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Analysis Heat Exchanger Network Steam Power Plant in Using Pinch (Case Study in PT POMI Unit 3 Power Plant Paiton)

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ABSTRACT

PT. POMI Paiton Unit 3 is one of big steam power plant in Indonesia that provide electricity with a capacity of 1 x 815 MW. This power plant requires a large amount of coal to produce electricity with a lot of large quantities, estimates of the total consume coal amounted to 3.06 million tons / year. The performance of the power plant PT. POMI Unit 3 can be optimized by modifying the Heat Exchanger Network (HEN). Pinch method is used to optimize HEN, this method provides a good opportunity in the design or in evaluating HEN system. Research has been carried capable increase efficiency of 0.5% of the power plant that was originally 28.45% to 28.95%, and can reduce fuel use by 1.71 kg / s initially as much as 97.99 kg / s to 96.28 kg / s, and can also be reconstructed from the re-arrangement of Heat Exchanger Network of Power Plant PT. POMI Unit 3 Paiton.

1. INTRODUCTION

World energy usage is increasing rapidly, this increasing energy caused by many of the world community highly dependent on energy to support day-to-day life. Based on the Agency for the Assessment and Application of Technology (2018) Ministry of Energy and Mineral Resources in Indonesia Energy Outlook 2018 [1] the electricity demand continues to grow rapidly in all sectors, especially in the household and commercial sectors. It increased on average by 6.0% per year until 2050 to 7.4 times that of consumption in 2016.

Generator Steam Power (power plant) is a power generation system that uses the energy of hot steam is converted into mechanical energy and transmitted to a generator to produce electricity [2, 3]. One of electricity producers that use this type of power plant steam is PT. POMI Unit 3 Paiton Power Plant with installed capacity of 1 x 815 MW. The power generated by three turbines installed one axis, the turbine HP (High Pressure), IP (Intermediate Pressure) and LP (Low Pressure). This unit using two types of feed system water heater which consist of 12 closed feedwater heater and an open feedwater heater.

Feedwater heater is useful to raise the temperature of water in the boiler. Feedwater heater source comes from the extraction on steam turbine, but this process reduces power generation by turbine. However, it can be reducing the thermal load of the boiler [4]. Pinch analysis is used to calculate the design or in evaluating a system height exchanger Networks (HEN) such as reduced operating costs, simplify processes, improve efficiency, reduction and capital investment planning [4-9].

2. RESEARCH AND METHOD

The research was conducted on components Feed Water Heater and Extraction Steam which is a component of Heat Exchangers where the Feed Water Heater as cold flow and Extraction Steam as the heat flow, function Feed Water Heater in Power Plant as preheating water will enter the boiler is expected to use the analysis Pinch can increase efficiency and energy savings as well as giving an overview of design more efficient on Heat Exchanger Network (HEN) geothermal plant PT. POMI Paiton [10].

2.1 Heat Exchanger Networks (HEN)

Heat exchangers network (HEN) is an arrangement of several heat exchangers that operate in an integrated manner in a process. This formation is expected to increase system efficiency. The design of the heat exchanger network is a key aspect in designing chemical processes, even in certain circumstances, to improve the composition of the heat exchanger network can reduce energy consumption in line with the reduction of capital by 20-30% [6, 8]. The HEN planning based on minimum energy requirements. The minimum number of HE (Umin,) is generally the number of process streams and utilities. The calculation of the (Umin) on a HEN required under energy needs minimum or maximum energy that can be recycled, or evaluation of heat exchanger network design that already exist can be done by using the graph Euler's theorem. This calculation can be completed by the following equation:

$$Umin = N\text{-}1 \tag{1}$$

Umin is the minimum number and N is the number of process streams and utilities.

2.2 Pinch analysis

Pinch analysis is done by calculating the balance of Mass and Energy Balance of System Processes and equality - equality based on the first and second law of thermodynamics. The equation used is as follows:

Heat capacity flow (CP)

$$CP = M \times Cp \tag{2}$$

The enthalpy change (ΔH), Law of Thermodynamics I

$$\Delta H = Q \pm W \tag{3}$$

The lack of change in the mechanical energy of W = 0, So the equation is transformed into ΔH = Q, and Q = C x (Tout - Tin), so that it becomes:

$$\Delta H = CP \times (Tout\text{-}Tin) \tag{4}$$

The thermal efficiency (η) is defined as the ratio of net business (WNET) generated against energy input (Qin). Thermal Efficiency Heat Exchanger can be formulated as follows [11]:

$$\eta = W\ net/Q\ in \times 100\% \tag{5}$$

3. RESULT AND DISCUSSION

Steam cycle power plant in PT. POMI Unit 3 has 10 main components as in Figure 1. The study was conducted on Heat Exchangers in Feed Water Heater with heat flow in the form of Extraction Steam or residual steam turbine propulsion seen on the red color line. Table 1 is preliminary data obtained from log sheet operations and production data. The data taken is as follows:

3.1 Problem analysis table

Analysis of the Problem Table aims to determine the value of the pinch and describes the maximum amount of heat energy exchange at each interval to determine the temperature and also the lack of energy in the process of heat exchange in each of the streams of hot and cold flow.

