Firefly Algorithm and particle Swarm Optimization for Economic Dispatch Optimization at PLTU Tanjung Jati B

Pressa Perdana S.S.
Electrical Engineering
Universitas Muhammadiyah Gresik
Gresik, Indonesia
pressa@umg.ac.id

***Abstract*— The ability of a power plant to supply a load determines the reliability of the electrical energy system. So that the power generated must always be equal to the amount of demand on the load at any time. Especially thermal generation units that are fossil fuel are very dependent on fuel requirements. The added burden will increase the quantity (amount) of fuel per unit time which will increase the cost per unit time. Fluctuations in electricity demand on the load side will cause fluctuations in fuel costs. In this regard, it is necessary to determine the correlation pattern of both, which is commonly called the output input of a power plant.**

Economic dispatch is an effort to minimize generator fuel costs. Economic dispatch problems can be solved using deterministic methods such as Lagrange multiplier and un-deterministic such as Particle Swarm Optimization (PSO), firefly algorithm (FA), genetic algorithm (GA), and others. In this study the application of the Firefly Algorithm (FA) method compared to the Particle Swarm Optimization (PSO) method to obtain minimum generation costs in the electrical system of Tanjung Jati B PLTU B. The simulation the results show that PSO method produces a combination of generating power at a more economical and stable cost compared to the FA method. however, both are very well used in economic dispatch problems.

Keywords*— *Economic Dispatch, Firefly Algorithm (FA), PSO

I. INTRODUCTION

One of the problems in the economical operation of a power plant is dispatch economics, which is how to get a minimum operating cost while still meeting existing and reliable limits [1,5-8]. Economics dispatch requires optimization by combining both linear and non-linear conditions, existing constraints and calculation algorithms. Some optimization methods have been applied to get economical and optimal operating costs. Some of them to solve this problem is by using the Firefly Algorithm (FA) and particle swarm optimization (PSO) technique .

Tanjung Jati B Steam Power Plant (PLTU) is one of the plants that supply electricity demand in the Java-Bali system. PLTU Tanjung Jati B has 4 units of generator with each generator has 660 MW of capacity. Present day, operating cost of the PLTU utilizes coal valued at United States Dollar (US $). This research discusses economical scheduling using the Firefly Algorithm (FA) method on the 4 units of the PLTU Tanjung Jati B with generator output power connected to one and the same main bus. Results of this research is a combination of power generated by each generator and the generation costs economical above the basic load of each generator, that is 330 MW and below the maximum limit of 660 MW and compare the results of optimization of the plant operation using FA method with the aiming PSO method to prove the validity of these two optimization methods. The optimization results will show the best and most economical method for economic dispatch problems at PLTU Tanjung Jati B.

II. METHODS OF ALGORITHM

A. Firefly Algorithm

The optimization method for economic dispatch in this study is Firefly Algorithm (FA). The Firefly Algorithm was introduced firstly by Xin-She Yang at Cambridge University in late 2008, which is based on flashing patterns and the behavior of fireflies [2-4].

Here are some terms used in Firefly Algorithm (FF) and their definitions :

a. Population is a collection of solutions represented by firefly.

b. Firefly is an individual in a population that consists of a collection of codes that represent solutions to problems.

c. The intensity of light is the value or size to evaluate firefly by other fireflies based on the intensity of the light. There are two important problems, namely variations in light intensity and formulation of attractiveness. Brightness in fireflies will be determined by the objective function and attractiveness proportional to brightness, so for every two fireflies that blink, fireflies with less bright light will move towards fireflies that are brighter in light. The intensity of light in fireflies is affected by the objective function. The level of light intensity for the problem of minimizing a firefly x can be seen as

$$I(x) = \frac{1}{f(x)} \quad (1)$$

The value of I (x) is the level of light intensity in fireflies, x, which is inversely proportional to solution of problem objective function that f (x) will look for.

B atractiveness is relative value, because the intensity of light must be seen and judged by other fireflies. Thus, the results of the assessment will differ depending on the distance between the fireflies with each other. In addition, the light intensity will decrease from the source because it is absorbed by the media, for example air. So that attractiveness can be determined (β) with the distance r as follows:

$$\beta = \beta_0 e^{-\gamma r^2} \quad (2)$$

With β_0 is the attraction when there is no distance between fireflies (r = 0) and $\gamma \in [0, \infty)$ is the light absorption coefficient.

