Modified an Automatic-Cleaning Strainer for Seawater Cooling System in Combined Cycle Power Plant

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***Abstract*—The power plant industries on the coast use seawater as a cooling water system. Seawater conditions in densely populated areas, such as Jakarta, have high levels of pollutants which can affect cooling water systems. To filter seawater from pollutants, a strainer is used due to reliability must be maintained. This research is located at a power plant in North Jakarta. This research describes the latest proposed design of an automatic-cleaning strainer that poses less risk to the system and is faster in the work process. The results of this design were implemented at the generating company. This design can maintain strainer reliability with a faster strainer cleaning process, which reduces the TTR (Time to Repair) in the generating unit from 3 hours to 5 minutes, with no risk of damage to the system due to foreign material in the cooling water system. In addition, the results of this research help improve plant operation and maintenance performance, by increasing EAF 1.11%, increasing 1 level in Maintenance Mix Cost and Manhour from Level 4 to Level 5, increasing Reliability Management by 0.1 level, and also reducing EFOR by 0.98%. Work processes that are carried out automatically via smartphones also contribute to the digitization of the power generation industry to make it more effective and efficient.**

Keywords—automatic-cleaning, power plant, reliability, seawater, strainer.

I. INTRODUCTION

Thermal power plants located on the coast are accustomed to using seawater as a cooling water system. In densely populated areas, such as Jakarta, seawater quality is of particular concern because it has a large potential for pollution. Research has shown that the distribution profile, concentration, and composition of microplastic pollution in Jakarta's seawater canals pose a very high risk of ecosystem pollution [1]. Organic pollutants are also in Jakarta's canals which can come from the mouths of several rivers, and this causes sea water in Jakarta's estuaries to be polluted [2]. Seawater which has a high concentration of organic pollutants can cause plugging due to the scaling of pollutants in the cooling water system [3]. There is a strong relationship between scaling and corrosion in the cooling water system of power plant will affect the reliability [4]. In power plants located on coasts, the role of strainers as a means of filtering seawater from pollutants is very important to maintain the reliability of the cooling water system.

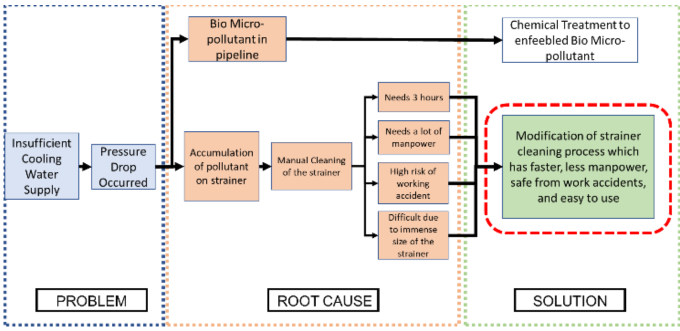

Fig. 1. Root Cause Analysis for Cooling System in Power Plant

Root Cause Analysis (RCA) has become a common method used in power plants, such as for more in-depth analysis of micro gas turbines [5] and algorithmic detection of anomalies as alarms at Nuclear Power Plants [6]. Figure 1 explains the RCA related to cooling water supply disruptions caused by the accumulation of seawater debris in the strainer. When the strainer has accumulated dirt, the strainer is cleaned manually by disassembling the strainer body. This method is an old method and has many disadvantages, such as a long process, requiring a lot of manpower, and a high risk of work accidents. Several researchers modified the strainer to suit the conditions of their respective plants.

A study shows the idea of optimizing the mesh size of debris strainers thereby reducing maintenance costs by 80% [7]. Another research shows a successful ceramic ultrafiltration as a pre-treatment for seawater in Oman [8]. Another ultrafiltration technology has been reported to be adapted in Egypt for water filtration [9]. There is also research that optimizes the filter housing (body strainer) so that the pressure drop can decrease and the flow rate capacity

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increases [10], and also a method for grade assessment of strainer filtration has been conducted [11]. The effect of strainer types used in ceramic flat-fan nozzles has been studied that shows different characteristics of flow and droplet velocity [12]. The research shows a study to design and analyze the optimum Y-type strainer that widely used in Industries [13]. T-type Strainer has been studied by increasing strainer body size and punch plate hole are giving a great improvement of the strainer's life time [14]. Another type of strainer, like bucket-type strainer, has been studied to optimized its capacity used in thermal power plant [15]. Meanwhile, the type of strainer that has a higher pressure drop capacity and the capacity to accommodate more dirt is the basket strainer type [16].

