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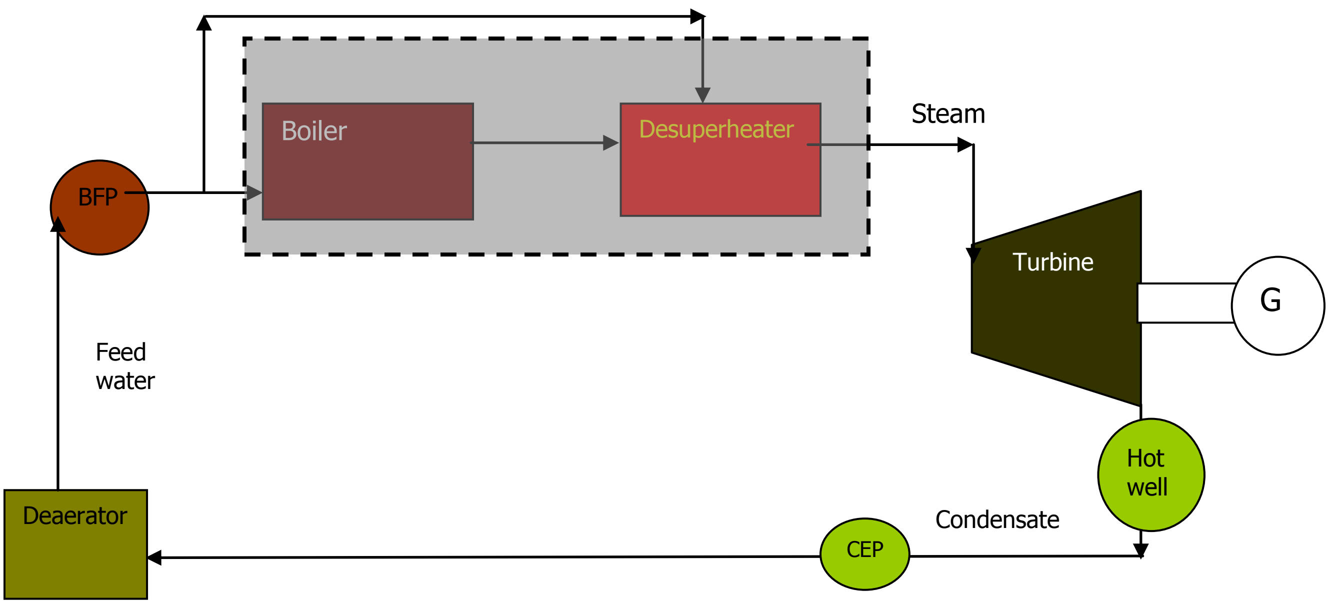
Issue # 1: June 2008

IGEN – Thermal Power Plant Corner

A schematic of steam-condensate-feed water system of a power plant is given below.

Assumptions:

1. The desuperheater water is taken from boiler feed pump discharge.
2. Presently there is no soot blowing system/ or the system is not working.
3. Power generation is constant at 110 MW and steam flow to turbine is constant at 390 TPH.



Existing system operation:

Estimation of operating cost of the existing system, before modifications on soot blowing is done below.

First, the energy balance of the boiler + desuperheater is done. From the above diagram consider the boiler + desuperheater as a single unit. This is shown in the shaded region enclosed by dashed line.

The energy streams are:

1. Energy flow in steam to turbine
2. Energy flow in feed water inlet to boiler
3. Energy flow in desuperheater water

Energy flow in steam to turbine (Output of boundary)

	Value	**Unit**	**Remarks/Methodology**
Power Generation Capacity	140	MW	Rated capacity, given
Actual Power Generation	110	MW	Actual generation capacity, given
Main steam flow to turbine	390	TPH	Actual steam requirement in turbine
Main Steam pressure	121	kg/cm2a	Given data
Main Steam Temperature	536	C	Given data
Enthalpy of main steam	3443.9	kJ/kg	Calculated enthalpy from software
Energy content in steam flow to turbine	**1343117404**	**kJ/h**	= Mass flow x enthalpy of steam

Total water flow delivered by the feed water pump is 390 TPH. Out of this, 30 TPH is taken for Desuperheating and 360 TPH water enter the boiler.

Energy flow in feed water inlet to boiler (Input to boundary)

Boiler feed water flow	360	TPH	Main steam flow - De sup. Water flow
Boiler feed pump pressure at inlet to drum	121	kg/cm2 a	Assumed data
Boiler feed water temperature	170	C	Assumed to be same as De Sup. Water temperature
Enthalpy of feed water at boiler inlet	724.8	kJ/kg	Calculated enthalpy from software
Energy Content in Boiler feed water inlet	**260944354**	**kJ/h**	

Energy content in desuperheater water is calculated below.

