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Application of Dragonfly Algorithm for Economic Scheduling Optimization and Power Plant Emissions

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Abstract *A reliable electrical grid the power plant scheduling system needs to optimize the plant's performance by considering the economic value and the value of emissions generated by the plant, in addition to the reliability and economic sectors. This system should also take into account the environmental impact, as well as the CO_2 and CH_4 emissions produced by the plant. This research will use the Dragonfly Algorithm with weighting parameters to schedule hydro and thermal facilities' emissions and economic activities. That the weighting value impacts production costs and emissions is demonstrated by the data acquired from the Dragonfly Algorithm simulation. If economic considerations take precedence in assigning weights, then low-cost generating will result in high-value emissions, and vice versa. The plant's Emission Intensity rating also meets the standards established by the government.*

Keywords - *Hydro Thermal Plant, Dragonfly Algorithm, CO_2, CH_4, and Emission Intensity*.

I. INTRODUCTION

Hydro Thermal Power Generation Systems such as Steam Power Plants (PLTU) and Hydroelectric Power Plants (PLTA) experience several problems including large operating costs and emissions produced by the plant. [1]. Therefore, optimization is needed to reduce operating costs and emissions caused by the plant.

The high operating costs of thermal plants such as Steam Electricity (PLTU) are caused by large costs and in power systems connected in an interconnection, generating units are also not in the same distance from the load center[17] . In addition, the generation cost of each unit will also be different. As a result, the generation process incurs a high production cost. Furthermore, environmental impact must be considered in an ideal power system.[2]. Thermal power plants are significant contributors to atmospheric pollution, emitting carbon dioxide (CO2), sulfur dioxide (SO2), and nitrogen oxides (NOx). [16]. In addition, hydroelectric power plants are also a source of greenhouse gas emissions, namely methane (CH_4). Aquatic sediments, especially lake, dam, or reservoir areas, are estimated to contain methane (CH_4) gas produced from the decomposition of microorganisms [3] and Methane Gas (CH_4) are more dangerous because they have a 21 times greater warming effect. [4].

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The solution to the problem that occurs is the optimization of Hydro and Thermal plants is one way that is quite economical to meet the electrical energy needs of customers [18] . Hydrothermal scheduling is also used to minimize gas emissions that result in environmental damage with requirements other than minimization of fuel costs by forming a combined hydrothermal scheduling [6]. In this study the authors will apply the Dragonfly Algorithm as hydrothermal scheduling with the aim of maximizing hydrothermal generation so as to solve economic and emission dispatch problems. In addition, there has not been much discussion about the Dragonfly Algorithm for optimizing operating costs and plant emissions. The dragonfly algorithm is theoretically an algorithm that mimics the behavior of dragonflies starting from the Exploration and Exploitation phases. The main purpose of the Exploration phase is that dragonflies create sub swarms and fly over different areas in dynamic swarms. exploitation phase. Dragonfly Algorithm has five factors: separation factor, merging factor, adjustment factor, food source factor, and predator factor [5].

II. RESEARCH METHODS

The research method that will be used in this research is quantitative research method. This research method is used to collect data obtained from a measurement at the plant and the author makes a program to calculate the production costs and emissions generated by the plant. The author uses Matlab Software and Dragonfly Algorithm as a decision maker in performing calculations to get the amount of production costs and emissions generated by the plant.

i. Power Plant Optimization

Generation load sharing in a power system operation is an important thing that requires coordination in scheduling the large load of electric power generated from the power plant center, so as to obtain a minimum generation cost [7]. Optimization can be done in several ways as follows.

1. Economical Scheduling (Economic Dispatch)

Economic scheduling is an attempt to determine the amount of power that must be supplied from each generator unit to meet a certain load by dividing the load on the generating units in the system in an economically optimal manner with the aim of minimizing generation operating costs [8].

2. Hydrothermal Short-term Scheduling

Hydrothermal scheduling aims to meet system demand as well as load forecasts for a period of several hours to a week by spreading its production between hydro and thermal plants. [9].

ii. Combined Economic and Emission Dispatch

is an optimization with the aim of mitigating the emission levels of all generating units and the costs incurred by the operating unit can be formulated using equation 1 [13]

Min $Objective = w1 \times F1\ (P_{si.m}) + w2 \times P_{Rm} \times F2\ (P_{si.m})$ (1)

In this study, plant emissions will be calculated based on data using equations 2 and 3.

