



Boiler drum level controller using Microcontroller

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Abstract— Boiler is a machine that produces steam from the water resulting from combustion of fuels such as fiber, coal, black oil, gas, and diesel. Commonly in industry they use PLC to move all operations of Boiler system. This project is mainly concerned on boiler control system by using microcontroller PIC 16F877A. If the drum feed water level goes to too low, the drum itself can become overheated, possibly resulting in catastrophe. Feed water and drum level control has two modes of automatic operation: single- and three-element control. The drum level set point for both modes is set by the operator. In a single-element control the difference between the drum level and the drum level set point provides the error signal that is used by the single-element controller to control the rate of water entering the drum by modulating the feed water flow control valve. Three-element control governs the three variables that are used in this control scheme: drum level, steam flow, and feed water flow. Three-element control is much more stable and robust than single-element control. In this project the total Drum level, feed water and steam flow are controlled by single Microcontroller IC using hi-tech embedded technology.

INTRODUCTION

1.1 COMPANY PROFILE

Our project “Boiler drum level Control using PIC microcontroller“ has been done at Mettur thermal power plant. The Mettur thermal power plant has the main function of generating the electricity and transmitting it all over Tamil Nadu. In this process, Boiler performs the vital role of production of saturated steam by burning the coal which is given as input. Here, our project deals with the control of the functions of boiler using PIC microcontroller. The essential parameters like the steam flow, feed water flow and drum level are monitored using microcontroller and safety of the boiler is enhanced.

1.2 METTUR THERMAL POWER PLANT

Mettur thermal power station is located in Mettur, Salem district in Tamil Nadu. It has four units, each unit can produce 210 MW. Its schematic diagram is represented below.

WORKING OF A BOILER

Boiler is a device for generation of steam for power generation. In thermal power stations water tube boilers are used. Boiler is suspended from the top on four columns and kept free from the bottom side for free expansion on downward direction.

Type of a boiler: Natural circulation, natural draft, tangentially fired, radiant, reheat type, dry bottom and pulverized fuel fired. Feed water is fed to the boiler drum through the economizer. Water then enters in bottom ring header through six numbers of down comers. In boiler furnace, coal is fired with fuel oil. The heat energy developed by combustion of coal in furnace is utilized for the evaporation of water in water walls. As the density of steam is lower than water, this water steam mixture enters in boiler drum without help of any pump. This is called natural circulation. In boiler drum, steam is separated from the mixture in three steps i.e. cyclone separators (Primary separators), secondary separators and screen dryers (Final separators). Steam that comes out of boiler is called saturated steam. This saturated steam is then passed through number of super heaters i.e. primary, platen and final for

superheating of steam to a temperature of 540°C. (pressure being 138 Kg/cm²)

When coal is burned in the boiler furnace, hot flue gases pass through the first pass and then to the second pass to the exit of boiler. Economiser and primary superheaters are placed in second pass one above the other, economiser being placed at the exit. The temp. of the flue gases in the combustion zone is 1200-1400 °C and after furnace 1000-1000 °C. The temp. of flue gas gradually decreases to 400 °C when it leaves second pass. The flue gas then goes through air pre heaters where its temp. drops down to 140°C. Primary and secondary air is passed through the air heater to increase the temp. This hot secondary air is sent to the furnace through wind box and hot primary air is sent to coal mill for heating pulverised coal and to transfer it up to the furnace.

Boiler is sealed from the bottom by seal water arrangement to prevent any ingress of atmospheric air into the boiler. Bottom of the boiler is shaped like a hopper. Bottom ash falls in the bottom hopper and after crushing it is transferred to ash handling plant. Fly ash along with the flue gases goes through ESP where fine ash is taken out and sent to the ash handling plant for further processing to the ash bunds.

Boiler drum, superheater and reheaters are fitted with safety valves for safety against the high pressures of the steam. Water attenuation system is provided for controlling the temp. of main and reheat steam. Burner tilting arrangement is also provided to control the temp. of steam. Soot blowers are provided at different locations of boiler to clean the boiler tubes.

