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INNOVATIVE POWER ENHANCEMENT SCHEME IN EXTRACTION CONDENSING STEAM TURBINES OF CPP IN ORIENT PAPER MILLS

Dr T.G.Sundara Raman*
Consultant(Energy & DC)

Dr C.S.Kashikar*
COO

A.K.Srivastava *
GM (Power Plant)

M. Deelachary*
AGM (Power Plant)

*Orient Paper & Industries Ltd.- Amlai.

Abstract:

In Pulp and Paper mills, Steam turbines are either Extraction Back Pressure or Condensing with or without Extraction units. It is standard practice as followed by the designer of Steam turbines to maintain constant cooling water flow rate through the condenser for exhaust steam condensation, irrespective of condensing steam loads. Power consumption of circulating cooling water pump is hence high and constant. This results in increased Net heat rate at lower condensing loads of Steam turbines.

In OPIL-Amlai, the 30 MW STG and 25 MW STG-both of M/s Siemens design - are multi-extraction condensing units, served by 2 cooling water pumps supplying cooling water at constant flows to each of the condensers in operation. OPIL Power Plant team in consultation with their Energy Consultant had conceived an innovative energy saving scheme of changing cooling water flow rates for varied condensing loads, by splitting cooling water flows from one cooling water pump only, with the other being stopped. As cooling water flow rates (5200m3/h)from each of the existing cooling water pumps are much more than that for condenser design(63TPH and 56TPH condensing steam at vacuum) requirement, cooling water flows shall be split at low and normal condensing loads. Since condensing loads are around 50% (26 to 34 TPH), one of the 2 MCW pumps shall be in operation, catering to both 30MW STG and 25 MW STG. With implementation of the above, huge power saving of ~12100 units/day [505 kW] is being achieved. Emission reduction accrued is ~500 tCO2e/m.

This innovative concept can be very well extended for changing cooling water flows for varied condensing loads of STG-be it of CPP/IPP/TPS; with net power gains and Emission reduction being immense especially for low and normal condensing loads.

Keywords: *Steam Turbine, Condenser-Cooling water circuit, Net Heat Rate, Cooling Water Pumps, Auxiliary Power Consumption, Spray Pond.*

1.0 Introduction:

In Thermal & Cogeneration plants, emphasis is on improving Net heat rate (& Cycle efficiency) of the steam turbo-generator; as power available for process is not gross power generated by STG, but is that deducted for auxiliary power consumption.

Table-1
Select Facets of Heat Rate

Net Power Available = Gross Power generation –Auxiliary Power Consumption [APC]

% APC = APC/Gross Power Generation * 100

Turbine Net Heat Rate [kcal/h-kW] = Turbine Gross Heat Rate/[100%-APC% /100%]

Turbine Cycle Efficiency [%] = [860/ Turbine Heat Rate] * 100

APC related to STG is primarily due to power consumed in condenser cooling water cycle [Cooling water pumps & Cooling tower fans]. As Cooling water pumps consume maximum power , focus is on reducing the same so as to ensure increased power available for process use as well as utilities.

Unlike in Thermal Power plants, where it is mainly power generated through exhaust steam to the turbine condenser, in the case of Cogeneration Power plants, steam is mainly extraction at lower pressures for process use with the balance for condensing. Hence with low and medium pressure steam through turbine extraction as required by process and utilities be drawn first, the exhaust steam flow at vacuum keeps varying on a continuous basis. As a matter of fact, there would be wide variation in condensing steam flows throughout the year of operation. Invariably, condenser load is always well below rated condenser design.

In Pulp and Paper mills, Steam turbines are either Extraction Back Pressure or Condensing with or without Extraction units. It is universal practice followed by the designer of Steam turbines to maintain constant cooling water flow rate through the condenser tubes for exhaust steam condensation, irrespective of condensing steam loads and to switch off one cooling tower fan at low condensing loads. Power consumption of circulating cooling water pump is hence always high and constant -irrespective of condensing loads. This results in increased Net heat rate at lower condensing loads of Steam turbines. All focus shall be on ways and means for achieving significant reduction in Net Heat Rate of Steam turbo-generators[STG].

2.0 Brief of STG Battery in operation with Condensing in place

Orient Paper Mills at Amlai is having HP Cogeneration units with 2 mutiextraction Condensing Steam turbo-generators in operation for last one decade [Commissioned during 2011]. 30 MW Steam turbine is integrated to a 150 TPH Coal fired High Pressure AFBC Boiler in operation. 25 MW Steam turbine is connected to both Chemical Recovery HP Boiler as well as Stoker based coal fired HP Boiler in operation. Design data of the two steam turbo-generators in operation are elicited in Table-1.

