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Optimal Power Flow For Non-Smooth Cost Function Using Particle Swarm Optimization On 150 Kv System

***Muh. Rais**
Faculty of Engineering and Informatics University of Patria Artha. Addres, Tun Abdul Razak Gowa - Indonesia
*muh.raisazisnawawi@gmail.com

Bustamin
Faculty of Engineering and Informatics University of Patria Artha. Addres, Tun Abdul Razak Gowa - Indonesia
bustamin@gmail.com

Mochammad Apriyadi Hadi Sirad
Department of Electrical Engineering, Universitas Khairun addres, Jusuf Abdulrahman 53 Gambesi Ternate - Indonesia
apriyadisirat@unkhair.ac.id

***Abstract* – Optimal power flow by considering the non-smooth cost curve using the meta-heuristic algorithm method, namely particle swarm optimization (PSO) in the 150 kV Sulselrabar electrical system. In this study, the PSO algorithm was used to optimize optimal power flow so that the cheapest generation price was obtained with a non-smooth cost curve and still considered the limitations of similarity and inequality. In this study, the PSO algorithm was used to optimize optimal power flow so that the cheapest generation price was obtained with a non-smooth cost curve and still considered the limitations of similarity and inequality. From the results of generation optimization using the Particle Swarm method, it produces the cheapest generation costs from other methods, namely Rp. 93,498,916.1,- / hour to generate power of 270.14 MW with losses of 25.73 MW. The Particle Swarm Optimization (PSO) method is able to reduce the cost of generating the Sulselrabar system by Rp. 34,382,857.58 / hour or 26.89%. From the results of generation optimization using the Ant Colony method, it resulted in a total generation cost of Rp. 94670335.98 / hour to generate power of 270,309 MW with losses of 25.91 MW. The Ant Colony method is able to reduce the cost of generating the Sulselrabar system by Rp. 33,211,437.70 / hour or 25.98%. From the results of generation optimization using the lagrange method, it resulted in a total generation cost of Rp. 117,121,631.08 / hour to generate power of 339.4 MW with losses of 25,016 MW. The lagrange method is able to reduce the cost of generating the Sulselrabar system by Rp. 10,760,142.60 / hour or 8.41%. The artificial intelligence method based on Particle Swarm Optimization (PSO) can well perform optimization of Optimal Power Flow, from the results of the analysis obtained the cheapest generation cost compared to the comparison method, Lagrange Method and Ant Colony artificial intelligence method.**

Keywords: Aliran Daya Optimal, Efek Valve Point, Kurva Biaya Non-Smooth, Particle Swarm Optimization.

I. INTRODUCTION

In the analysis of an optimal power flow, there are two important issues to pay attention to, namely the analysis of power flow and the price of generation. In an *economic dispatch* we have one restriction which is that the total generation must be equal to the total load and power lost. Each plant has its own cost curve. In a plant sometimes a *non-smooth* cost curve is found. This *non-smooth* cost curve can be caused by *valve point effects*. The influence of this *non-smooth* cost curve makes calculations with conventional methods difficult to find results. By using the *Particle Swarm Optimization method,* this *non-smooth* problem can be solved.

For power flow analysis, there are several constraints that must be considered, namely *equality* and *inequality constraints*. These limitations are in the form of limiting line power and limiting the minimum and maximum voltage on each *bus*. The voltage on a bus must be in a certain range of values so that *undervoltage* and *overvoltage* do not occur. The flow of power passing through a line must comply with the maximum requirements because the cable passed has a certain capacity to flow power. The voltage on the *bus* is also worth paying attention to

The development of technology in a plant makes the problem of finding the value of generation costs more complex. This is complicated by the existence of *equality* and *inequality constraints* in an optimal power flow. *Inequality constraints* certainly cannot be solved by conventional methods such as power flow with the Lagrange or Newton-Rhapson methods. The *non-smooth* cost curve is also a major problem in determining the cheapest generation cost. This *non-smooth* characteristic is obtained due to the effect of valve opening and the use of variegated fuel.

This research will discuss the creation of a method for solving optimal power flow problems based on *a non-smooth* cost curve. The limitations in making this program are carried out with Matlab software and data used by the Sulselrabar transmission system, *non-smooth cost curves* due to the influence of valve effects, and using pln bus voltage limit standards. After an analysis of the creation of an OPF program, a PSO is planned that is easier to find and determine objective functions by looking at the limitations that have been given.

