A Case Study on Availability Losses in a Condenser for a 210 MW Thermal Power Unit in India

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Abstract

In this paper, an attempt has been made to study the various availability losses in the condenser for five different loads of a 210 MW thermal power unit installed at Bandel Thermal Power Station in West Bengal, India. In each load, the task efficiency of the condenser has also been assessed to measure how effectively the thermal interaction between the steam and circulating water has taken place. From the study, it is revealed that the availability lost in the condenser increases with increase in load. Loss due to internal irreversibility has also been noted to be increasing with increase in load. The external irreversibility in condenser is found to have higher values at higher loads. The task efficiency of the condenser has been observed to be increasing from around 2.8% at 100 MW to 3.5% at 210 MW load.

Nomenclature

A	availability, [kJ/kg]
ALC	availability lost in condenser, [MW]
C.E.P.	condensate extraction pump
EIL	loss of availability due to external irreversibility, [MW]
h	specific enthalpy, [kJ/kg]
IIL	loss of availability due to internal irreversibility, [MW]
L.P.	low pressure
LPH	low pressure heater
m	mass of steam per unit mass of main steam, [kg/kg of main steam]
M	mass flow rate of main steam, [kg/sec]
Mcw	mass flow rate of cooling water, [kg/sec]
s	specific entropy, [kJ/kg-K]
T	temperature, [K]
TE	task efficiency, [%]
0	pertaining to environmental condition
1	inlet to condenser
2	hot well exit
3	LPH # 1 drain exit
cwi	cooling water inlet
cwo	cooling water outlet

Introduction

It is well established that up to 1970, the energy was viewed as abundant and cheap. The increase in energy resource consumption, occurred in each passing year, was not a source of general concern. After the mid 1970's oil shock, the perception on energy has gradually changed. The studies on energy and their judicious use have got importance day by day and the studies on energy was also concerned with the changing availability of resources and their relation to technical activity [1]. In this regard, the effective methods are considered to be the optimal use of energy resources, energy efficiency improvements, and the reduction of unavoidable losses. For this, availability analysis for each equipment of any plant, like processing plant, power plant, co-generation plant e.t.c., and its study are gaining popularity at faster rate in prescribing the optimal use of energy by reducing losses and thus ensuring the economical running of the plant. The availability analysis enables the appropriate performance measures and criteria to be set up with which respectively to measure and judge the performance of any plants and devices [2].

A number of studies [3-10] have been carried out in the field of availability analysis and assessment of irreversibilities for various devices and plants. From the survey, it is evident that while activities had been carried out mostly in studying the irreversibilities in the cycle, boiler, furnaces, and in the processes of expansion, compression, and combustion etc., for steam power plants and cogeneration systems, there exists a void as far as the study on different availability losses in a condenser, for an operating power plant or cogeneration system, is concerned. In this paper, an endeavour has been made to study on the various availability loss components in the condenser of a 210 MW thermal power unit installed at Bandel Thermal Power Station, under West Bengal State Electricity Board (WBSEB), in West Bengal, India. During the analysis, the thermo-mechanical availability aspect has been considered

Mathematical Formulation

The schematic diagram for the analysis domain is illustrated in Fig. 1.

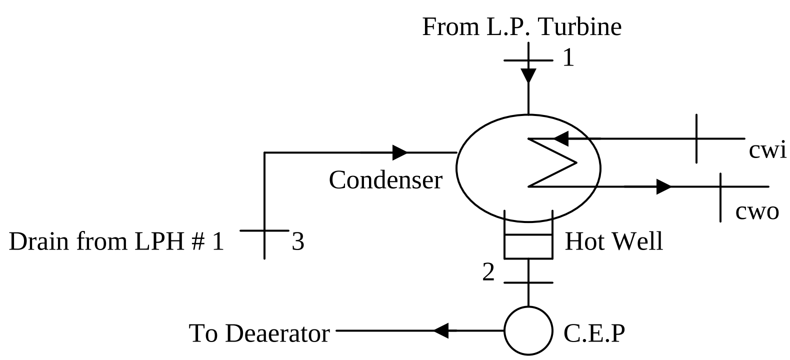

Fig. 1 Schematic flow diagram for analysis domain

For the purpose of analysis, the availability lost in the condenser, losses due to internal and external irreversibilities, and the task efficiency for the condenser have been evaluated as,

