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OPTIMIZATION OF CONDENSER BACKWASH METHOD TO MAINTAIN CONDENSER PERFORMANCE DURING THE BACKWASH PROCESS IN PLTGU GRATI

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ABSTRACT

The condenser is a device used to change the water vapor phase that has been used to rotate the turbine blade into a liquid phase by condensing it. When the condenser tube is dirty, it can disrupt the steam condensation process, which affects the efficiency of the condenser. The overcome this problem, a condenser backwash is carried out. The Condenser backwash has influenced unit efficiency, but backwash activities reduce production by decreasing vacuum condensers and steam turbine loads. When the vacuum condenser backwash process decreases + - 24 mmHg and the steam turbine load decreases + - 8 MW, the condenser backwash process is carried out from the control room with the observation of parameters from the local area or equipment. Backwash condensers are done one by one as needed. The condenser type in PLTGU Grati Block I is a crossflow type with two sides, side A and side B. Each side of the condenser has a different sequence backwash condition. This study will be carried out with a backwash method other than the sequence of automatic sequences. In the normal condenser backwash activity, there is a decrease in steam turbine load ± 8MW and a reduction in vacuum ± 24 mmHg. Due to a certain period, the condenser performance is reduced because one side of the condenser is not irrigated by seawater at the switching valve. The heat transfer in the condenser is reduced, impacting a steam turbine and vacuum condenser load. Based on the calculation results, the greater the valve inlet opening when the condenser backwash, the less vacuum and steam turbine load decreased even if there was no reduction in load. The backwash method that can be done to keep the vacuum condenser and steam turbine load stable is by maneuvering the valve inlet, outlet, and condenser backwash valve. The analysis results were a more stable decrease in steam turbine production in 0 MW and a decrease in the vacuum of 14 mmHg.

Keywords: Condenser; Backwash; Vacuum; Workload
Paper type Research paper

INTRODUCTION

PLTGU Grati is one of the plants owned by PT Indonesia Power, which supports the company's program to become a plant with operational excellence. Being a plant with operational excellence is not easy. In addition to the machine's reliability to continue operating according to its operating conditions, it must also have a high level of engine efficiency. PLTGU Grati has 2 blocks, block I with a capacity of 450 MW consists of 3 Gas Turbines (GT) @100 MW and 1 Steam Turbine (ST) @150 MW, while block II with a capacity of 300 MW consists of 3 GT @ 100 MW that is still operating open cycle. In its operation, PLTGU Grati has entered into the interconnection system of the Java Bali system whose P2B dispatchers control loading pattern settings.

To maintain the engine's thermal efficiency consistently high, one of the important components in the Grati PLTGU cycle is the condenser [1]. A condenser is a device used to convert the phase of water vapor that has been used to rotate the turbine spoon into a liquid phase by condensation [2][3]. Condensers condense steam by heat transfer, where seawater flowing in the pipes in them with a temperature of about 30ºC cools the steam from the turbine LP which is 70ºC so that the steam that meets the condenser volume shrinks to liquid. The condensing steam in the condenser will make the pressure inside become a vacuum, which impacts increasing the steam turbine load [4]. When operating, the condenser tube can become dirty thus interfering with the steam condensation process.

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To overcome these problems to maintain the performance of the condenser and the reliability of the unit, the condenser backwash is carried out.

A backwash condenser is a method of cleaning the condenser tube by providing a backflow of seawater in the opposite direction from its normal flow [5]. This cleaning method impacts the improvement of the condenser vacuum and steam turbine load. In the operation of the condenser backwash, sometimes the steam turbine will experience losses, namely, load lowering and vacuum condenser. This is the impact of the condenser backwash activity during valve switching. A new method is needed to reduce the condenser machine's losses.

METHOD

Cooling system

Power plants will operate properly if supported by supporting equipment such as cooling systems. Grati's PLTGU cooling system consists of closed and open cooling. Closed cooling systems are applied to Gas Turbine (GT) and Steam turbine (ST) cooling systems using a freshwater medium that constantly rotates cooling equipment in closed cycles [6]. An open cooling system is applied to the ST cooling system to cool closed-cycle cooling water and as a steam heat absorber output from the turbine to condense into the water again as a raw material for steam making in HRSG [7].