B. Particle Swarm Optimization (PSO)

Particle Swarm Optimization (PSO) was developed firstly by Eberhard and Kennedy in 1995. This algorithm was inspired by behavior of bird and fish population in finding food. In PSO algorithm, bird and fish populations are called swarm. While each individual bird or fish is called a particle. The best food position achieved by the population represents the optimal value sought by this algorithm [2-4].

When a particle finds the best position, the other particles will move towards the particle. But when there are other particles that find a better position than the first best particle, then all particles will change direction to the second better particle. This process will continue continuously until it gets the best particle position. The speed of movement of each particle is formulated by equation (3). And the distance of the transfer of particles from the initial position to the best particle is defined by equation (4).

The size of the swarm or population chosen depends largely on the problem at hand. Each problem has its own characteristics. The size of the swarm that is generally used ranges from 20 to 50. And generally the values for acceleration coefficients c_1 and c_2 are 2.0. However, the value of the acceleration coefficient can be determined according to what is used in different studies, usually the values of c_1 and c_2 are the same and are in the range between 0 to 4.

$$v_i^{k+1} = v_i + c_1 r_1 (Pbest_i - x_i^k) + c_2 r_2 (Gbest - x_i^k) \quad (3)$$

$$x_i^{k+1} = x_i + v_i^{k+1} \quad (4)$$

Keterangan,
i = particle
k = number of iterations
c_1 and c_2 = constants
P_{best} = the best position ever achieved by each particle
G_{best} = the best position achieved by each iteration
r_1 dan r_2 = random numbers

III. METHODS

A. Research Flow

The This research was carried out in several stages of research. In Figure 1 you can see the method steps research in this study.

The first step is to look for Tanjung Jati B PLTU generator data. This data was obtained from the results of previous research [3]. Next, the calculation is done using Matlab Software to get the input output characteristic equation for each generator. Which then the input-output characteristic equation of each generator is used to calculate the characteristics of the fuel cost equation and the rate of increase in fuel costs. Then the simulation of Economic Dispatch uses the FA and PSO methods to get the most economical distribution of generator power.

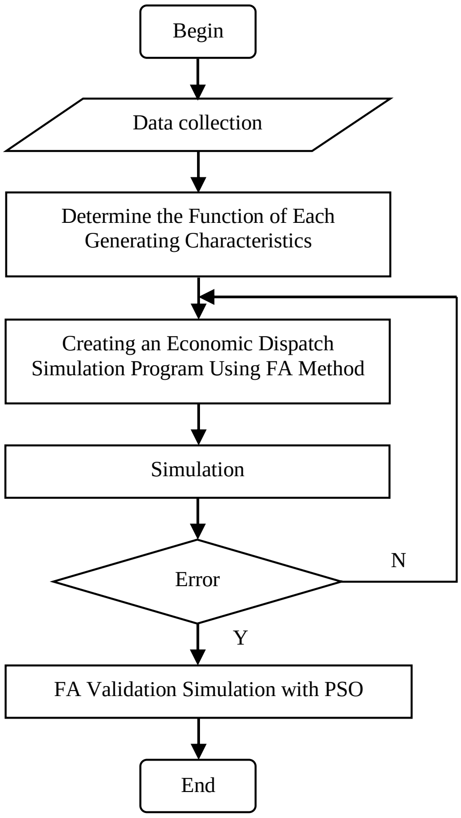

Fig. 1. Research Flow Chart

B. System Design

The purpose of this simulation program is to economically schedule each unit of the Tanjung Jati B power plant by considering the limits of each plant itself so that the power demand can be met with minimal generation costs.

Generators from each generating unit cannot generate power beyond their maximum limits and cannot be operated below the minimum limit. In this case the Tanjung Jati B PLTU unit has the following limitations [1]:

$$F_i(P_i) = a_i + b_i P_i + c_i P_i^2 \quad (5)$$

Where,

$F_i(P_i)$ = fuel cost, $ / hour

P_i = the power produced, MW

a_i, b_i, c_i = fuel cost coefficient

C. Capacity of generating units

Generators from each generating unit cannot generate power beyond their maximum limits and cannot be operated below the minimum limit. In this case the Tanjung Jati B PLTU unit has the following limitations [4]:

TABLE I. POWER LIMITS OF TANJUNG JATI B POWER PLANT

Generator	Lower Limit (MW)	Upper Limit (MW)
STG 1	330	660
STG 2	330	660
STG 3	330	660
STG 4	330	660