Table 1 : Design Data Of 30Mw & 25 Mw Steam Turbo-Generators [1,2]

Parameter		**30 MW**	**25 MW**
		Multistage extraction Condensing	**Multistage extraction Condensing**
Design & Manufacturer		**Siemens**	**Siemens**
Inlet			
HP Steam flow	TPH	148	167
Steam Pressure	Ksca	88	56
Steam Temperature	°C	510	435
Extrn-1			-
Steam flow	TPH	15	
Steam Pressure	Ksca	24.6	
Extrn-2		-	
Steam flow	TPH		85
Steam Pressure	Ksca		12.5
Extrn-3			
Steam flow	TPH	62	19
Steam Pressure	Ksca	5	4.5
Extrn-4			
Steam flow	TPH	7	6
Steam Pressure	Ksca	1.65	13
Exhaust -Vacuum			
Steam flow	TPH	64	57
Steam Pressure	Ksca	0.115	0.099
Power Generation	MW	30	25

With the existing both STGs have exhaust steam condensing units, the condensing steam flows are split between the 2 TG units. Both the Steam turbines are with water cooled condensers integrated at turbine exhaust. Design details of the Condensers in operation since 2011, are elicited in Table -2 as under.

Table 1 : Design Data Of 30Mw & 25 Mw Steam Turbo-Generators [1,2]

Parameter	**Units**	**30 MW STG**	**25 MW STG**
Exh Steam Flow	**TPH**	**62.5**	**56**
Vacuum Cdsr	Ksca	0.115	0.1
Exh. Steam Enthalpy	Kcal/kg	559	550
HT Area of Condenser	M2	1156	1300
CW flow rate	M3/h	3829	4135
CW temp in	°C	33	33
CW temp out	°C	41.4	40

2.1.Spray.Pond

Cooling water used for exhaust steam condensation is in closed circulation connected to spray pond wherein the warm water return from the condensers is cooled through fine spray mist cooling through spray nozzles located in huge spray pond. The spray pond is 90 metres long and 36 metres wide and it had been designed for handling 12000 m3 /h of luke-warm water being sprayed as mist for cooling, through the well designed spray nozzles located all around equally spaced. Sprayed cooled water is collected in water concrete basin [3 metres in depth]. As can be seen from Fig.1. the spraying system is spraying the luke-warm cooling water return from both the 30 MW STG as well as 25 MW STG condensers [water cooled].

Fig.1 Spray Pond View with water spray from the Nozzles

Table - 3 : Cooling Water Pump Characteristics [5]

Manufacturer : Flowmore Limited

Model F-5821-600-500 ; Stage -1 ; Ref : HSC-F1-0206 ; Speed : 994 RPM

Flow	**Head**	**Effy**	**Power**		**Flow**	**Head**	**Effy**	**Power**
M3/h	**mWC**	**%**	**kW**		**M3/h**	**mWC**	**%**	**kW**
2500	49	68	520		**5000**	35	90	525
3000	46.5	76	530		**5250**	32.5	88	535
3500	44	83	530		**5500**	31	85	540
4000	41.5	88	530		**6000**	25.5		
4500	38	90	530					

2.2 OPIL CPP- Distribution of Cooling Water flows from CW Pumps

Main pipe-line is connected with the 2 CW pumps to a single pipeline. Hence with 2 CW pumps in operation , the entire pipe length upto Steam turbine battery is a single unit and hence carries combined flows from the 2 CW pumps.

The overdesigned cooling water pumps with very high flow rate [5200 -5500m3/h each at 3 ksc] pumping through the cooling water circuit had been in operation all along. With these high cooling water flows through the cooling water circuit, the resultant power consumption of both pumps in operation is as high as 1.0 -1.1 MW.

The requirement of Cooling water flows are far less [70%] even at rated high condensing loads [56 TPH and 63 TPH] . Moreover, being Cogeneration plant, steam from steam turbines is first extracted at various pressures for catering to process and balance only is being led to turbine exhaust at vacuum for condensation in the respective condensers. Hence condensation steam loads would be just around 25 TPH to 35 TPH [50 % of rated capacity]. In the absence of VFD in place ,cooling water flows through the condenser tubes could not be lowered as designed for. Cooling water flows had to be kept constant at all loads of operation of the 2 steam turbines.

3.0 Path to Innovative Energy Solution [6]

In depth study was undertaken to find ways and means for reducing the high power consumption of the cooling water pumps in operation. The cooling water flows to the condensers need to be reduced by 30 to 35 % to match the design flow requirements at rated condenser load. This could be done only through throttling of the control valve at pump discharge – as there was no VFD in place [being HT motor]. It was decided to drop this idea of high investment for HT VFDs- as OPIL had decided to go in for new sets of Steam turbines with one of Extraction Back pressure and the other with energy efficient multiextraction condensing steam turbines.

