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A Case Study on Reducing Coal Consumption of Cogeneration Power Plant

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Abstract-This case study is carried out at M/s Raymond UCO Denim Private Limited Yavatmal for 6 MW cogeneration power plant. The aim of this work is to reduce the coal consumption of cogeneration power plant by recovering some amount of heat of steam which is actually wasted in current cogeneration power plant system. This loss of heat takes as steam is condensed in condenser. This heat can be recovered by circulating DM water as a cooling water in condenser thus extracting the heat of steam and then using this DM water as feed water of boiler. Due to this the amount of coal required for heating the boiler water to a desired temperature is reduced. We have calculated the annual savings of coal which we will obtain if we use DM water as a cooling water in the condenser. Also in current system the pressure reducing and desuperheating system is used for reducing pressure and temperature of steam. The same objective can be obtained if we replace this system by a turbine and in addition to this we also get power as steam is expanded in turbine.

Index Terms- Raymond UCO Denim Pvt. Ltd, coal, DM water and PRDS system.

1. INTRODUCTION

Raymond is one of the leading group in the Indian textiles market. Denim plant ofYavatmal is one of the largest Denim fabric producer in India. Raymond UCO Denim is well recognized in India and created a favourable image in international market. Raymond Yavatmal has been very keen on energy conservation from the beginning and has adopted all the latest technology available for Energy conservation. Raymond has its own power plant and produces its own power for the operations carried out in the Raymond. The power plant is of cogeneration type from which the heat is utilized for processing of clothes and cotton materials. Steam power plants are producing about half of the total power requirement in India. In a steam Power plant, thermal energy is used to raise steam that is used to run steam turbines to produce mechanical energy. This mechanical energy is converted into electrical energy in a generator. Steam power plants are suitable for large scale production of electrical power and supply of process steam for denim cloth manufacturing.

2. LITERATURE REVIEWS

Darshan H Bhalodia, Darshit B Parikh in his paper on “A case study of thermodynamic analysis of cogeneration power plant” in IRJET journal used the first law of thermodynamics in order to determine various losses occurring in the plant in order to improve the performance of the power plant . They have studied Energy flows in a boiler. They calculate the boiler efficiency using indirect method after estimating various heat losses in the boilers. From results they find the overall thermal efficiency of the plant by computing the individual efficiency of the boiler (79.4%), steam turbine (33.57%), and generator (98%) appears to be 26.2 %.

Anjali T H and Dr. G Kalivarathan, in his paper on “ Reducing coal consumption by recovering heat” in journal IRJET has done the Thermodynamic analysis of the thermal power plant to increase the efficiency and reliability of steam power plants. Most of the power plants are designed by the energetic performance criteria based on first law of thermodynamics only.. The present work deals with the comparison of energy and exergy analysis of thermal power plant stimulated by coal. Generally, it is predicted that even a small improvement in any part of the plant will result in a significant improvement in the plant efficiency. Factors affecting efficiency of the Thermal Power Plant have been identified and analyzed for improved working of thermal power plant. Hence they use the energy analysis and exergy analysis based on the first law of thermodynamics and second law of thermodynamics respectively, to identify the locations and magnitudes of losses in order to maximize the performance of a 15 MW thermal power plant in a paper mill, to evaluate the boiler, turbine and condenser efficiencies.

P.Vivek, P. Vijayakumar, has studied the heat recovery steam generator or HRSG and found that it produces steam that can be used in a process it works both on closed and open cycle. They came up with an idea that using closed cycle technology, we can recycle the waste heat from the turbine. in cogeneration plant, mostly they are using open cycle technology.. So they suggested that the exhaust gas will be sent by using proper outlet from cogeneration unit and by studying we found that the closed loop system should be incorporated in order to reduce losses and to obtain best possible results.