D. *Characteristics of generating units*

Characteristics of STG 1, STG 2, STG 3 and STG 4 generating units at Tanjung Jati B PLTU

- STG 1

TABLE II. STG 1 POWER GENERATION

Power (MW)	Cost ($)	Power (MW)	Cost ($)
350	12562,1	500	17556,2
360	12879,78	520	18259,14
400	14172,3	540	18970,8
420	14831,64	560	19691,18
440	15499,7	580	20420,28
450	15837	640	22659,9

Graphic function of the quadratic function of the generator unit 1 can be seen in Figure 2.

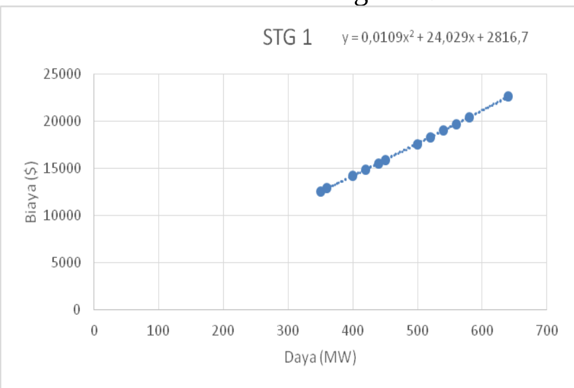

Fig. 2. Characteristics of STG 1

The characteristic equation for unit 1 generator is

$$C_1 = 2816.7 + 24.029P + 0.0109P^2 \quad (6)$$

- STG 2

TABLE III. POWER GENERATION OF STG 2

Power (MW)	Cost ($)	Power (MW)	Cost ($)
350	11973,95	500	16362
360	12248,2	520	16992,52
400	13371,4	540	17632,72
420	13948,72	560	18283,4
440	14536,52	580	18944,56
450	14834,35	640	20990,92

Graphic function of the quadratic function of unit power generation 2 can be seen in Figure 3.

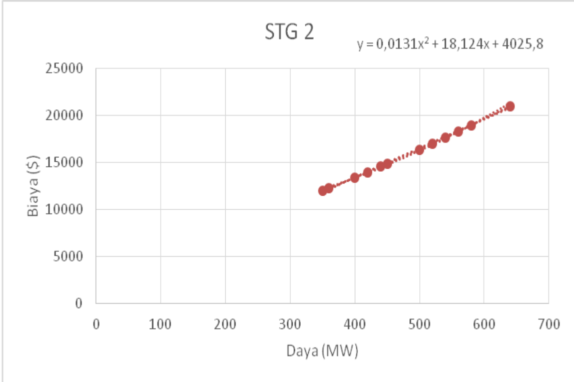

Fig. 3. Characteristics of STG 2

The characteristic equation for unit 2 generator is

$$C_2 = 4025.8 + 18.124P + 0.0131P^2 \quad (7)$$

- STG 3

TABLE IV. POWER GENRATION OF STG3

Power (MW)	Cost ($)	Power (MW)	Cost ($)
350	11139,95	500	15128,9
360	11390,34	520	15698,5
400	12414,1	540	16276,98
420	12939,3	560	16864,34
440	13473,38	580	17460,58
450	13743,75	640	19302,58

Graphic function of the quadratic function of unit power generation 3 can be seen in Figure 4.

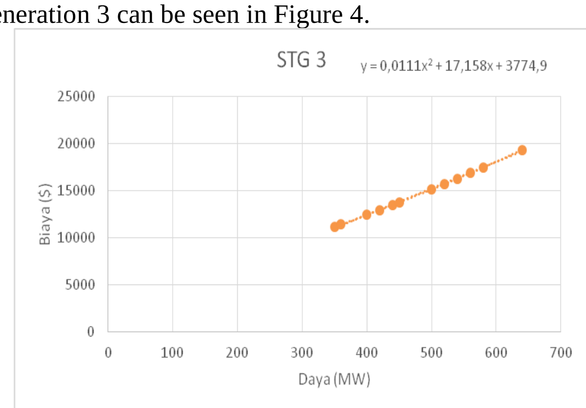

Fig. 4. Characteristics of STG 3

The characteristic equation for unit 3 generator is

$$C_3 = 3774.9 + 17.158P + 0.0111P^2 \quad (8)$$

- STG 4

TABLE V. POWER GENRATION OF STG4

Power (MW)	Cost ($)	Power (MW)	Cost ($)
350	11174,1	500	15396
360	11438,62	520	16000,06
400	12520,9	540	16613,8
420	13076,56	560	17237,22
440	13641,9	580	17870,32
450	13928,2	640	19827,7

