ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Study and Analysis of High Pressure By-Pass Control System in Thermal Power Plant

M.Kishore
M.Tech Student,
Mallareddy Engineering College, Telangana.

P. Shankar Babu
Associate Professor & HOD,
Department of EEE,
Mallareddy Engineering College, Telangana.

Abstract:

HP bypass system is most widely used in modern power plant for by passing the excess steam back in to the condenser using a pressure reduction and temperature reduction valves. The bypass system acts as a fail trip system which gets activated when there is a turbine trip, and during startup and shutdown of the boiler, to reduce fuel consumption and make the plant economical and safeto operate. The total sub system is called as De-super heating system. The system can be controlled by various methods of which we are using the control using pressure and temperature reduction valves using Enthalpy based PID controllers. Usage of PID controllers based on enthalpy, a thermodynamic property which is a function of temperature and pressure is a novel feature of this experiment.

Key Terms:

Enthalpy, Control valve, PID Control,Main steam, Down steam, Start up, Load swing.

I. INTRODUCTION:

The HP bypass system is a safety mechanism which is used to control and monitor the pressure & temperature in the power plant. The thermal power plants use coal as fuel to heat water which is converted into steam in a boiler. The steam is which is generated at high temperature and pressure is directed into the turbine which rotates due to the force felt by the turbine blades. The turbine in turn rotates the generator coupled to it which generates electricity. In thermal power plants, thermal energy is converted into mechanical and then into electrical energy by using boiler, turbine and generator. The various physical parameters monitored in the plant are pressure,temperature,flow, fuel rate,fluid level etc. Suitable Instrumentation is put in place to measure and control the various physical parameters to ensure smooth and economical operation of the power plant.

II.OVER VIEW OF THERMAL POWER PLANT:

The Thermal power plant mainly consists of Boiler, Turbine and Generator where the water heated in the boiler is converted into steam and projected on to the turbine blades which rotate the turbine and the generator coupled together to convert the mechanical energy to electrical energy. The power plant works on the principleof modifiedRankine cycle.

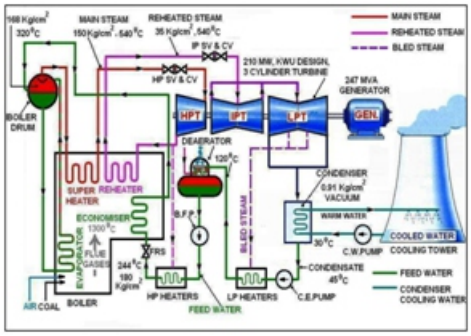

Fig 1:Thermal power plant

In a coal based power plant, coal is transported from coal mines to the power plant, unloaded and moved into the furnace using conveyor belts. As the coal from the mines is of non-uniform size, it is taken throughcrushers and crushed to a size of 20mm or less. From the crusher, coal is either stored in dead storage which serves as reserve coal supply in case of coal supply bottleneck or to the live storage in the raw coal bunker in the boiler house. Raw coal from the raw coal bunker is supplied to the Coal Mills by a Raw Coal Feeder. The powdered coal from the coal mills is carried to the boiler in coal pipes by high pressure hot air. The pulverized coal air mixture is burnt in the boiler in the combustion zone. Generally in modern boilers tangential firing system is used. The temperature in fire ball is of the order of 1300 deg. C. The boiler is constructed using multiple water tubes hanging from the top. Water is converted into steam in the boiler and steam is separated from water in the boiler Drum.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

The saturated steam from the boiler drum is taken to the Low Temperature Super heater, Platen Super heater and Final Super heater respectively for super heating. The superheated steam from the final super heater is taken to the High Pressure Steam Turbine (HPT). From the HPT the outgoing steam is taken to the Re heater in the boiler to increase its temperature as the steam becomes wet at the HPT outlet. After re heating this steam is taken to the Intermediate Pressure Turbine (IPT) and then to the Low Pressure Turbine (LPT). The outlet of the LPT is sent to the condenser for condensing back to water by a cooling water system. This condensed water is collected in the Hotwell and is again sent to the boiler in a closed cycle. The rotational energy imparted to the turbine by high pressure steam is converted to electrical energy in the Generator. [1]