- Generated electrical energy = capacity × operating time
- Fuel energy $= \frac{Electrical\ energy\ generated}{Thermal\ Efficiency}$
- Fuel Consumption $= \frac{\text{Fuel Energy}}{Net\ Caloric\ Value}$
- CO_2 Emissions $= \text{Fuel Consumption} \times \%\text{C of fuel} \times \frac{44}{12}$ (2)

Or you can use equation 3.

- CO_2 Emissions $= \frac{\text{power} \times \text{operation time} \times \text{CO2 Emissions factor}}{Plant\ Efficiency}$ (3)

In addition to the calculation of the amount of emissions in this study, it calculates the PLTU CO_2 Emission Intensity limit set by the Indonesian government. The PLTU emission limit refers to the amount of emissions produced by per unit of electrical energy produced which is expressed in units of grams of CO_2 per kilowatt-hour. Emission intensity is used as an indicator of the efficiency and environmental impact of the plant. In Indonesia, the PLTU emission intensity limit is regulated by Permen LHK No.15 Tahun 2019 [10]. In addition, the government has set a target to reduce greenhouse gas emissions through the Nationally Determined Contribution (NDC) in the Paris Agreement. Emission intensity of coal-fired power plants in Indonesia ranges from 800-1050 gCO_2/kWh. Calculation of emission intensity using equation 4.

$$\text{Emission Intensity} = \frac{Total\ CO2\ Emissions\ (kg)}{Energy\ produced\ (kWh)} \quad (4)$$

iii. Dragonfly Algoritmh

The Dragonfly algorithm functions as a decision maker starting with static as the starting point and an energetic crowd of dragonfly behaviors. [9]. Moreover, the swarming behavior is similar in both major stages of optimization via the heuristic meta-algorithm, namely investigation and utilization. This behavior is represented by the following mathematical model using Equations 5-9 [11].

1. Separation Behavior:

   $S_i = \sum_{j=1}^{n} X - Xj$ (5)
2. Coordinated flight guarding behavior with dragonfly groups:

   $Ai = \frac{\sum_{j=1}^{n} Vj}{N}$ (6)
3. Behavior is close to each other for each individual (Cohesion):

   $Ci = \frac{\sum_{j=1}^{n} Xj}{N} - X$ (7)
4. Foraging behavior:

   $F_i = X^+ - X$ (8)
5. Enemy avoidance behavior:

   $E_i = X + X$ (9) [19]

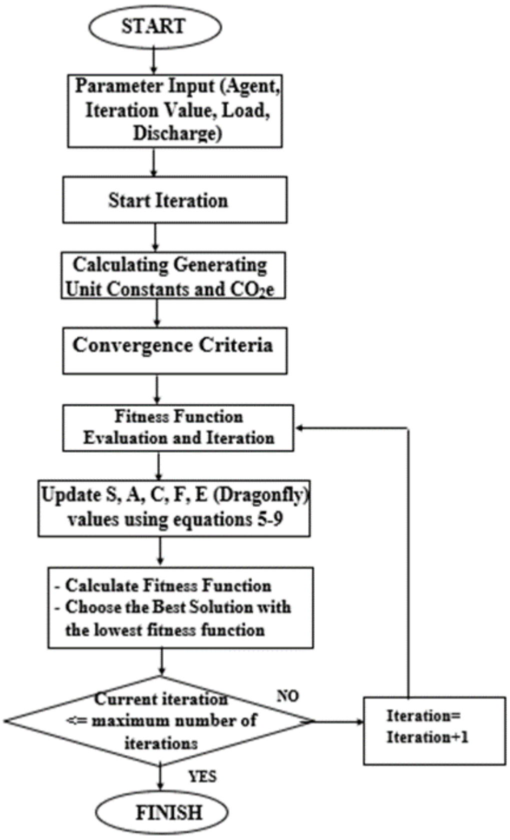

Figure 1: Dragonfly Algorithm Flowchart.