Energy flow in water to Desuperheater (Input to boundary)

Desuperheater water flow	30	TPH	Given data
Pressure	129	kg/cm2 a	Given data
Temperature	170	C	Given data
Enthalpy	725.3	kJ/kg	Calculated enthalpy from software
Energy content in Desuperheater water	**21758981**	**kJ/h**	= Mass flow x enthalpy of water

Net output energy flow from boiler + desuperheater

= Energy flow in steam to turbine - Energy flow in feed water inlet to boiler - Energy flow in desuperheater water

= 1343117404 – 260944354 – 21758981 = 1060414069 kJ/h

Given that Boiler efficiency = 80%.

Input energy to boiler and cost of fuel is estimated below.

Net energy output of boiler	1060414069	kJ/h	Energy content in main steam - energy in boiler feed water - energy in De sup. Water
Boiler efficiency	80%		Given data

Input energy to boiler	1325517586	kJ/h	Output energy / boiler efficiency
Calorific value of fuel	4600	kcal/kg	Given data
	19260.2	kJ/kg	kJ = Kcal x 4.187
Fuel consumption rate	68.82	TPH	Input energy in fuel / Calorific value of fuel
Cost of fuel	1800	Rs/Ton	Given data
Cost of fuel consumption	**123878.9**	**Rs/hour**	Fuel consumption x fuel cost

The specific electricity generation cost is calculated as total fuel input cost divided by total electricity generated, on an hourly basis.

Hourly electricity generation = 110 MW x 1000 = 110000 kWh.

Specific electricity generation cost	1.13	Rs/kWh	Total fuel input cost/total electricity generated
Revenue realised per kWh	2.00	Rs/kWh	Given data
Net Cash flow	0.87	Rs/kWh	Revenue per kWh - cost per kWh
Annual operating hours	7000.00	hours	Given data
Annual Cash flow	672847967	Rs	Net cash flow x operating hours

Thus the annual cash flow (revenue minus cost) is **Rs 67,28,47,967**
(Rs 67.28 Crores/year)

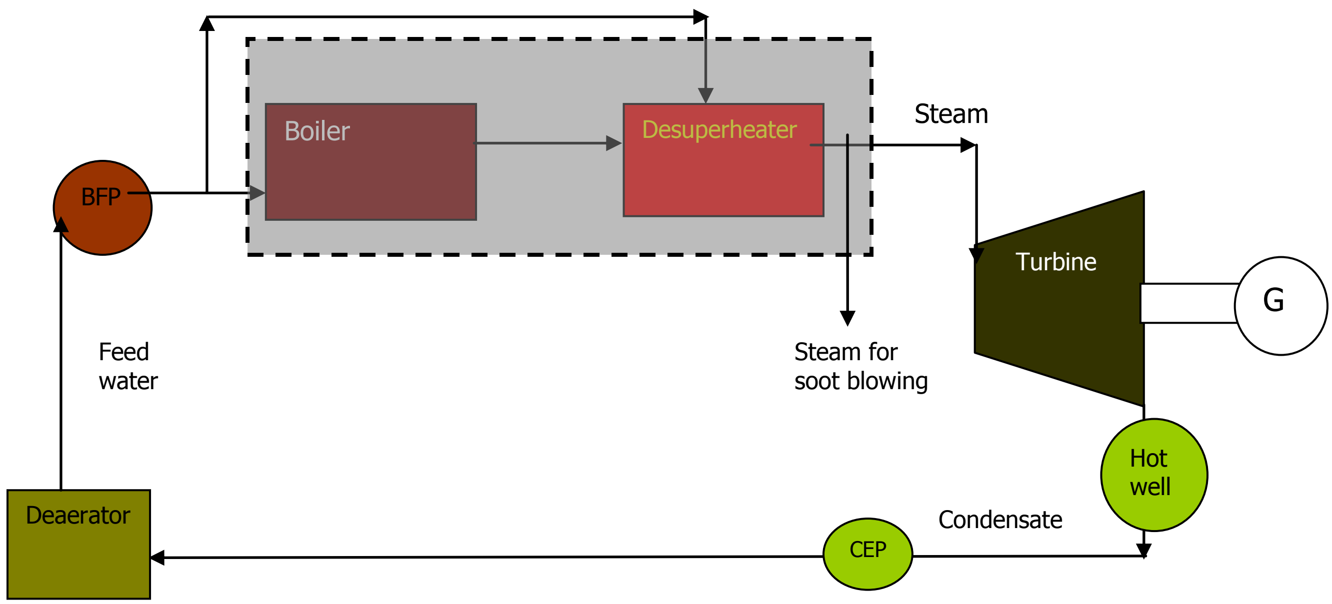
System operation after modification:

Now, we will estimate the total energy cost by modifications in soot blowing and reducing the desuperheater water flow. The energy balance in this case will involve an additional stream, for soot blowing.

