CHAPTER 3

EXPERIMENTAL SET-UP

3.1 INTRODUCTION

Combustion is the rapid oxidation of fuel in a mixer of fuel and air. The product of combustion is carbon dioxide, which is also called flue gas (Sam Dukelow 1991). Boiler absorbs heat energy from the flue gas and generates steam. The steam at a predetermined pressure is fed into the turbine. If there is change in steam pressure due to change in load (steam flow), the heat input to the flue gas has to be changed. This is achieved only by regulating fuel and airflow in proper ratio for the combustion in the boiler, which is directly proportional to the steam pressure. From the cost and safety point of view, it is very difficult to fabricate lab scale set-up for real time combustion system involving furnace, combustor, air and fuel modulators, burners for firing, drum and super heater etc., Hence in the present work, the dynamic changes of steam pressure, drum pressure, turbine first stage pressure, oxygen content in the flue gas due to load disturbance are derived from the computer simulated combustion system.

The objective of combustion control is to maintain constant pressure at the inlet to the turbine irrespective of change in load. This is achieved only by regulating the fuel and air flow to the combustion chamber of the boiler. For every load there is a unique set point for fuel and air. Once the set point is reached, it is concluded that the desired turbine inlet pressure has reached. Thus, in the present work, the manipulated variables are air and fuel flow to the boiler with respect to the set value.
A lab scale experimental set-up is designed and fabricated to find out optimum PID parameters for the control of air and fuel flow based on behavior modeling approach for various dynamic behaviors as dealt in chapter 2 and also to carry out the closed loop studies of conventional PID, cascaded PID, adaptive fuel set point based cascaded PID, conventional fuzzy, cascaded fuzzy and adaptive fuel set point based cascaded fuzzy controllers.

3.2 HARDWARE DESIGN

The important components of the lab scale experimental set-up include an oil tank, oil pump, compressor, rotameter, control valves, current-to-pressure (I/P) converter, and differential pressure transmitter (DPT), orifice, pressure regulators (PR) and control panel as shown in Figure 3.1. There are two distinct control loops, for air and fuel control. Electronic components include a stand-alone computer, input/output (IO) card along with signal conditioner, alarm card, digital indicators and RS232 communication card.

![Figure 3.1 Schematic of hardware setup for implementing combustion control scheme](image-url)
In the fabricated set-up, the fuel pumped from the fuel tank will return back to the tank via control valve, rotameter and flow transmitter (In practice, the fuel flow will be admitted to the boiler for combustion). Fuel flow transmitter will give the analog signal corresponding to the actual fuel flow. The pressurized air from the compressor is regulated from a pressure of about 100 psi to about 20 psi and fed to the control valve positioner and I/P converter. One more tapping from air compressor is used as combustion air, which is allowed to go to atmosphere via air control valve and air flow transmitter. (In practice, the air flow will be admitted to the boiler for combustion). Air flow transmitter will give the analog signal corresponding to the actual airflow. These analog signals are interfaced with the computer through I/O card. The processed signals from computer through I/O card are given to I/P converter as manipulated value to operate the air and fuel valves. The fabricated hardware and the front panel view for the lab scale experimental set-up are shown in Figure 3.2 and Figure 3.3 respectively. Design specifications of the lab scale experimental setup are presented in Table 3.1.
Table 3.1 Design Specifications of the Lab Scale Experimental Setup

<table>
<thead>
<tr>
<th>Component</th>
<th>Specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil reservoir Tank</td>
<td>MS with inner side fiber coated. (30 Litres capacity)</td>
</tr>
<tr>
<td>Centrifugal Pump</td>
<td>Tullu80 (1300 LPH)</td>
</tr>
<tr>
<td>Orifice Plate</td>
<td>SS316 (10 mm dia)</td>
</tr>
<tr>
<td>Differential pressure</td>
<td>ABB (4-20 MA) 24V</td>
</tr>
<tr>
<td>Transmitter</td>
<td></td>
</tr>
<tr>
<td>Control Valve with</td>
<td>RK, Air to open, Linear. Spring range (0.2 to 1</td>
</tr>
<tr>
<td>Positioner</td>
<td>Kg/cm²)</td>
</tr>
<tr>
<td>Electro-Pneumatic</td>
<td>Watson Smith, Input 4-20 MA, Output 3-15, Psi</td>
</tr>
<tr>
<td>Converter</td>
<td></td>
</tr>
<tr>
<td>Air regulator with filter</td>
<td>Placka, 0-15 Kg</td>
</tr>
<tr>
<td>Input-output card</td>
<td>VAD 103, 8 Channel 12 bit ADC</td>
</tr>
<tr>
<td></td>
<td>2 Channel 4-20 MA input</td>
</tr>
<tr>
<td></td>
<td>2 Channel 4-20 MA output</td>
</tr>
</tbody>
</table>
3.3 SOFTWARE DESIGN

