Cooling water dispersion delivered from Jeneponto Steam Power Plant

by

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Abstract. Generally, a steam power plant is built near the shore in order to obtain water in large volume as a main material in cooling process. It is the case to Jeneponto power plant, where the cooling water is redistributed from its source with different temperature condition. This temperature will disperse in coastal water out of power plant which is driven by tidal current. The aims of this study is to model a hydrodynamic pattern around steam power plant and temperature distribution pattern of cooling water in spring and neap tidal phases. The method used in this study is a 2D-mathematical model of hydrodynamics and heat transport. The result showed the tidal current tends northward during high tide and southward to during low tide. The temperature tends to disperse northward during the high tide and southward during low tide. The southward disperse is more dominant than northward disperse.
Keywords: temperature dispersion, tidal currents direction, and steam power plant

1. Introduction

In an energy sector, especially the electricity subsector is one of the main drivers of economic development in all countries including Indonesia. The need for electrical energy in Indonesia has continued to increase in the last few decades, to meet the electricity needs, a number of power plants were built. The types of generators built generally are thermal power plants / steam power [1]. In the South Sulawesi region there is a Jeneponto steam power plant (PLTU) with a capacity of 2x125 MW which is built on an area of approximately 100 hectares to meet the electricity needs of the people of South Sulawesi [2].

The operation of a power plant installation generally uses sea water as a cooler. The sea water that has been used as a cooler will be discharged back to the sea at different temperatures, but to reduce the temperature before being discharged back into the sea, the cooling water is first flowed through a cooling channel. Cooling water that re-enters the sea still have temperatures above the ambient temperature of sea water [3]. If cooling water discharged into the sea does not match the normal temperature of the sea, then the life of the marine biota around the disposal of cooling water will be disrupted [4]. Some results of the study suggest that only fish, crustaceans and mollusc can withstand high temperatures. The maximum temperature that can be tolerated by fish is 38.1^{0}C, crustaceans 37.9 ^{0}C and molluscs 36.7^{0}C [3]. Heat distribution are a diffusion process, where the distribution occurs to the difference in gradient temperature, so the temperature moves from high temperature to low temperature [5].

To find out the distribution of cooling water from waste products, a mathematical model of hydrodynamic model and heat transport simulation is used [6]. Water temperature greatly determines the quality of water because the temperature changes affect the physical, chemical and biological processes of water bodies [7]. In a study conducted by Hasriyani (2014), a prediction simulation of heat distribution plan for PLTU phase II units 3 and 4 with an increase in temperature of 2.4^0C-3.8^0C to the waters of Punagaya from ambient temperature 32^0C [8]. Therefore, this research was carried out in order to model the distribution of cooling water from the drainage channel of the PLTU Jeneponto to the surrounding waters when the PLTU was operating, by creating a distribution scenario based on the temperature of the cooling water coming out of the disposal outlet.

2. Steam Power Plant

The steam power plant (PLTU) is a power plant that uses steam power as the main driver of the turbine, to produce electricity. The PLTU has a by-product in the form of hot water where the temperature is higher than the temperature of the water before being used for cooling. The amount of cooling water needs depends on the maximum capacity of the PLTU units, in general the use of cooling water at full load for each megawatt is 45-55 m^3/second. Cooling water with a relatively high temperature, with a large volume, and continuously discharged into the water will affect the rise in water temperature from the initial conditions (ambient temperature) [4]. Based on Regulation of the Minister of Environment number 8 of 2009 concerning waste water quality standards for businesses and / or activities of thermal power plants, the maximum temperature of the cooling source (heat water) is 40^0C and salinity at a radius of 30 m from the disposal location of waste water to the sea , the salinity level of wastewater must be the same as the natural salinity [9].

3. Impact of Hot Water Waste on Marine Biota

Temperature changes unnaturally indirectly affect biota, where the carrying capacity of the habitat is lost. For example in coral reef habitats, with changes in temperature, the solubility of oxygen and calcium carbonate (calcite or aragonite) in water will change. Furthermore, it will affect the solubility of metal (metal) contamination and other toxic materials which are assimilated by the physiological process of biota. Hot water waste from a power plant installation is usually discharged directly into the sea, increasing the water temperature and causing thermal pollution. A temperature increase of 10 degrees can accelerate the metabolic activity of aquatic biota to twice the usual. Because each type of aquatic biota has a different metabolic speed, the aquatic biota can only live at a different range of temperatures for each group of biota [10].

