Study of Debris Filter Valve Opening Angle Adjustment for NPHR Improvement in Kaltim Teluk CFPP

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Abstract - Many things can affect the Net Plant Heat Rate (NPHR) value, including operating parameters, fuel and equipment’s condition. The performance target of NPHR for Kaltim Teluk CFB CFPP based on specifications is 3430 kCal / kWh. Operational data shows that the NPHR of Unit #1 and Unit #2 is higher then the performance target. Analysis of operation and maintenance data showed that the low average net load and high condenser back pressure are the dominant problems that caused heat loss. One way to minimize heat loss and improve NPHR performance can be done by maximizing debris filter cleaning process through adjusting valve opening angle which can reduce differential pressure and finally reduce the backpressure at the condenser. With the flow simulation inside the debris filter, in order to achieve maximum flow rate with acceptable erosion rate, the optimum cleaning reached at valve opening angle 75°-60° and with this cleaning method, heat loss can be reduced 14.96 kCal/kWh and 50.09 kCal/kWh for unit #1 and unit #2 respectively.

1. Introduction
The performance of a power plant can be seen from the value of the plant's heat rate. Net Plant Heat Rate (NPHR) is defined in units (kCal / Kwh) and is simply the amount of heat input given to the system divided by net power generated by the system [1][2]. If a power plant has a heat rate that is greater than its baseline, it indicates a decline in plant performance. Several factors can be the cause of this decline, including a decrease in fuel quality, equipment failure, bad combustion system tuning and others. This performance degradation can affect the operational quality in the form of increasing the operating costs caused by increasing the amount of fuel used for heat input. Besides, the increase in the NPHR value will cause power plant merit orders to drop. Some of the statistical methods will be used to analyze existing problems.

The unit for this study is Kaltim Teluk CFPP with an installed capacity of 2 x 110 MW. This power plant serves the 150 kV Mahakam system line. The type of power plant is a coal-fired power plant using Circulating Fluidized Bed (CFB) combustion system manufactured in China. The power plant began construction in 2012 and began commercial operation in 2015.
1.1. NPHR Data collection

The data used in this research are secondary operational unit data taken from the power plant daily report and monthly performance report from the period March 2017 to December 2019 (34 months).

Table 1. Monthly operational data between march 2017 – December 2019

| Periode | Prod Bruto 1 | Prod Bruto 2 | Prod Net 1 | Prod Net 2 | Serv Hour 1 | Serv Hour 2 | Load Bruto 1 | Load Bruto 2 | Load Net 1 | Load Net 2 | NPHR 1 | NPHR 2 | Kcal/kWh |
|---------|--------------|--------------|------------|------------|-------------|-------------|--------------|--------------|------------|------------|----------|----------|-----------|
| Mar ’17 | 29,088.2     | 22,715.9     | 24,095.3   | 17,604.4   | 415.9       | 326.5       | 69.9         | 69.6         | 57.9       | 53.9       | 3,035.4  | 3,120.1  |
| Apr ’17 | 49,205.1     | 44,082.6     | 30,169.0   | 35,815.5   | 746.5       | 650.0       | 65.9         | 68.6         | 53.8       | 55.1       | 3,680.0  | 3,411.1  |
| May ’17 | 49,203.1     | 66,635.2     | 30,043.6   | 53,833.3   | 746.5       | 1,244.1     | 65.9         | 54.4         | 52.3       | 44.0       | 3,586.8  | 4,064.5  |
| Jun ’17 | 49,205.1     | 103,610.4    | 38,482.2   | 83,935.5   | 746.5       | 1,944.1     | 65.9         | 53.3         | 51.5       | 41.2       | 3,643.6  | 3,888.8  |
| Jul ’17 | 72,484.2     | 124,425.2    | 75,645.2   | 100,268.5  | 1,120.5     | 2,400.7     | 67.4         | 51.8         | 51.4       | 41.8       | 3,811.8  | 3,892.4  |
| Aug ’17 | 112,367.3    | 124,425.2    | 92,210.9   | 100,268.5  | 1,666.2     | 2,400.7     | 67.4         | 51.8         | 51.3       | 41.8       | 3,571.7  | 3,894.0  |
| Sep ’17 | 112,367.3    | 166,127.7    | 92,210.9   | 134,234.8  | 1,666.2     | 3,063.9     | 67.4         | 54.2         | 51.3       | 41.8       | 3,571.7  | 3,978.9  |
| Oct ’17 | 112,367.3    | 201,738.3    | 92,210.9   | 160,038.9  | 1,666.2     | 3,806.7     | 67.4         | 53.0         | 53.3       | 41.4       | 3,571.7  | 4,064.0  |
| Nov ’17 | 119,159.1    | 224,098.8    | 97,434.9   | 182,940.1  | 1,811.3     | 4,225.0     | 65.7         | 53.0         | 53.7       | 43.3       | 3,607.5  | 4,079.3  |
| Dec ’17 | 138,507.8    | 252,888.9    | 115,289.6  | 206,850.2  | 2,337.1     | 4,773.8     | 61.9         | 53.0         | 50.6       | 43.3       | 3,547.6  | 3,961.2  |