3. EXPERIMENTAL WORK

3.1 Details study of Existing System

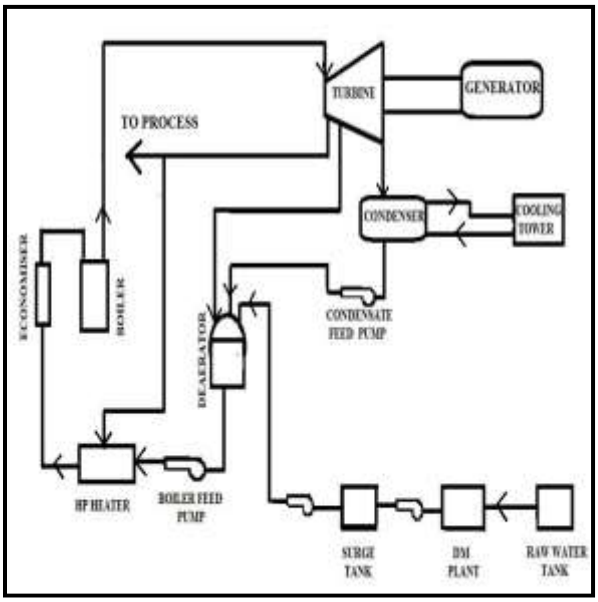

Fig. 1: Existing System

3.1.1 Working

In the existing cogeneration system out of total steam produced 70% steam is condensed in condenser then fed into the boiler. 25% of steam produced is used for process purpose which requires heat and the remaining 5% steam is bleed steam.

Initially the raw water is stored in raw water tank. The resources of raw water may be river or spring water or may be some other resource. The raw water is then processed in the DM plant to make the water demineralized and then the DM water is stored in the surge tank. This processing is one of the most important part of power plant because if water contains minerals then they form scaling on the surface of boilers and corrode it. This will affect the life of boilers also. The DM water is then passed into the deaerator. In which the dissolved gases from feed water is removed. Then the feed water is then passed through HP heater by boiler feed pump and then to the economizer where the feed water is then preheated by the exhaust gases of boiler. And finally the feed water is fed into the boiler. In the boiler the crushed coal is fed as per load requirement from the coal bunkers. Then the coal is burned in the furnace by the hot air and fuels. The water then continuously heated where it first gets converted into saturated steam and then into superheated steam. This superheated steam is then enters the turbine through the insulated pipes. In the turbine the steam is expanded and it exerts a pressure on the blade of turbines due to which the turbine rotates. As the turbine is coupled with the generator hence the electricity is generated.

Some amount of steam is then extracted for processing. The heat of this steam is extracted for some useful purpose and the water and vapor mixture is then released. As this much amount of water is reduced from feed water, hence we have to add the make up water to fulfill the amount of feed water. Some steam called as bleed steam and auxiliary steam is also used for functions of some auxiliaries. And the most part of steam is sent to the condenser. In the condenser the steam enters through inlet and the cooling water comes through another inlet and is circulated in condenser through the tubes. As the cooling water flows it absorbs the latent heat of steam due to conduction and hence converts the steam into condensate. The cooling water after extraction of latent heat is then passed to cooling tower. The cooling tower in the industry is of artificially induced draft cooling tower. In cooling tower the cooling water is dropped from high level and the air is sucked from lower level to high level with the help of fans fitted at top of cooling tower passing through the cooling water. As a result the heat transfer takes place between air and cooling water and the air takes the heat of cooling water and then released into atmosphere. This part of heat is gone waste in existing system. The cooling water is then again circulated through the condenser with the help of the high pressure pumps. Now the condensate then passes to the deaerator by the condensate feed pump. From the deaerator the condensate again passed to the boiler via a HP heater.

The hot gases from the boiler are passed through the boiler bank coils then economizer and then air preheater to utilize the heat of hot gases before exhausting in atmosphere. The hot gases before exhausting in atmosphere first passes through a device called as electrostatic precipitator. This device removes the pollutants from gases which can harm to the surrounding atmosphere. And finally the hot gases are exhausted through the chimney.

