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Jetty Extension Study Due to Addition of Power Capacity on Thermal Water Dispersion at PLTGU Grati Pasuruan

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Abstract

PLTGU (Gas and Steam Power Plant) is a combination of gas power plant and steam power plant. PLTGU requires a cooling water system during its operational life. The amount of cooling water required will increase along with the increase in power capacity of the power plant. This project aims to study the jetty extension due to the addition of power capacity on thermal water dispersion at PLTGU Grati, Pasuruan. The method used is hydrodynamic modeling using Delft3D. The results show that the alternative model can reduce the cooling water temperature by an average of 0.7975 ^{o}C at the inlet canal. However, this decrease does not have a significant effect on the thermal power plant efficiency, because it only takes a 2.5 ^{o}C increase in seawater temperature to reduce efficiency by 0.33%. This study also found that the alternative model is at risk of increasing sedimentation rate. Therefore, it is suggested to use the existing jetty design or conduct further research to find a more optimal solution.

Keywords: Delft3D; Hydrodynamic Model; Thermal Power Plant; Thermal Water Dispersion

1. Introduction

One of the most urgent and large quantities needed of today is electrical energy. Recorded the population of Indonesia amounted to 264.2 million in the year 2018 and increased to 278.7 million in 2023 [10] BPS, so the need for electricity in Indonesia becomes a serious problem if not planned well in the future. Slowly but surely, all subsidiaries of PT. PLN (Persero) also contributed in the addition of power plant power is no exception PT. Indonesia Power Business Unit of PLTGU Grati Power Plant [11].

The study on impact of thermal cooling water dispersion to the environment [5-7] and coastal region [1-4] still has been of interest until now. It is a great method using hydrodynamic model for spatial prediction analysis even with scenario. Delft3D is software capable of modeling coastal processes numerically and digitally displayed. A numerical models on hydrodynamic can be build as 1-dimensional, 2-dimensional, or 3-dimensional model that presented as grid on Delft3D. The study was conducted to determine the best form of jetty extension in retaining the thermal water dispersion and preventing it from entering the water inlet channel again. In this case aided using Delft3D program.

2. Materials and Methods

2.1 Research Sites

The position of PLTGU Grati is at latitude -7.6517^{o} so that it goes into the southern part of the earth (BBS). The beach in Grati PLTGU is classified into the north coast, where the sea position is between Java Island and Madura Island. There is a

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water-inlet channel and a water outlet channel where the water channel canal length is 1000 m and two jets are installed along 500 m with jetty spacing of 100 m to block sediment and hot water from entering the water inlet channel (figure 1).

Fig. 1. Research sites at PLTGU Grati [6]

2.2 Environtmental Conditions

The following bathymetric data (figure 2) is measured in November 2014, where the area under review is ± 4397m × 2557m. Depth refers to low water spring (LWS). Depth in inlet in average is -0.5 m to -1.5 m. It has been processed and found that the type of tidal in the Grati PLTGU is a mixed double-skew type (occurring two times and twice receded within 24 hours). The tidal analysis uses the least squares method with the value of Formzhal = 1.0725.

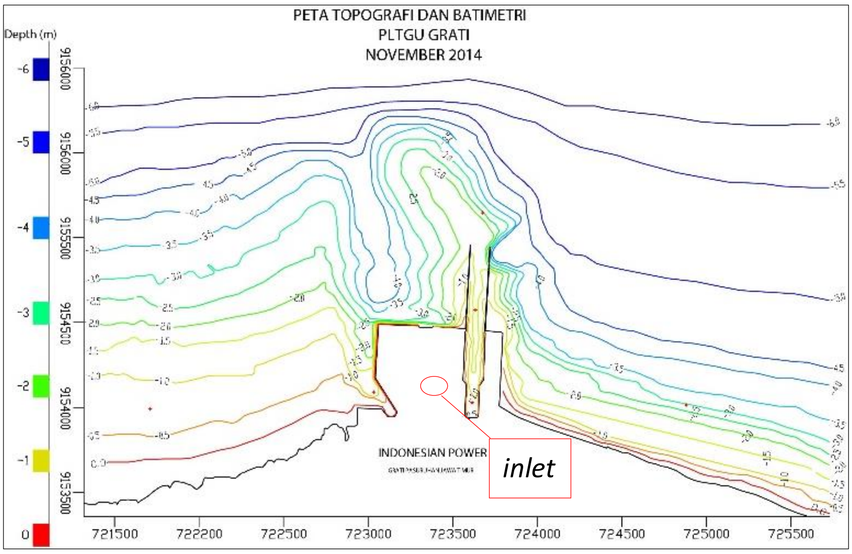

Fig. 2. Bathimetry map of thermal power plant area

Wave data of 10 years (2004-2014) were analyzed that the direction of the incident wave is from eastward. The sea in the Grati PLTGU area is a closed area where in the north there is Madura Island and in the south there is Java Island. This indicates that the direction from the east is reasonable (figure 3).