Figure 1. Normal Distribution of Production data

The normal distribution of operational data is shown at figure 1. Performance data is processed using the process capability report to see the actual NPHR performance of the power plant compared to the contract target of the power plant performance of 3430 kcal/kWh as shown in figure 2. From the analysis, it can be seen that the average NPHR of the Unit #1 is 3645.3 kcal/kWh with a standard deviation of 264.3 kcal/kWh. When compared with the performance target of 3430 kcal/kWh as the upper limit value, there are 91.18% of data outside the range of specification limits. Meanwhile, the
average NPHR of Unit #2 is 3659.73 kCal/kWh with a standard deviation of 290.5 kCal/kWh. When compared with 3430 kCal/kWh performance targets as an upper limit value, there is 55.88% of the data outside of the range specification limits.

The process capability report shows that the performance of Kaltim Teluk CFPP is still quite far from the target value of the performance contract both in terms of average and standard deviation distribution. It is necessary to analyze the factors contributing to heat loss that increases the NPHR value of Kaltim Teluk CFPP, to meet its performance targets.

![Process Capability Report for NPHR 1](image1)
![Process Capability Report for NPHR 2](image2)

**Figure 2.** Process Capability Curve of NPHR

1.2. **NPHR Data analysis**

The distribution of the control chart shows that there is a relationship between the average load of the plant and the NPHR. When the average load is below the lower bound value, the NPHR is above the upper limit value. As shown in **figure 3**, it appears that the greater the average load, the NPHR value will decrease.

![Scatterplot of NPHR vs Net Load Unit #1](image3)
![Scatterplot of NPHR vs Net Load Unit #2](image4)

**Figure 3.** Regression Analysis between net load and NPHR of a generator

The analysis is continued by using a review of monthly performance test data. The results of the performance test show the components causing the operational performance decrease in the form of heat loss. Each component and the amount of heat loss is tabulated using the Pareto loss of output (PLO) as shown in **figure 4**.
1.3. Root cause and Action plan

Table 2. Action plan correlated with system affecting NPHR in Kaltim Teluk CFPP$^{a,b}$

| NO | SYSTEMS                     | EFFECT                        | ROOT CAUSE                                      | ACTION PLAN                                                |
|----|-----------------------------|-------------------------------|-------------------------------------------------|------------------------------------------------------------|
| 1  | Condenser Back Pressure    | Heat Loss 118 kCal/kWh       | 1. Debris Filter Plugging                       | 1. Upgrade Debris Filter                                   |
|    |                             | (Equals to Rp 19 mil/day)     | 2. Fouling Tube Condenser                       | 2. Online Cleaning improvement                              |
|    |                             |                               | 3. Failure of CWP Impeller                      | 3. Reverse Engineering for CWP Impeller                    |
| 2  | LP Turbine Efficiency      | Heat Loss 72.8 kCal/kWh      | 1. CV Gland Steam abnormal                      | 1. Modul CV Gland Steam Replacement                        |
|    |                             | (Equals to Rp 15 mil/day)     | 2. Leakage at turbine extraction pipeline      | 2. Turbine extraction piping and gasket replacement        |
| 3  | Main Steam Flow            | Heat Loss 61.4 kCal/kWh      | 1. CV Main Steam Hunting                        | 1. Modul CV Main Steam replacement                        |
|    |                             | (Equals to Rp 13 mil/day)     | 2. Single mode for all load variation at CV Main Steam | 2. Mode single-sequence CV Main Steam Optimization         |
| 4  | Auxiliary Power            | Heat Loss 20.9 kCal/kWh      | 1. Desain and material not standard             | 1. Upgrade Crusher, Coal Feeder and Fan                    |
|    |                             | (Equals to Rp 4.5 mil/day)    | 2. Coal moisture, increasing power needed for crusher, Coal Feeder and Fan | 2. Dome installation                                       |
| 5  | Outlet Gas Temperature     | Heat Loss 20.2 kCal/kWh      | 1. Bed Temperature not optimal                  | 1. Combustion Tuning                                       |
|    |                             | (Equals to Rp 4 mil/day)      | 2. Dirt at element tube back pass area          | 2. Optimization of Soot blowing process                    |

$^{a}$ Coal Calorific number for Performance Test 4200 kCal/kWh

$^{b}$ Coal price Rp 494.5/-/kg
Pareto Loss Output shows the ranking of components contributing to the largest heat loss for Kaltim Teluk CFPP. From the PLO analysis, it can be proposed a method of improvement. The PLO output improvement method is tabulated as table 2. The highest PLO rating is backpressure condenser (Vacuum Condenser) of 118 kCal/kWh or equal to 19 million Rupiah per day assuming a coal calorific value of 4200 kCal/kWh and coal price of Rp 494,5/kg. The possible improvement for better NPHR is by reducing backpressure at condenser by increasing debris filter cleanliness.