The availability at any point

$$A = (h - h_0) - T_0 (s - s_0) \tag{1}$$

Availability lost in the condenser

$$ALC = M [m_1 (A_1 – A_2) + m_3 (A_3 – A_2)] \quad (2)$$

Loss of availability due to internal irreversibility

$$IIL = M [- \{ 1.0 – (T_0 / T) \} q_c + m_1 (A_1 – A_2)] \quad (3)$$

where, q_c is the loss of heat in condenser in kJ / kg, which is given by,

$$q_c = m_1 (h_1 – h_2) + m_3 (h_3 – h_2) \quad (4)$$

Loss of availability due to external irreversibility

$$EIL = M [m_1 (A_1 – A_2)] + Mcw (A_{cwi} – A_{cwo}) \quad (5)$$

Task Efficiency

$$TE = [\{ Mcw (A_{cwo} – A_{cwi}) \} / \{ M \times q_c \}] \times 100 \quad (6)$$

Results and Discussion

The loads, considered during the analysis, are 100 MW, 150 MW, 175 MW, 200 MW, and 210 MW respectively. All the calculations have been made on the basis of available plant data taken from the manual for the unit [11] and the data has been depicted in Table 1. The different computed components required in assessing the different losses and task efficiency for the condenser have been highlighted in Table 2. During computation, the temperature of the environment has been considered to be 300.16 K. The results of the analysis have been presented in Table 3.

Table 1 Plant data

Node	Parameter	Load (MW)				
		210	200	175	150	100
-	M (kg/sec)	186.1	173.1	149.4	126.4	86.1
-	Mcw (kg/sec)	7500	7500	7500	7500	7500
1	Temp. (K)	319.76	319.16	317.16	316.26	313.56
	Pr. (Abs.) (kN/m^2)	10.199	9.905	9.218	8.532	7.355
	Dryness fraction	0.958	0.960	0.965	0.972	0.992
2	Temp. (K)	319.46	318.86	317.36	315.86	313.16
	Pr. (Abs.) (kN/m^2)	10.003	9.708	9.022	8.335	7.257
3	Pr. (Abs.) (kN/m^2)	26.969	25.105	22.065	18.927	14.906
cwi	Temp. (K)	306.16	306.16	306.16	306.16	306.16
cwo	Temp. (K)	315.96	315.36	314.26	313.16	311.16

The effects of condensation of steam and mixing of LPH # 1 drain at hot well have been considered for the assessment of availability lost in the condenser. From the study, it is revealed that availability lost in the condenser increases with increase in load. This may be attributed due to higher temperature of steam at the inlet to condenser at higher load. Considering the effect of condensation process and heat transfer respectively, the loss of availability due to internal irreversibility has been estimated. The loss of availability due to internal irreversibility is also noted to be increasing with increase in load. The irreversibility occurring in the heat transfer process from exhaust steam to cooling water has been considered in computing the loss of availability due to external irreversibility for the condenser. The loss of availability due to external irreversibility is found to have higher values at higher loads.

Table 2 Computed components

Component	Load (MW)				
	210	200	175	150	100
m_1 (kg/kg of main steam)	0.728	0.732	0.743	0.751	0.774
A_1 (kJ/kg)	139.3	137.9	130.8	118.9	101.5
A_2 (kJ/kg)	1.97	1.83	1.15	1.11	0.66
m_3 (kg/kg of main steam)	0.021	0.019	0.017	0.013	0.010
A_3 (kJ/kg)	8.08	7.13	5.85	4.45	3.12
A_{cwi} (kJ/kg)	0.015	0.015	0.015	0.015	0.015
A_{cwo} (kJ/kg)	1.595	1.471	1.260	1.051	0.734
q_c (kJ/kg)	1660.9	1677.5	1711.4	1742.5	1840.3

Table 3 Analysis results

Component	Load (MW)				
	210	200	175	150	100
ALC (MW)	18.5	17.2	14.3	11.1	6.7
IIL (MW)	22.1	20.6	17.3	13.5	8.1
EIL (MW)	14.2	13.6	11.1	8.1	4.3
TE (%)	3.5	3.4	3.2	3.0	2.8

The reduction of external irreversibility at lower loads may be explained on the basis of the difference between the temperature of L.P. Turbine exhaust steam and the mean temperature of cooling water. This difference in temperature decreases with decrease in load. Task Efficiency has been assessed by the ratio between availability gain in circulating water and the heat lost in the condenser. This component reflects the measure how effectively the heat interaction between the steam and circulating water has taken place. The task efficiency of the condenser has been observed to be increasing from around 2.8% at 100 MW to 3.5% at 210 MW load.

Conclusion

The study in this paper presents the methodology to estimate the various irreversibility losses and the effectiveness of heat interaction between the steam and cooling water in a condenser at different loads for an operating thermal power unit. The results of this analysis provide the following conclusions:

- Availability lost in the condenser increases with increase in load.
- The loss of availability due to internal irreversibility decreases with decrease in load.
- The loss of availability due to external irreversibility is higher at higher load.
- The task efficiency increases marginally from 2.8% at 100 MW load to 3.5% at 210 MW load.

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