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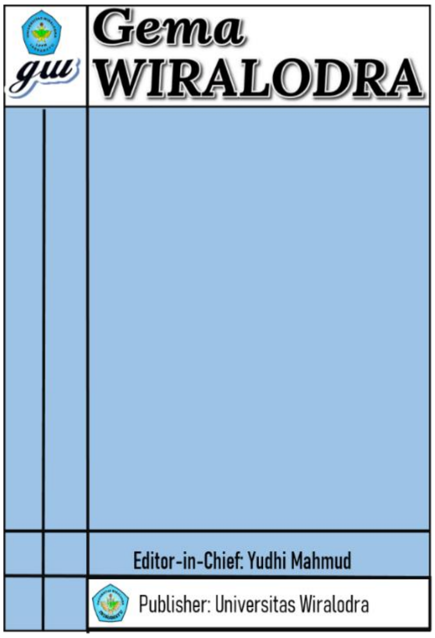

Optimization of abnormal high-pressure heater (HPH) operating pattern to reduce heatrate of adipala power plant 1 X 660 MW

Muhammad Ridwan[a*], Ahmad Analial Ghulam[b]
[a]Institut Teknologi PLN, Indonesia, m.ridwan@itpln.ac.id
[b]Institut Teknologi PLN, Indonesia

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Original Article

Optimization of abnormal high-pressure heater (HPH) operating pattern to reduce heatrate of adipala power plant 1 X 660 MW

Muhammad Ridwan[a*], Ahmad Analial Ghulam[b]
[a]Institut Teknologi PLN, Indonesia, m.ridwan@itpln.ac.id
[b]Institut Teknologi PLN, Indonesia

[*]Corresponding author: m.ridwan@itpln.ac.id

Abstract
PLTU Adipala has three HPH (High-Pressure Heaters) essential to its operations. In The current condition, these three HPH are in a series, which is, if the middle HPH has a problem during the cycle experiences and must be out-serviced, then the after HPH also must be out-serviced. This situation can increase the heat rate value because two HPH are out of service. Therefore, an alternative mode of HPH operation is needed to press the increase of heatrate and prevent a decrease in generator efficiency simultaneously. Simulations were carried out to obtain the most optimal operating pattern. This simulation was carried out using the Cycle Tempo software. For each condition, the heat balance cycle is made in the Cycle Tempo software and filled in with the parameters. Then, it runs to obtain the simulation results. The first condition is a normal HPH operating has a heat rate of 2071.4 kcal/kwh. The second condition is where HPH 7 and 8 are out of service and have a heat rate of 2161 kcal/kwh. The third condition is only HPH 7 that is out of service, and HPH 8 is streamed to HPH 6 with a heat rate of 2118 kcal/kwh. The fourth condition is only HPH 7, which is out of service, and HPH 8 is streamed to the condenser, which has a heat rate of 2150 kcal/kwh.
Keywords: High Pressure Heater, Cycle tempo, Heatrate

1. Introduction

Steam Power Plant (PLTU) is one of the dominant power plants in Indonesia, especially Java (Fikri et al., 2020). Almost more than 60% of electricity on the island of Java is supplied from PLTU (Redaputri, 2021). So that the reliability of a PLTU is needed so that electricity needs on the island of Java continue to run normally (Tampubolon & Dalimi, 2023) (Paryono et al., 2019). In addition to reliability, a PLTU must also have a high-efficiency value to compete with other PLTU so that it can produce cheaper electrical energy. So, to get a high efficiency value, every main piece of equipment at the PLTU must be kept operational to work in normal conditions.

One of the main components of a PLTU is the Feedwater Heater (Fadlullah et al., 2022). Feedwater heaters play a role in maintaining the reliability and efficiency of a power plant (Shadiqin, 2015). Feedwater Heater serves to increase the temperature of condensate water (Condensate Water) and feedwater (Feedwater) (Luo et al., 2016). Feedwater heaters utilize heat that comes from leaks in turbines called steam extraction turbines (Wijaya & Widodo, 2019). With the use of turbine extraction steam, condensate water, and feeder water will experience a temperature increase so that the water that will enter the boiler has a higher enthalpy and temperature (Oyedepo et al., 2020). This can reduce the amount of fuel that will be used for the combustion process in the boiler so that the thermal efficiency of the plant will be higher.