Automatic-cleaning on basket type strainers makes it possible to return the pressure drop to normal values by utilizing the maneuver of the backwash system control valve [17]. However, the pressure drop can increase again in a short time, making this model ineffective. The study shows a computational fluid dynamic approach to analyze a pressure drop in automatic-cleaning strainer [18]. Another type of automatic cleaning is by utilizing a helical blade that is coiled inside the strainer and connected to a DC motor [19]. When the motor is operated, the helical blade will rotate, utilizing water flow from the system, which then cleans the strainer. Another type uses a brush model that is connected to a motor so that the brush can rotate to clean the strainer [20]. Both types have the potential to trap foreign material in the cooling water system because both the helical blade and brush can come off their respective shafts, endangering the cooling water system.

TABLE 1. DIRECT COMPARISON OF THE EXISTING AND THE PROPOSED DESIGN

No	Description	The Existing Design			The Proposed Design
		Backwash Type	Helical Blade Type	Brush Type	
1	Time for the strainer to reach a dirty state again	Fast	Low	Low	Low
2	The potential for foreign material from equipment to clog the strainer	Low risk	High risk	High risk	Low risk
3	Ease in the manufacturing process	Moderate	Hard	Hard	Moderate
4	Strainer cleanliness level	Low	High	High	High

This research introduces the latest automatic-cleaning strainer model developed by the author for the basket strainer type. As shown in Table 1, The new model addresses the limitations of existing designs by allowing the strainer to be cleaned without disassembly, preventing foreign material from harming the cooling water system, and ensuring more effective cleaning with consistent pressure drop intervals. The primary goal of this research is to present a new, more effective design for an automatic-cleaning strainer system, developed through simulations and experimental tests, that minimizes the risk of system failure. Additionally, the study explains how this innovative model can be implemented in power plants to enhance overall plant performance.

II. METHODS

This research was conducted at the Combined Cycle Power Plant (CCPP) located in North Jakarta, where the strainer plays a crucial role in filtering seawater used in the steam turbine cooling system. The quality of Jakarta's seawater, heavily influenced by urban pollutants, presents significant challenges for this filtration process. Various studies have highlighted the high levels of contaminants in the seawater, including suspended solids and organic materials, which increase the risk of clogging within the strainer and disrupt the cooling water flow to the steam turbine. Such interruptions can reduce the thermal efficiency of the turbine, potentially leading to reduced power output, known as derating.

If left unaddressed, these issues could compromise the reliability and efficiency of power generation, resulting in higher operational costs and decreased energy supply stability. Given the critical role of the strainer, modifications to include an automatic-cleaning mechanism are essential to ensure timely removal of accumulated debris without requiring manual disassembly, significantly reducing downtime and maintenance needs. This adaptation would not only improve cleaning efficiency but also decrease reliance on manual labor, minimizing human error and the risk of damage to the strainer components. Additionally, an automated system could better handle fluctuating pollution levels in seawater, ensuring a more consistent cooling water flow to the steam turbines. By enhancing the reliability of the filtration process, these modifications would directly support the plant's ability to maintain steady power output, contributing to regional electricity supply stability. This research aims to assess the potential benefits and implementation strategies of these modifications, focusing on achieving a more sustainable and efficient power generation process at the CCPP.

A. *The Existing Manual-Cleaning Strainers and The Latest Technology of Automatic-Cleaning Strainers*

The existing strainer system at the Combined Cycle Power Plant (CCPP) in North Jakarta, which is the primary focus of this research, poses considerable challenges in maintaining operational efficiency. The strainer, which is critical for filtering debris and preventing clogging in the system, is not equipped with automatic cleaning capabilities in its current design. As a result, any build-up of contaminants within the strainer necessitates manual cleaning, which can disrupt the continuous operation of the power plant. This limitation is a significant drawback for a facility that relies on consistent flow rates to maintain optimal performance. Thus, exploring potential modifications to enable automatic cleaning has become an essential aspect of improving the plant's maintenance strategies.