Graphic function of the quadratic function of unit power generation 4 can be seen in Figure 5

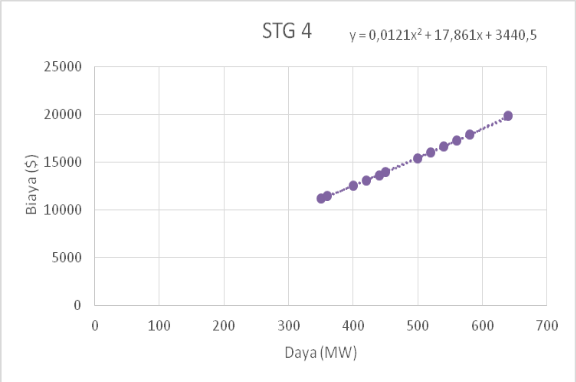

Fig. 5. Characteristics of STG 4

The characteristic equation for unit 4 generator is

$$C_4 = 3440.5 + 17.861P + 0.0121P^2 \quad (9)$$

From the above calculations, the PLTU Tanjung Jati B power plant consisting of 4 STG units has the following characteristics:

1. STG 1
   $C_1 = 2816.7 + 24.029P + 0.0109P^2$
2. STG 2
   $C_2 = 4025.8 + 18.124P + 0.0131P^2$
3. STG 3
   $C_3 = 3774.9 + 17.158P + 0.0111P^2$
4. STG 4
   $C_4 = 3440.5 + 17.861P + 0.0121P^2$

E. Process of Firefly Algorithm

According to Yang (2014), Firefly Algorithm is run in the following way:

1. Initialize the Firefly Algorithm parameter.
2. Generate initial population as much as firefly. Calculate the light intensity of each firefly, I(x), based on the value of objective function, f (x).
3. Compare the light intensity of each firefly with firefly. If there is a firefly with greater light intensity, the firefly movement will be updated using the movement equation.
4. Determine the G-best. For the first iteration, the best firefly (the biggest light intensity) is G-best.
5. Comparing the best firefly for each iteration with the G-best obtained. If the best firefly light intensity is bigger than G-best then the firefly becomes G-best.
6. Perform movement with the equation

$$x_{i\_new}^k = x_{i\_lama}^k + \alpha\left(rand - \frac{1}{2}\right) \quad (10)$$

   To firefly best and combine with other firefly to become the initial population in the next iteration.
7. Perform processes above until the iteration limit is met.

F. Process of Firefly Algorithm

The standard procedure for implementing the PSO algorithm is as follows:

1. Initialize population from particle with random position and velocity in a search dimension space.
2. Evaluation of the desired fitness optimization function in the variable d in each particle.
3. Comparing the fitness evaluation particle with the Pbest. If the value is better than the Pbest value, then the Pbest is set to the same value and Pi is the same as the particle location that X_i has in dimensional space d.
4. Identification of particles in the environment with the best results so far.
5. Update velocity and particle position.
6. Return to step 2 until the criteria are met, usually stopping at a fairly good fitness value or up to the maximum number of iterations.

The size of the swarm or population chosen is dependent on the problem at hand. The commonly used swarm sizes range from 20 to 50. It has been studied for a long time that PSO only needs a swarm size or a smaller population than other evolutionary algorithms to get the best solution. And generally the values for acceleration coefficients c_1 and c_2 = 2.0. However, the value of the acceleration coefficient can be self-determined which is used in different studies, usually the values of c_1 and c_2 are the same and are in the range between 0 to 4.

IV. RESULTS AND DISCUSSION

The simulation results of economic generation from Tanjung Jati B PLTU can be seen in table 6 and table 7 below. From the simulation results with 30 times iterations, it is found that the economic generation costs of FA and PSO have values that are mostly the same, even though there are some power of generator has value closer. However, PSO at a power of 1900MW and 2300MW produces a more economical generation power compared to the FA method. This is because during the simulation, the FA method produces different values or is not stable every time it is simulated on the same power. Sometimes it produces the most economical generation value, sometimes producing more expensive values.