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Research on Optimal Power Flow in several electrical systems has been widely carried out, both based on conventional methods and artificial intelligence methods, including the following. Rajaei et al [1-3] discusses Power Flow Analysis Using Newton Raphson's Method, [4] discusses Power Flow Analysis Using the Flower Pollination Method, [5] discusses Power Flow Analysis Using Bisection Method, [6] discusses Power Flow Analysis Using Gravitational Search Method. Meanwhile, Power Flow research on the Sulselrabar electrical system, previously there has also been carried out, [7] discusses Power Flow Analysis and Transmission Disturbances (Using Newton Raphson's Method), and [8] discusses Power Flow and Short Circuit Analysis (Using Newton Raphson's Method). From this research, it shows the road map of research that has been carried out in the Sulselrabar electrical system. From the review, the research that has been carried out is still within the scope of the study or reviewing the power flow profile in the system.

Previously the authors had tested the effectiveness of the PSO algorithm for case studies on the IEEE 14 bus electrical system, and showed optimal results compared to using conventional methods. In addition, the effectiveness of the PSO algorithm also provides optimal results in its application in the Sulselrabar electrical system, such as [9] which discusses the implementation of PSO for optimization of power system stabilizer parameters in generators in the Sulselrabar electrical system. In some other systems the use of the PSO algorithm for optimization of the electric power system shows optimal results, such as in the Java Bali system. [10] which discusses optimal power flow.

Based on the description of the research conducted above, this research proposes an optimal power flow analysis (Optimal Power Flow) in the Sulselrabar electrical system, with the proposed method using an artificial intelligence method based on Particle Swarm Optimization (PSO).

II. METHOD AND DESIGN

The OPF problem has a lot to do with optimizing power performance in *steady state* conditions with regard to objective functions when subjected to many restrictions. For optimal active power *dispatch*, the objective function *f* is the total generation cost which can be expressed as follows.

$$F = \sum_{i=1}^{N} C_i\,(P_{Gi}) = \sum_{i=1}^{N} ai + bi\,P_{Gi} + ci\,P_{Gi}^{\,2} \qquad (1)$$

Where

N : number of generating units
Ai, bi, ci : cost coefficient of the generating unit
Pgi : Real power generation of the I-th unit.
i = 1.2 ... N

Limitations of similarity :

$$F = \sum_{i=1}^{N} P_i = P_D + P_L \qquad (2)$$

Where:

P_i = Power generated unit i
P_D = total power required
P_L = power and line losses on transmission

Limitations of inequality include

- Branch flow limits :

  $$|Si| \le S_i^{max} \qquad i = 1,2 \ldots nl \qquad (3)$$

  Where nl : number of channels
- Voltage on the bus :

  $$|E_D|^{min} \le E_i \le |E_D|^{max} \quad i = 1,2 \ldots nd \qquad (4)$$

  Where nd : number of load buses
- Generator MVAR

  $$Q_{Gi}{}^{min} \le Q_{Gi} \le Q_{Gi}{}^{max} \qquad (5)$$

  Slack bus MW

  $$P_G{}^{min} \le P_G \le P_G{}^{max} \qquad (6)$$

Generating units with steam turbine valves show a wide variety of fuel cost functions. This valve opening effect produces the ripples shown in figure (1), the cost function being a non-linear function in a high order. Therefore equation (1) must be replaced with equation (7) to consider the effect of the valve. On this cost curve, a sinusoidal function is added to the quadratic function of that cost curve. The increase in the cost function of the generating unit with the valve effect is represented as follows .

$$F_i\,(P_{GI}) = a_i + b_i\,P_{Gi} + c_{Gi}P_{Gi}{}^2 + |e_i \times \sin(f_i \times (P_{Gi\,min} - P_{Gi}) \qquad (7)$$

Where e i and f i are the coefficients of the generator i that reflect the valve effect.

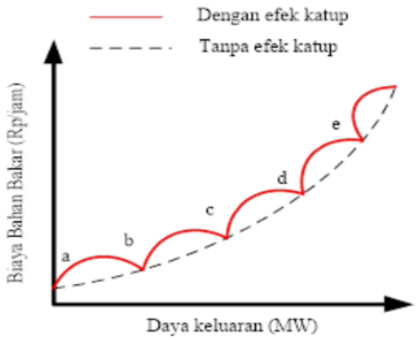

Figure 1. Fuel cost vs output power curve for a 6-valve steam turbine

Particle Swarm Optimization (PSO) is a population-based optimization method first developed by Kennedy and Eberhart in 1995, inspired by the social behavior of a group of birds and fish. The PSO has optimization tools that provide a population-based search procedure where each individual is called a particle. The particle changes its position every time. The collection of particles that are potential solutions is called *a swarm*. In PSO systems, particles hover around a multidimensional search space.