4. Continuity and Momentum (2DH)

Integration of continuity and momentum equations to look for 2DH equations, used assumptions and simplifications as follows [11]:

1. The average depth value is considered representative enough to represent values of magnitudes that change along the flow depth
2. The speed and acceleration of the vertical direction are considered very small, so they are ignored
3. The hydrostatic pressure distribution applies throughout the depth
4. Base slope of both small horizontal directions

With this simplification, the continuity and momentum equations for the 2DH model are as follows [12]:

Continuity equation

$$\frac{\partial h}{\partial t} + \frac{\partial uh}{\partial x} + \frac{\partial vh}{\partial y} = 0 \quad (1)$$

Equation Momentum

On the x axis:

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$$\frac{\partial hu}{\partial t}+\frac{\partial hu^2}{\partial x}+\frac{\partial huv}{\partial y}=-gh\frac{\partial \eta}{\partial x}-\frac{h}{\rho_0}\frac{\partial p_a}{\partial x}-\frac{gh^2}{2\rho_0}\frac{\partial \rho}{\partial x}+\frac{\tau_{sx}}{\rho_0}-\frac{\tau_{bx}}{\rho_0}-\frac{\partial}{\partial x}[hT_{xx}]+\frac{\partial}{\partial y}[hT_{xy}] \quad (2)$$

On the y axis:

$$\frac{\partial hv}{\partial t}+\frac{\partial huv}{\partial x}+\frac{\partial hv^2}{\partial y}=-gh\frac{\partial \eta}{\partial y}-\frac{h}{\rho_0}\frac{\partial p_a}{\partial y}-\frac{gh^2}{2\rho_0}\frac{\partial \rho}{\partial y}+\frac{\tau_{sy}}{\rho_0}-\frac{\tau_{by}}{\rho_0}-\frac{\partial}{\partial x}[hT_{xy}]+\frac{\partial}{\partial y}[hT_{yy}] \quad (3)$$

Where :

H (x,y,t) : The depth of water varies with time (m)

η (x,y,t) : Elevations of Sea level (m)

u (x,y,t) : Average speed of depth on the x axis (m/s)

v (x,y,t) : Average speed of depth on the y axis (m/s)

g : Gravitational acceleration (m^2/s)

ρ : Sea water density (kg/m^3)

ρ_0 : Reference water density (kg/m^3)

p_a : Surface pressure

τ_{sx} : Direction surface tension of x axis

τ_{sy} : Direction surface tension of y axis

τ_{bx} : Basic voltage of the x axis

τ_{by} : Basic voltage of the y axis

T_{xx} : Shear stress of x axis direction

T_{xy} : Normal voltage y direction towards x axis

T_{yy} : Shear stress of y axis direction

5. Transport Equations

The distribution of water quality which is a substance in the form of solution and particles can be known by the transport module approach. Some dynamic model approaches used to describe water quality refer to the development of a 2-D model based on momentum equations and continuity equations by considering the depth where h = η + d is [12]:

$$\frac{\partial h}{\partial t}+\frac{\partial \overline{hu}}{\partial x}+\frac{\partial \overline{hv}}{\partial y}=hS \quad (4)$$

Where:

h : Total depth water (m)

η (x,y,t) : Sea level elevation (m)

d : Depth Water (m)

S : Magnitude of discharge in this case channel discharge (m^3/s)

u(x,y,t) : Average speed of depth on the x axis (m/s)

v(x,y,t) : Average speed of depth on the y axis (m/s)

Transport of a component in the waters depends on the current, where in the waters, the dominant currents are generated by tides. For the temperature distribution the equation used in modelling is the following 2D heat transport equation:

$$\frac{\partial h\bar{T}}{\partial t}+\frac{\partial h\bar{u}\bar{T}}{\partial x}+\frac{\partial h\bar{v}\bar{T}}{\partial y}=hF_T+hT_sS \quad (5)$$

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Where :

h : Total water depth (m)

$\bar{T}$: Average temperature to depth (^{0}C)

T_S : Temperature at source /*source* (^{0}C)

S : Magnitude of discharge in this case channel discharge (m^3/s)

u (x,y,t) : Average speed of depth on the x axis (m/s)

v (x,y,t) : Average speed of depth on the y axis (m/s)