PLTU Adipala has three types of feedwater heaters which are distinguished based on working pressure and heat transfer process. The three feedwater heaters are High Pressure Heater (HPH), Low Pressure Heater (LPH), and Open Feedwater Heater or Deaerator. High-Pressure Heaters (HPH) and Low-Pressure Heater (LPH) are types of Close feedwater heaters where in operation the turbine extraction steam is not in direct contact with feedwater. A closed feedwater heater is a type of shell and tube heater. Where the turbine extraction steam is on the shell side and the feeder water is on the tube side. An open Feedwater Heater or Deaerator is a type of open heater where turbine extraction steam and feeder water come into direct contact inside the heater. Dearator in addition to being a feeder water heating medium is also a deaeration medium to discharge oxygen gas that is not dissolved in water into the atmosphere.

In its operation, feedwater heaters have their respective roles to increase the thermal efficiency value of the Adipala coal-fired power plant. So, if there is one heater experiencing interference, it will reduce the efficiency value and increase the heat rate of the plant. With this incident, the plant operator needs to know how much the heatrate changes to plan the operating pattern to get the best value with heater interference. To minimize losses due to increased plant heat rate. This research was conducted by calculating heat balance under normal conditions and simulating abnormal conditions due to heater interference under the existing configuration at the Adipala PLTU.

2. Method

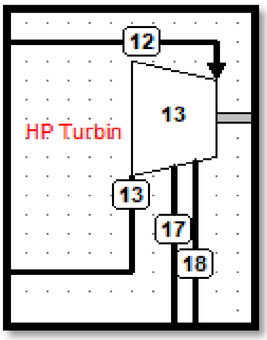
Thermodynamic Calculations

Thermodynamic calculations are used to obtain *heatrate data* under normal operating conditions (Sorgulu & Dincer, 2018). The initial parameter data is obtained from the normal operating parameters in the DCS PLTU Adipala. The initial step is to determine the enthalpy value of each equipment parameter and calculate the mass fraction of each *heater*. After that calculate the work on turbines, boilers, and pumps to get the value of *heatrate* and efficiency using the following equation:

a) HP Turbine Work

Figure 1

HP Mass Flow Turbine

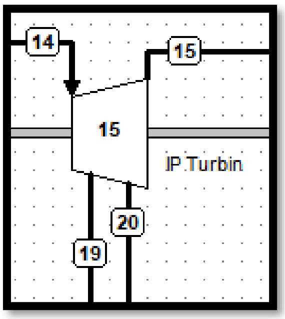


$$\frac{W_{HPT}}{\dot{m}_{12}} = (h_{12} - h_{17}) + [(1 - y_8) \cdot (h_{17} - h_{18})] + [(1 - y_8 - y_7) \cdot (h_{18} - h_{13})]$$

b) Turbine IP Work

Figure 2

Turbine IP mass flow



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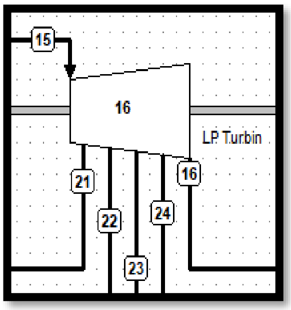
$$\frac{W_{IPT}}{\dot{m}_{12}} = [(1 - y_8 - y_7) \cdot (h_{14} - h_{19})] + [(1 - y_8 - y_7 - y_6) \cdot (h_{19} - h_{20})] + [(1 - y_8 - y_7 - y_6 - y_D) \cdot (h_{20} - h_{15})]$$

c) Turbine LP Work

Figure 3

LP Turbine mass flow



$$\frac{\boldsymbol{W_{LPT}}}{\boldsymbol{\dot{m}_{16}}} = [(1 - y_8 - y_7 - y_6 - y_D) \cdot (h_{15} - h_{21})] + [(1 - y_8 - y_7 - y_6 - y_D - y_4) \cdot (h_{21} - h_{22})] + [(1 - y_8 - y_7 - y_6 - y_D - y_4 - y_3) \cdot (h_{22} - h_{23})] + [(1 - y_8 - y_7 - y_6 - y_D - y_4 - y_3 - y_2) \cdot (h_{23} - h_{24})] + [(1 - y_8 - y_7 - y_6 - y_D - y_4 - y_3 - y_2 - y_1) \cdot (h_{24} - h_{16})]$$