In the current cleaning procedure, the strainer must be disassembled from its housing, a task that requires halting the flow of fluids through the system to ensure safe handling. The strainer components, once removed, are cleaned manually outside of the system's main structure. This manual process is not only labor-intensive but also time-consuming, leading to a temporary reduction in the plant's operational capacity. The reliance on skilled personnel to conduct the disassembly, cleaning, and reassembly introduces a level of variability in the quality of maintenance. Any mistakes during these steps could lead to inefficient filtration, potential damage to the strainer, and increased risks of unplanned shutdowns. Consequently, the manual cleaning method can indirectly contribute to higher operational costs due to increased labor demands and potential delays in resuming normal operations.

Given these challenges, there is a growing need to evaluate the feasibility of retrofitting the existing strainer system to support automatic cleaning mechanisms. Such a system would allow for continuous operation with minimal human intervention, thereby reducing the risk of downtime and enhancing the overall efficiency of the power plant. An automatic cleaning mechanism would involve the integration of self-cleaning filters or backwashing systems that can remove debris without requiring manual disassembly. This upgrade would not only streamline the maintenance process but also extend the lifespan of the strainer by minimizing the physical handling of its components. Implementing an automated solution could significantly improve the plant's operational resilience, ensuring a more stable and reliable power supply. Therefore, this research aims to provide insights into the potential benefits of such modifications, highlighting their role in achieving a more efficient and sustainable energy production process at the CCPP.

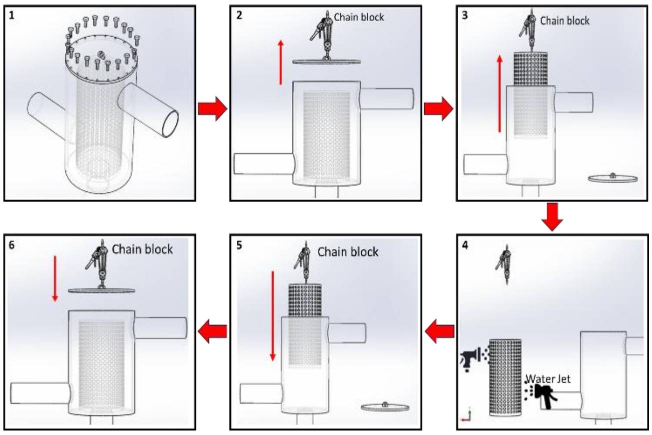

Fig. 2. Manual Cleaning Process of Existing Strainer

The manual cleaning process of the strainer, as illustrated in Figure 2, is labor-intensive and time-consuming, posing significant challenges to the maintenance operations on the power plant. Personnel assigned to this task must first unscrew the bolts and remove the strainer cover, followed by carefully disassembling the strainer from its housing, which requires precision and skill to avoid damaging the components. The cleaning itself is done manually, demanding thorough attention to detail to ensure that all debris is completely removed, as any residue could impair the efficiency of the filtration system. Once the cleaning is complete, the strainer must be meticulously reassembled and secured back into place, a process that must be executed with care to prevent any leaks or malfunction when the system resumes operation.

This entire procedure not only demands a considerable amount of time but also requires a substantial number of personnel and specialized equipment, making it a resource-heavy and costly activity. Moreover, the manual nature of this procedure increases the risk of work-related accidents, such as injuries during disassembly or damage to the delicate strainer components, potentially resulting in delays and additional repair costs. These factors can significantly impact the performance and operational efficiency of the power generation process, as any delays or accidents during maintenance can lead to unplanned downtime, reduced power output, and interruptions in energy supply.