A. PROPOSED SYSTEM

The purpose of the drum level controller is to bring the drum level up to the boiler start-up condition and maintain the level at constant steam load. A dramatic decrease in this level may uncover boiler tubes, allowing them to become overheated and damaged. An increase in this level may interfere with the process of separating moisture from steam within the drum, thus reducing boiler efficiency and carrying moisture into the process or turbine. The three main options available for drum level control are

- i). single level drum level controller
- ii). two element drum level controller
- iii). three element drum level controller

B. DETAILS OF HARDWARE

BOILER DRUM

Boilers in power plants and process plants have large drums to house the steam-water mixture, to hold large quantity of water required for steam generation, and ensure

steam quality. Drums weigh anywhere 100 to 250 tons with very high thickness. Manufacturing of these drums need special machines and process.

Power and process boilers have a large cylindrical vessel called the Drum. Early boilers had as many as four drums, but present day boilers have either one or two drums. A 210 MW boiler drum weighs about 130 tons. The drums of bi-drum boilers can be anywhere near 100 tons. The boiler drums have large stubs welded, many instrument tapings, safety valve stubs, and internals to maintain the quality of steam and distribute the feed water, and a facility to dose the chemicals uniformly across the length of the drum. Boiler drums are generally made of carbon steel plates of varying thickness depending on the design pressure of the boiler separating the steam from steam water mixer and discharging to Boiler outlet header pipes. It houses all internals used for steam purification after being separated.



Total Height of Boiler Drum = 630 mm.

Drum Pressure = 150 Kg/cm²

Drum Temperature = 540 °C

Drum Location = 52.5 meters in Boiler Area

FCV Valve

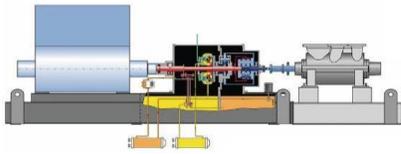
Feedwater is pumped from Boiler Feed pumps (BFPs) to drum through Full Load Control Valve (FCV) and Economizer coils. The closing and opening of FCV, the Boiler Drum Level to be maintained with Differential pressure reference across the FCV valve. FCV valve is placed on 18 Mtr of Boiler areas