Only other option available was to stop one of the 2 operating CW pumps which would effect lowered cooling water flow suiting lower condensing flows of operation . Alongside with lowered pressure losses across CW pipe line , there would be marginal increase in CW flow from the operating pump [5300-5500 m3/h] distributing between the 2 condensers. Flow through the condenser tubes would still be 70 % of the design flow and that too at rated steam condensation [63 TPH & 57 TPH]. Refer Table-4.

Table 4 : Cooling water Flow Re-distribution Concept

Parameter	30 MW STG	25 MW STG	Combined
Design -2 CW pumps in operation			
• Condensing Steam flow	63 TPH	56 TPH	119 TPH [100%]
• Rated Cooling water flow	3829 m3/h	4135 m3/h	7964 m3/h
• CW Pump 1 & 2 discharge flow	5000-5200 m3/h [135%]	5000-5200 m3/h [130%]	[130% to 135%]
• Total CWP discharge flow	10000-10400 m3/h		[130%]
With 1 of 2 CW Pumps in operation			
• Operating Condensing steam flow	25 to 35 TPH	25 to 35 TPH	50 to 65 TPH [40% to 55%]
• CW Pump flow discharge	5200-5400 m3/h		[65 %]
• CW flow through each Condenser	2600-2750 m3/h [70%]	2600-2750m3/h [65%]	[65% to 70%]

3.1 Energy Solution

Instead of fretting away valuable power for CW pumps, after in-depth internal discussions with the plant personnel, decision was taken to stop one of the cooling water pumps in operation -especially when the condensing loads were 25 to 30 TPH. This would effect reduction in auxiliary power consumption through CW pump by over 0.5 MW [50% of existing figure]. This innovative concept of varying cooling water flow rates for the condensers[6] was in principle cleared by M/s Siemens Ltd. ,the designer of Steam turbines[7] . To take it further, for the proposed new extraction condensing steam turbine , design is one of varied cooling water flows through the condenser for high & low condensation loads.

4.0 RESULTS & ANALYSIS

Implementation of the concept of dual cooling water flow rates through condensers by stopping one of the pumps was taken up during mid Sep. 2023. Comparative study & analysis of the steam turbines with 2 CW pumps (before) and 1 unit (after) in operation are detailed in Table –5 [8].

Table 5 : Cooling Water Pumps -Power Optimization [2 No.vs 1 No. Running]

Parameter	Units	2 CW Pumps	1 CW Pump
Date		**17 Sep 2023**	**23 Sep 2023**
CW Pumps	**In Operation**	**1 &2**	**1**
STG		**25 MW**	**25 MW**
Condensation flow	TPD [TPH]	613 [251/2]	472 [20]
Condenser Vacuum	Ksc	0.85	0.82
CW Temp-in	°C	33	35
CW Temp-out	°C	37	42/43
STG		**30 MW**	**30 MW**
Condensation flow	TPD [TPH]	573 [24]	611 [251/2]
Condenser Vacuum	ksc	0.88	0.85
CW Temp-in	°C	32	34
CW Temp-out	°C	36	42
Total Condensation	TPD [TPH]	1186 491/2	1083 45
Avg. Power Consumption-CWP	**Units/day**	**24050**	**12250**
	kW	**1.002**	**0.510**
Power consumption reduction	kW	Base	**0.492**
CW flow from CW Pump	M3/h	10200	5200
CW Pressure	Kscg	2.6-2.8	1.5

With one CW pump off, water -side pressure drop is lowered by 60 to 70 % [which is inclusive of pressure drop across both set of condenser tubes]. With pressure loss reduction, inevitably cooling water flow from a single CW pump in operation had increased [as per the pump characteristics]. Hence is the cooling water flow of 5300 to 5500 m3/h being obtained with 1 CW pump in operation.

In the early days of the scheme implementation [Sep. '23], to start with, during the period when the total condensing loads are low[< 50 to 55 %], one CW pump was operated. At other times with higher combined condensing loads, both the CW pumps had to be operated.

With the onset of winter, the temperature of cooling water being quite low, one can very well operate with 1 CW pump for all times[Nov. and Dec. '23] of turbine operation of course with condensing loads of 50% to 55%. The last 4 month daily operational Power consumption data with the CW pump(s) as recorded is depicted in Fig.2.