To address these challenges, various types of automatic-cleaning strainers have been developed by manufacturers and researchers worldwide, offering advanced solutions that automate the cleaning process, reducing the need for manual intervention. These automated systems promise to enhance the speed and safety of the cleaning process, minimize the risk of human error, and support more reliable and efficient power plant operations. By integrating such technologies, power plants could greatly improve maintenance efficiency, reduce the risks and costs associated with manual strainer cleaning, and ensure a more stable and continuous power supply.

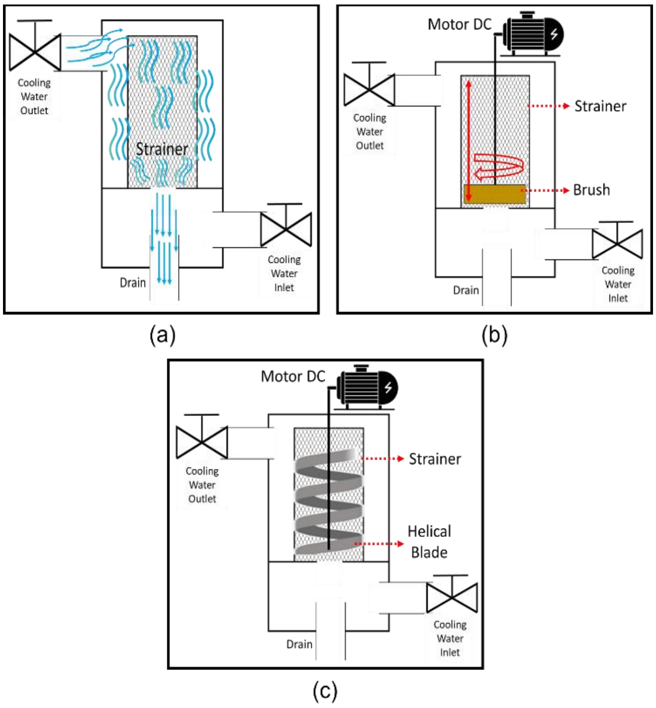

Fig. 3. (a) Strainer Tipe Backwash, (b) Automatic-Cleaning Strainer with Brush, (c) Automatic-Cleaning Strainer with Helical Blade

Figure 3 presents an overview of the most recent automatic-cleaning strainers design. Figure 3 (a) is a backwash strainer type. This type rinses the dirt in the strainer using the flow from the strainer outlet by opening the outlet valve. Dirt that is rinsed from the strainer is disposed of through the strainer drain line. This type has the potential for re-plugging to occur more quickly (increased pressure difference) because not all the dirt stuck to the strainer can be rinsed out so it is considered ineffective. Figure 3 (b) is an automatic-cleaning strainer type that uses a brush to rinse dirt on the strainer. The brush can rotate throughout the strainer using a motor installed on top of the strainer cover. The automatic-cleaning strainer type that uses a helical blade is depicted in Figure 3 (c). This type uses water that flows into a helical blade which rotates using a DC motor. The water flow that rotates through the helical blade can rinse the dirt on the strainer. However, both brush type and helical blade automatic-cleaning strainers have the risk of foreign material entering the cooling system, namely loose brushes and metal debris, thereby endangering the cooling system.

B. The Proposed Automatic-Cleaning Strainer Design

The Automatic-Cleaning Strainer design concept from this research includes the main design, spray nozzle design, and automation system design.

1) Main Concept Design

The main design includes the entire automatic-cleaning strainer system. The main concept of this design is that the strainer is cleaned internally (without disassembling the strainer) using a spray nozzle which rinses the dirt on the strainer using air and water. The spray nozzle can move up and down automatically so that strainer cleaning can be done effectively and efficiently.