A closed cooling system is a cooling system that circulates a cooling media in the form of water [8]. The media used in the closed cooling system is water channeled by the pump to the heat exchanger equipment and back to the pump [9]. The quantity of water is maintained with a pipe stand. The quality must be maintained from the corrosive oxygen content by injecting chemicals such as hydrazine through chemical injection tanks. The closed cooling system in PLTGU is divided into two: the gas turbine closed cooling system and the steam turbine closed cooling system. The closed cooling system in the gas turbine serves to cool the cooling equipment in all GT blocks, while in ST cooling water cools equipment on ST, HRSG, and auxiliary common.

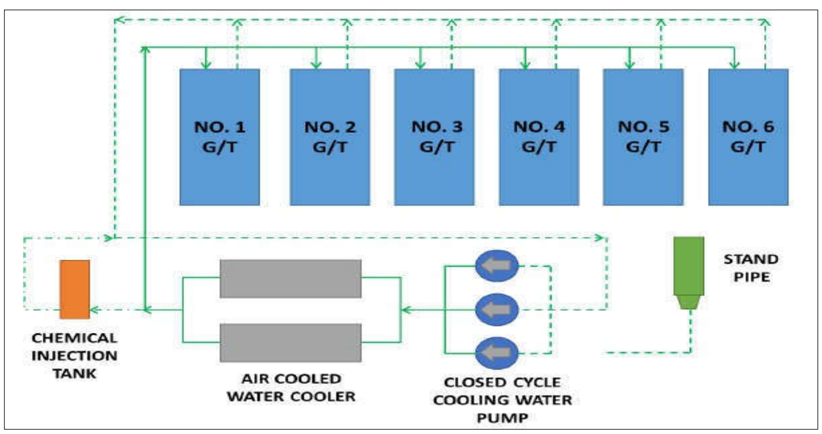

Figure 1. Gas Turbine Closed Cooling System

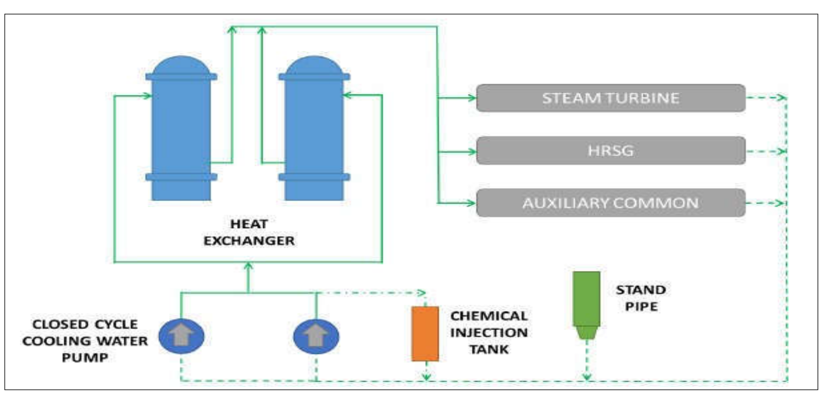

Figure 2. Steam Turbine Closed Cooling System

The open cooling system plays a role in cooling the closed-cycle cooling water on the steam turbine through the Heat Exchanger (HE) and cooling the steam that has been used to rotate the turbine spoon to condense on the condenser. This system uses seawater as a cooling medium derived from seawater intakes, then pumped by a circulating water pump (CWP) to the condenser and heat exchanger. There is a screening system to filter seawater in seawater so that water pumped by CWP avoids solid waste that can interfere with the cooling system's performance. A circulating Water Pump (CWP) is a pump used to pump seawater towards the condenser [10]. In PLTGU Grati Block I there are two CWPs with the same specification. The operation of the number of CWP in operation depends on the condition of the steam turbine loading.