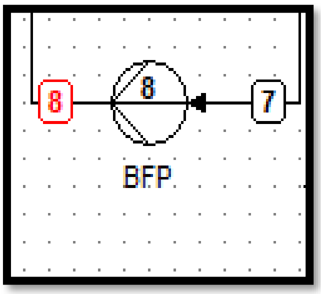
d) Working Boiler

Qboiler = Qmainsteam + Qreheat.

e) BFP Work

Figure 4

BFP mass flow

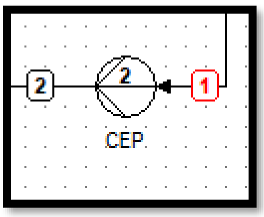


$$\frac{\boldsymbol{W_{BFP}}}{\boldsymbol{\dot{m}_{12}}} = (\boldsymbol{h_8} - \boldsymbol{h_7})$$

f) CEP Work

Figure 5

CEP mass flow



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$$\frac{W_{CEP}}{\dot{m}_{12}} = (1 - y_8 - y_7 - y_6 - y_D).(\boldsymbol{h_2} - \boldsymbol{h_1})$$

g) Heatrate

$$Heatrate = \frac{Working\ Boiler}{(Turbin\ work - Pump\ Work)}$$

h) Efficiency

$$Efficiency = \frac{(Turbin\ work - Pump\ Work)}{Working\ Boiler}\ x\ 100$$

Modeling and Simulation

Modeling and simulation were carried out using *Cycle Tempo 5.0 software* by entering parameter data obtained from the DCS PLTU Adipala. The modeling scheme is carried out based on predetermined conditions. The following condition scheme is used:

Table 1
HPH conditioning configuration

Condition	HPH 8	HPH 7	HPH 6	Description of Conditions
Condition 1				Normal Operation
Condition 2				- HPH 7 interference and out service - HPH 8 in outservice because HPH 7 outservice
Condition 3				- HPH 7 interference and outservice - HPH 8 inservice by opening the drain to the condenser
Condition 4				- HPH 7 interference and outservice - HPH 8 inservice with simulated bypass drain to HPH 6

Cycle Tempo 5.0 software will perform thermodynamic analysis on each condition of the PLTU cycle that has been made. The results of the analysis are in the form of work values in boilers, turbines, and generators as well as *gross* and *nett efficiency values* of the PLTU cycle.

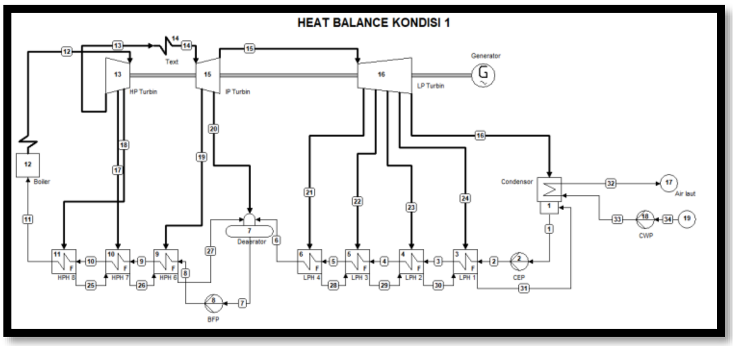
3. Result and Discussion

a. Normal Conditions of Operation (Condition 1)

The simulation results on *cycle tempo,* in condition 1 have an efficiency of 40.6% with a heatrate of 2,114.4 kcal/kwh. This is because in this condition *the feedwater* gets heat from all operating HPHs. *Feedwater* occurs through heat transfer from extraction steam obtained from turbine extraction steam. So that the temperature and enthalpy *of the feedwater outlet* are high before entering the boiler. This condition can reduce the heat needed by the boiler to reach the enthalpy value and temperature according to the design before entering the HP Turbine because some of the heat in the *feedwater* or *mainstream* has been obtained from the regenerative process at the HPH.