Table 1 is the data needed for the analysis process pinch. The value of the specific heat capacity (CP) resulting from the calculation by using Eq. (2). This preliminary data is the result of the extraction of data that has not changed ΔTmin.

ΔTmin obtained from the analysis in Table 2 is by way of determining the smallest of temperature differences in the flow of hot or cold flow contained in the data used.

Table 2 shows the smallest value of ΔT is ΔTmin allowable value that is equal to 19,755°C. After determining the value of ΔTmin, will dilakuakan analysis on the problem of table.

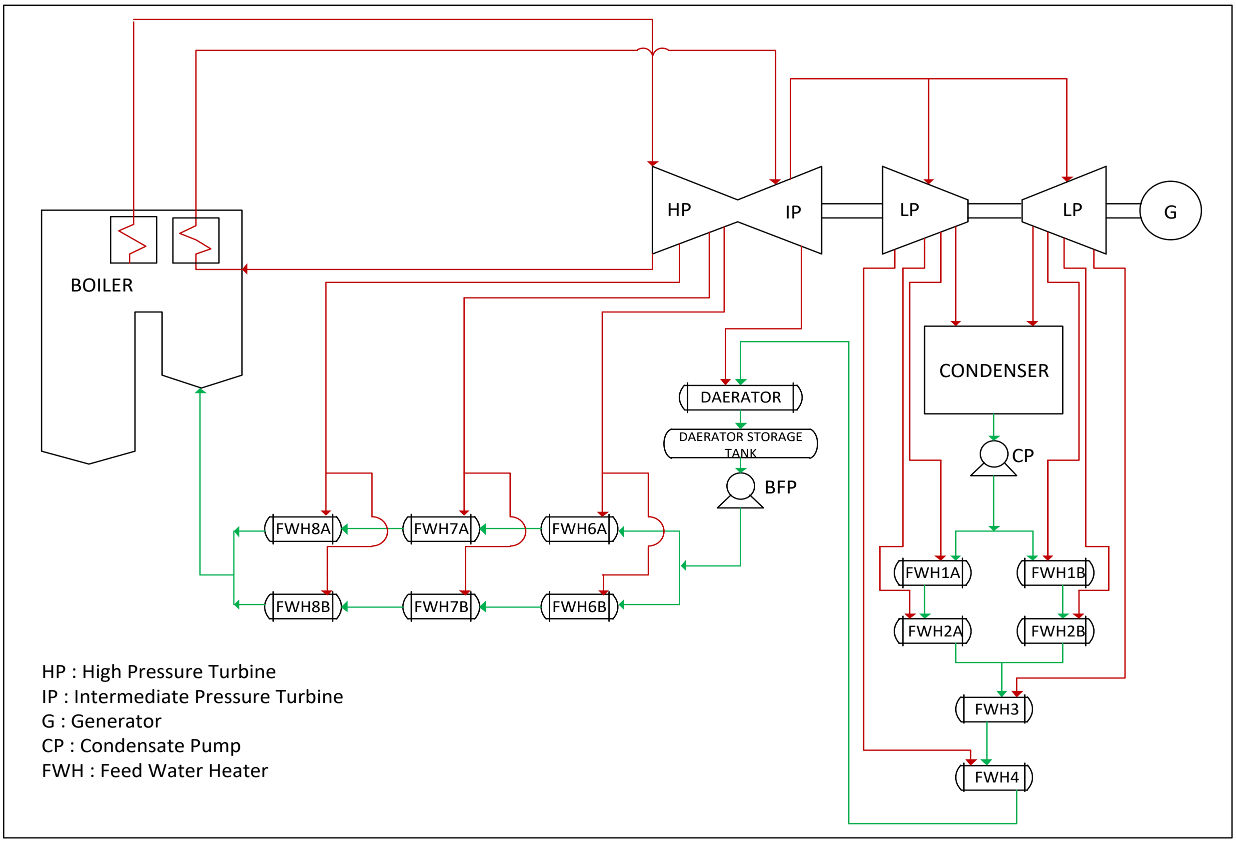

Figure 1. Schematic of steam power cycle power plant PT POMI Unit 3

Table 1. Initial data analysis pinch

No.	Component	Tin (°C)	Tout (°C)	M (kg / s)	Cp (kJ / kg°C)	CP (kW / °C)
1	LP FWH No. 1A	37.794	59.718	226.409	4.174	945.03117
2	LP FWH No. 1B	38.283	59.914	226.409	4.174	945.03117
3	LP FWH No. 2A	59.718	84.329	226.409	4.182	946.84244
4	LP FWH No. 2B	59.914	84.247	226.409	4.182	946.84244
5	LP FWH No. 3	84.329	105.33	226.409	4,203	951.59703
6	LP FWH No. 4	105.3	137.92	226.409	4.244	960.8798
7	deaerator	138.34	167.37	220.2	4.32	951.264
8	HP FWH No. 6A	174.35	200.97	265.063	4.352	1153.5542
9	HP FWH No. 6B	174.45	201.06	265.063	4.352	1153.5542
10	HP FWH No. 7A	200.97	238.64	265.063	4.487	1189.3377
11	HP FWH No. 7B	201.06	238.82	265.063	4.488	1189.6027
12	HP FWH No. 8A	238.64	263.95	265.063	4.69	1243.1455
13	HP FWH No. 8B	238.82	264.16	265.063	4.692	1243.6756
14	LP Extraction No. 1A	60.965	40.963	247.7	4.182	1035.8814
15	LP Extraction No. 1B	61.727	41.972	247.5	4.182	1035.045
16	LP Extraction No. 2A	127.2	62.853	9.422	38.49	362.65278
17	LP Extraction No. 2B	126.98	63.47	9.326	38.9	362.7814
18	LP Extraction No. 3	189.61	89.514	104.1	1,918	90.35698
19	LP Extraction No. 4	283.71	109.07	12.15	14.78	179.577
20	LP Extraction No. 5	373.94	167.37	11.02	12.13	133.6726