The energy streams are:

1. Energy flow in steam to turbine
2. Energy flow in Soot blower steam
3. Energy flow in feed water inlet to boiler
4. Energy flow in desuperheater water

A schematic of the system is given below.



Note that in both cases, the output from the boundary is the steam flow to turbine, the energy content of which is constant.

Energy flow in steam to turbine (Output of boundary)

	Value	**Unit**	**Remarks/Methodology**
Power Generation Capacity	140	MW	Rated capacity, given
Actual Power Generation	110	MW	Actual generation capacity, given
Main steam flow to turbine	390	TPH	Actual steam requirement in turbine
Main Steam pressure	121	kg/cm2a	Given data
Main Steam Temperature	536	C	Given data
Enthalpy of main steam	3443.9	kJ/kg	Calculated enthalpy from software
Energy content in steam flow to turbine	**1343117404**	**kJ/h**	= Mass flow x enthalpy of steam

Energy Flow in steam for soot blowing (Output of boundary)

Steam requirement for Soot blower	110	Tons/day	Given data
	4.58	Tons/h	Daily consumption/24 hours
Main Steam pressure	121	kg/cm2 a	Given data
Main Steam Temperature	536	C	Given data
Enthalpy of soot blowing steam	3443.9	kJ/kg	Calculated enthalpy from software
Energy requirement for soot blowing	**15784499**	**kJ/h**	= Mass flow x enthalpy of steam

The desuperheater water flow is expected to be 7 TPH, as per given data.

Energy flow in this stream is calculated below.

Desuperheater water spray flow	7	TPH	Given data
Pressure	129	kg/cm2 a	Given data
Temperature	170	C	Given data
Enthalpy	725.3	kJ/kg	Calculated enthalpy from

			software
Energy content in Desuperheater water	**5077096**	**kJ/h**	= Mass flow x enthalpy of water

Boiler feed water flow will be more in this case, compared to the first case, due to the fact that the desuperheater flow has reduced and soot blowing steam requirement has increased.

Boiler feed water flow	387.58	TPH	Main steam flow -De sup. Water flow + Soot blowing steam flow
Boiler feed water pressure	130	kg/cm2 a	Assumed data
Boiler feed water temperature	170	C	Assumed to be same as De Sup. Water temperature
Enthalpy of feed water at boiler inlet	725.4	kJ/kg	Calculated enthalpy from software
Energy Content in Boiler feed water inlet	**281135969**	**kJ/h**	Mass flow of feed water x enthalpy

We have seen that the desuperheater water flow has reduced from 30 TPH to 7 TPH by providing soot blowing. By better heat transfer, boiler efficiency has improved and the boiler is now able to generate more steam.

Additional heat absorbed by water/steam in boiler by improving heat transfer, resulting in less Desuperheating	**62527602**	kJ/h	Difference in Desuperheater flow x difference in enthalpy of steam and feed water = (30 – 7) x 1000 x (3443.9 – 725.9)

Net energy output of boiler	1010161237	kJ/h	Energy content in steam to turbine - energy in boiler feed water - energy in De sup. Water + energy in steam for soot blowing – additional heat gained by water in boiler due to improved heat transfer
Boiler efficiency	80%		Given data
Input energy to boiler	1262701546	kJ/h	Output energy / boiler efficiency

The annual net cash flow is calculated below.

Calorific value of fuel	4600	kcal/kg	Given data
	19260.2	kJ/kg	kJ = Kcal x 4.187
Fuel consumption rate	65.56	TPH	Input energy in fuel / Calorific value of fuel
Cost of fuel	1800	Rs/Ton	Given data
Cost of fuel consumption	**118008.3**	**Rs**	Fuel consumption x fuel cost
Specific electricity generation cost	1.07	Rs/kWh	Total fuel input cost/total electricity generated
Revenue realised per kWh	2.00	Rs/kWh	Given data

Net Cash flow	0.93	Rs/kWh	Revenue per kWh - cost per kWh
Annual operating hours	7000.00	hours	Given data
Annual profit	**713942146.3**	Rs	Net cash flow x operating hours

The annual cash flow (revenue minus cost) is **Rs 71,39,42,146**
(Rs 71.39 Crores/year)

Saving calculations:

Saving in Fuel consumption = 68.82 – 65.56 TPH = 3.26 TPH of coal

Annual fuel saving = 3.26 x 7000 = 22820 Tons/year.

Net cost saving compared to baseline scenario = 71.39 – 67.28 Rs Crores
= Rs 4.1 Crores/year.

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