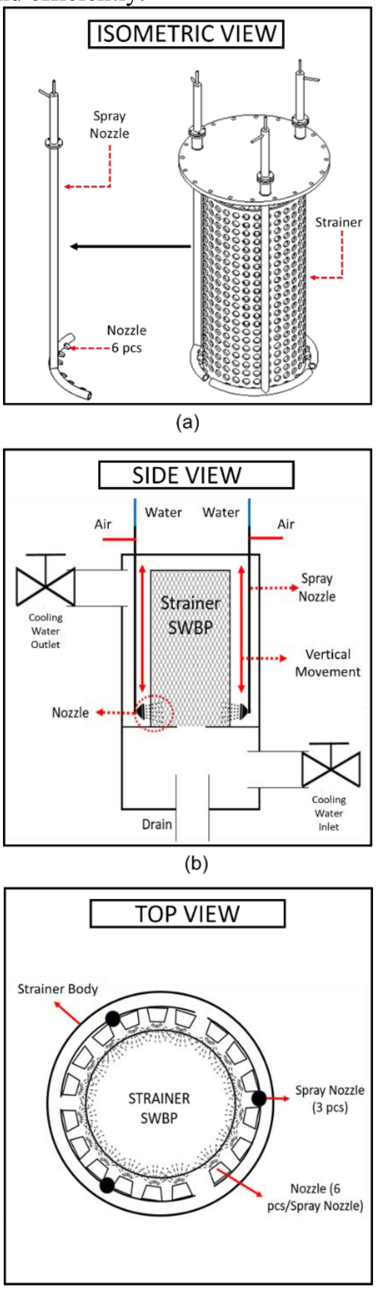

Fig. 4. Proposed Design of Automatic-Cleaning Strainer, (a) Isometric View, (b) Side View, (c) Top View

Figure 4 shows the research design concept carried out. Figures 4 (a), Figure 4 (b), and Figure 4 (c) explain the design of the automatic-cleaning strainer from isometric, side, and top views. This design uses water and air combined to produce momentum in the Spray Nozzle. This design uses 3 lever spray nozzles, each lever spray nozzle consists of 6 flat spray nozzles made from Stainless Steel 316 material due to its resistance to corrsive environment [21] [22] [23], although a new approach of High-Density Polyethylene (HDPE) used in sea water is already studied [24]. The lever spray nozzle pipe measures 1 inch with the nozzle using a 0.5-inch flat pipe.Add author names horizontally, moving to a third row if needed for more than 8 authors. The nozzle shape is made to adjust the air and water pressure used [25]. From the experimental results, maximum water output momentum was obtained so that the strainer could be cleaned optimally. Air pressure is set at 8 bar and water pressure at 3 bar. To maximize the cleanliness of the entire strainer surface from top to bottom, the spray nozzle can be moved up and down so that all strainer dirt can be rinsed completely. The rinsed strainer dirt is disposed of through the existing drain line so that the strainer can work properly.

2) Spray Nozzle Design

There are three Spray Nozzle levers that surround the outer diameter of the strainer, with each lever having six nozzles that can shoot water and air to rinse the dirt on the strainer.

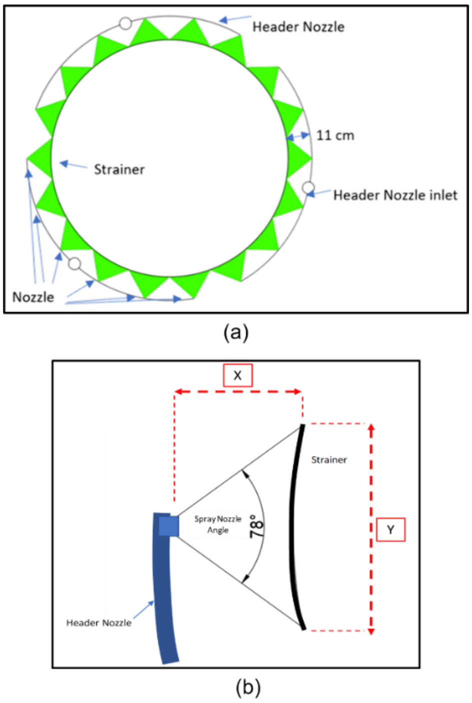

Fig. 5. (a) Spray Nozzle Arrangment Design, (b) Spray Nozzle Angle Design

Figure 5 explains the design of the spray nozzle. Figure 5 (a) shows the arrangement design of spray nozzle. Figure 5 (b) shows the angle design of spray nozzle. With a distance between the nozzle and the strainer of 11 cm, the spray angle is set optimally at 78 degrees, this ensures optimal rinsing and produces clean results. By adjusting the air pressure and water entering the column, you will get an optimal spray angle for each nozzle of 78 degrees. With this angle, the cleaning process on the strainer will be optimal, because every area of the strainer will be rinsed well. With an optimal flushing angle of 78 degrees, 18 nozzles are needed around the strainer, and to make the job of rinsing the strainer easier, all nozzles are placed on three nozzle headers, and six nozzles each are attached to each nozzle header. Because the diameter of the strainer is large (close to 100 cm), the isosceles triangle principle can be applied, or the juring calculation method.