21	HP Extraction No. 6A	462.84	178.74	11.65	9.274	108.0421
22	HP Extraction No. 6B	462.84	178.74	11.65	9.274	108.0421
23	HP Extraction No. 7A	312.04	203.35	20.83	19.78	412.0174
24	HP Extraction No. 7B	312.04	204.54	20.94	19.95	417.753
25	HP Extraction No. 8A	363.17	243.08	15.31	17.11	261.9541
26	HP Extraction No. 8B	363.17	243.08	15.34	17.11	262.4674

Table 2. The temperature difference (ΔT)

No.	Component	Tin (°C)	Tout (°C)	ΔT (°C)
1	LP FWH No. 1A	37.794	59.718	21.924
2	LP FWH No. 1B	38.283	59.914	21.631
3	LP FWH No. 2A	59.718	84.329	24.611
4	LP FWH No. 2B	59.914	84.247	24.333
5	LP FWH No. 3	84.329	105.326	20.997
6	LP FWH No. 4	105.299	137.922	32.623
7	deaerator	138.337	167.367	29.03
8	HP FWH No. 6A	174.354	200.9715	26.618
9	HP FWH No. 6B	174.447	201.057	26.61
10	HP FWH No. 7A	200.972	238.638	37.666
11	HP FWH No. 7B	201.057	238.817	37.76
12	HP FWH No. 8A	238.638	263.952	25.314
13	HP FWH No. 8B	238.817	264.164	25.347
14	LP Extraction No. 1A	60.965	40.963	20.002
15	LP Extraction No. 1B	61.727	41.972	19.755
16	LP Extraction No. 2A	127.2	62.853	64.347
17	LP Extraction No. 2B	126.979	63.47	63.509
18	LP Extraction No. 3	189.606	89.514	100.09
19	LP Extraction No. 4	283.708	109.066	174.64
20	LP Extraction No. 5	373.944	167.367	206.58
21	HP Extraction No. 6A	462.839	178.737	284.1
22	HP Extraction No. 6B	462.839	178.737	284.1
23	HP Extraction No. 7A	312.042	203.348	108.69
24	HP Extraction No. 7B	312.042	204.539	107.5
25	HP Extraction No. 8A	363.168	243.076	120.09
26	HP Extraction No. 8B	363.168	243.076	120.09

Table 3 is data that has undergone a shift in temperature resulting from the treatment ΔTmin. ΔTmin for the heat treatment temperature is the temperature value each ΔTmin reduced by 1/2, while for the hot temperature value each plus 1/2 ΔTmin. Next will be analyzed on the Problem Table Algorithm to determine the energy requirements of each flow of heat or cold flow.