This shows the FA method produces a wider expansion compared to PSO. Although on several simulations, the expansion carried out sometimes produces optimum values and sometimes not. However, in general, the FA and PSO methods can be applied in determining the economic generation of electric power systems.

TABLE VI. RESULT OF FIREFLY ALGORITHM

Firefly Algorithm					
Power (MW)	STG 1 (MW)	STG 2 (MW)	STG 3 (MW)	STG 4 (MW)	Cost ($/jam)
1300	310.0000	330.0000	330.0000	330.0000	44044.64
1500	330.0000	341.7857	381.1060	447.1083	49354.11
1700	330.0000	403.3962	447.4455	519.1583	54931.16
1900	330.0000	462.9106	514.0472	593.0422	60829.45
2100	352.7251	518.5970	572.5031	656.1748	67041.15
2300	424.0553	578.0902	637.8545	660.0000	73537.91
2500	520.9482	659.0518	660.0000	660.0000	80386.97

TABLE VII. RESULT OF PSO ALGORITHM

PSO Algorithm					
Power (MW)	STG 1 (MW)	STG 2 (MW)	STG 3 (MW)	STG 4 (MW)	Cost ($/jam)
1300	310.0000	330.0000	330.0000	330.0000	44044.64
1500	330.0000	341.9168	381.0442	447.0390	49354.11
1700	330.0000	403.2139	447.4057	519.3804	54931.16
1900	330.0000	464.5109	513.7691	591.7200	60829.40
2100	352.7016	518.8466	572.5983	655.8535	67041.15
2300	424.3635	578.4814	637.1551	660.0000	73537.90
2500	521.0625	658.9375	660.0000	660.0000	80386.97

V. CONCLUSION

Simulation results of Firefly Algorithm and Particle Swarm Optimization from 1300-2500MW of power generation produce distribution of generation power of each generator that is not much different and the generation costs are mostly the same. However, in two of the seven cases, namely in 1900MW and 2300MW of power generation, the generation costs generated from the PSO method are more economical than the generation costs generated by the FA method. PSO produce cost of $60829.40 in 1900MW and $73537.90 in 2300MW. While, FA produce cost of $60829.45 in 1900MW and $73537.91 in 2300MW. Even so, the difference is very little. This is because the simulation results from the FA method produce different values each time the simulation is on the same power. Sometimes economical and sometimes more expensive. However, in general, the FA and PSO methods can be applied in determining the economic generation of electric power systems.

REFERENCES

[1] M. E. Elhawary and Christensen G. S, 1979, "Optimal Economic Operation of Electric Power System", Academic Press.

[2] Surya, P. P. D. I. (2017). Jurnal Teknologi Elektro , Universitas Mercu Buana ISSN : 2086 - 9479 Kecerdasan Buatan Berbasis Particle Swarm Optimization , Ant Colony Optimization Dan Firefly Algorithm Untuk Meredam Osilasi Gangguan Pada Sistem Pembangkit Listrik Pressa P . Surya Den, 8(3), 200–205

[6] Stevenson, Jr, W. D, 1994, Analisis SIstem Tenaga Listrik, 4th ed, Erlangga, Bandung.

[7] Sulasno, 1993, Power Pembangkit Tenaga Listrik, Setya Wacana, Semarang.

[8] Wahyudi, B, 2004, Pengantar Struktur Data dan Algoritma, Andi, Yogyakarta.

[9] Wood, A. J and Woolenberg, B. F, 1996, Power Generation, Operation and Control, John Wiley & Sons, New York.

[10] Yang, X. S, 2009, Firefly Algoritm for Multimodal Optimization, Cambridge, Inggris.

[3] Yulianto, A., & Winardi, B. (1968). Optimasi Economic Dispatch Pada Unit Pembangkit Pltu Tanjung Jati B Menggunakan Metode Sine Cosine Algorithm.

[4] K. Habsyi and P. Perdana, "Penggunaan Metode Firefly Algorithm untuk Optimasi Economic Dispatch pada PLTU Tanjung Jati B", SinarFe7, vol. 1, no. 1, pp. 189-194, Jul. 2018.

[5] Yulianto, A., Winardi, B., & Karnoto, K. (2017). Optimasi Economic Dispatch Pada Unit Pembangkit Pltu Tanjung Jati B Menggunakan Metode Sine Cosine Algorithm. Transient, 6(4), 534-341