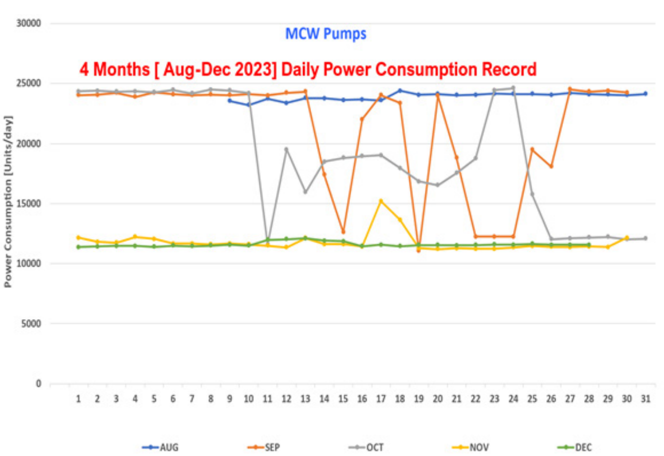
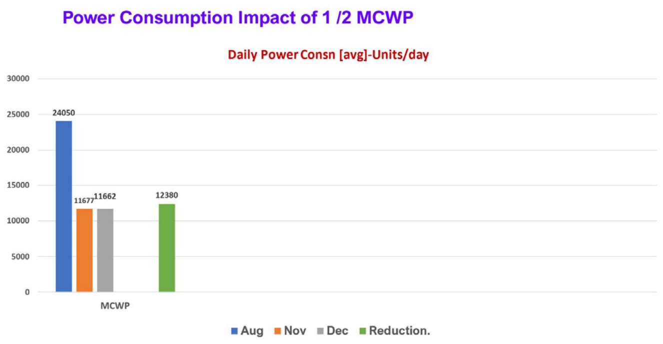


Fig.2.Cooling water pump(s) Power consumption Daily Record–4 Months[Aug-Dec2023]

Reduction in APC through the CW pumps is clearly brought out in Fig.3. as under



ig.3. *Power savings with one cooling water pump alone in operation*

4.1 APC reduction & Net Heat Rate

With lowered CW pump power consumption of over 0.5 MW , reduction in APC achieved is of the order of 2 % [0.5 MW out of ~24 to 26 MW total power generation]. Alongside Turbine Net heat rate had lowered by 2 %.

4.2 Emission Reduction

Through effecting power consumption reduction of over 12000 units/day , Carbon Emission Reduction accrued is around 500 tCO2e/month .

5.0 ADVISORY & RECOMMENDATIONS

Till the newly proposed Back pressure STG comes on range, the above innovative scheme of logic alongwith course correction of steam turbine and condenser internals be adopted for gaining valued incremental jump in Net power generation with minimal investment but without the need for additional resource [in the form of fuel].

As advocated, cooling water flow measurement was done once as desired.

In order to ensure good water mist spraying through the spray nozzles, as per our recommendations, cooling water flow distribution through the existing spray nozzles shall be further optimized.

As lukewarm water leaving the condensers is cooled through spray mist system through spray nozzles located evenly in the adjacent spray pond, in order to ensure good water mist spraying through spray nozzles and enhanced cooling , as per our advise, cooling water flow distribution through existing nozzles is being optimized.

In case of the condensing flows from either of the turbines exceed 50% [say 30 TPH] , it is recommended to operate both the turbines. Also during the summer ,when the ambient temperature would be high -especially during day time, as also the turbines with the condensers are more than a decade in operation, it is advisable for the ensuing season, to operate both the cooling water pumps when the STG condensing load is more than 25 to 27 TPH. To summarize, with on-set of summer, with rise in ambient conditions and hence CW temperature, it is recommended to operate both CW pumps with combined condensation flows exceeding say 55 TPH.

6.0 Way Forward -Path-way

Not waiting for the proposed new EE Back pressure Turbine in place replacing the existing Extraction condensing 25 MW Steam turbine, it is being planned to a) go in for either VFD for the existing Cooling water pump or b) buy a new EE CW pump of revised input specifications alongwith LT motor of much lower rating and VFD to adjust for actual flow conditions to suit.

Through this add-on Energy solution, there would be further reduction in APC -with resultant Net power generation all through the season &reduction in Net heat rate on a continuous and sustained basis -be it summer day or winter night and without concern for varying condenser loads.

7.0 Conclusions

Through varied & optimized cooling water pumping flows through the condenser tubes-cooling water circuit to suit varying condensing rates in the cogeneration units, auxiliary power consumption is greatly reduced as being demonstrated by the live case study of the 2 multiextraction condensing steam turbines in OPM . This facet had resulted in increased net power available for process -thereby improving significantly turbine net heat rate[APC reduction:2% at present operating power generation loads].

7.1 Cross-Sector Application of the Concept

This innovative concept is a boon for all cogeneration plants in diverse industries of other industrial sectors, in that energy savings are huge with varying the cooling water flows (with Cooling water pump with VFD) through the condenser according to the condensing loads -more so during low condensing loads of operation.

Acknowledgment

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