1.4 Debris Filter blocking
Kaltim Teluk CFPP is currently experiencing a number of reductions in this vacuum condenser. Most of the indications that the vacuum condenser drops due to the temperature rise at the cooling condenser outlet and the alarm on the differential pressure debris filter. This is likely to occur because of the dirt on the debris filter which clogs the cooling condenser flow. This debris filter is not equipped with a self-cleaning system. So, if there is dirt on the debris filter, it needs to be manually cleaning.

Kaltim Teluk CFPP using the condenser -type N-7800-1 with 2 inlet steam, with a total cooling area 7800 m², the pipe diameter 25x0.5 / 25x0.7 mm with TA2 titanium material. The vacuum process is assisted by a vacuum pump with a capacity of 160kW to maintain the vacuum condenser in the normal operating pressure of 86.7 kPa, maximum at = -90 kPa and will trip at -78 kPa [3]. However, during operation, the vacuum condenser is guarded in the vicinity of = -86kPa. Several times the vacuum condenser on unit 2 has decreased but the vacuum operation has been carried out 2 units of the vacuum pump after it returns to normal. But a few days later there was a decline back to the time of -83kPa with the condition of 2 vacuum pumps operating, if left unchecked can cause a unit trip (forced outage).

The decrease in the vacuum condenser on unit #2 accompanied by an increase in the temperature of the cooling condenser side B indicates that the cooling flow rate is slowed / slow so that the heat transfer takes place too long between the steam condensate and the water cooling which causes the temperature of the air outlet cooling to cool the condenser rises to > 45 ° C on side B while on side A the temperature is maintained between 42-43 ° C as shown in figure 5.

![Figure 5. temperature of the cooler vs vacuum condenser](image)

After an investigation, it was found that the flow rate that was obstructed caused by a B side debris filter strainer located between circulating water inlet and condenser shown in figure 6. Small plastic impurities were blocking the strainer holes, the dirt should not reach the debris filter as shown in Figure 7. The cleaning of the debris filter itself is now done manually through manholes on the debris filter. In the manual book, there is a way to clean online by utilizing water turbulence by adjusting the angle of the inlet condenser valve leading to the blow up line so that dirt that is attached to the debris filter can be released and exit through the blow-up pipeline to the condenser outlet.

In this study, we want to know the position of inlet valve opening angle that produce most effective
way to clean the strainer from dirt blocking its holes to decrease heat loss in the condenser system.

Figure 6. Diagrams for Debris filter system

Figure 7. Dirt on the debris filter.

2. Method

2.1. Inlet condenser valve angle simulation
Inlet condenser valve is a butterfly valve, that used to regulate fluid flow through its pipe [4]. Flow and velocity of the fluida will vary with the valve opening [5]. A butterfly valve has an advantage from other models for its small pressure loss between in and out section [6]. A simulation has been done on debris filter shown in figure 8(a) by changing several parameters to get the best mass flow compared to the current conditions. For unit #1 The distance between the debris filter and inlet valve is 1500 mm. As a consideration, increasing flow will increase erosion rate [7].

In this study, valve opening angle adjusted figure 8(b)(c), the mass flow rate in outlet debris to blow up and the erosion rate inside the pipeline recorded to get the optimal valve angle which resulting higher flow at outlet debris to blow up but still in lower erosion rate.
2.2. Debris filter cleaning based on simulation data

Based on this simulation data, debris filter cleaning was conducted to see the cleaning results in real condition. After that, unit will be operated at normal operation, so we can calculate the heat loss reduced with this cleaning method.

3. Result and discussion

3.1. Simulation results

This simulation can be seen in figure 9, with maximum flow rate at 329,76 kg/s can be reached at valve opening 60° as seen at figure 9(a). A higher flow rate means higher power to wash the strainer, resulting in cleaner and lower differential pressure at the strainer. This angle, 60° opening angle or 30° form full open position proven to be the best valve opening position that effectively increases water discharge [8].
Figure 9. Simulation with different inlet valve opening angle, (a) Flow direction (b) Erosion rate

Figure 10. (a) Mass flow rate, (b) erosion rate vs inlet valve opening angle from 90° to 50° simulation result for unit #1

Figure 11. (a) Mass flow rate, (b) erosion rate vs inlet valve opening angle from 90° to 70° simulation result for unit #2
The same simulation also conducted for unit #2 which has a different distance between debris filter and inlet valve at 1000mm. The best simulation as seen in figure 11(a) is obtained with mass flow 321.7 kg/s at the opening angle 75°.