3.2 Detail Study of Modified System

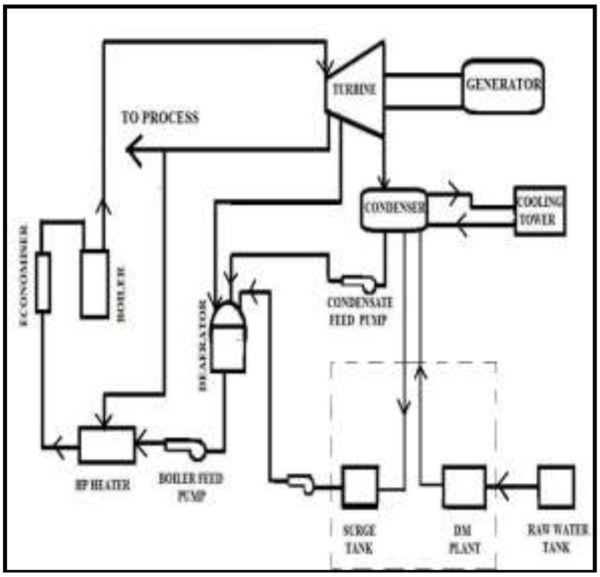

Fig. 2: Modified System

3.2.1 Working of Modified System

As seen in modified system we had made certain changes in the existing which is shown by the dotted lines. The path of water is changed in the modified system. Now the water instead of going directly in the surge is passed through the condenser and then goes into surge tank. Due to this change the water gets preheated and its enthalpy is increased because of which less heat energy is needed to convert it into the steam

As we see that the heat of steam after in condenser goes waste. Hence we have suggested the new modified system by which we can reduce the coal consumption of the power plant.

Initially the raw water is stored in raw water tank. The resources of raw water may be river or some other resource. The raw water is then processed in the DM plant to make the water demineralized and then the DM water is stored in the surge tank. This processing is one of the most important part of power plant because if water contains minerals then they form scaling on the surface of boilers and corrode it. This will affect the life of boilers also. The DM water is then passed into the deaerator. In which the dissolved gases from feed water is removed. Then the feed water is then passed through HP heater by boiler feed pump and then economizer where the feed water is then preheated by the exhaust gases of boiler. And finally the feed water is fed into the boiler. In the boiler the crushed coal is fed as per requirement from the coal bunkers. Then the coal is burned in the furnace by the hot air and fuels. The water then continuously heated where it first gets converted into saturated steam and then into superheated steam. This superheated steam is then enters the turbine through the insulated pipes. In the turbine the steam is expanded and it exerts a pressure on the blade of turbines due to which the turbine rotates. As the turbine is coupled with the generator hence the electricity is generated. Some amount of steam is then passed for processing. The heat of this steam is extracted for some useful purpose and the water and vapor mixture is then released. As this much amount of water is reduced from feed water, hence we have to add the make up water to fulfill the amount of feed water. This water comes from DM plant and then fed into the boiler through the deaerator.

We have suggested changes in this path of the DM water. Before feeding to boiler we first circulate the DM water through the condenser by directly connecting the DM water pipe to condenser. Now the DM water is circulated through the condenser it gets heated and then it stored in the already insulated surge tank from where it is then fed into the boiler. Thus we have utilized the heat of steam which in existing system is going waste.