F_T : Horizontal diffusion temperature

For the decay process in the heat transport module the following equation is used:

$$F = 0.2388/(\rho.Cp.h).[(4.6\ 0.09(Tref + Tr) + 4.06w)\ \exp\ (0.033\ (Tref + Tr))] \quad (6)$$

Where :

Tref : Temperature references (^{0}C)

Tr : Temperature increase (^{0}C)

ρ. : Water density (kg/m^3)

Cp : Specific heat (cal/kg ^{0}C)

W : Wind velocity (m/s)

6. Method

Research area is administratively located on coordinates of 5°37'16,095" SL and 119 ° 32'41,827" EL. Location of research in particular is disposal region of wastewater/cooling water of PLTU of Jeneponto, Punagaya village,Bangkala sub-district, Regency of Jeneponto which get influences from tidal waves of the sea. The method used in this study is 2D hydrodynamic models and heat transport.

7. Conclusion

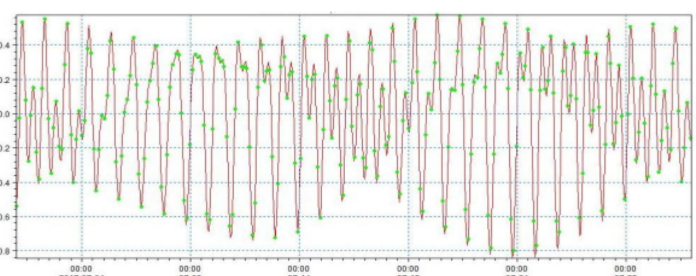

Figure 1 Tidal Domain Research

Tidal

From the results of this research, it is obtained that type of mixed tide mainly diurnal in which within a single day one pair of high tide and low tide occur for once each with different height of elevation. but sometimes, two pairs of high tide and low tide occur within one day with a massive differences on elevation within certain time . Numbers of highest high tide in 0.573 m and numbers of lowest low tide is -0.844 m.

Table I. Determination of high and low tides

Charcteristic	Formula	Level (cm)	Tidal Range (cm)

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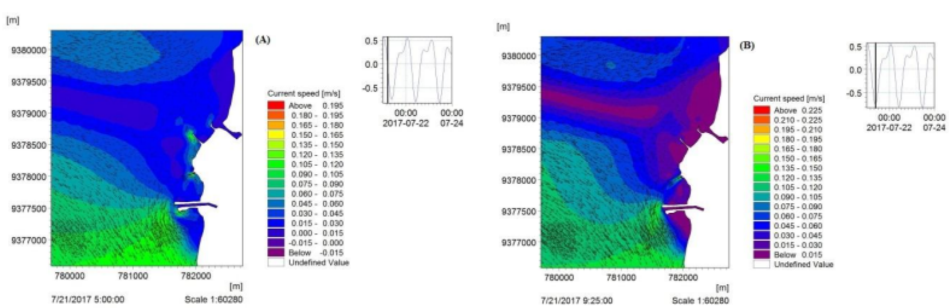
HAT	LAT + 2(K1+O1+S2+M2)	172.251	72.825	
MHHWS	LAT + 2*(S2+M2) + (K1+O1)	128.603	29.177	
MHHWN	LAT + O1 + K1+ 2*M2	122.869	23.443	
MSL		99.42	0	Neap tide = 46.8 Spring tide =58.34
MLLWN	LAT + K1 + O1+ 2*S2	75.982	-23.443	
MLLWS	LAT + K1 + O1	70.248	-29.177	
LAT	MSL-K1-O1-S2-M2	26.600	-72.825	

Where :
HAT : *Highest Astronomical Tide*
LAT : *Lowest Astronomical Tide*
MHHWS : *Mean Higher High Water Spring*
MLLWS : *Mean Lower Low Water Spring*
MHHWN : *Mean Higher High Water Neaps*
MLLWN : *Mean Lower Low Water Neaps*
MSL : *Mean Sea Level*
From the table above to show that value ride install it amounting to 145.65 cm.