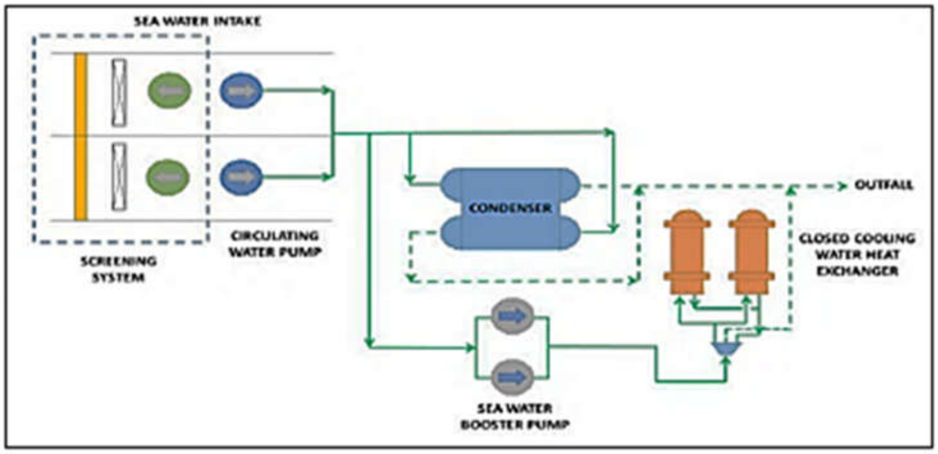

Figure 3. Steam Turbine Pltgu Grati Open Cooling System

Table 1. Specification Circulating Water Pump

Type	Sulzer BSm 1150 single stage
Quantity	25200 m^3/h
Discharge head	11.8 m
Speed	371 rpm
Power	942,4 kW

CONDENSER

A condenser is a heat exchanger that condenses steam turbine output at pressures below atmospheric pressure. Optimal condenser performance can improve the efficiency and work produced by steam turbines [11]. The condenser pressure is made a vacuum to accelerate the steam condensation from the turbine to increase its efficiency. Seawater flow rate and cooling temperature have an important role in the heat transfer process in the condenser. Low seawater temperatures make heat transfer even better. The greater the flow rate also makes heat transfer better, thus increasing the efficiency of the condenser [12].

The better the vacuum conditions in the condenser can increase the production rating load of the steam turbine [13]. When the amount of cooling water is reduced, the vacuum condition on the condenser will decrease. This can occur when the tube on the condenser is blocked by solid waste; the adverse impact will result in derating steam turbine production, and if the vacuum continues to fall it can cause a trip. Therefore, cooling water and condenser hygiene are important elements in thermal plants.

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Table 2. Condenser Design at PLTGU Grati

Type	Radial Flow Surface Cooling
Cooling surface area	12670 m^2
Cooling water flow	46070 m^3/h
Inlet cooling water temperature	30°C
Vacuum	697 mmHg
Cooling water velocity in tubes	2.35 m/s
Water Box Material: Carbon steel with neoprene rubberThickness : 3mm Mechanical properties : Grade SS400 JIS / A-283-Gr.D ASTMTensile strength : 340 – 470 (N/mm^2) Neoprene rubber tensile strength: 4Mpa	
Tubes Number : 15382 Thickness : 0.5 mm Maximal Press : 4 kg/m^2Diameter : 22.23 mm Length : 11797 mm	

A backwash condenser is a method of cleaning the condenser tube by providing a backflow from its normal flow direction. In the condenser backwash process, the opening of the valve inlet, outlet, and valve backwash condenser is set so that the flow on both sides goes in the same direction or the flow direction on one of the condensers reverses from its normal flow [14].

a b

Figure 4. (a) Normal condenser flow direction, (b) direction of condenser flow during backwash

Research methods

Research preparation is done when the steam turbine operates with a specific load. When the steam turbine operates, the condenser condition is already in normal operation and a state of vacuum pressure. Steps that must be done in the preparation of research include:

1. Make sure the Circulating Water Pump is operational.
2. Ensuring the condition of the condenser valve motor can operate normally.
   a. Motor Valve Inlet Condenser A
   b. Motor Valve Outlet Condenser A
   c. Motor Valve Backwash Condenser A
   d. Motor Valve Inlet Condenser B
   e. Motor Valve Outlet Condenser B
   f. Motor Valve Backwash Condenser B
3. Ensure the pressure condition of the condenser vacuum is above 680 mmHg.
4. Ensuring the steam turbine load is safe for research.
5. Ensuring the operating parameters of the steam turbine are safe for condenser backwash.

The condenser backwash process is carried out from the control room to observe parameters from the local area or equipment. Backwash condensers are done one by one as needed. The condenser

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type in PLTGU Grati Block I is a type of crossflow with two sides, side A and side B. Each side of the condenser has a different sequence backwash condition. This study will be carried out with a backwash method that is different from the sequence of automatic sequences.