3.3 Initial Cost Investment of Modification

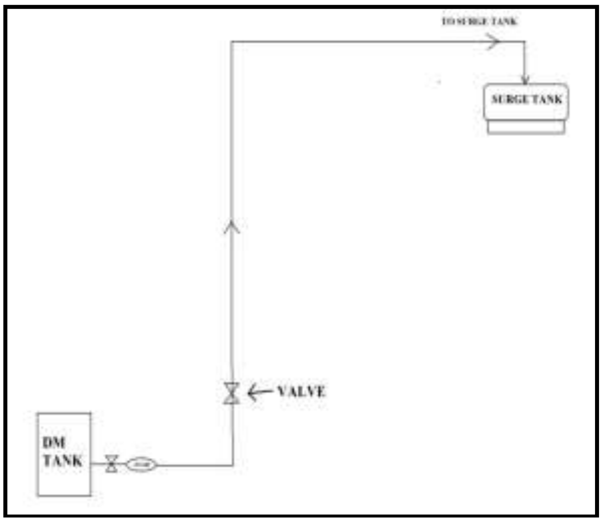

Fig. 3: Close View Of Existing DM Water Line

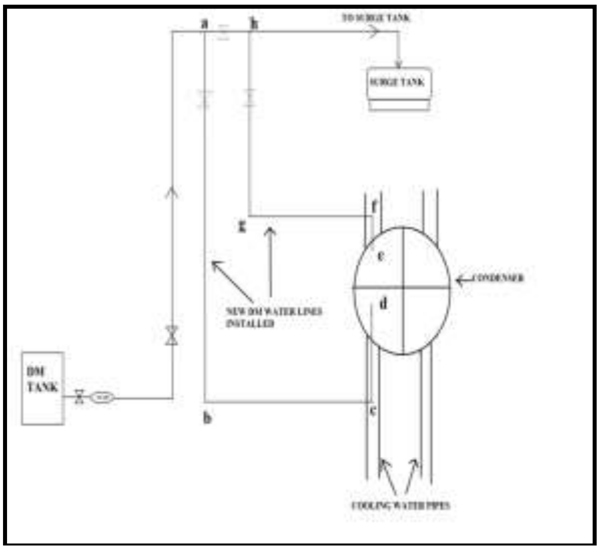

Fig 4: Close View Of New Installed DM Water Lines

Cost estimation for connecting the condenser tubes to the surge tank line –
A) Direct material cost estimation –

Table.1 Cost Estimation

Sr No	Component	Material/ Type	Quantity	Size	Unit Rate	Price
1	Valves	butterfly	3 unit	4 inch	3450	10350
2	Pipes	Stainless steel				
	Pipe a-b	Stainless steel	20 m	4 inch	6100	122000
	Pipe c-d	Stainless steel	10 m	4 inch	6100	61000
	Pipe e-f	Stainless steel	4 m	4 inch	6100	24400
	Pipe f-g	Stainless steel	2 m	4 inch	6100	12200
	Pipe g-h	Stainless steel	10 m	4 inch	6100	61000
3	Elbow	Stainless steel	8 unit	4 inch	1800	48800
4	Weld electrode		1 kg	2 cm	4200	4200
5	Pressure gauge	0 – 10 kg/cm^2	2 unit	-	1245	2490
6	Temperature gauge	0 – 100 ˚C	2 unit	-	635	1270
Total						Rs. 347710

The cost estimation not include the labour cost because has its own salaried competent maintenance staff members. Hence the total cost of the new installation will only include the direct material cost which is Rs. 347710 /-

Pay back period = $\frac{Paybackperiod}{investment}$
= $\frac{347710}{691200}$
= 0.52 year

Also,
Return on investment = $\frac{691200-347710}{347710}$= 98.78 %.

4. RESULT AND CALCULATION :

4.1 Result :

In Raymond there is control room from where all the power plant working can be monitored controlled. This is possible because of software called as "YOKOGAWA", which is made by a Japanese company. Due to this software we can control and visualize all the working parameters of the power plant. It shows all the parameters like steam inlet temperature, steam outlet temperature, mass flow rate , pressure of steam at inlet to turbine, power generated, etc. this data is stored on monthly basis for record purpose or to compare the performance of power plant for different months. From the same software we have collected the data for September (2017) month for our calculations.
The various data are shown as below:-

Table. 2: Parameters Of Cogeneration Power Plant

Sr. No.	Parameters	Quantity
1	Total steam generated	22051 Tonne
2	Steam inlet to turbine	21102 Tonne