III. Enthalpy:

"It is defined as the amount of heat content in steam" Enthalpy (H) is thermodynamic property which defines the total heat of the system and equals the Sum of internal energy (U) and product of pressure(P) and volume(V). The mathematical representation of Enthalpy is as follows [2]

$$H=U+PV \qquad (1)$$

The unit of measurement for enthalpy in the International System of Units (SI) is the joule, but other historical, conventional units are still in use, such as the British thermal unit and the calorie. The practical approach to measure or estimate enthalpy is to measure the temperature and pressure using sensors. The measured values of pressure and temperature are used for reference in the Moiller's chart from which enthalpy is obtained.[3]

IV. HIGH PRESSURE BY-PASS SYSTEM:

The steam bypass system is generally used during the following modes of operation: start-up and shutdown, steam turbine trip, steam turbine no-load or low-load operation, and simple-cycle operation . The schematic describes the general description of the By-pass system where the main steam entering the turbine by passes in to the condenser using a pressure reduction and temperature reduction valve the total steam is not sent on to the turbine only 60% is projected on to turbine.[4] If there is no bypass system then we would have to shut down the boiler if there is any turbine trip and hence it acts as isolation between the turbine and a boiler.

The main steam pressure is around 220 bar and temperature is 540o C and the dowm steam pressure is 40 bar and 300o C.When the main steam enters the turbine expansion takes place which reduces some of its pressure and temperature the similar expansion should happen in the bypass system to maintain thermal balance.

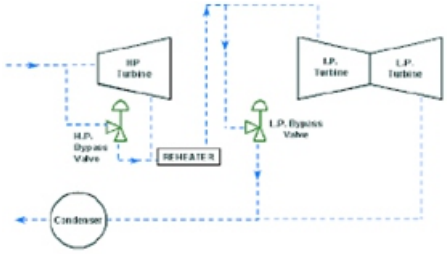

Fig 2:HP By-pass system with re-heater

Start up:

In the startup condition the water in the boiler is heated and the block valve is closed and the bypass pressure valve is kept open and the steam passes through it until the pressure in the system reaches the 220 bar pressure and 550o C. Later the block valves are opened and the bypass pressure valve is shut down. The main purpose of the bypass system is to isolate boiler and turbine making the power plant economical by reducing the fuel cost required to heat the water.

Shut down:

When there is a turbine trip or load swing the pressure valves are opened to reduce the pressure and temperature valves reduce the steam temperature to re-heater level or condenser level in some power plants i.e, 300oC and 40kg/cm2 and the amount of water to be sprayed to reduce the steam temperature is calculated using mass balance equation and energy balance equations.

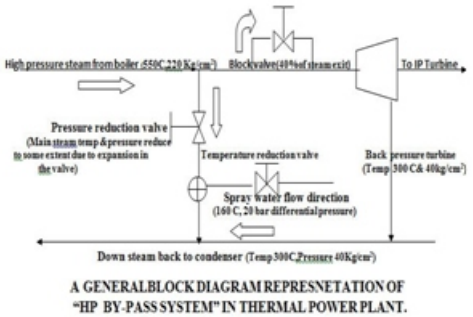

Fig 3:A block Diagram representation of Hp By-pass system with De-super heating system

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

V. CONTROLVALVE:

Control valves are valves used to control conditions such as flow, pressure, temperature, and liquid level by fully or partially opening or closing in response to signals received from controllers that compare a "set point" to a "process variable" whose value is provided by sensors that monitor changes in such conditions. Control Valve is also termed as the Final Control Element.The opening or closing of control valves is usually done automatically by electrical, hydraulic or pneumatic actuators. Positioner are used to control the opening or closing of the actuator based on electric, or pneumatic signals. These control signals, traditionally based on 4-20mA signals or 0-10V for HVAC systems. The pressure control valve may be linear where the flow rate is directly proportional to pressure drop and for the temperature control valve the difference between the temperatures directly proportional to the flow rate.
The relation for the flow rate and pressure drop is

$$Q=kv\sqrt{(p2-p1)} \qquad (2)$$

Q-flow rate
Kv- flow coefficient
p2,p1-pressure differences

There are different control valve characteristics which define the relation between the flow rate and pressure drop and the kv is defined by the manufacturer which defines the amount of flow rate across the valve for given standard temperature and pressure[5].There are different pressure and temperature control valves which are used in the thermal power plants depending up on the capacity of the plant and the valve itself is chosen based on the flow coefficient.