iv. Determining the Himmelblau Point

The Himmelblau point is a mathematical function point to determine the maximum and minimum values of a function in the context of optimization. Function in optimization, with a mathematical formula:

F (x, y) = (x^2 + y – 11) ^2 + (x + y^2 – 7) ^2 (10)

v. Methane Gas Emissions in Reservoirs

Methane is a greenhouse gas expressed as a mole fraction of 1,745 nmol/mol parts per billion. [12]. The sources of methane gas are divided into 2, namely natural sources and human activities. Natural sources include wetlands, geological emissions, lakes, and plants [20]. Meanwhile, methane originating from human activities comes from reservoirs, mining activities, fossil fuel use, livestock and agricultural activities, and landfills. [4].

Reservoir is one of the sources of methane gas formed at the bottom of the reservoir due to the activity of methanogens microorganisms under anaerobic conditions. [3]. Methane Gas calculation method in hydropower reservoirs or reservoirs based on the GHG Emission Reduction and / or Uptake Calculation Methodology [14]. Calculation of CO_2 emission from water reservoir activities with equation 11.

$$PE_{HP.y} = \frac{EF_{Res} \text{ X } TEG_y}{1000} \times \text{GWP } CH_4$$

$$CO_2 \text{ Emissions} = \frac{\text{CH4 Emissions}}{\text{GWP CH4}} \qquad (11)$$

GWP CH_4: Global Warming Potential (1 CH_4 is equivalent to 28 CO_2)[15].

III. RESULTS AND DISCUSSION

The results of this study are obtained from the results of mathematical calculations without weighting and scheduling simulations with weighting values on the system with dragonfly algortima to get the amount of production costs and emission values and prove the effect of weighting values on the results of the study.

i. Data Analysis

The application of the Dragonfly Algorithm is used as a decision maker. which is based on social behavior and how to find food for dragonflies in nature with the ability of adaptive dragonflies, communicating with other members in a population in optimizing foraging. The use of the dragonfly algorithm to find the position with Figures 2 and 3 is the form of the Himmelblau function of this research in matlab.

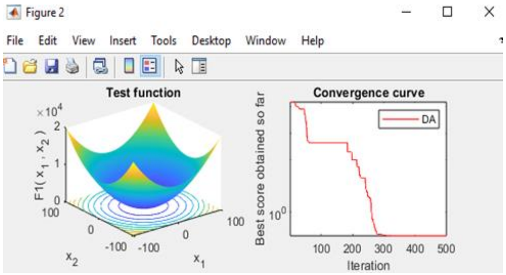

Figure 2: Test Function.