Based on Figure 5, if the distance between the spray nozzle and the strainer to be rinsed (X) is 11 cm, and the spray angle is 78 degrees, then the area of the strainer rinsed by the nozzle (Y) is as follows:

$$Y = 2(X)tan(\frac{78}{2})$$

$$Y = 2(11)tan(39)$$

$$Y = 17{,}82 \text{ cm} \quad (1)$$

If the diameter of the strainer is 100 cm, then the number of nozzles needed (n) is as follows:

$$n = \frac{\pi D}{Y}$$

$$n = \frac{(3{,}14)(100)}{(17{,}82)}$$

$$\boldsymbol{n = 17{,}62 \approx 18}$$

Thus, the nozzles needed are 18 and are divided into three segments and each segment has 6 nozzles.

3) Automatization Design Scheme

Figure 6 explains a simple schematic of the automatic control system used in this innovation. The air supply first enters the air dryer to maintain the air quality of the pneumatic actuator. Next, the air pressure is kept constant with a pressure regulator. The Solenoid Valve is used to regulate the pneumatic actuator's air path to move up or down based on the limit switch that is touched by the limit switch lever. The inline pressure regulator is used to ensure that the air supply after the solenoid valve remains constant so that the movement up and down of the spray nozzle and pneumatic actuator remains smooth without vibration.

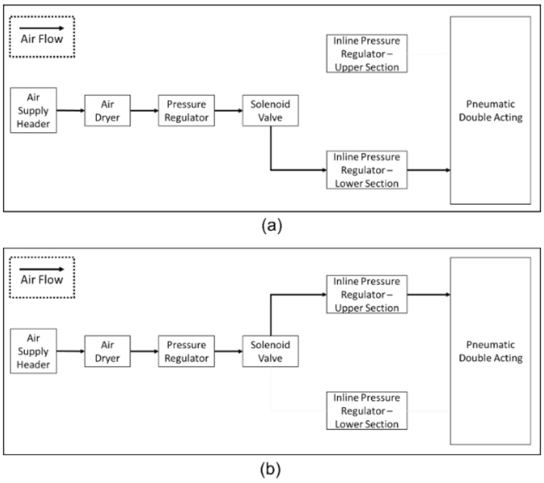

Fig. 6. Strainer Automatization Scheme, (a) Pneumatic Moves Upwards, (b) Pneumatic Moves Downwards

III. Results and Discussion

This section explains the implementation process and implementation results of automatic-cleaning strainer modification research.

A. Implementation Research Process

This research was implemented on CCPP located in Jakarta. The strainer unit used for implementation is the Sea Water Booster (SWBP) strainer as a sea water strainer in the cooling water system.