VI .MATHEMATICAL MODELLING OF BY-PASS SYSTEM

(A)CONTROL VALVE:

The control valve modeling is done to obtain the transfer function of the pressure regulating valve and temperature control valve. Here we derive the relation between the stem opening and pressure drop. As discussed earlier the down steam pressure of 40kg/cm2 is regulated. When there is change in up steam pressure the amount of stem opening required to reduce the pressure up to 40kg/cm2 is estimated using the formula

((P1-P2) / P1) ×100=percentage(%) of stem opening (3)

Where P1-Up steam pressure, P2-Down steam pressure
Eg: If Main steam pressure is 220kg/cm2 and down steam pressure is 40kg/cm2 then the percentage(%) of stem opening is 81.1.And the different stem opening values are obtained at different pressures. Here we choose the down steam pressure as a constant at 40kg/cm2 and change the up steam pressure from 220 to 80 kg/cm 2 and tabulated the values. Applying curve fitting and Inverse Laplace transform we obtain the transfer function.

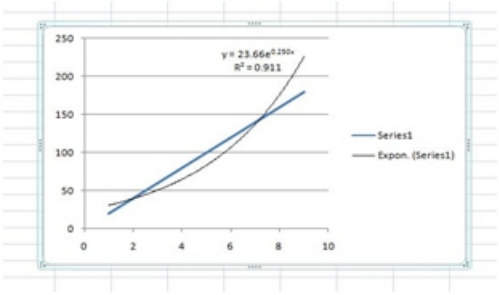

Fig:4 Shows the relation between stem opening and Differential pressure.

By taking the inverse LaplaceTransfrom for the equation we get the transfer function.
And similarly we derive the transfer function for a temperature control valve. Here the relation is derived between the temperature difference and stem opening,which is given by the formula

((T2-T1)/T2)×100=percentage(%)of stem opening (4)

Where T2 is the down steam temperature and T1 is the up steam temperature. The transfer function is same as PRV .since the same temperature and pressure conditions are to be met by the temperature control valve only the flow coefficient is changed [5].

(B) SPRAY WATER CALCULATION:

Here in mathematical modeling we first calculate the amount of water to be sprayed by using the spray control valve to maintain the constant temperature and pressure in down steam. Let the main steam mass be M1,H1 be the enthalpy of main steam. Let HW be spray water enthalpy and MW be the spray water mass. The resultant down steam mass is given as M2 and H2 down steam enthalpy.

M1+MW=M2 (5)

And the mass and energy balance of the system are taken to calculate the amount of spray water to be sprayed

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

M1H1+MWHW = M2H2 (6)
M1H1+MWHW = (M1+MW) H2 (7)
M1H1+MWHW = M1H2+MWH2 (8)
M1H1-M1H2 = MWH2-MWHW (9)
M1H1-M1H2 = MW (H2-HW) (10)
MW=(M1H1-M1H2) / (H2-HW) (11)

The down steam parameters are always a function of pressure. For the given saturated pressure temperature is obtained and main steam is function of both temperature and pressure.

(C) PID CONTROLLER:

The PID controller is used to control the steady state response of the system and improve the time response of the system and attain the stability.The formula of the PID control used is:

Po=Kp×ep+Ki*∫_0^t▒ep(t) +Kdd(ep)/dt (12)