During the flight process, each particle determines its own position based on its own experience (this value is called the Pbest) and based on the experience of its neighboring particles (this value is called the Gbest). The process of searching for Pbest and Gbest can be illustrated in the following image

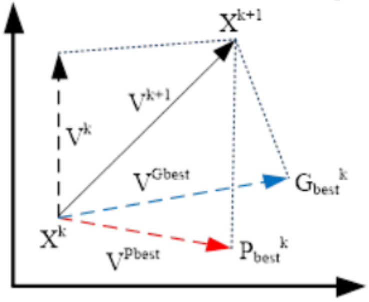

Figure 2. Pbest and Gbest search concepts from PSO

This modification can be represented as a concept of speed. The speed of each agent can be formulated from the following equation.

$$v_{k+1} = w.v_k + c_1 rand \times (P_{best} - x^k) + c_2 rand \times (G_{best} - x^k) \quad (8)$$

Using the above equation, certain velocities that will gradually get closer to Pbest and Gbest can be calculated. The current position (search in solution space) can be obtained from the following equation.

$$x^{k+1} = x^k + v_{k+1} \quad . \quad k = 1,2 \ldots n \quad (9)$$

Where

X^k	: current search point
X^{k+1}	: modified search position
V^k	: current speed
V^{k+1}	: modified agent speed
Vpbest	: pbest-based speed
Vgbest	: speed based on gbest
n	: number of particles in the group
m	: number of members in the particle
$pbest_i$	: pbest dari agen k
$gbest_i$	: gbest dari kelompok
w	: Heavy Function of K Agent Speed
c_i	: weight coefficient

Ufor the following terms - c1 and c2 are 2 positive constants, r1 and r2 are random numbers ranging from 0 to 1, w is the inertial weight and is defined as an iteration function of k as follows :

$$w(k) = w_{max} - \left(\frac{w_{max} - w_{min}}{max.iter}\right) \times k \quad (10)$$

To ensure uniform speed of all dimensions, the maximum speed is as follows.

$$v^{max} = \frac{(x^{max} - x^{min})}{N} \quad (11)$$

Where N is the specified maximum number of iterations

III. RESULTS AND DISCUSSION

The input-output equation can actually be obtained with the help of Matlab, and is displayed in the following input-output characteristic table.

Table 1. Input-Output Characteristics of Sulselrabar thermal plant

Generating Unit	Input-Output Equation (liters/hour)
PLTD Pare-Pare	714.0000 + 567.4000P - 3.2941P²
PLTD Suppa	2070 + 178.6P + 0.4P²
PLTU Barru	2805.6 + 251.6P - 0.11976P²
PLTU Tello	558 + 174.5P + 1.375P²
PLTD Agrekko/T.Lama	771.975 + 160P + 2.7397P²
PLTD Sgmnsa	617.625 + 477.25P - 4.1667P²
PLTD Arena/Jeneponto	629.475 + 176.3P + 4.8052P²
PLTD Matekko/Bulukumba	506.25 + 124.9P + 9.4444P²
PLTD Pajelasang/Soppeng	432 + 66.2P + 12.5P²
PLTGU Sengkang	4418.89 + 38.0952P + 0.021898P²
PLTD Malea/Makale	165.75 + 409.5P + 5.7692P²
PLTD Palopo	103.5 + 112.4P + 50P²

All PLTD and PLTG use HSD (*High Speed Diesel*) with a perliter price of Rp. 8,700, while PLTU uses MFO (Marine Fuel Oil) fuel with a perliter price of Rp. 6,300. The fuel cost equation of each such plant is obtained by multiplying the input-output equation of the plant by the price of its fuel.

For example, for pare pltd with an input-output equation, namely: 714.0000 + 567.4000P - 3.2941P² (Liters / Hour), with the price of fuel used Rp. 8700, then the fuel cost equation is obtained:

$$(714.0000 + 567.4000P - 3.2941P^2) \text{ x Rp. } 8700$$
$$= 6211800 + 4936380P - 28658.67P^2$$

Using the same formula, the full fuel cost equation is shown in the following table.

