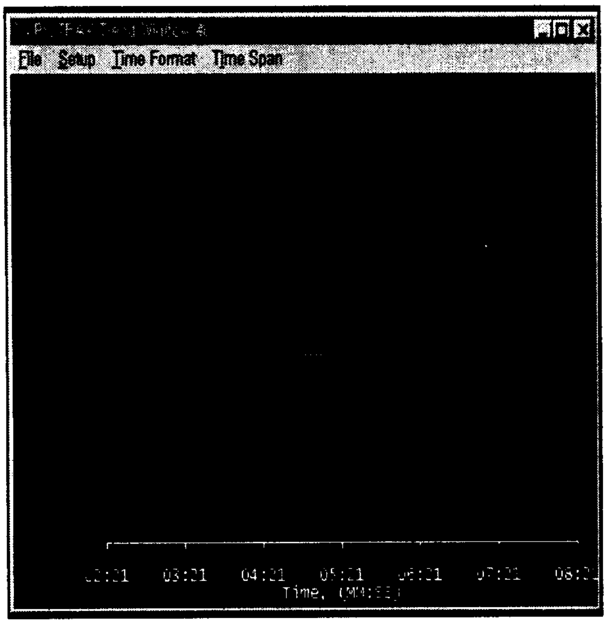

Figure 6. Furnace Outlet Gas Temperature

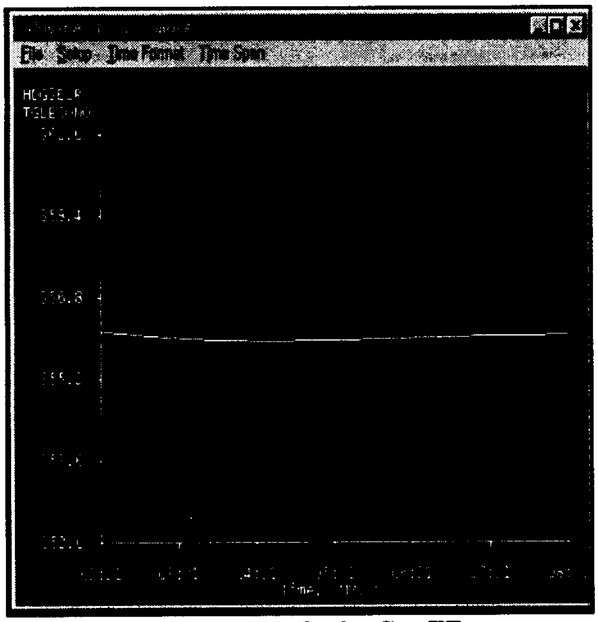

Figure 7. Economizer Outlet Gas TEmperature

6. CONCLUSION

As previously mentioned, KEPCO has started a new project of developing Windows NT based full scope replica simulator for Hadong Fossil power plant, 500MWe once-through boiler type in 1998. In this project KEPRI had developed Boiler System, the core part of the Simulation and integrated the system with other process systems.

Though project will be finished in January of 2000, the performance of the boiler system was quite satisfactory.

It was stable enough to conform the criteria of ISA and well match with original data. After the project is finished in January 2000 when all FAT and SAT are finished, KEPRI will not only gain core technology to develop Plant Simulation technology but also have technology to analyze problems during abnormal operation.

7. REFERENCE

[1] ProTRAX Analyst's Instruction Manual
[2] Data Books for Hadong Fossil Power Plant
[3] Operation Diagram for Hadong Fossil Power Plant