Ocean current
Current velocity in the surrounding area of Jeneponto PLTU could be seen on the following models:



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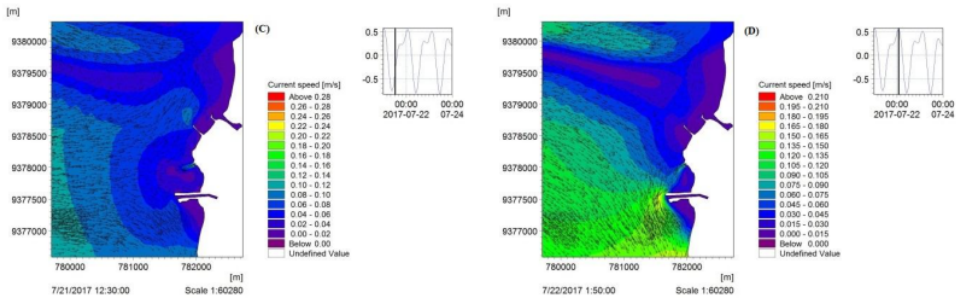

Figure 2 Velocity of Ocean Current

Figure **A** portray current velocity of phase heading to low tide condition, figure **B** portray current's velocity of lowest low tide phase, figure **C** portray current's velocity of phase heading to high tide condition and figure **D** portray current's velocity of high tide phase. On condition heading to low tide, velocity of the current's is 0.03-0.12 m/s with the current moves southward, on the lowest low tide velocity of the current is 0.01-0.03 m/s with current begin turning around and moving northward . On condition heading to the high tide velocity of the current is 0.02-0.1 m/s with current moves northward, on high conditions of high velocity of the current is 0.01-0.04 m/s with current already move southward.

Heat Dispersion

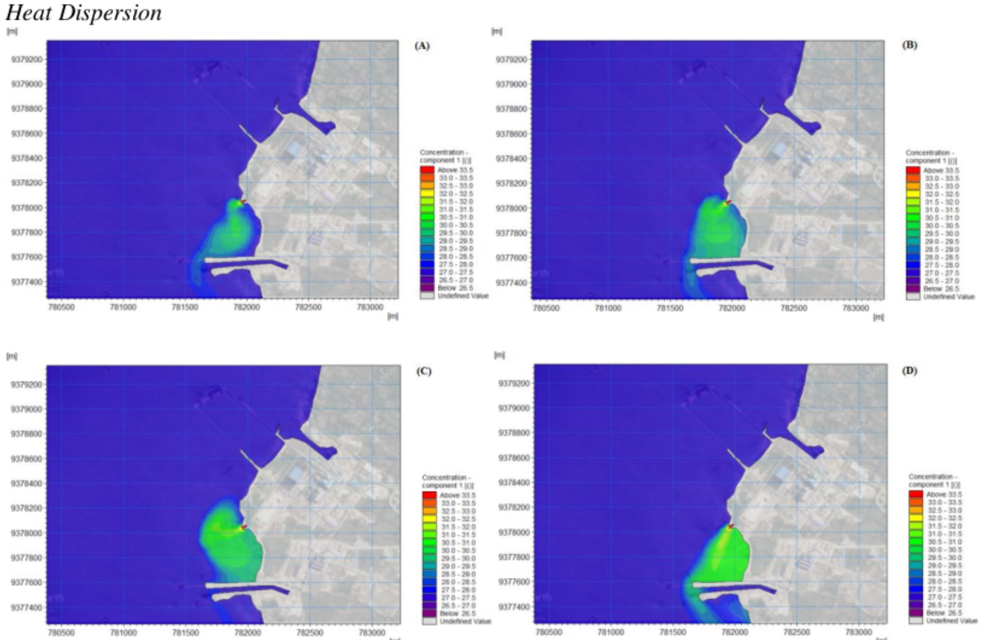

Figure 3 Heat Dispersion

Figure **A** portray heat dispersion of phase heading to low tide condition, figure **B** portray heat dispersion of lowest low tide phase, figure **C** portray heat dispersion of phase heading to high tide condition and figure **D** portray heat dispersion of high tide phase. From heat distributions simulations, It can be seen that farthest distance of heat dispersion not exceeding numbers of 500 m already changes due to ambient temperature / temperature of environment , escalation of highest temperature dominantly happen Southern part owing to the current that moves affect the process of heat dispersion on waters. From those models statistic test was then conducted by utilizing linear regression method by comparing the data of field and model measurement. Result of statistic test shows value of model's accuracy at 1.54891, this value increasingly approach number of 0 (zero) means that it is increasingly accurate. With that much of value then it can be stated that accurate constructed model is at 98.45109% with significances value is at 0.027.

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