Table 4 shows the population of the relationship between the flow or cold flow and heat flow. Results from Table Problem analysis algorithms were used to describe the cascade diagram as shown in Figure 3 is used to analyze the utility of hot and cold utility also has a function as determining the value of a pinch. Pinch value is determined by addressing energy shortage, minus the value of the Cascade diagram showing a lack of energy that is used to achieve the desired temperature

Based on Figure 2 it can be seen that the pinch is 51,0875°C. Pinch Point value lies in the utility value of 0 (zero) then pulled straight to determine the temperature that corresponds to the Problem Pinch table algorithms.

3.2 Composite curve analysis, shifted composite and grand composite

Composite curve analysis, composites and Grand Composite shifted using the data from the analysis of the problem of table.

3.2.1 Composite curves

Analysis of the composite curve in Figure 3. The curves obtained from the relationship between the temperature in the hot stream and the cold stream of the Heat Flow. Heat flow curve depicted on the red line and the cold flow curve drawn from the blue line, Value pinch it can be seen from a position adjacent stream.

3.2.2 The curve shifted composites

Analysis shifted composite curves have the same process with a composite curve, the difference lies in the shift of the curve caused by a shift in the temperature of the treatment ΔTmin so that it can be seen that the curve of the yield curve ΔTmin treatment of cold flow and heat flow into contact as shown in Figure 4.

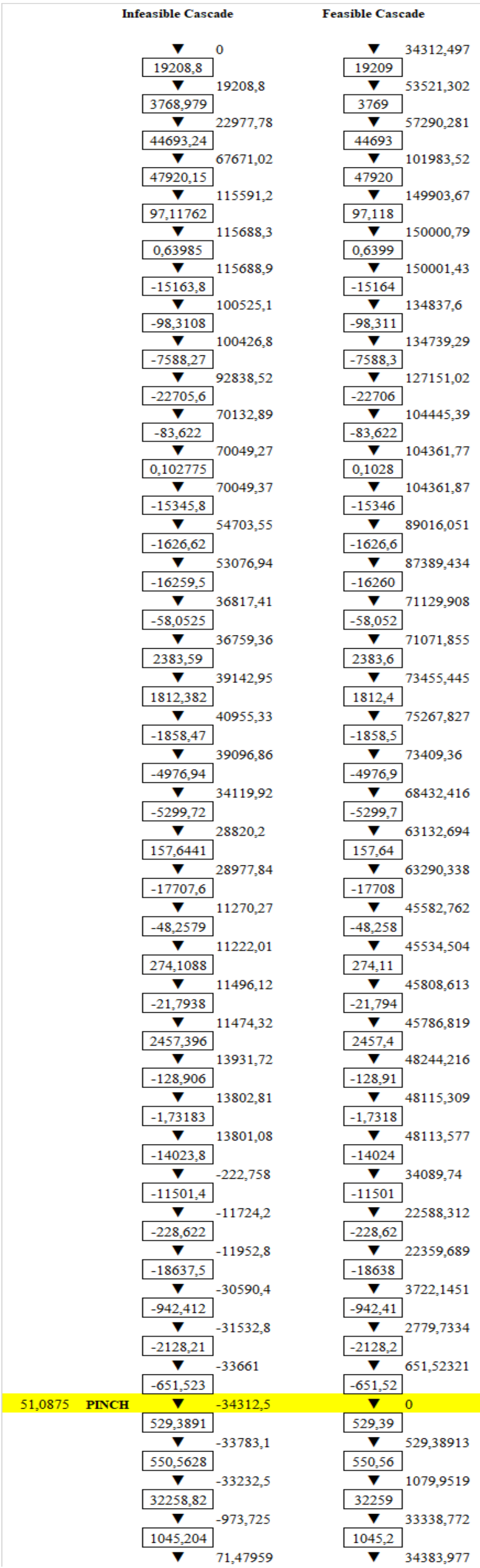

Figure 2. Cascade

3.2.3 Grand composite curve

Grand composite curve in Figure 6 derived from net heat flow graph with temperatures already in the pan or the temperature shifted. Grand composite curves are used to establish the utility of multiple targets. Grand composite curve also illustrates the difference between the possible heating of the heat flow to the heating required by cold flow.

Based on Figure 4 and Figure 5 knowable differences before and after analyses flow pinch. Figure 4 shows the distance between the hot and cold flow far enough when compared with Figure 5. The effect of distance between the cold flow and heat flow caused by the temperature difference is greater the distance between the flow, the greater the energy needs, loss of energy, and more little effectiveness. Heat Value Recovery when two streams of hot and cold streams are combined in Figure 4 is 380555,9744kW and in Figure 5. amounting 346,243.4772 kW. Heat Recovery value obtained from slices of the curve, while the remainder of the slices on each of the heat flow curve or cold flow is minimum energy demand.