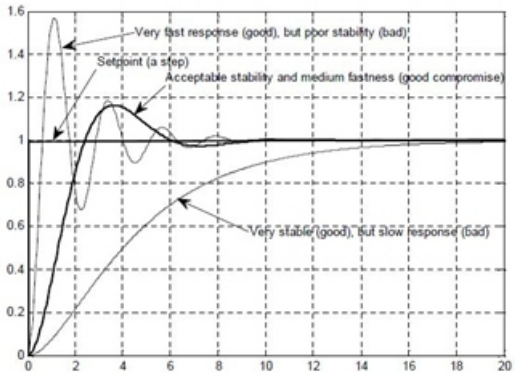

Fig 5: Response Of PID Controller When Tuned at Different Points

VII OPERATION OF THE HIGH PRESSURE BY-PASS CONTROL SYSTEM

The down steam pressure acts as a set point for the pressure reduction valve and depending upon the differential pressure the stem opening occurs and by using the formula we determine the flow rate across the valve due to the stem opening there occurs a pressure drop across and also temperature reduction due to the valve expansion the volumetric flow rate (m3/hr) is converted in to mass flow rate (kg/hr) by multiplying with 1000. The PID controller is used to control the pressure reduction valve, where main steam enthalpy is H1 and mass of main steamis M1.And the stem opening is directly calculated by using the output from the prv control transfer function and the stem opening determines the flow coefficient Kv by using the curve fitting tool the relation between the stem opening and flow coefficient varies for different pressures which effects the flow rate.After the pressure reduction valve there exists pressure and temperature drop and the Temperature reduction valve is used to spray water to the main steam so that the main steam pressure and temperature are reduced to the down steam set point, where spray water mass is MW and enthalpy of spray water is HW. The amount of spray water is calculated in the spray water quantity calculation is done by using the mass and energy balance equations. As similar explained in the prv valve there exists a relation between the stem opening and flow coefficient and the differential pressure results in flow across the valve but the temperature acts as set point for it. The amount of flow rate is determined by the differential pressure across the valve. The temperature difference acts as a set point and the stem opening is determined by using the relationship between stem opening and flow coefficient.The PID controller takes the set point of the differential temperature and the spray water is sprayed on the main steam to maintain the thermal balance. The steady state response of the control valve is thus improved.

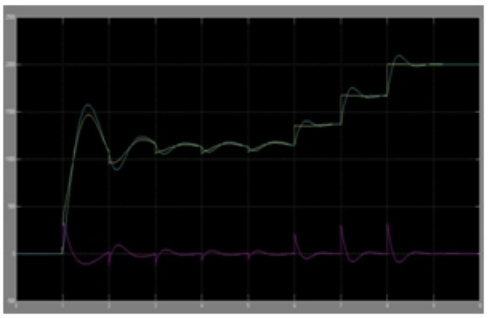

Fig7:Spray water Quantity for different Temperature and pressure

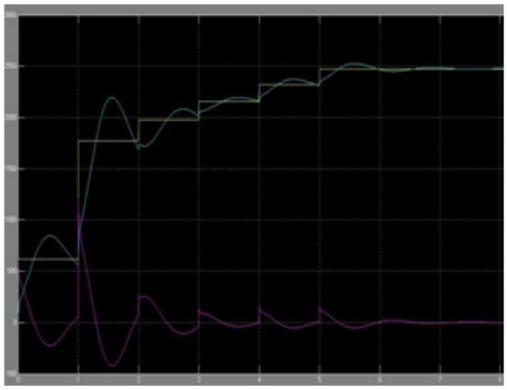

Fig 8:Response of the PID controller for different pressures

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

VIII CONCLUSION:

The "Enthalpy based control of the HP bypass system" is studied and analyzed by using Matlab andSimulink. The steady state response of the system at various temperature and pressures is observed. The above simulation is helpful to modern power plants to analyze the pressure and temperature parameters and maintain them within limits and to ensure safe operation of the power plant.

IX REFRENCES:

1. Power plant engineering-www.electrical4u.com
2. Power sector engineering – www.indianpower sector .com
3. Laws of Thermodynamics - www.wikipedia.org
4. Control system overview –Krishna swamy - pdf
5. HP-Bypass system-KOSO-www.KOSO.com - pdf
6. Control valve flow coefficients data sheet – www.easy-flow valves .com
7.Matlab/SimulinkVersion 2009 b

Authors Profile:

Mr.P.Sankar Babu

HOD & Associate Professor in the Department of Electrical and Electronics Engineering , Pursuing Ph.D at JNTUH Hyderabad ,have finished Master of Technology from S.N.I.S.T., Hyderabad qualified through GATE, Completed Bachelor of Technology from Dr. S.G.I.E.T Prakasam.I have 10 years experience in teaching field & published 23 papers which includes 8 International Journals, 9 International Conferences and 6 national conferences.