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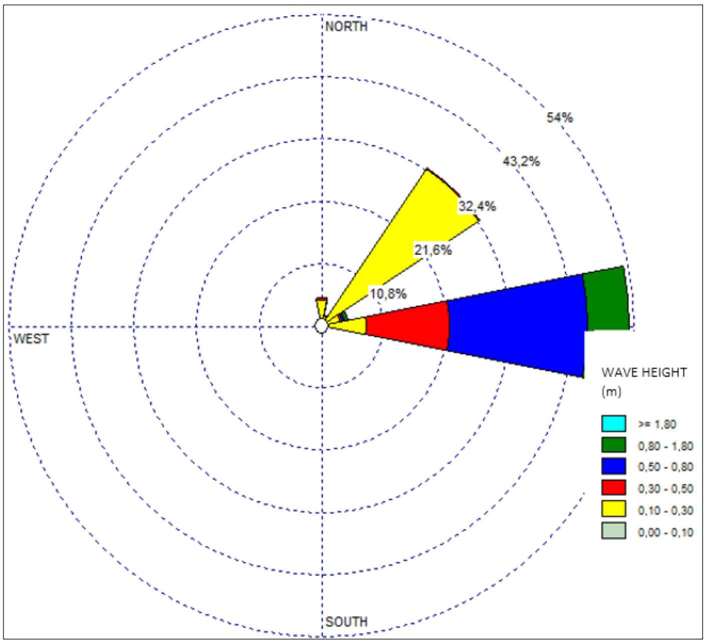

Fi. 3. Wave rose at PLTGU Grati area

2.3 Model Description

The pattern of currents in a body of water is very important to understand because it greatly influences the dispersion of thermal cooling water. Therefore, it is necessary to have a good understanding of the dynamics of this current movement. Simulation of water flow and its elevation variations can actually be simulated with several equations.

General equations that can be used to simulate water flow and elevation variations for estuaries, bays and coastal areas include continuity and momentum equations in hydrodynamic modeling. These equations are hydrodynamic equations as 2D unsteady flow in one layer which is assumed to be vertically equal. The basic principles of the conservation of mass and momentum equations which include the continuity, momentum and dispersion-advection equations which are vertically integrated so that they can explain fluid flow in varying depths [8]

Continuity equation :

$$\frac{\partial \zeta}{\partial t} + \frac{\partial p}{\partial x} + \frac{\partial q}{\partial y} = 0 \quad (1)$$

Momentum equation at X-axis :

$$\frac{\partial p}{\partial t} + \frac{\partial}{\partial t}\left(\frac{p^2}{h}\right) + \frac{\partial}{\partial y}\left(\frac{pq}{h}\right) + gh\frac{\partial \zeta}{\partial x} + \frac{gp\sqrt{p^2+q^2}}{C^2.h^2} - \frac{1}{\rho_w}\left[\frac{\partial}{\partial x}(h\tau_{xx}) + \frac{\partial}{\partial y}(h\tau_{xy})\right] - \Omega p - fVV_x + \frac{h}{\rho_w}\frac{\partial}{\partial_x}(p_a) = 0 \quad (2)$$

Persamaan Momentum Sumbu-Y :

$$\frac{\partial q}{\partial t} + \frac{\partial}{\partial y}\left(\frac{q^2}{h}\right) + \frac{\partial}{\partial x}\left(\frac{pq}{h}\right) + gh\frac{\partial \zeta}{\partial y} + \frac{gq\sqrt{p^2+q^2}}{C^2.h^2} - \frac{1}{\rho_w}\left[\frac{\partial}{\partial y}(h\tau_{yy}) + \frac{\partial}{\partial x}(h\tau_{xy})\right] - \Omega p - fVV_y + \frac{h}{\rho_w}\frac{\partial}{\partial_y}(p_a) = 0 \quad (3)$$

Where x,y are coordinate in cartesian system (m), t is time (s), ξ (x,y,t) are water level (m), p,q (x,y,t) are density flux at x, y axis, and τ_{xx},τ_{xy},τ_{yy} are sheer stress due to turbulent and viscosity. As for temperature distribution analysis, heat dispersion modeling with advection/dispersion equation is utilized. This equation delivered by Ramming and Kowalik [13] as:

$$\frac{\partial T}{\partial t} + \frac{\partial uT}{\partial x} + \frac{\partial vT}{\partial y} + \frac{\partial wT}{\partial z} = F_T + \frac{\partial}{\partial z}\left(D_v\frac{\partial T}{\partial z}\right) + \hat{H} + T_S S \quad (4)$$

Where D_v is vertical Eddy viscosity coefficient Ĥ is heat change during atmospheric heat transfer, T_S is temperature value in the exiled water (if any), F_T is horizontal diffusion.