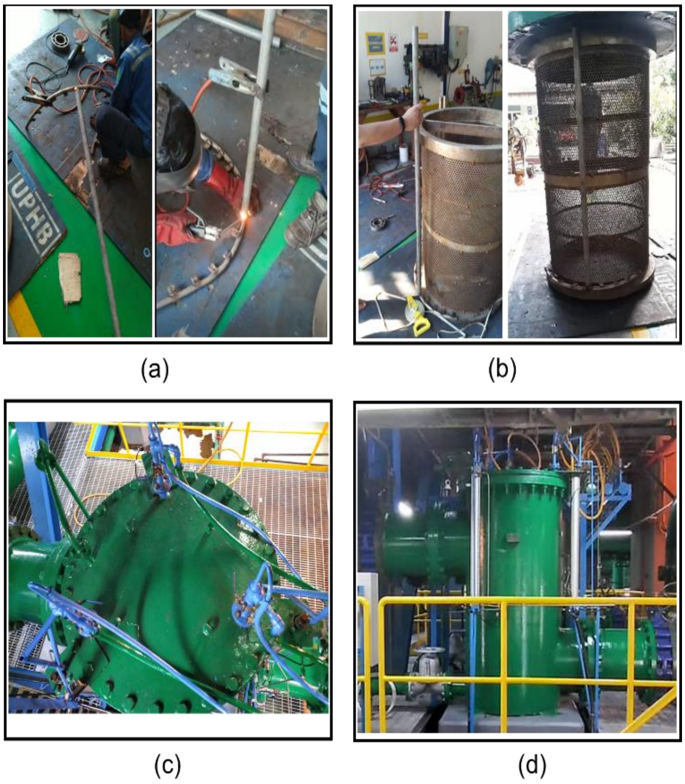

Fig. 7. (a) Spray Nozzle Fabrication, (b) Spray Nozzle to Cover Strainer Assembly, (c) Cover to Body Strainer Assembly, (d) Final Assembly of Automatic-Cleaning Strainer

The fabrication process for modifying the automatic-cleaning strainer can be seen in Figure 7. The spray nozzle was made using a welding method using 316 stainless steels. This material was chosen because it is resistant to rust (Fereidooni et.al, 2018). This needs to be taken into account because the flowing fluid is sea water which has high corrosive properties. The manufacture of the spray nozzle is shown in Figure 7 (a) and Figure 7 (b). In Figure 7 (c) and Figure 7 (d), a modified automatic-cleaning strainer has been installed in the relevant PLTGU unit. A pneumatic cylinder has also been installed for automatic up and down movement of the spray nozzle.

B. *Research Implementation Results*

The results of this research have been implemented since 2021 on CCPP located in Jakarta. From the implementation process, an evaluation of the results of the implementation of the automatic-cleaning strainer modification was obtained. The implementation results are shown in Figure 5.

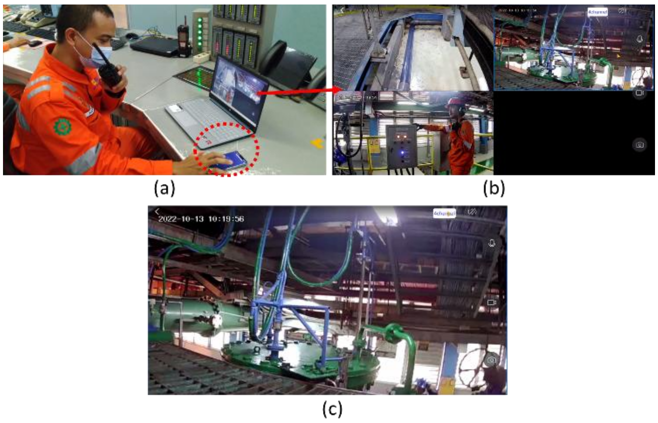

Fig. 8. (a) Operator operates Automatic-Cleaning Strainer using Smartphone in Control Room, (b) Monitoring Strainer Cleaning Process via Camera, (c) Monitoring Spray Nozzle Movement via Camera

In Figure 8 (a), the operator in the Central Control Room (CCR) operates the automatic-cleaning strainer via smartphone. The strainer cleaning process can be carried out without the need to disassemble the strainer and the operator simply monitors the movement of the spray nozzle up and down, as in Figure 8 (b) and Figure 8 (c). The operator touches the on button on the smartphone to activate the automatic-cleaning strainer without having to go to the equipment location. The cleaning process is monitored by operators at the CCR via closed-circuit television (CCTV) cameras for 5 minutes. During these 5 minutes, the automatic-cleaning strainer cleans and rinses dirt from the strainer. Once completed, the operator only needs to monitor the difference pressure (DP) parameter from the CCR, if the value is normal then the cleaning process has been completed.