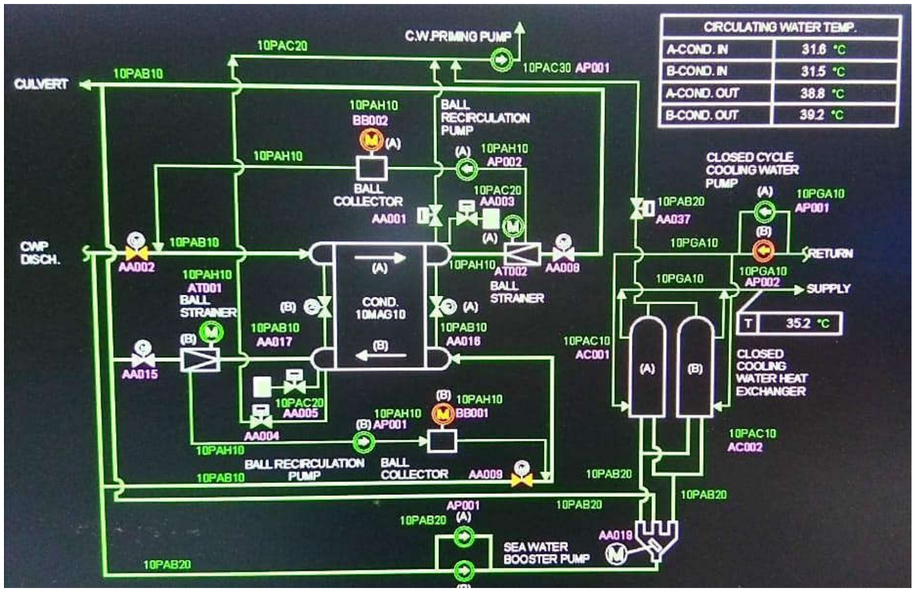

Figure 5. Condenser at PLTGU Grati

Normal condenser state of operation
Motor Valve Inlet condenser A = Open 100 %
Motor Valve Outlet Condenser A = Open 50 %
Motor Valve Backwash Condenser A = Close Motor

Valve Inlet
Condenser B = Open 100 %
Motor Valve Outlet condenser B = Open 50 %
Motor Valve Backwash condenser B = Close

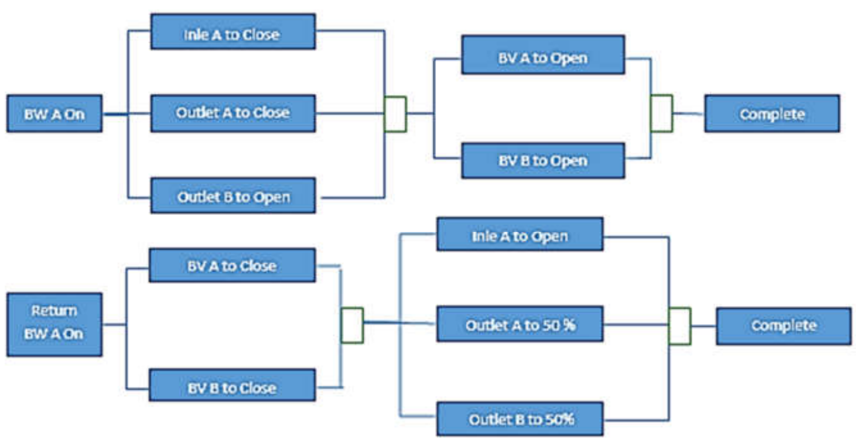

Figure 6. Sequence Backwash Condenser side A

For sequence backwash condenser in side B valve position is opposite of side A. Backwash alternative is done by increasing the opening percentage of the condenser inlet 5% Alternative method backwash condenser.

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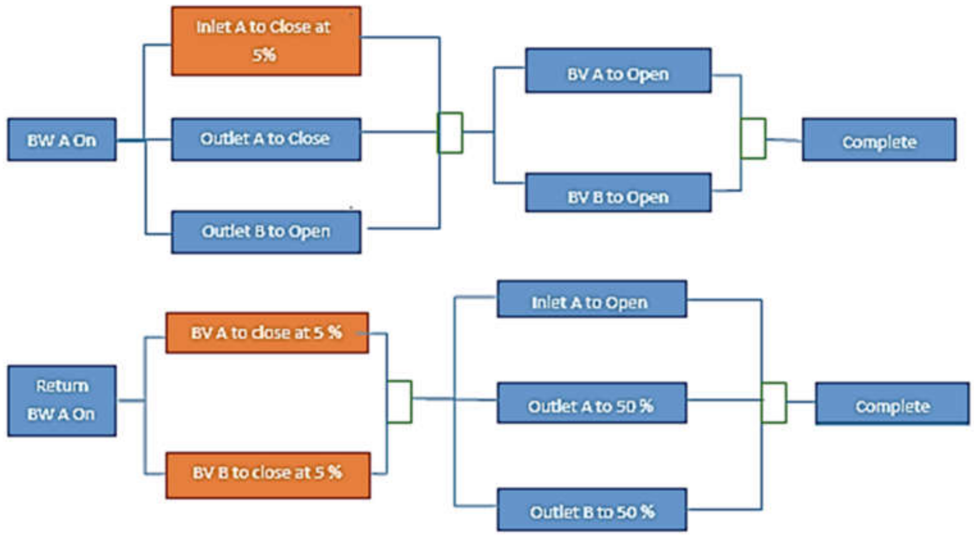

Figure 7. The B-side condenser backwash process is the opposite of the A-side condenser backwash.