Figure 6

(a) Heatbalance of normal operating conditions and (b) Cycle Tempo simulation results



delivered	No.	Apparatus	Type	Energy [kW]	Totals [kW]
Absorbed	12	Boiler	1	1231995.12	
power	14	Reheater	2	320935.16	
					1552930.25
Delivered	1	Generator	G	660000.00	
gross power					660000.00
Aux. power	8	BFPT	8	8996.79	
consumption	2	CEP	8	1245.95	
	18	CWP	8	5843.72	
		BFPT		8000.00	
		CEP		4000.00	
					28086.46
Delivered					
net power					631913.56
Efficiencies	gross			42.500 %	
	net			40.692 %	

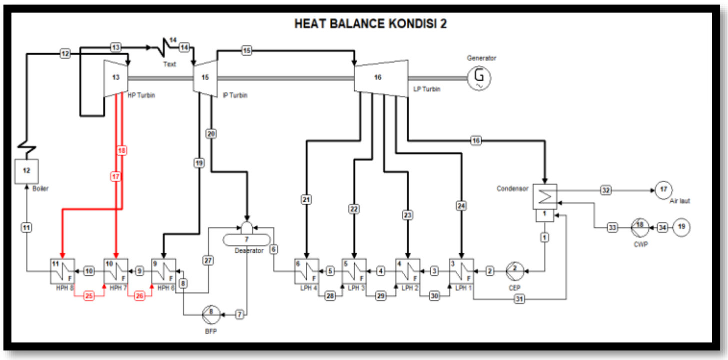
(a) (b)

b. Simulation Results of Hph Condition 7 &; 8 *Outeservice* (Condition 2)

From the simulation results in this condition, an efficiency value of 37.5% and *a heatrate* of 2,293.8 kcal/kWh were obtained. This condition is simulated when HPH 7 experiences interference so that it cannot be operated. As a result, HPH 8 which is at the next level also cannot be operated because the flow to HPH 7 must be stopped. So, in this condition, only HPH 6 is operated normally.

Figure 7

(a) Heat balance condition 2 and (b) Cycle Tempo simulation results



delivered	No.	Apparatus	Type	Energy [kW]	Totals [kW]
Absorbed	12	Boiler	1	1360397.25	
power	14	Reheater	2	331539.66	
					1691937.00
Delivered	1	Generator	G	660000.00	
gross power					660000.00
Aux. power	8	BFPT	8	8061.95	
consumption	2	CEP	8	1286.33	
	18	CWP	8	6032.08	
		BFPT		7000.00	
		CEP		3000.00	
					25380.36
Delivered					
net power					634619.62
Efficiencies	gross			39.009 %	
	net			37.508 %	

(a) (b)

c. Simulation Results of HPH 7 *Outservice Conditions* Hph 6 &; 8 Inservice (Condition 3 Bypass Mode)

The simulation results in this condition obtained *a heatrate* value of 2,145 kcal/kWh and an efficiency of 40.1%. This condition is simulated when HPH 7 experiences interference so that it cannot be operated. Then to continue operating HPH 8 which is at the next level, the normal drain of HPH 8 to HPH 7 must be outserviced. The condensation results of HPH 8 are then flowed to HPH 6 through a drain bypass (pipe no. 36). In this condition, only HPH 7 is out serviced, while HPH 8 and 6 continue to operate.

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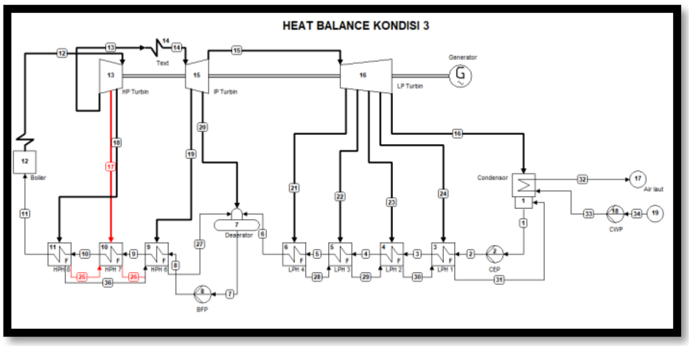
Figure 8
(a) Heatbalance kondisi 3 dan (b) Hasil simulasi Cycle Tempo