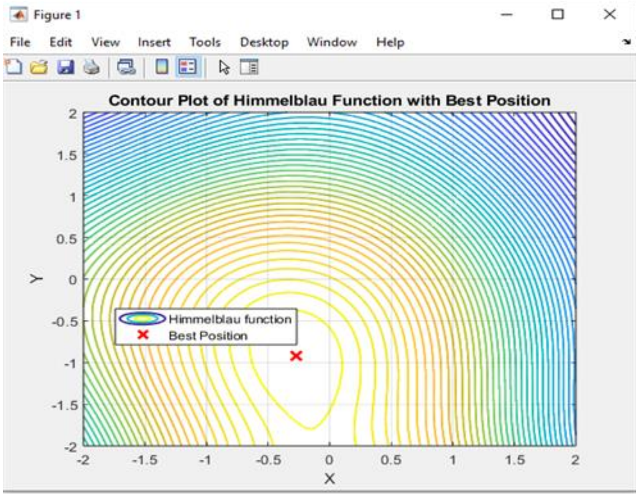

Figure 3: Plot of the Himmelblau function

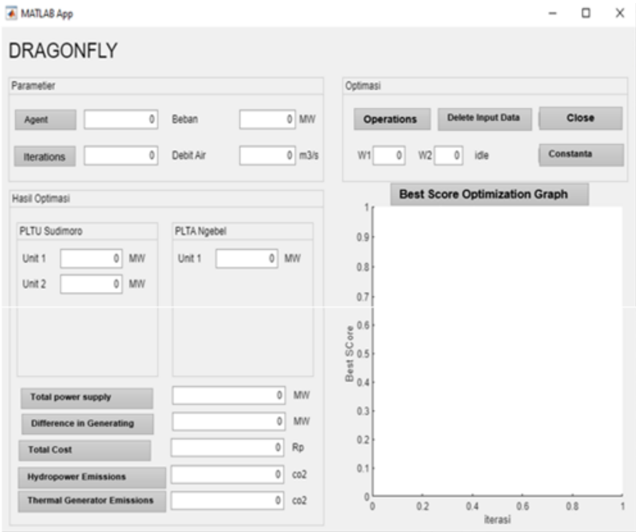

Figure 4. Dragonfly Algorithm GUI.

In Figure 4 there is a parameter icon as optimization input on the operation icon on the optimization results of PLTU unit 1 and unit 2 power and hydropower unit 1 using the Dragonfly algorithm.

ii. Calculation Result.

In this research case, the calculation of PLTU CO_2 emissions uses a systematic calculation using equation 3.

- Calculation of CO_2 emissions of Unit 1 PLTU

$$CO_2 \text{ emissions} = \frac{569.8 \text{ MW} \times 1000 \times 24 \text{ Jam} \times 0{,}8}{33}$$

$$= 3.315.200 \text{ kg}CO_2$$

$$= 3315{,}2 \text{ Ton } CO_2.$$

- Calculation of hydropower CO_2 emissions

  Calculation of hydropower CH_4 and conversion to CO_2 using equation 11.

$$PE_{HP.y} = \frac{90\ \text{kg}\frac{\text{CH4e}}{\text{MWh}} \text{X}\ 2.25\ MWh}{1000} \times 28$$

$$= 5{,}6\ \text{tonCH}_4$$

$$CO_2 \text{ emissions} = \frac{\text{Emisi CH4}}{GWP\ CO2}$$

$$= \frac{5{,}6}{28}$$

$$= 0{,}2\ \text{tonCO}_2\text{e}.$$

iii.Simulation Results.

To produce a link between plant operating costs and emissions is to weight the plant operating costs W1 and plant emissions weight W2. The value of the weighting factor is 0 to 1. If the economic factor of plant operating costs is prioritized, the weighting value of W1 = 1 and W2 = 0. And if the emission value is prioritized, the weighting value of W1 = 0 and W2 = 1. The weighting value in the simulation of each case is contained in the table.

Table 1. Weighting values of simulation cases.

Case	Generator Cost Weight W1	Plant Emission Weight W2
1	1	0
2	0,25	0,75
3	0,5	0,5
4	0,75	0,25
5	0	1

In the first case only prioritizes the optimization of generation costs In the third case optimization is planned to balance between generation costs and plant emissions. In the fifth case only prioritizes efforts to reduce plant emissions.

In case 1, the weighting prioritizes reducing production costs. The simulation results are in table 2.

Table 2. Simulation Results of Case 1 W1=1 and W2=0.

Date	W1= 1	W2= 0		Hydropower emission (TonCH_4) with equation 11
	Production Cost (Rp.)	emissions (ton CO_2e/day)		
		PLTU	PLTA	
1	Rp336,336,876	186.2	0.14	3.92
2	Rp342,637,549	282.2	0.15	4.20
3	Rp335,918,472	184.3	0.15	4.20
4	Rp335,917,400	187.5	0.15	4.20
5	Rp340,657,093	281.3	0.15	4.20
6	Rp340,657,336	238.8	0.15	4.20
7	Rp337,057,199	188.9	0.15	4.20

In case 3, the optimization weighting is planned to balance between generation costs and plant emissions. The simulation results are in table 3.

Table 3. Simulation Results Case 3 W1=0.5 and W2=0.5.

Date	W1= 1	W2= 0		Hydropower emission (TonCH_4) with equation 11
	Production Cost (Rp.)	emissions (ton CO_2e/day)		
		PLTU	PLTA	
1	Rp336,337,807	166.58	0.13	3.64
2	Rp342,638,864	169.8	0.15	4.20
3	Rp336,158,539	166.4	0.10	2.80
4	Rp335,918,527	166.3	0.13	3.64
5	Rp340,658,042	168.7	0.11	3.08
6	Rp340,658,688	168.8	0.14	3.92
7	Rp337,058,584	166.9	0.13	3.64

In case 5, the weighting only prioritizes efforts to reduce plant emissions. The simulation results are in table 4.