DISCUSSION

In the normal condenser backwash activity of data Table 3, we know there is a decrease in steam turbine load ± 8MW and a decrease in vacuum ± 24 mmHg. This is because, at a certain period, the condenser performance is reduced because at the time of switching valve one side of the condenser is not irrigated by seawater so that the heat transfer in the condenser is reduced, which has an impact on the load of steam turbine and vacuum condenser. After the research, the greater the valve inlet opening when the condenser backwash, the decrease in vacuum and steam turbine load decreased even no decrease in load.

Table 3. Normal Condenser Backwash Data

No	Date	Load (MW)	Vacuum (mmHg)	Duration (hours)
1	30 January 2019	8	24	167
2	6 February 2019	7	20	181
3	16 February 2019	6	22	171
4	20 February 2019	6	22	172
5	6 March 2019	7	23	168
6	10 March 2019	8	25	172

In Figures 8 and 9, it can be seen the greater the opening of the inlet valve condenser vacuum is decreased not too high, which has the impact on the steam turbine load. On the backwash with one CWP, the most optimal opening is at 45%, while with two CWP at 50%. In Figures 8-9, the load decreases until there is no decrease in load because the vacuum decrease decreases each opening rate of the valve inlet.

On the condenser pressure chart in Figures 10-11, the greater the opening percentage of the condenser's valve will increase. On the pressure chart with one CWP, the increase in pressure is not very significant compared to the two CWP, which reached 1.7 kg/cm^2 at the opening of 50%.

This increase in pressure is caused by flow turbulence in the condenser during the valve opening switch. But compared to the strength of tube material according to the MHI design manual, which is 4 kg/m^2, it can be categorized as increasing pressure still at the safe limit. Another risk when the backwash process is the presence of shock loads on the generator when the network requires more load so that the turbine work increases, which will result in steam flow to the condenser getting bigger. The greater the flow of steam will affect the lower vacuum. While the shock load in the form of a relatively safe load decrease in turbine work because the reduction in load will reduce the number of flow stream so that the condenser work will be lighter. But this shock load is rare because it has been limited by the control system of the steam turbine and the generator itself. The testing data needs to be reviewed and analyzed regarding heat transfer and condenser effectivity when backwashing the decrease in turbine steam load and condenser vacuum.

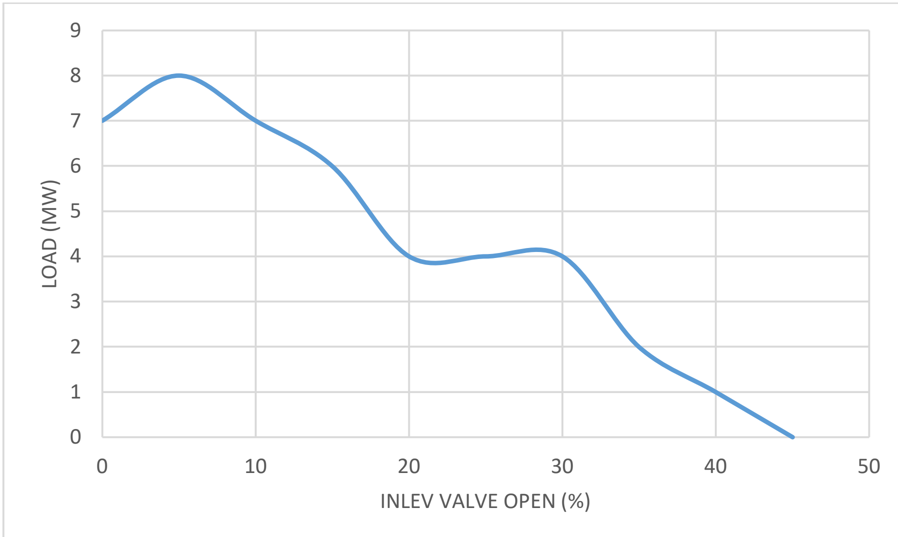

Figure 8. Graph of the relationship between the entry valve opening and the load decrease with a single CWP (Circulating Water Pump)