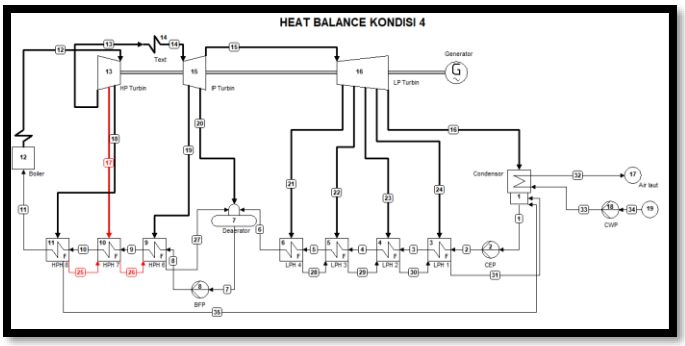
	No.	Apparatus	Type	Energy	Totals
				[kW]	[kW]
Absorbed	12	Boiler	1	1230477.62	
power	14	Reheater	2	345347.62	
					1575825.25
Delivered	1	Generator	G	660000.00	
gross power					660000.00
Aux. power	2	CEP	8	1241.28	
consumption	8	BFPT	8	8936.21	
	18	CWP	8	5821.90	
		BFPT		8000.00	
		CEP		4000.00	
					27999.39
Delivered					
net power					632000.62
Efficiencies	gross			41.883 %	
	net			40.106 %	

(a) (b)

d. Simulation Results of HPH 7 *Out Service Conditions* Hph 6 &; 8 Inservice (Condition 4 Condenser Modes)

The simulation results in this condition obtained *a heatrate* value of 2,175 kcal/kWh and an efficiency of 39.5%. This condition is simulated when HPH 7 experiences interference so that it cannot be operated. Then to continue operating HPH 8 which is at the next level, the normal drain of HPH 8 to HPH 7 must be outserviced. The results of HPH 8 condensation then flow to the condenser through the emergency drain (pipe no. 35). This is because HPH 8 drain cannot be drained to HPH 7 which is *out serviced*. In this condition, only HPH 7 is out serviced, while HPH 8 and 6 continue to operate.

Figure 9
(a) Heat balance condition 4 and (b) Cycle Tempo simulation results



	No.	Apparatus	Type	Energy	Totals
				[kW]	[kW]
Absorbed	12	Boiler	1	1263527.25	
power	14	Reheater	2	332298.78	
					1595826.12
Delivered	1	Generator	G	660000.00	
gross power					660000.00
Aux. power	2	CEP	8	1486.06	
consumption	8	BFPT	8	9302.84	
	18	CWP	8	6125.03	
		BFPT		8000.00	
		CEP		4000.00	
					28913.92
Delivered					
net power					631086.06
Efficiencies	gross			41.358 %	
	net			39.546 %	

Normal operating conditions (condition 1) have the highest efficiency value of 40.6% and the lowest *heatrate* of 2,114.4 kcal/kWh. This is because, in condition 1, all HPHs are operated normally. So that the steam heat of turbine extraction can be utilized optimally for regenerative processes in HPH.

The condition closest to the efficiency value in normal conditions is condition 3, which is 40.1% and *a heatrate* of 2,145 kcal/kWh. In this condition, 2 HPH is operated normally so that the utilization of extraction steam can be done more optimally than condition 2 and condition 4. The condensation results from HPH 8 are flowed to HPH 6 so that the utilization of drain water can be more optimal because not much heat is wasted.

Furthermore, condition 4 has an efficiency value of 39.5% and a *heatrate* of 2,175 kcal/kWh. Greater than conditions 2 but lower than conditions 1 and 3. In this operating pattern,

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2 HPHs operate normally so that the extraction steam can be utilized for heating in HPH 6 and 8. However, there is a heat loss from this operating pattern due to the waste of water from HPH 8 condensation to the condenser. So, the condensation water mixes with condensate water and must go through reheating in LPH 1 to the Deaerator.