C. *Evaluation of Research Implementation*

The results of the implementation evaluation are explained in Table 2. The parameters included in this evaluation are Time to Repair (TTR), Manpower Required, Tools Used, Work Accident Risk, Differential Pressure (DP), Closed Cooling Water Heat Exchanger (CCW HE) outlet temperature, and Maintenance Mix Cost and Manhour (MMCM). From this table, it can be concluded that the method resulting from this research functions much better than the existing method on CCPP in the form of manual cleaning.

TABLE 2. RESULTS OF RESEARCH IMPLEMENTATION

No	Evaluation Parameter	Manual Cleaning (Before Implementation)	Internal Cleaning System (After Implementation)
1	TTR	3 Hours	5 minutes
2	Manpower Required	5 manpower	1 manpower
3	Tools	1. Chainblock 2. Slogging Wrench 46 3. Wire Rope 4. Hammer 5. Shackle 6. Combination Spanner Set 46 7. Combination Spanner Set 19	Smartphone or panel button.
4	Work Accident Risk	1. Fall 2. Slipped 3. Pinched 4. Struck 5. Overwritten 6. Electric Shock	-
5	DP	Before cleaning: 0,672 Bar **After cleaning: 0,140 Bar**	Before cleaning: 0,666 Bar **After cleaning: 0,135 Bar**
6	CCW HE Outlet Temperature	Before cleaning: 41,52°C **After cleaning: 38,4°C**	Before cleaning: 41,3°C **After cleaning: 38,2°C**
7	MMCM	Level 4	Level 5

From Table 2, the maintenance mix cost and man hour level increases by 1 level, which means that there is cost savings in maintenance according to plan and the number of efficient working hours in accordance with the maintenance plan for man hour. Apart from that, there has been a reduction in the Time to Repair of SWBP strainer work from 3 hours to 5 minutes with automatic operation and digitization using a smartphone.

D. *Enhancements for the Corporate Key Performance Index*

The results of this research are useful for generating corporate performance by supporting the achievement of various KPIs (Key Performance Index), such as EAF (Equivalent Availability Factor), EFOR (Equivalent Forced Outage Rate), and reliability management. Year 2020 for before implementation and year 2021 for after implementation.

TABLE 3. POWER PLANT KEY PERFORMANCE INDEX ENHANCEMENT

No.	Indicator	Year 2020	Year 2021	Change
1	EAF	95.60 %	96.71 %	1.11 %
2	EFOR	1.03 %	0.05 %	0.98 %

3	Reliability Management	2.20	2.30	0.10

Implementation of research carried out on CCPP located in North Jakarta since 2021 August has resulted in changes in several KPIs. Based on where EFOR and EAF come from, from corporate operational performance reports. As shown in Table 3, there has been an increase in EAF of 1.11%, which means that the generator has succeeded in providing electricity according to loading demand, a decrease in EFOR of 0.98%, which means that the generator has fewer disturbances that cause derating or forced outage, and an increase in reliability management of 0.10 so that it can It is said that the reliability of generating companies has increased.

IV. Conclusion

The author's automatic-cleaning strainer model has greatly improved the reliability and efficiency of cooling water systems in seawater-cooled power plants. By automating the cleaning process, it reduces the Time to Repair (TTR) from 3 hours to just 5 minutes, minimizing disruptions and keeping the system free of debris that could damage sensitive parts. The lack of manual cleaning also reduces the risk of system damage and ensures consistent performance. This model not only improves reliability but also boosts plant performance, increasing the Equivalent Availability Factor (EAF) by 1.11%, leading to more efficient power generation and less downtime. Maintenance costs and efforts have also been optimized, with the plant moving from Level 4 to Level 5 in Maintenance Mix Cost and Manhour classification. The Reliability Management index improved by 0.1, and the Equivalent Forced Outage Rate (EFOR) dropped by 0.98%, reducing unexpected shutdowns. Furthermore, the integration of automatic cleaning operations via smartphone interfaces aligns with the broader trend of digital transformation in the power generation industry. It enables remote monitoring and control, simplifying maintenance tasks and improving overall operational efficiency. This digitization not only modernizes maintenance processes but also sets a benchmark for future advancements in automated power plant management, offering a scalable solution for other facilities looking to enhance their reliability and efficiency through technological innovation.

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