Table 4. Simulation Results Case 5 W1=0 and W2=1.

Date	W1= 1	W2= 0		Hydropower emission (TonCH_4) with equation 11
	Production Cost (Rp.)	emissions (ton CO_2e/day)		
		PLTU	PLTA	
1	Rp365,293,804	166.4	0.10	2.80
2	Rp346,614,179	169.6	0.11	3.08
3	Rp336,161,697	166.3	0.10	2.80
4	Rp335,942,079	166.28	0.10	2.80
5	Rp343,520,511	168.5	0.11	3.08
6	Rp340,661,196	168.5	0.12	3.36
7	Rp341,388,372	166.8	0.11	3.08

Table 2-4 shows that the weighting value has an impact on the final plant's emissions and production cost. A higher W1 value results in a lower manufacturing cost but a higher emission value. Conversely, the manufacturing cost is higher and the emission value is lower if W2 is higher than W1. Additionally, while it did not happen on every test day, the balance weighting of production costs and emission values fell as well. Figures 5 and 8 show the simulation results of the weighting of the production cost-emissions connection.

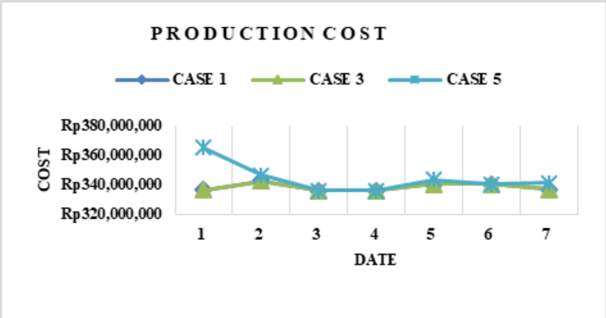

Figure 5: Production Cost Chart

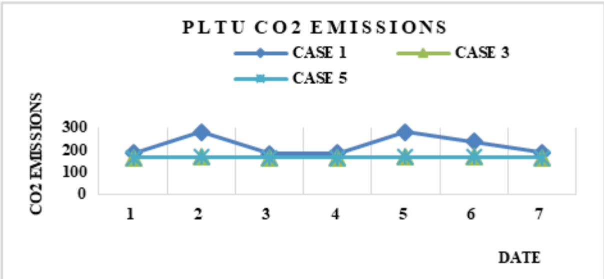

Figure 6. PLTU emission value graph

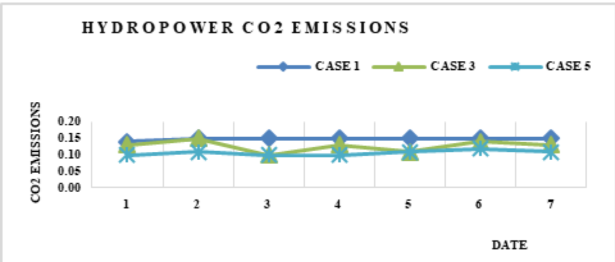

Figure 7: Graph of CO_2 emission value of hydropower plant

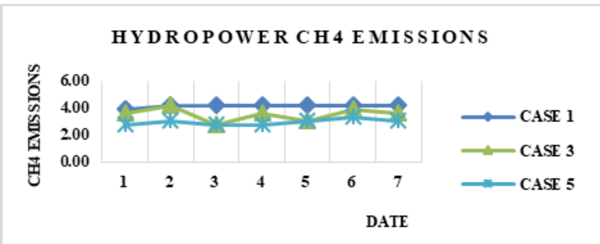

Figure 8: Graph of hydropower plant CH_4 emission values.