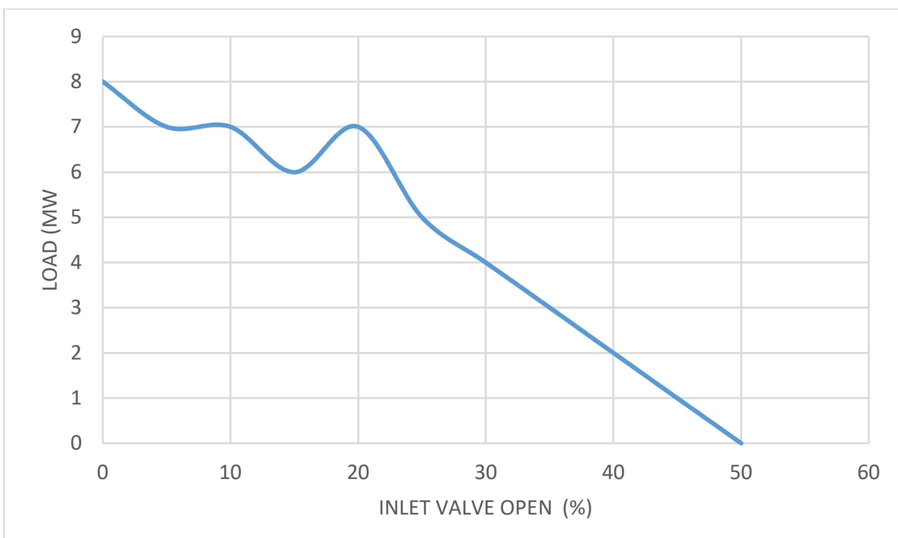

Figure 9. Graph of the relationship between the entry valve opening and the load decrease with double CWP (Circulating Water Pump)

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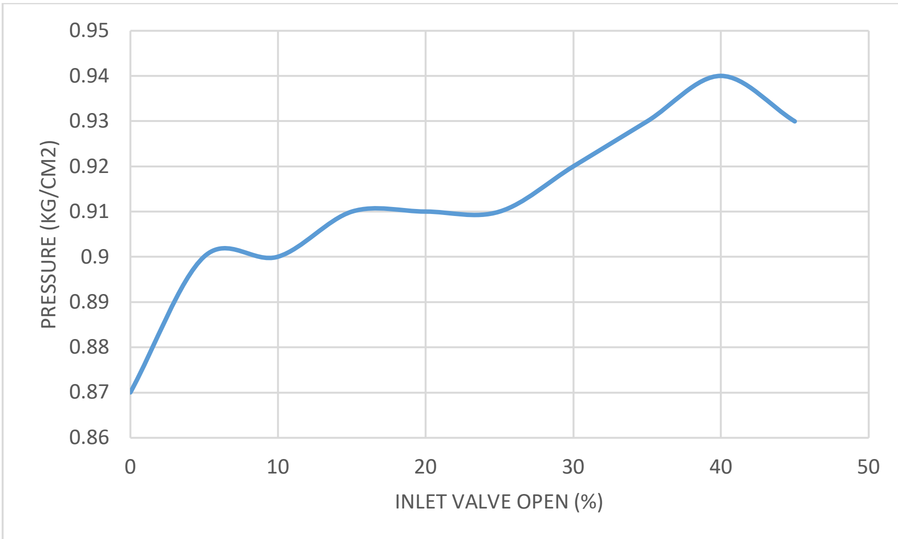

Fig. 10. Graph of the relationship between the entry valve opening and the condenser pressure with a single CWP (Circulating Water Pump)