Based on Figure 6, known that touches the curve shifted diagram Pinch Temperature is a value that is 51.0875°C, the diagram on the highest position that is equal to 34321.49717 Duty Heating kW, and the diagram on the bottom shows the Cooling Duty is equal to 34383.97676 kW.

3.3 Efficiency analysis

Analysis of the efficiency of using Eq. (5) with WNET is the turbine output value and Qin is the value of the input energy. The efficiency obtained is the efficiency of the entire power plant.

Based on Table 5 it can be seen that pinch analysis is able to reduce energy consumption in the process of electricity production in power plants PT POMI Unit 3 is equal to 34383.98 kW. Later in Table 6 and Figure 6 note that the analysis pinch able to increase the efficiency of 0.506%, and in Table 7 and Figure 7 known that pinch analysis is also able to reduce fuel consumption that is equal to 1.714 kg / s.

3.4 Grid diagram

Heat Exchanger Design Network is a procedure combining the two streams of hot and cold with mutual objectives and optimize energy transfer requiring less additional energy (either heating or cooling [12]. Diagram grid work according to the rules of analysis Pinch i.e. (Figure 8), no additional heat below Pinch utilities, no additional utility over Pinch cold, and there is no heat transfer across the pinch. If there is displacement across Pinch, then it must be set back Pinch to add some heat on the top of the Pinch and a cold load at the bottom of the Pinch.

Diagram design grid on the final results use a split or separation of flow, flow separation occurs because of lack of appropriate flow if integrated so that the necessary separation with no violation of the rules on the CP using design data from Table 3.

Based on the results of the design grid diagrams have been obtained, derived design modifications to the flow diagram of Feed Water Heater and a new Steam Extraction. Here is a flow diagram after Pinch analysis (Figure 9).

Table 3. ΔTmin problem 19,755°C

No.	Component	Tsin (°C)	Tsout (°C)	CP (KW / °C)	H (KW)	ΔH (KW)
1	LP FWH No. 1A	47.67	69.60	945.03	20718.86	
2	LP FWH No. 1B	48.16	69.79	945.03	20441.97	
3	LP FWH No. 2A	69.60	94.21	946.84	23302.74	
4	LP FWH No. 2B	69.79	94.12	946.84	23039.52	
5	LP FWH No. 3	94.21	115.20	951.60	19980.68	
6	LP FWH No. 4	115.18	147.80	960.88	31346.78	
7	deaerator	148.21	177.24	951.26	27615.19	
8	HP FWH No. 6A	184.23	210.85	1153.55	30704.73	
9	HP FWH No. 6B	184.32	210.93	1153.55	30696.08	
10	HP FWH No. 7A	210.85	248.52	1189.34	44797.59	
11	HP FWH No. 7B	210.93	248.69	1189.60	44919.40	
12	HP FWH No. 8A	248.52	273.83	1243.15	31468.98	
13	HP FWH No. 8B	248.69	274.04	1243.68	31523.45	380,555.97
14	LP Extraction No. 1A	51.09	31.09	1035.88	20719.70	
15	LP Extraction No. 1B	51.85	32.09	1035.05	20447.31	
16	LP Extraction No. 2A	117.32	52.98	362.65	23335.62	
17	LP Extraction No. 2B	117.10	53.59	362.78	23039.88	
18	LP Extraction No. 3	179.73	79.64	90.36	20047.27	
19	LP Extraction No. 4	273.83	99.19	179.58	31361.69	
20	LP Extraction No. 5	364.07	157.49	133.67	27613.68	
21	HP Extraction No. 6A	452.96	168.86	108.04	30694.98	
22	HP Extraction No. 6B	452.96	168.86	108.04	30694.98	
23	HP Extraction No. 7A	302.16	193.47	412.02	44783.82	
24	HP Extraction No. 7B	302.16	194.66	417.75	44909.70	
25	HP Extraction No. 8A	353.29	233.20	261.95	31458.59	
26	HP Extraction No. 8B	353.29	233.20	262.47	31520.24	380,627.45