Table 2. Thermal plant fuel cost equation Sulselrabar

Generating Unit	Input-Output Equation (liters/hour)
PLTD Pare-Pare	6211800 + 4936380P - 28658.67P²
PLTD Suppa	18009000 + 1553820P + 3480P²
PLTU Barru	17675280 + 1585080P + 754.488P²
PLTU Tello	3515400 + 1099350P + 8662.5P²

PLTD Agrekko/T.Lama	$6716182.5 + 1392000P + 23835.39P^2$
PLTD Sgmnsa	$5373337.5 + 4152075P - 36250.29P^2$
PLTD Arena/Jeneponto	$5476432.5 + 1533810P + 41805.24P^2$
PLTD Matekko/Bulukumba	$4404375 + 1086630P + 82166.28P^2$
PLTD Pajelasang/Soppeng	$3758400 + 575940P + 108750P^2$
PLTGU Sengkang	$27839000.000 + 240000.00P + 137.9539P^2$
PLTD Malea/Makale	$1442025 + 3562650P + 50192.04P^2$
PLTD Palopo	$900450 + 977880P + 435000P^2$

The data used in this study was when there was a peak load during the day on. The total system load at the time of this peak load was 402.1 MW. The loading and generation data on each bus can be seen in the following table.

Table 3. Sulselrabar system bus data at peak daylight load

Bus Name	Types of Buses	Load		Generation	
		P (MW)	Q (Mvar)	P (MW)	Q (Mvar)
Bakaru	Generator	2.1	0.2	126	-5.2
Pinrang	Generator	11.3	-2.3	0.3	0.0
Pare-Pare	Generator	8.3	-1.0	20.2	5.4
Suppa	Generator	-	-	52.0	18.9
Barru	Generator	4.6	1.5	37.8	0.0
Tello	Generator	38.5	16.0	44.7	19.9
Tello Lama	Generator	11.6	10.7	19.3	0.0
Sgmnsa	Generator	2.8	2.5	12.5	3.4
Jnpnto	Generator	1.9	3.6	9.3	0.0
Blkmba	Generator	3.5	2.7	9.1	0.0
Sinjai	Generator	6.4	4.4	3.5	-0.5
Soppeng	Generator	7.5	9.3	15.0	7.5
Sengkang	Slack	12.4	6.0	164.5	-2.8
Makale	Generator	3.9	1.7	3.6	0.0
Palopo	Generator	22.5	6.9	5.1	0.0
Borongloe	Generator	3.5	0.0	7.1	1.0
Polmas	Beban	6.9	2.3	-	-
Majene	Beban	5.1	1.9	-	-
Mamuju	Beban	8.3	1.0	-	-
Pangkep	Beban	14.9	7.7	-	-
Bosowa	Beban	19.7	3.5	-	-
Tel. Lama	Beban	-	-	-	-
Panakukkang	Beban	28.1	8.4	-	-
Tanjung Bunga	Beban	30.5	12.4	-	-
Talasa	Beban	7.9	3	-	-
TIP	Beban	-	-	-	-
Bone	Beban	15.1	6.3	-	-
Sidrap	Beban	13.2	6.0	-	-
Maros	Beban	4.7	2.2	-	-
Pangkep D	Beban	-	-	-	-
Tonasa	Beban	39.4	22.8	-	-
Mandai	Beban	19.7	2.1	-	-
Daya	Beban	24.1	1.6	-	-
TelloA	Beban	-	-	-	-
TelloB	Beban	-	-	-	-
Barawaja	Beban	5.2	0.0	-	-
Bontoala	Beban	18.5	0.0	-	-

To test the optimization of the Particle Swarm Optimization (PSO) method, in this study the simulation results used a comparison method of *the Lagrange* and *Ant Colony Optimization (ACO) methods*. Table 4 shows *the real* generation and cost for the Sulselrabar thermal system unit at peak load during the day before being optimized.