3	Extraction steam to denim	5795.6 Tonne
4	Bleed steam to deaerator	1266.69 Tonne
5	Feed water consumption	22097 Tonne
6	Raw water consumption	23097 Tonne
7	Power generated	3386.2 MWH
8	Auxiliary power consumption	428.3 MWH
9	Coal consumption	4781.8 Tonne
10	Temperature of cooling water at inlet of condenser	30.28 ˚C
11	Temperature of cooling water at outlet of condenser	41.36 ˚C
12	Cooling water flow rate in condenser	1400 Tonne/hour
13	Average GCV of coal	3800×4.184 =15899.2 kJ/kg
14	Total DM water consumption	5970 Tonne/Month
15	Cooling water consumption	10552 Tonne

4.2 Calculations :

4.2.1 Calculation For Existing System **:**

Now as we know,
Heat lost by exhaust steam in condenser = heat gained by cooling water in the condenser.
Therefore,
Heat gained by cooling water = mass of cooling water × specific heat of water × $(T_{cw(out)} - T_{cw(in)})$
$= 1400 \times 4.184 \times (41.36 - 30.28) \times 10^3$
= 64902208 KJ/hr
Assuming 82% efficiency, This heat lost is equivalent to loss of $64902208/15899.2$ × 0.82= 3348 Kg/hr of coal. Thus if we calculate the amount of coal loss for 1 month it comes out to be 3348 × 24 × 30 = 2410.5 tonne. This loss is equal to near about 60% of total coal consumption for one month.

4.2.2 Calculation For Modified System :

Now if circulate the make up DM water before feeding into boiler through the condenser then it will take heat from steam and gets heated. But as the cooling water requirement is more than the DM water requirement to be feed in boiler hence only a part of steam heat can be utilized and still some heat goes waste. So the amount of heat recovered from steam can be calculated as ,

Heat gain by DM water = mass of DM water × specific heat of DM water × $(T_{DM(out)} - T_{DM(in)}$
$= 8.29 \times 10^3 \times 4.184 \times (41.36\text{-}30)$
= 394025.68 KJ/hr

Heat gain by DM water = 109.45 KJ/s.

Assuming 82% efficiency of heat recovery, we can save $394025.68/15899.2$ × 0.82= 20.32 Kg/hr of coal. If we calculate it for month then we can save 14.63 tonne of coal per month.
After implementing of this system the total coal consumption per month is reduced to 4767 tonne from 4781.8 tonne

Table. 3: Saving Of Coal

Sr No	Entity	Per Day	Per month	Per year
1	Coal savings (tonne)	0.48	14.4	172.8
2	Savings at rate (Rs 4000/tonne)	1920 Rs	57600 Rs	691200 Rs

The main focus of the power plant, to improve the economy is on reducing the coal consumption. And we have targeted the same aspect, to improve the economy and performance of cogeneration power plant. Thus we can save about 6.9 lakh rupees per year for if we implement our system.
As per our calculation we get the total estimate of about Rs. 347710 /- . But this cost is only at the time of installation and become the permanent dead investment. As we are saving Rs.691200 /- per year, so we can recover the installation coat in only about half anyear.After half an year all the savings will becomes the profit of the industry.

5. MERITS AND DEMERITS OF SYSTEM UNDER STUDY:

5.1 Merits

- As we are saving the coal hence, consumption of coal is reduced.
- As amount of coal used is reduced hence the pollution is reduced.
- The cost of installation new system can be recovered within few months.
- Clean water quality of DM water reduces condenser tubes choking.
- Cooling water consumption is less and hence the reduction in cooling water pumping power consumption.

5.2 Demerits

- The system has to be shut down for modifying the system.
- There may chances of damaging the system.

6. CONCLUSION :

From the above experiment & result analysis it is very clear that we can efficiently reduce the coal consumption without much investing on the existing plant by reusing the heat of the steam which in current system is going waste. But we can recover about only 45% - 50% of total heat contained in steam due to some losses. By analytical calculations we have found that we can save about Rs. 691200 annually by implementing the new system. Our calculations are restricted to only some part of condenser tubes as we are utilizing only few tubes of condenser. The industry can easily modify the existing system without much investing on existing system which can be recovered in few month and after which the all savings will became the profit of the industry.

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