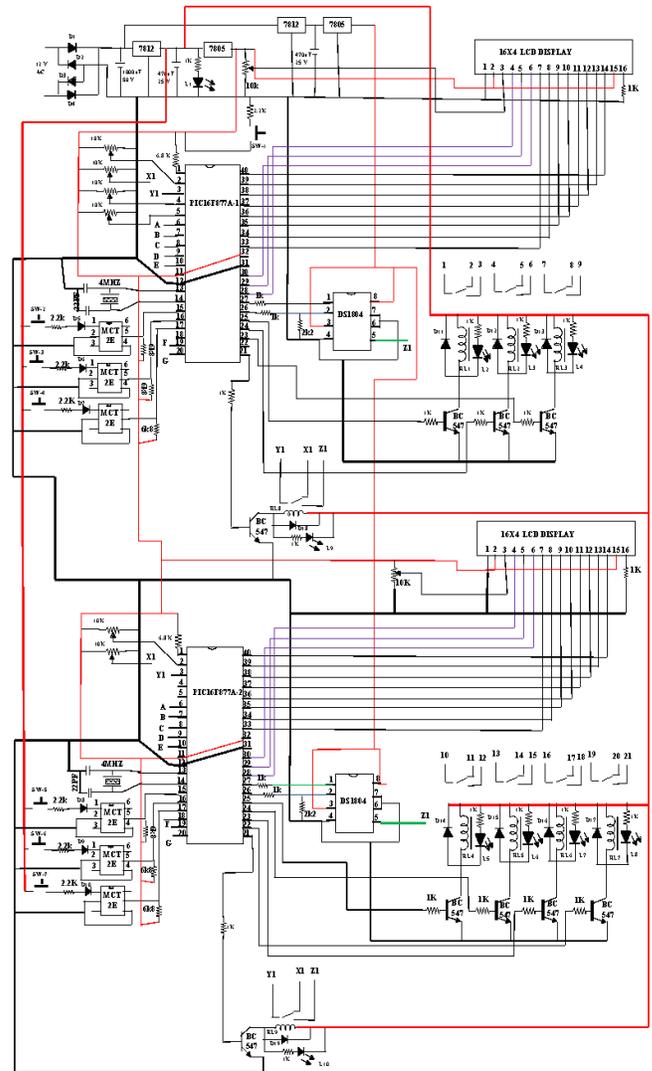
BOILER FEED PUMPS

BFP Motors are High capacity Motors i.e 3500 KW and 6.6 KV supply. These motors run at constant speed. Motor shaft was hydraulic coupled with Main pump. To increase or decrease the oil pressure of hydraulic coupling, main pump speed to be changed and also changes the Feed water flow to the boiler. One Pneumatic cylinder has placed on hydraulic coupling of main pump.

Pneumatic cylinder shaft was connected to hydraulic coupling oil line. Pneumatic cylinder operation to increase or decrease the oil pressure of hydraulic coupling and increase or decrease the Feed water flow. BFP pumps are located in 4.5 meters of Turbine area. Totally 3 numbers of BFP pumps are available in one 210 MW Generating plant. Two BFPs are running continuously for supplying Feed water to the Boiler Drum. One BFP is in standby condition for any plant emergency operation.



CIRCUIT DIAGRAM



CIRCUIT OPERATION

Circuit diagram consist of one no. full wave bridge rectifier, one no. stand by full wave bridge rectifier, six no's of Opto-coupler digital input circuits, seven no's of potential free relay operated contacts for digital outputs, one no 8-bit Flash memory type PIC micro controller and 16X2 line HD LCD display for display the analog output for the project parameters. Regulator IC-2 is used to regulate the Microcontroller and LCD power supply, IC-1 is used to constant power supply to the Relay operating coils. Variable resistor (VR1) is used to vary the contrast of LCD Display. Variable resistor (VR2) is used to Set (Anti-clock wise to Increase) the Required Drum Level in Boiler. VR3 is used to vary the Drum Level in the Process parameter of the Boiler. VR7 is used to vary (Clock-wise to Increase) the Feed water flow to the Boiler Drum and VR8 is used to vary the (Clock-wise to Increase) Main Steam Flow to the Turbine inlet. VR5 is used to set the Differential Pressure across the FCV valves and VR6 is

used to vary the Differential Pressure across the FCV valves in Process parameters. Switch (SW-1) is used to increase the Drum level by manually by adjusting the BFP scoop or FCV valves in manual mode condition and Switch (SW-2) is used to decrease the Drum level by manually by adjusting the BFP scoop or FCV valves in manual mode condition.

Switch (SW-3) is used to change the drum level manual control mode into Auto control mode. Switch (SW-4) is used to select Drum level control by Differential pressure control mode either BFP scoop control mode. Switches (SW5 & 6) are activating by any Process deviation in plant either internal protection fault in any equipment in Turbine trip and Generator Trip. Switch (SW7) is used to Master Reset of the microcontroller in any abnormal condition. Two no's 22pf ceramic capacitors are used to reduce the noise in frequency generation of crystal oscillator. The Green LED (L1) indicates "Power ON" of the circuit. 2 PIN connectors (CN1 to CN7) are used to inputs are given to the circuit and 3 PIN connectors (CN8 to CN14) are used to operate any external device like Circuit Breaker and motors. LED's (L2 to L8) are used to indicate the corresponding Relay ON of the circuit. LCD upper line to indicate the digital display of project parameters like Drum Level set value, Drum Level Process value, Feed water flow and Main Steam Flow difference, differential Pressure set value across the FCV valves and differential Pressure in process value across the FCV valves. LCD lower line to indicate, any fault in drum level control system trouble, drum level High / Low and Differential pressure set and Process value variation. Transistors (T1 to T7) are used to switching purpose of Relay coils.