The scheduling and load sharing scenario uses the Dragonfly Algorithm. The purpose of using this method is to determine the load of each unit in each state within 24 hours. The scheduling procedure includes a combination of thermal generation and hydro generation. In addition, the characteristics of each thermal generating unit and the fuel price of each thermal generating unit load and the value of emissions generated by thermal plants that will be borne by thermal plants for 24 hours with a combination of 2 thermal generating units thermal generating units.

iv. Emission Intensity

Calculate the amount of PLTU emission intensity by using equation 4. PLTU CO_2 Emission Intensity that has been set by the Indonesian government. The PLTU emission limit refers to the amount of emissions produced by per unit of electrical energy produced. The emission intensity of coal-fired power plants in Indonesia ranges from 800-1050 gCO_2/kWh depending on the efficiency of the plant and the quality of the type of coal used.

- Emission Intensity in the Case of August 1, 2024 Without Weighting.

$$\text{Emission Intensity} = \frac{331.52 \times 1000}{569.8 \times 1000}$$

$$= 0.582 \text{ kg } CO_2/\text{kWh}$$

$$= 582 \text{ g } CO_2/\text{kWh}.$$

The results of the calculation of Emission Intensity on the results of emission values using weighting are in tables 6-8.

Table 6. Emission Intensity of Case 1 with Weighting.

Date	PLTU		Total Load	W2= 0 Emissions (tons)		PLTU Emission Intensity	
	Unit 1	Unit 2		PLTU	PLTA	$kgCO_2$/ kWh	gCO_2/ kWh
1	285.3	284.5	569.8	186.2	0.14	0.327	327
2	293	287.3	580.3	282.2	0.15	0.486	486
3	284.5	285	569.5	184.3	0.15	0.324	324
4	288.1	281	569.1	187.5	0.15	0.329	329
5	292	285	577	281.3	0.15	0.488	488
6	288	289	577	238.8	0.15	0.414	414
7	287	284	571	188.9	0.15	0.331	331

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Table 7. Emission Intensity of Case 3 with Weighting.

Date	PLTU		Total Load	W2= 0		PLTU Emission Intensity	
	Unit 1	Unit 2		Emissions (tons)			
				PLTU	PLTA	$kgCO_2/kWh$	gCO_2/kWh
1	285.3	284.5	569.8	166.58	0.13	0.292	292
2	293	287.3	580.3	169.8	0.15	0.293	293
3	284.5	285	569.5	166.4	0.10	0.292	292
4	288.1	281	569.1	166.3	0.13	0.292	292
5	292	285	577	168.7	0.11	0.292	292
6	288	289	577	168.8	0.14	0.293	293
7	287	284	571	166.9	0.13	0.292	292

Table 8. Emission Intensity of Case 5 with Weighting.

Date	PLTU		Total Load	W2= 0		PLTU Emission Intensity	
	Unit 1	Unit 2		Emissions (tons)			
				PLTU	PLTA	$kgCO_2/kWh$	gCO_2/kWh
1	285.3	284.5	569.8	166.58	0.13	0.292	292
2	293	287.3	580.3	169.8	0.15	0.293	293
3	284.5	285	569.5	166.4	0.10	0.292	292
4	288.1	281	569.1	166.3	0.13	0.292	292
5	292	285	577	168.7	0.11	0.292	292
6	288	289	577	168.8	0.14	0.293	293
7	287	284	571	166.9	0.13	0.292	292

Based on Table 6-8, the Intensity of Pacitan PLTU using Emission power after Weighting with the Dragonfly Algorithm, the Intensity value is below the range set by the Indonesian government, which is in the range of 800-1050 gCO_2/kWh. The smallest Emission Intensity value is 292 gCO_2/kWh. So the Pacitan PLTU has good performance in reducing greenhouse gas emissions.

IV. CONCLUSIONS

Based on the research results, the weighting value of each case will affect production costs and emission values. The results of scheduling optimization simulations using the Dragonfly Algorithm from thermal plants and hydro plants on August 1 to 7, 2024 at the Sudimoro Pacitan PLTU and Ngebel Ponorogo Hydropower Plant by applying weighting factors can reduce production costs and emission values. Weighting by prioritizing production costs can reduce production costs by 8% of thermal plant production costs. While weighting factors that prioritize reducing emission values can reduce PLTU emissions by 51% emissions, reducing hydropower CO_2 emissions by 50% emissions from emission values without weighting with emission values with weighting the Dragonfly Algorithm system. In addition, it reduces the smallest Emission Intensity by 16% and the largest by 50%.

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