Conditions with the lowest efficiency value are condition 2 which is 37.5% and *heatrate* of 2,293.8 kcal/kWh where 2 HPH is not operating so the utilization of extraction steam is not optimal. This causes a decrease in boiler inlet temperature so that it requires more boiler heat to get the same relative load.

Figure 10
Graph of plant efficiency under each condition

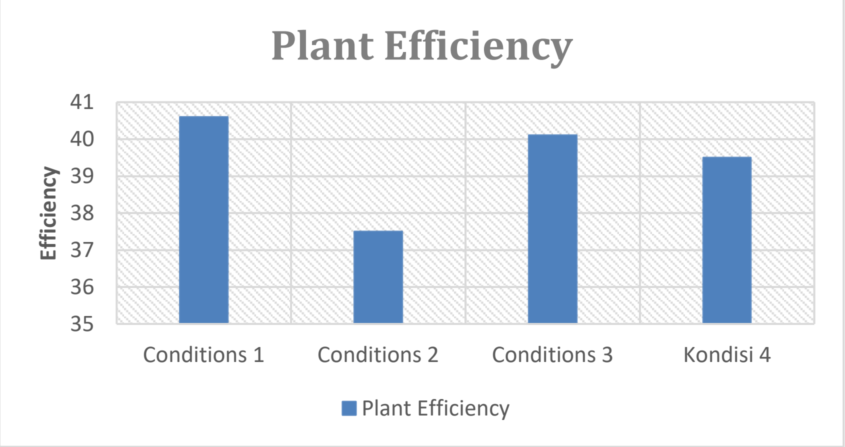
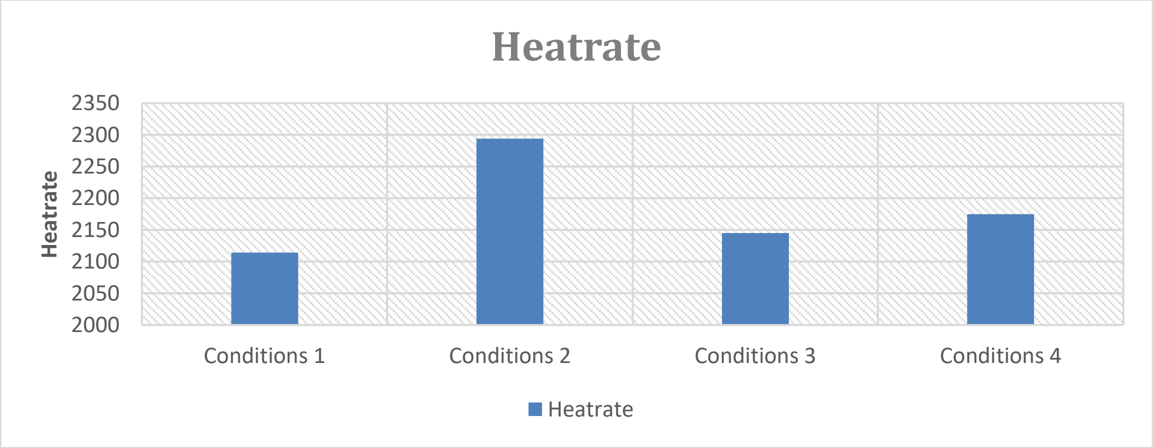


Figure 11
Graph of plant heatrate in each condition



4. Conclusion

From the simulation results above, it was found that condition two had a heatrate value of 2,293.8 kcal/kWh with a plant efficiency of 37.5%. For condition three, it has a heatrate value of 2,145 kcal/kWh with a generation efficiency of 40.1%. While condition four has a heatrate value of 2,175 kcal/kWh with a plant efficiency of 39.5%. Of all the conditions simulated, the most optimal HPH operating pattern (close to normal operation) is condition three with a heatrate of 2145 kcal/kWh and an efficiency of 40.1%. It is necessary to conduct similar studies with more complex problem limits to get a value that is closer to the conditions in the field and

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a review is needed related to SOPs for handling HPH disturbances to avoid a significant increase in heatrate and a decrease in plant efficiency value.

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