From the two simulation above, we can conclude that the distance between the inlet valve and debris filter affects flow characteristic. But maximum flow for both conditions can be reached at the opening of about 75° - 60°. In a real experiment, this range will be used to see whether the cleaning can be effective or not.

3.2. Actual cleaning results

Actual cleaning process with valve opening adjustment based on the simulation conducted at unit #1 to see differential pressure reduction as seen in figure 12. Inlet valve opening angle adjusted with valve opening angle adjuster until it shows opening at 70°. As the result, debris filter DP can be reduced from 62.77 kPa to 11.41 kPa, condenser pressure after debris increase from 15.95 kPa to 48.46 kPa. The complete parameter can be seen in table 3. This results little bit different from the simulation in figure 12. This can occur as the effect of inaccuracy reading of valve opening angle at local. Valve angle reading conducted with arrow marks in the outside body only, we cannot make sure the opening inside the valve.

![Cleaning process based on simulation result](image)

**Figure 12.** Cleaning process based on simulation result

| NO | CONDITION | DP DEBRIS (kPa) | CONDENSER INLET PRESS (AFTER DEBRIS) (kPa) | CONDENSER OUTLET PRESS (kPa) | LOAD (MW) | VACUUM (kPa) |
|----|-----------|-----------------|-------------------------------------------|----------------------------|-----------|--------------|
| 1  | Before Cleaning (Inlet Valve Full Open) (19/06/2020) | 62.77 | 15.95 | -1.41 | 57.73 | -87.24 |
| 2  | Half Condenser, Cleaning Preparation (Inlet Valve Full Closed) (29/06/2020) | 1.43 | -2.53 | -2.47 | 37.97 | -88.95 |
| 3  | Cleaning Process (Inlet Valve Open 70%) (29/06/2020) | 9.06 | 46.16 | 15.57 | 48.01 | -88.46 |
| 4  | After Cleaning | 11.41 | 48.46 | 18.80 | 78.83 | -89.08 |

**Table 3.** Differential Pressure (DP) debris filter and other parameter before and after cleaning with valve opening angle adjustment.
Table 4. Effect from debris filter cleaning

| No | Program background | Program Name | Unit (Entity) | Parameter of Performance | Performance | financial benefit (Rp. Mil/Yr) |
|----|--------------------|--------------|---------------|--------------------------|-------------|-----------------------------|
|    | Condenser back pressure increase 0.008 bara (-87.60 kPa) | Scheduled Debris Cleaning | 1 | heat loss 50 kCal/kWh lower | Heat losses 67.21 kCal/kWh lower, Heat losses 17.21 kCal/kWh lower | saving production cost Rp. 11.92 million/day | saving production cost Rp. 11.92 million/day |
|    | Condenser back pressure increase 0.012 bara (-87.20 kPa) | Scheduled Debris Cleaning | 2 | heat loss 50 kCal/kWh lower | Heat losses 102.35 kCal/kWh lower, Heat losses 62.35 kCal/kWh lower | saving production cost Rp. 11.97 million/day | saving production cost Rp. 11.97 million/day |

Table 4 taken from monthly operational report Kaltim Teluk CFPP at June 2020. It shows that debris filter cleaning conducted giving heat loss reduction from 67.21 kCal/kWh to 52.25 kCal/kWh for unit #1 and from 102.35 kCal/kWh to 52.26 kCal/kWh for unit #2, both process using the same procedure described above.

4. Conclusions
Operational data shows that the average NPHR of PLTU #1 is 3645.3 kCal/kWh with a standard deviation of 264.3 kCal/kWh, while the average NPHR of PLTU #2 is 3659.73 kCal/kWh with a standard deviation of 290.5 kCal/kWh. The NPHR performance target based on specifications is 3430 kCal/kWh. The analysis shows that the dominant causes of NPHR that do not fit the target specifications are low average net load and increased backpressure condenser. One method to increase NPHR performance that already proven is by cleaning debris filter strainer with adjusting inlet condenser valve opening angle. Adjusting this valve around 70° can improve cleanliness at strainer and improve debris filter strainer differential pressure. Heat loss can be reduced 14.96 kCal/kWh and 50.09 kCal/kWh for Kaltim teluk CFPP unit #1 and unit #2 respectively.

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