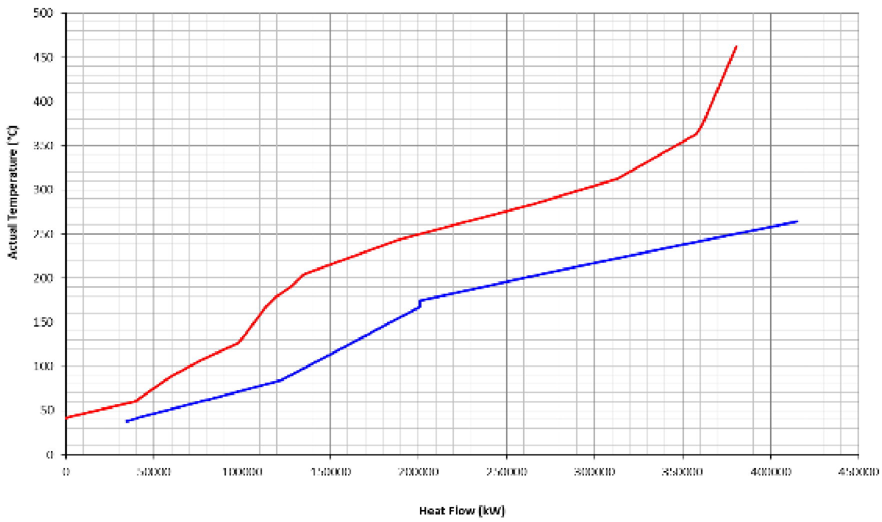

Figure 3. Composite curve

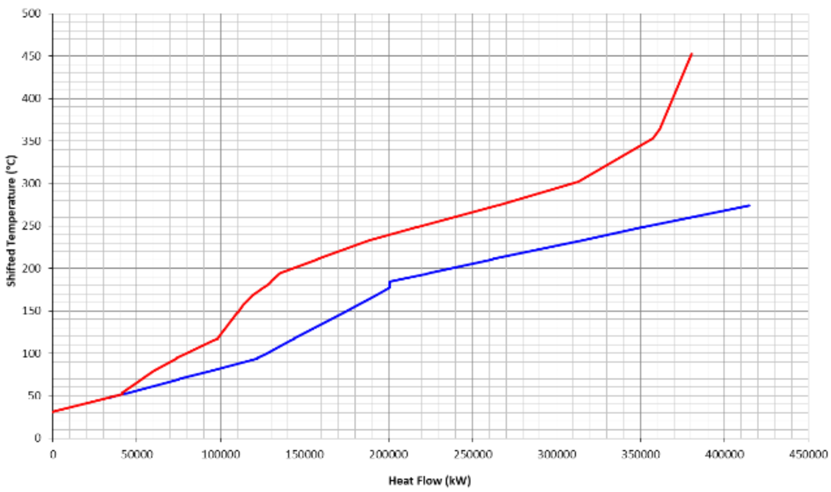

Figure 4. The curve shifted composites

Table 4. Problem table algorithm

Shift Temperature	Interval	Steam Population	$T_{(i+1)}-T_i$	$\sum CP_{Hot} - \sum CP_{Cold}$	H	demand / Surplus
°C			°C	kW/°C	kW	
452,9615						
364,0665	1		88,895	216,0842	19208,805	surplus
353,2905	2		10,776	349,7568	3768,9793	surplus
302,1645	3		51,126	874,1783	44693,2398	surplus
274,0415	4		28,123	1703,9487	47920,1493	surplus
273,8305	5		0,211	460,2731	97,1176	surplus
273,8295	6		0,001	639,8501	0,6399	demand
248,6945	7		25,135	-603,2954	-15163,829	demand
248,5155	8		0,179	-549,2225	-98,3108	demand
233,1985	9		11,562	-495,4147	-7588,2673	demand
210,9345	10		22,264	-1019,8362	-22705,6337	demand
210,8495	11		0,085	-983,7877	-83,622	demand
210,849	12		0,0005	205,55	0,1028	demand
194,6615	13		16,1875	-948,0042	-15345,8172	demand
193,4705	14		1,191	-1365,7572	-1626,6168	demand
184,3245	15		9,146	-1777,7746	-16259,5261	demand
184,2315	16		0,093	-624,2204	-58,0525	demand
179,7285	17		4,503	529,3338	2383,5901	surplus
177,2445	18		2,484	729,6222	1812,3815	surplus
168,8595	19		8,385	-221,6418	-1858,4665	demand
157,4895	20		11,37	-437,726	-4976,9446	demand
148,2145	21		9,275	-571,3986	-5299,722	demand
147,7995	22		0,415	379,8654	157,6441	surplus
117,3225	23		30,477	-581,0144	-17707,5757	demand
117,1015	24		0,221	-218,3616	-48,2579	demand
115,2035	25		1,898	144,4198	274,1088	surplus
115,1765	26		0,027	-807,1772	-21,7938	demand
99,1885	27		15,988	153,7026	2457,3964	surplus
94,2065	28		4,982	-25,8744	-128,9065	demand
94,1245	29		0,082	-21,1199	-1,7318	demand
79,6365	30		14,488	-967,9623	-14023,8377	demand
69,7915	31		9,845	-1168,2507	-11501,4281	demand
69,5955	32		0,196	-1166,4394	-228,6221	demand
53,5925	33		16,003	-1164,6282	-18637,5443	demand
52,9755	34		0,617	-1527,4096	-942,4117	demand
51,8495	35		1,126	-1890,0623	-2128,2102	demand
51,0875	36		0,762	-855,0173	-651,5232	demand
48,1605	37		2,927	180,8641	529,3891	surplus
47,6715	38		0,489	1125,8952	550,5628	surplus
32,0945	39		15,577	2070,9264	32258,8205	surplus
31,0855	40		1,009	1035,8814	1045,2043	surplus