2.4 Input Parameters

The data in table 1 below becomes the boundary input on the model.

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Table 1. Input data parameters flow and wave model

Item		Value
Time Frame		30 hari, 01 01 2014 - 30 01 2014
Gravity		9,81 m/s^2
Density of Sea Water		1025 kg/m^3
Bed Roughness Chezy Coef.		Uniform = 7,5
Salinity		31 ppt
Sea Water Temperature		average 29.18 deg. celcius
Heat flux - night 00.00	Relative Humidity	average 60%
	Air Temperature	average 24.31 deg. celcius
	Cloud Coverage	minimum 9%
	Radiation	0 J/m^2
Heat flux - noon 12.00	Relative Humidity	average 60%
	Air Temperature	average 29.86 deg. celcius
	Cloud Coverage	minimum 9%
	Radiation	1.32 J/m^2
Discharge before addition of power	Discharge	14.15 m^3/s
	Salinity	3 ppt
	Water Temperature	average 36.75 deg. celsius
Discharge after addition of power	Discharge	38.92 m^3/s
	Salinity	3 ppt
	Water Temperature	average 36.75 deg. celsius
Wave	Significant Height	1.72 m
	Significant Periode	6.86 s
	Directional	nautical 90^o
	Spread	4 direction
	Spectral	Jonswap

2.5 Validation

Validation is performed to unravel the magnitude of the deviation between field observation data and data that been obtained from simulation model. Then data validity is teremined for the next simulation.

3. Result and Discussion

3.1 Tidal Validation

At the same time step, obtained the validation results between measurement data and data model results with error of 8.97%. The comparison graph is shown in figure 4.

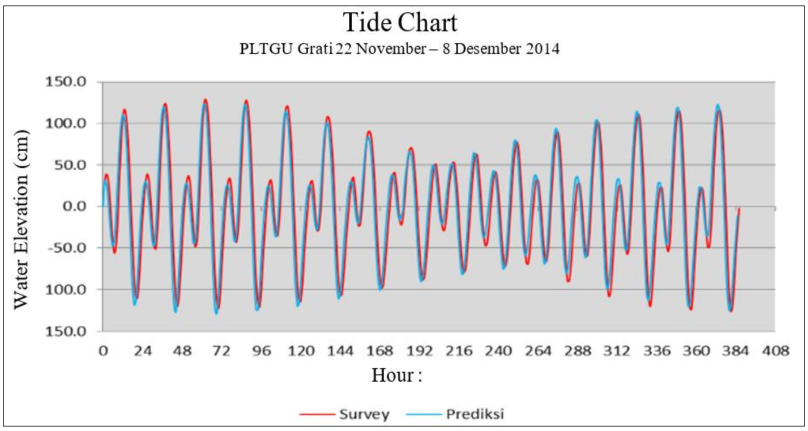

Fig. 4. Tidal Validation Result

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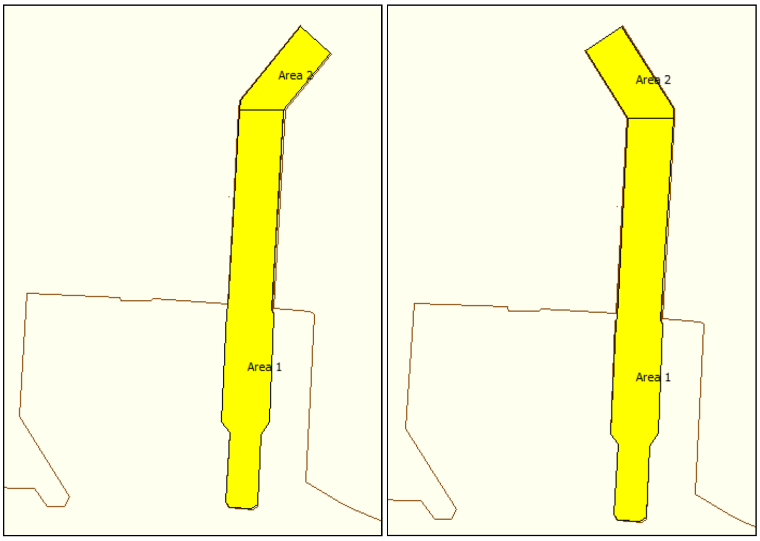
3.2 Alternative Model 1 and Alternative Model 2

In figure 5 (a) an Alternative jetty model 1 is designed with a right-handed 51° to X-axis with a right jetty length of 200 m and a left-handed jetty of 272 m. In figure 5 (b) the Alternative jetty model 2 is designed with a left-handed 58° to the X-axis with a right jetty length of 200 m and a left-handed jetty of 272 m.