The basic combustion simulation software was developed using C++ language, under the Windows environment, enabling to simulate the turbine inlet steam flow, drum pressure, turbine inlet pressure, turbine first stage pressure, oxygen in flue gas, position of steam, fuel and air feed valves, within-drum temperature and pressure, and within-furnace temperature under various operating conditions.

The simulation system was loaded with the following performance based responses collected from 210 MW thermal power station. 1) Load vs. turbine inlet pressure, 2) Load vs. turbine first stage pressure, 3) Steam flow vs. oxygen in flue gas, 4) Load vs. fuel flow and 5) Load vs. air flow. And also the energy balance, heat rate, combustion equations, excess air and performance calculations were loaded.

![System Software Management Diagram](image-url)

**Figure 3.4 System software management**
The software design consists of the following routines as shown in Figure 3.4. Diagnostic, initialization, declaration of the inputs, data collection, assignment of the inputs to the variables, computation of deviation error signals, assignment of the output variables, assignments of the results to the respective modules, set point calculation, the energy balance, heat rate, combustion equations, excess air and performance calculations, manipulation of data for display on the monitor, recorder and printer, data logging, assignment of data for alarm and protection modules and data communication interface.

The set points for the various air flow and fuel flow controller schemes are derived from the computer simulated combustion system. Regulation of air and fuel flow take place to maintain the above set points. Once the set point is reached, it is concluded that the objective of the combustion control is maintained (which is equivalent to maintain the required turbine inlet pressure). The block diagram representation of computer-simulated data is presented in Figure 3.5.
Once a load change (dynamic or steady state) is initiated through operator’s console, the simulated combustion system will develop set values for air, fuel and oxygen controllers. The actual values are interfaced with the computer through input card and compared with the set value to produce error signal to the respective controller (conventional / intelligent). The controller output is applied to the respective valves through output card and I/P converters.

The lab scale simulation setup for boiler, turbine, generator, combination of boiler-turbine-generator and electrical interlock simulators are shown in Figure 3.6-3.10. Over view of experimental set-up for air/fuel flow and air flow controller are shown in Figure 3.11-3.12.

The data and responses required for the design were collected from 210 MW thermal power station and are provided in the appendices A1.1-A1.6.

Heat rate calculation, heat and mass balance for combustion, boiler performance, determination of excess air (from flue gas analysis) and technical data of boilers for 210 MW thermal power plant are provided in the Appendices A2 - A6.

3.4 CONCLUSION

A lab scale experimental set-up is designed and fabricated to obtain optimum PID controller parameters based on behavior response model and also to carry out the closed loop studies of fuel and air flow for conventional PID, cascaded PID, adaptive fuel set point based cascaded PID, conventional fuzzy, cascaded fuzzy and adaptive fuel set point based cascaded fuzzy controllers.

Once a load change (dynamic or steady state) is initiated through operator’s console, the simulated combustion system will develop set values for air, fuel and oxygen controllers. The actual values are interfaced with the computer through input card and compared with the set value to produce error
signal to the respective controllers (conventional/intelligent). The controller output is applied to the respective valves through output card and I/P converters. The lab scale simulation setup for boiler, turbine, generator, combination of boiler-turbine-generator and electrical interlock simulators are interfaced with the experimental set-up for air/fuel flow and air flow to conduct experiments.

Figure 3.6 Boiler simulator
Figure 3.7 Turbine simulator
Figure 3.8 Generator simulator
Figure 3.9 Boiler-Turbine-Generator simulator

Figure 3.10 Power plant electrical interlock simulator
Figure 3.11 Overview of experimental set-up for air flow and fuel flow control

Figure 3.12 Overview of experimental set-up for air flow control