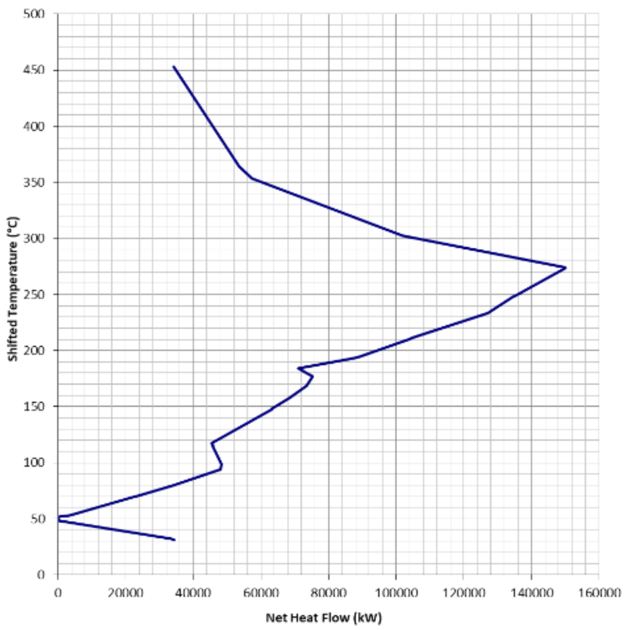

Figure 5. Grand composite curve

Table 5. Data calculation of efficiency

	Value	Unit
HHV Coal	20058.10	kJ / kg
wnet Turbine	559,099.97	kW
Early Qin	1,965,493.22	kW
Qin After Pinch Analysis	1,931,109.24	kW
Qin reduction	34383.98	kW

Table 6. Efficiency

	Value	Unit
Early Plant Efficiency	28.445785	%
Efficiency After Pinch Analysis	28.952271	%
Increased Efficiency	0.5064857	%

Table 7. Rate of fuel consumption

	Value	Unit
Initial Usage Fuels	97.99	kg / s
Use of Fuel After Pinch Analysis	96.275781	kg / s
Usage Fuels Reduction	1.714219	kg / s