Step-4

Any deviation in process parameters like Drum level set and process value, DP set and Process value and Feed water and Main Steam Flow difference the microcontroller to hold the operation. Normalized the circuit parameters and Reset the microcontroller by using switch SW-7.

Step-5

Normalized the circuit and Reset the microcontroller by using switch SW-7. Vary the earth leakage current in VR6, leakage current exceed the set value the earth fault is occur at the same time Master & Slave relays ON and also the corresponding alarm contacts relay ON.

Step-6

The manual mode control SW-1 and SW-2 are used to increase or decrease the drum level by BFP scoop

Operating Procedure

Transformer 12V AC supply is connected to the connector CN1 in circuit diagram.

Step-1

Switch ON the Transformer primary supply (230V AC). Power ON LED (L1) to glow. The LCD displays the project parameters like Drum Level SET, Drum Level, FW-MS Flow, DP SET and DP Actual.

Step-2

The drum level set and process values are close to each other otherwise the drum level high / low fault to indicate in LCD lower line. Total drum level height is 630mm. The middle of the drum level is 315mm. Deviation in drum level set and process value to vary the VR-2 and VR-3. The DP set and process values are close to each other otherwise the DP high / low fault to indicate in LCD lower line. In DP mode condition the DP across the FCV is around 6 Kg/cm². So, the DP set value is around 6 Kg/cm². Deviation in DP set and process value to vary the VR4 and VR5.

Step-3

Feed water Flow and Main steam Flow difference is around 80 T/Hr the Drum level controls automatically change to manual mode. So, that difference is minimum to possible to control the drum level in Auto mode control.

mode or either DP mode. Process parameters are normal value, to select drum level control by scoop mode or DP mode by changing the SW-4 and the SW-3 to ON the auto mode. The variation in drum level or DP, the corresponding Relay will be operate and maintain the drum level in auto control mode. Process parameters are changed my manually or control operation, the auto mode control of drum level change to manual mode. Drum level control system trouble relay will operate for alarm to operator and the corresponding fault displays in LCD lower line.

Step-7

Feed water flow to Boiler Drum is around 650 T/Hr and Main steam flow to the Turbine Inlet is around 650 T/Hr. So, the normal full load condition the difference between FW flow and MS flow in around Zero. The Generator Load variation or Boiler fuel firing disturbances, difference that the above parameters are increased. Feed water flow and Main steam flow difference is around 80 T/Hr, the drum level control auto mode into manual mode.

Step-8

Normalized the circuit and Reset the microcontroller by using switch SW-7. The closed loop operations of Drum level control by scoop mode either DP mode and control the drum level around 315mm in generator full load condition

PROTEUS SOFTWARE

PROTEUS

Proteus is software for microprocessor simulation, schematic capture, and printed circuit board (PCB) design. It is developed by Labcenter Electronics. PROTUES combines advanced schematic capture, mixed mode SPICE simulation, PCB layout and auto routing to make a complete electronic design system. The PROTUES product range also includes our revolutionary VSM technology, which allow you to simulate micro-controller based design, complete with all the surrounding electronic.