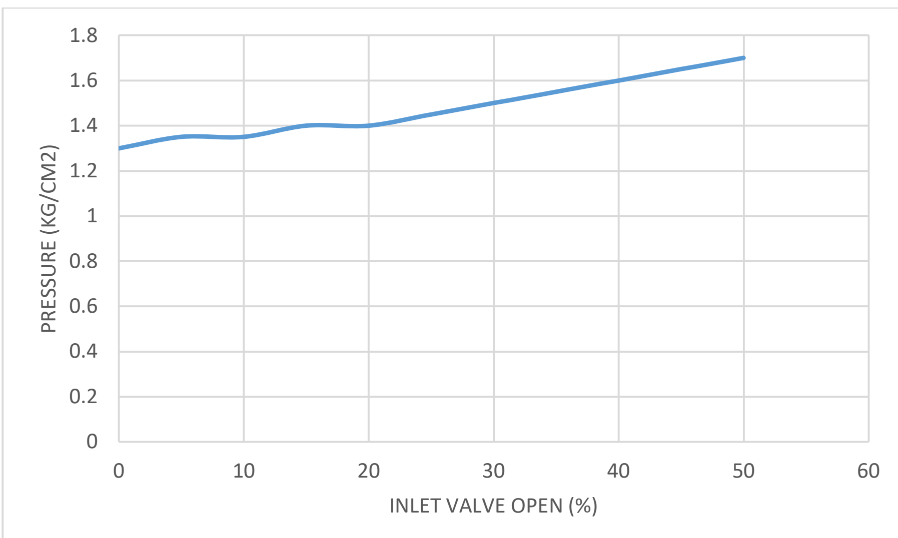

Fig. 11. Graph of the relationship between the entry valve opening and the condenser pressure with double CWP (Circulating Water Pump)

Table 4. Turbine efficiency

Parameter	Normal Operation	Normal *Backwash*	New Method
Inner Pipe Convection Coefficient *(hi)* W/m^2K	8506.85	14811.29	7754.055
Outer Pipe Convection Coefficient *(ho)* W/m^2K	28815.11	28845.294	28845.36
Overall heat transfer coefficient (U) W/m^2K	2597.403	3004.807	2518.89
Heat Rate (Q) MW	242.064	140.0259	234.664
Effectiveness	0.99493	0.99126	0.99477
Effectiveness (%)	99.493	99.126	99.477

Advantages of Turbine Efficiency

Efficiency is the comparison of inputs and outputs in working equipment. In this study, the efficiency of steam turbines can be calculated by the formula from the manufacturer Mitsubishi heavy Industry with the following formula:

$$Efficiency\ ST = \frac{860\ x\ 100}{heat\ Rate}$$

$$Heat\ rate = \frac{HP\ Steam\ Flow\ x\ 1000\ (HP\ Steam\ Ent - Condensate\ Ent) + LP\ Steam\ Flow\ x\ 1000\ (\ Lp\ Steam\ Ent - Condensate\ Ent}{ST\ Product\ x\ 1000}$$

In this calculation, a sample of data was taken on May 22, 2019, at a load of 90 MW with the following values: *HP Steam Pressure*: 37.3 kg.cm^2
HP Steam Temperature : 504.5 ^{o}C
HP Steam Flow : 282.2 T/h
LP Steam Pressure : 5.21 kg/cm^2
LP Steam Temperature : 156.6 ^{o}C
LP Steam Flow : 56.53 T/h
Condensate Pressure : 15.05 kg/cm^2
Condensate Temperature : 39.9 ^{o}C

From the data above obtained the enthalpy value was as follows:
HP Steam Enthalpy : 3459.9 kj/kg
LP Steam Enthalpy : 2758.5 kj/kg
Condensate Enthalpy : 168.42 KJ/kg

Calculation of Steam Turbine efficiency in Normal Operation

$$Heat\ rate = \frac{282.2\frac{T}{h}x\ 1000\left(3459.9\frac{kj}{kg} - 168.42\frac{kj}{kg}\right) + 56.53\ T/h\ x\ 1000\ (\ 2758.5\frac{kj}{kg} - 168.42\frac{kj}{kg})}{90\ MW\ x\ 1000}$$

$$= \frac{928855656\ kj + 146417222.4\ kj}{90000\ kWh}$$

$$= 11947.476\ Kj/kWh$$
$$= 2855.5153\ kcal/kWh$$

$$Efficiency\ ST = \frac{860\ x\ 100}{heat\ Rate}$$
$$= \frac{860\ x\ 100}{2855.5153\ kcal/kWh}$$
$$= 30.12\ \%$$

Calculation of Steam Turbine Efficiency at Normal Backwash

Loss on normal backwash average – average 8 MW

$$Heat\ rate = \frac{282.2\frac{T}{h}x\ 1000\left(3459.9\frac{kj}{kg} - 168.42\frac{kj}{kg}\right) + 56.53\ T/h\ x\ 1000\ (\ 2758.5\frac{kj}{kg} - 168.42\frac{kj}{kg})}{(\ 90 - 8)\ MW\ x\ 1000}$$

$$= \frac{928855656\ kj + 146417222.4\ kj}{82000\ kWh}$$

$$= 13113.084\ kj/kWh$$

$$= 3134.1023\ kcal/kWh$$

$$Efficiency\ ST = \frac{860\ x\ 100}{heat\ Rate}$$

$$= \frac{860\ x\ 100}{3134.1023\ kcal/kWh}$$

$$= 27.44\ \%$$

From the calculation above, it can be known that the normal backwash method will reduce the efficiency of the steam turbine by 2.68%, which impacts the increasing heat rate.