Figure 6. Efficiency

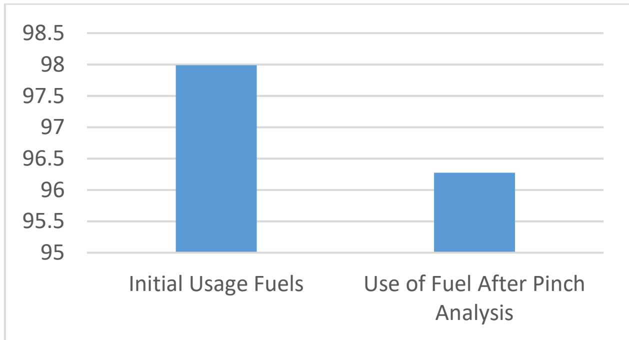

Figure 7. Rate of fuel consumption

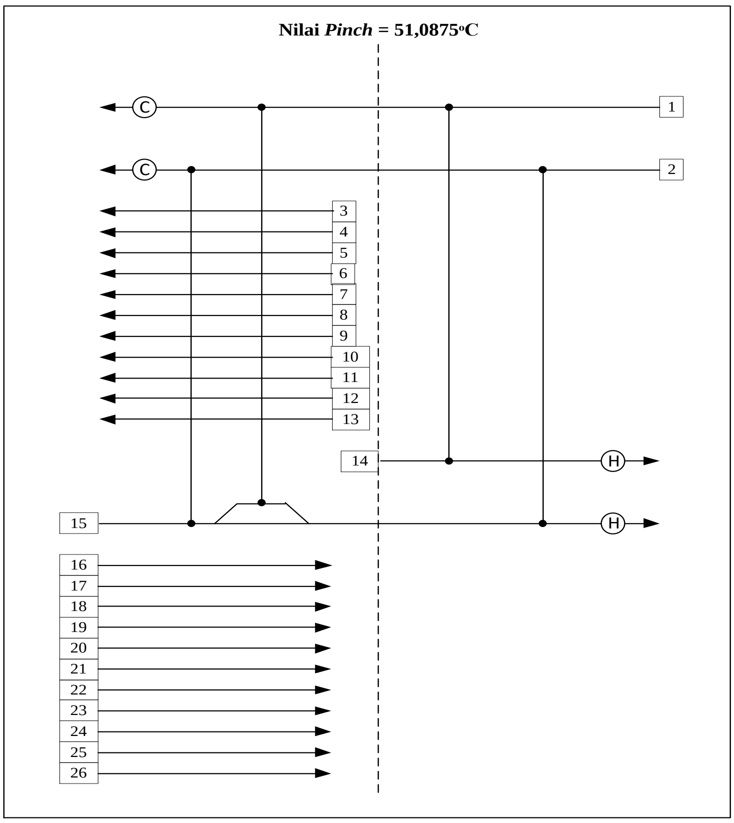

Figure 8. Diagram design grid

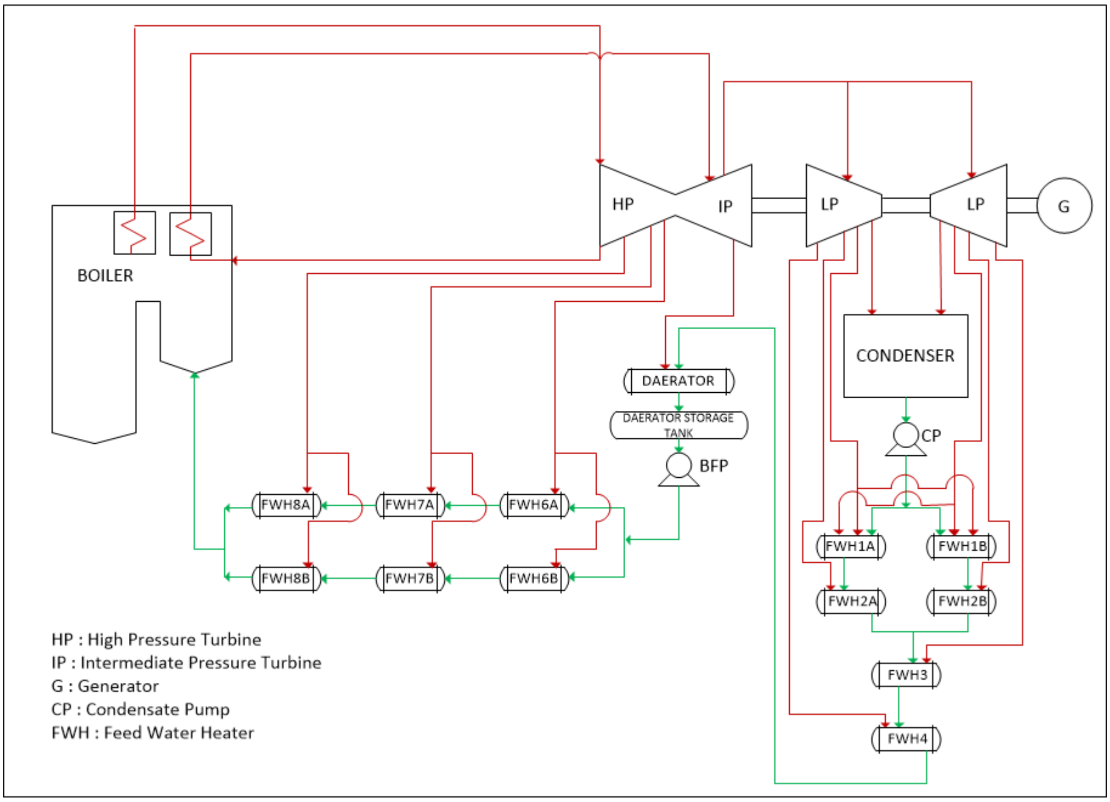

Figure 9. Flow diagram after pinch analysis

4. CONCLUSION

Based on the analysis that has been done, it can be concluded as follows:

(1) Pinch analysis is able increase efficiency of 0.5% of the power plant that was originally 28.45% to 28.95%, and can reduce fuel use by 1.71 kg / s initially as much as 97.99 kg / s to 96.28 kg / s.

(2) Pinch analysis is able to reconstruct the arrangement of the Heat Exchanger Network of Power Plant PT. POMI Unit 3 avoid writing long formulas with subscripts in the title; short formulas that identify the elements are fine (e.g., “Nd–Fe–B”).

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