PRODUCT FEATURES

- ISIS Schematic Capture an easy to use yet and extremely powerful tool
- PROSPICE Mixed mode SPICE Simulation industry standard SPICE3F5 simulator upgradeable to our unique virtual system modeling technology
- ARES PCB Layout
- Modern Graphical User Interface standardized across all modules
- Runs on Windows 98/ME/2000/XP or Later
- Technical Support direct form the author
- Rated best overall products

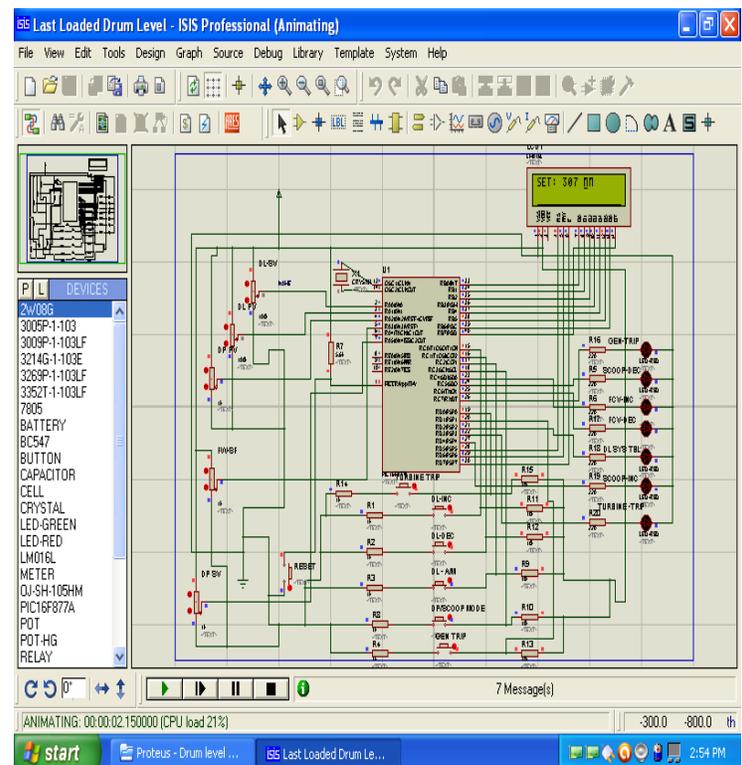
SYSTEM COMPONENTS

- ISIS Schematic Capture - a tool for entering designs.
- PROSPICE Mixed mode SPICE simulation - industry standard SPICE3F5 simulator combined with a digital simulator.

- ARES PCB Layout - PCB design system with automatic component placer, rip-up and retry auto-router and interactive design rule checking.
- VSM - Virtual System Modelling lets cosimulate embedded software for popular micro-controllers alongside hardware design.
- System Benefits Integrated package with common user interface and fully context sensitive help.

Proteus is an ambitious approach with a potential to touch many aspects of healthcare. Several prototype software tools developed have validated the core features of the Proteus approach.

SIMULATION RESULT



MERITS & DEMERITS

MERITS

- Power saving is acquired in BFP Motors

- Smooth drum level control can be obtained for any load variation
- Feed water flow can be linearly controlled
- To minimize the blow down of Boiler

DEMERITS

- FCV –A & B is not separately implemented
- This system is not applicable for coal calorific value variations
- This system is not applicable for generator under varying load operations

CONCLUSION & FUTURE ENHANCEMENTS

In this Project Boiler Drum Level Control by three element method such as drum Level, Feed Water Flow and Steam Flow measurement are made. Existing Differential Pressure across FCV measurement and operates the FCV valve to maintain the drum level. In this method the Boiler Feed Pump discharges header pressure and feed water flow gets interrupted and thus Boiler Feed Pump motor will have additional load at the time of FCV close condition. In our new proposed system, FCV valve is made to be fully opened and feed water flow and discharge header pressure are made free to move from BFP to boiler drum. Thus BFP pumps do not have any additional load at the time of drum level variation. In Thermal Power plant maximum auxiliary power consumption only depends on the BFP Motors. So,

two BFPs are running continuously and that hourly power consumption is 7MWhr. (7000000 Units / Hr).Proposed drum level control system helps in energy conservation in thermal power station and also maintains the constant drum level for any load variation in generator.

In future, variable frequency based BFP motor speed control method can be implemented with slight new modifications through which some additional power saving can be obtained

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