Table 4. Real Thermal Generation Load at peak load day

Generation	Real System		
	Active Power (MW)	Cost (Rp/jam)	Losses (MW)
PLTD Pare-Pare	20.200	9423279.229	
PLTD Suppa	52.000	10821756.000	
PLTU Barru	37.800	8837173.034	
PLTU Tello	44.700	6996479.963	
PLTD Agrekko/T.Lama	19.300	4246022.692	
PLTD Sgmnsa	12.500	5161016.719	
PLTD Arena/Jeneponto	9.300	2335660.071	
PLTD Matekko/Bulukumba	9.100	2109689.765	
PLTD Pajelasang/Soppeng	15.000	3686625.000	
PLTGU Sengkang	164.500	71052067.022	
PLTD Malea/Makale	3.600	1491805.384	
PLTD Palopo	5.100	1720198.800	
	393.1	127881773.68	24.956

From the results of the analysis in the case study of the peak load during the day generation before being optimized, the generation load charged to the thermal unit was 393.1 MW, with a total generation cost of Rp. 127,881,773.68,-. The losses generated before optimization were 24,956 MW. The total system load amounted to 402, 100 MW. 4 hydro generation units each: Plta Bakaru 126 MW, PLTM Teppo Pinrang 0.3 MW, PLTA Tangka Manipi Sinjai 3.5 MW, PLTM Bili-Bili 7.1 MW. Furthermore, by using the proposed method, namely by using a smart method based on Particle Swarm Optimization (PSO), more optimal generation results are obtained. As a comparison method in this study, *the Lagrange* and *Ant Colony* methods were used. More is shown in Table 5.

Grafik optimization of generation costs and *global best tour* on the *Ant Colony* method can be seen in figures 4 and 5. The graph of Ant *Colony's* optimization results shows that generation costs decrease with each iteration even though in some iterations there are slight oscillations. Figure 4 shows how Ant Colony performs in lowering generation costs. In the graph, oscillations occur until around the 41st iteration. This shows that from the beginning of the iteration to the 41st iteration, the ant colonies in each iteration produced different optimal journeys (optimal solutions). While figure 5 shows the global best tour conducted by ant colonies. The best tour global graph shows the best objective function values that the algorithm can perform from the beginning of the iteration to the maximum iteration (100).

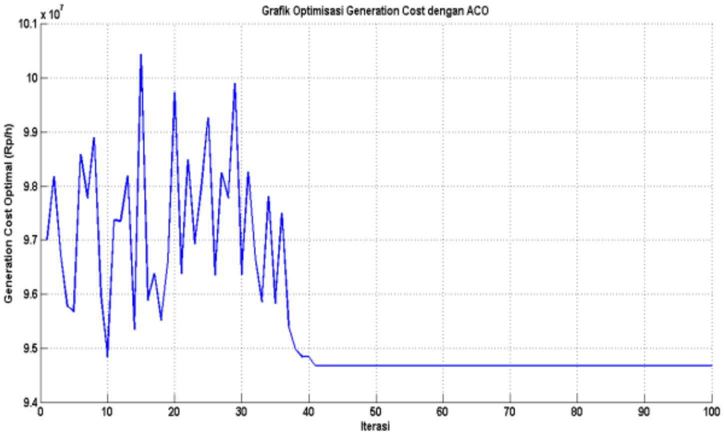

Figure 4. Graph of optimization of Sulselrabar system generation costs at peak daylight loads using *Ant Colony Optimization (ACO)*

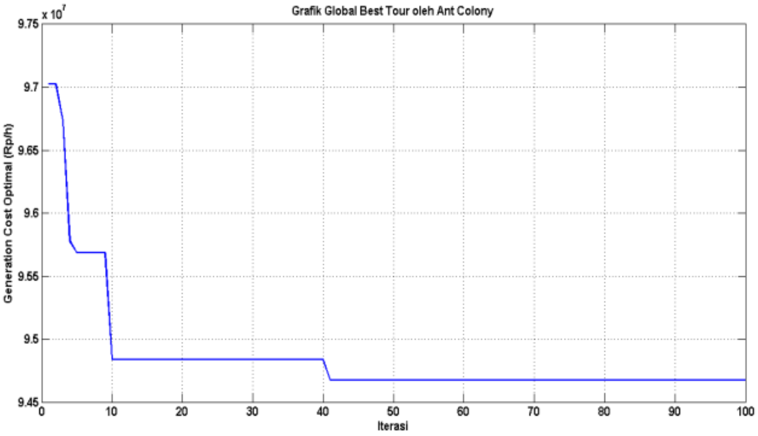

Figure 5. Global chart of Sulselrabar system tour at peak daylight loads using *Ant Colony Optimization (ACO)*

Grafik optimization of generation costs can be seen in figure 6. *The Particle Swarm Optimization* optimization result graph shows the minimum generation cost compared to the Lagrange and Ant Colony methods. Figure 6 shows how *Particle Swarm* performs in optimizing the cheapest generation costs. The computational process is carried out for 50 itrations. From the convergence graph, the performance of Particle Swarm was obtained, which found the generation cost on iteration 19 with a fitness function value of 9.349779e+07.