(a) (b)

Fig. 5. Alternative (a) and existing (b) design

3.3 Numerical Modeling Result

The current distribution is the result of modeling of a combined tidal current with a wave-generating current. The increased discharge causes the spread of the discharge flow to expand. This has an impact on the widespread of hot water (figure 6-7). Temperature comparison before and after addition of power are presented in table 2. It is found that the temperature under existing conditions after power addition is greater than 0.149°C for the lowest and greater 0.181°C for the highest than the existing temperature before the addition of power.

Table 2. Comparison of Existing Condition Temperature Before and After Power Addition

Condition	Temperature - Deep Inlet	
	Lowest (°C)	Highest (°C)
Measurement Data	27.869	28.534
Before Addition of Power	28.369	28.580
After Addition of Power	28.518	28.761

Characteristic of the current distribution at high tide is the direction of the dominant current toward the coastline. While at low tide, the dominant currents will leave the coast. Since the dominant current direction leaves the shore, it may allow hot water to reach at the mouth of the inlet canal.

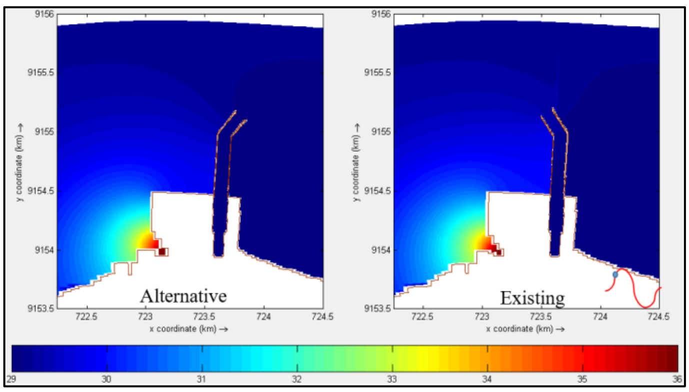


Fig. 6. Water temperature when maximum tidal during addition power

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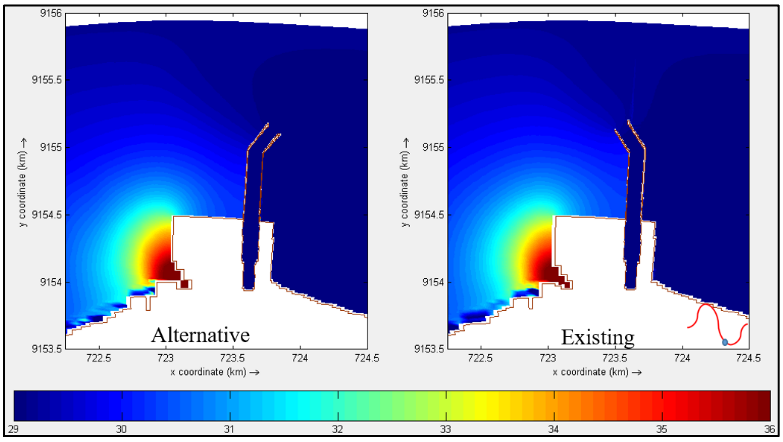

Fig. 7. Water temperature when minimum tidal during addition power

In the scenario of power addition, figure 5 - 6 shows the condition of the water temperature when high and low tide. At low tide is a critical condition because of the dominant current toward the open sea. Alternative design is quite effective in suppressing thermal water compared to existing both at high and low tide. Table 3 shows the comparison of temperature rate between alternative model and existing model. According to table 3, the alternative model showing good performance decrease temperature of thermal cooling water on average 0.7975 °C, but the design of alternative model that openly faced to north east might increase the risk of sedimentation inside of inlet canal considering the dominant wave coming is from east. The impact of increasing seawater temperature of 2.5 °C to power plant system efficiency, only decrease 0.33% [12]. Still the best choice is on existing jetty design. It might be good option if we add sediment transport factor on the next research.

Table 3. Comparison water temperature in existing and alternative model

Condition	Temperature - Deep Inlet	
	Lowest (°C)	Highest (°C)
Existing after addition of power	28.518	28.761
Alternative after addition of power	27.578	28.106
Deviation	0.940	0.655

5. Conclusions

This study has investigated the effect of jetty extension on thermal water dispersion at PLTGU Grati, Pasuruan using Delft3D hydrodynamic modeling. The results show that the alternative model that extends the jetty parallel to the flow direction can reduce the cooling water temperature by an average of 0.7975 °C at the inlet canal. However, this decrease does not have a significant effect on the thermal power plant efficiency, because it only takes a 2.5 °C increase in seawater temperature to reduce efficiency by 0.33% [12]. In addition, the alternative model also poses a risk of increasing sedimentation rate in the inlet canal and its surroundings. Therefore, this study recommends using the existing jetty design that is more optimal in terms of thermal water dispersion and sedimentation control. Further research can be done to optimize the jetty design by considering other factors such as cost, safety, and environment.

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