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CONCLUSION

The results of the backwashing method testing show that using the new backwash method can reduce losses due to backwash because there is no decrease in steam turbine load. In backwash with one CWP pump, the most optimal backwash occurs at the valve inlet opening at 45% with a 14 mmHg vacuum decrease. In contrast, on the backwash with two CWP pumps, the most optimal backwash occurs at the valve inlet opening 50% with a vacuum decrease of 14 mmHg lower than the vacuum decrease on the normal backwash with an average decrease of 24 mmHg. The new backwash method has potential risks. The potential risk is increased pressure that can harm the condenser tube due to flow turbulence during the backwash process. But it is still within the safe limit because it is still under the maximum pressure tube design of 4 kg / m2 while the highest condenser pressure increase reaches 1.7 kg / m2. The performance value of the condenser can be measured from the effectiveness value of the condenser. At normal times condenser operation has an effectivity value of 99.493%. At the time of normal backwash, there was a decrease in condenser efficiency to 99,126%. With the new backwash, the method has an effectivity value of 99.477%. Judging from the effectivity value of the condenser with the new backwash method is better than the normal backwash of 0.351%.

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REFERENCES

[1] Y. G. Mussalli, “Condenser macrofouling control technologies,” Stone and Webster Engineering Corp., Boston, MA (USA), 1984.

[2] I. Rosyadi, D. Satria, and C. Cecep, “Pengaruh Penurunan Vacuum Pada Saat Backwash Condenser Terhadap Heat Rate Turbin Di Pltu,” *FLYWHEEL J. Tek. Mesin Untirta*, no. 1, 2016.

[3] W. Allen, D. Anderson, and B. Mayer, “Pickering B Nuclear Power Generating Station Condenser Performance Improvement,” in *International Joint Power Generation Conference*, 2003, vol. 36924, pp. 29–37.

[4] A. S. Z. Lini and B. Rudiyanto, “Penentuan Nilai Efektivitas Condenser di PLTU Paiton Unit 5 PT. YTL Jawa Timur,” *J. Ilm. Rotary ISSN*, vol. 2540, p. 8704, 2016.

[5] M. A. Molan, “Cooling System And Condenser Problems In Dr. Shareef Power Station.” Sudan University of Science and Technology, 2005.

[6] F. Hamrang, A. Shokri, S. M. Mahmoudi, B. Ehghaghi, and M. A. Rosen, “Performance analysis of a new electricity and freshwater production system based on an integrated gasification combined cycle and multi-effect desalination,” *Sustainability*, vol. 12, no. 19, p. 7996, 2020.

[7] S. Fleischli and B. Hayat, “Power plant cooling and associated impacts: the need to modernize US power plants and protect our water resources and aquatic ecosystems,” *Nat. Resour. Def. Counc*, 2014.

[8] A. Sakoda and M. Suzuki, “Simultaneous transport of heat and adsorbate in closed type adsorption cooling system utilizing solar heat,” 1986.

[9] O. Culha, H. Gunerhan, E. Biyik, O. Ekren, and A. Hepbasli, “Heat exchanger applications in wastewater source heat pumps for buildings: A key review,” *Energy Build.*, vol. 104, pp. 215–232, 2015.

[10] Y.-Y. Ma, S. Yan, Z.-G. Yang, G.-S. Qi, and X.-Y. He, “Failure analysis on circulating water pump of duplex stainless steel in 1000 MW ultra-supercritical thermal power unit,” *Eng. Fail. Anal.*, vol. 47, pp. 162–177, 2015.

[11] M. S. Bhatt and N. Rajkumar, “Performance enhancement in coal fired thermal power plants. Part II: steam turbines,” *Int. J. Energy Res.*, vol. 23, no. 6, pp. 489–515, 1999.

[12] Z. Li, H. Zhang, H. Chen, J. Zhang, and C. Cheng, “Experimental research on the heat transfer and water recovery performance of transport membrane condenser,” *Appl. Therm. Eng.*, vol. 160, p. 114060, 2019.

[13] D. Strušnik, "Integration of machine learning to increase steam turbine condenser vacuum and efficiency through gasket resealing and higher heat extraction into the atmosphere," *Int. J. Energy Res.*, 2021.

[14] A. E. Kabeel, Z. M. Omara, and F. A. Essa, "Enhancement of modified solar still integrated with external condenser using nanofluids: An experimental approach," *Energy Convers. Manag.*, vol. 78, pp. 493–498, 2014.