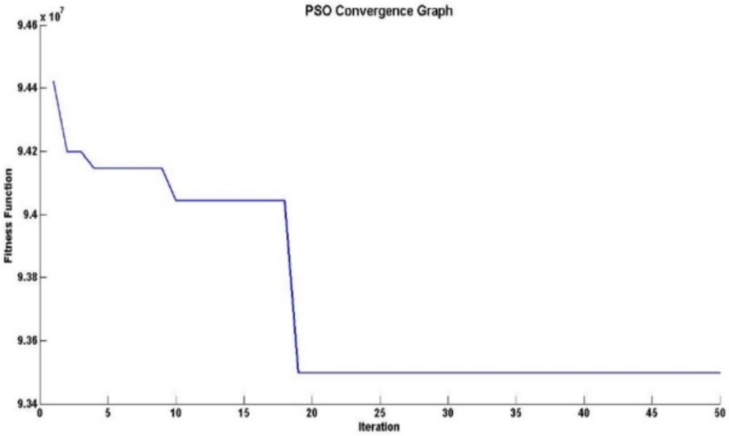

Figure 6. Particle *Swarm Optimization (PSO)* convergence graph

From the results of generation optimization using the *Particle Swarm* method, it resulted in a total generation cost of Rp. 93,498,916.1,-/hour to generate power of 270.14 MW with *losses* of 25.73 MW. Meanwhile, using the *Ant Colony* method resulted in a total generation cost of Rp. 94,670,335.98,-/hour to generate power of 270,309 MW with losses of 25,918 MW, while using the lagrange method, it resulted in a total generation cost of Rp. 117,121,631.08,-/hour to generate power of 339.4 MW with *losses* of 25,016 MW. In the *real system*, the total generation cost is Rp. 127,881,773.68,-/hour to generate power of 393.1 MW with losses of 24,956 MW. From the results of this simulation, it can be concluded that the *Particle Swarm Optimization (PSO)* method is able to reduce the cost of generating the Sulselrabar system by Rp. 34,382,857.58,-/hour or 26.89% at peak loads during the day. Meanwhile, by using Ant Colony, it is able to reduce the cost of generating the Sulselrabar system by Rp. 33,211,437.7,-/hour or 25.98% at peak night loads. Meanwhile, by using the lagrange method, it is able to reduce the cost of generating the Sulselrabar system by Rp. 10,760,142.60 ,-/hour or 8.41% at peak load during the day. 4 hydro generating units each are maximized because it is the cheapest generation. The Sengkang PLTGU generating unit acts as a *slack* bus in this system, which produces the most expensive thermal generation cost of Rp. 54,117,894.45,-/hour, with a generated power of 103.36 MW. While the cheapest thermal generation unit at the Palopo PLTD plant is Rp. 456,941.03,-/hour, with a generated power of 1.99 MW. For more results shown in table 5 and figure 7 below.

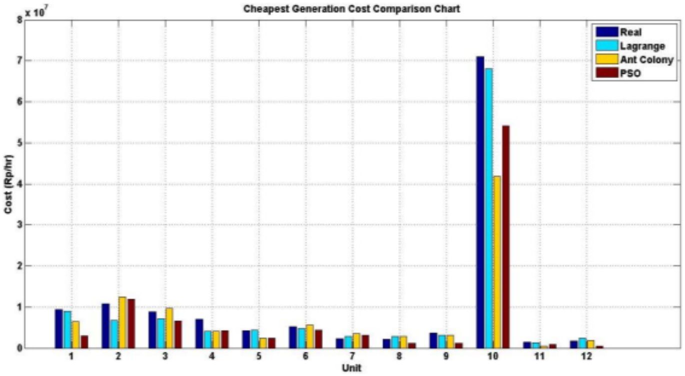

Figure 7. Daytime peak load generation cost comparison

IV. CONCLUSION

From the results of generation optimization using the Particle Swarm method, it produces the cheapest generation costs from other methods, namely Rp. 93,498,916.1,-/hour to generate power of 270.14 MW with losses of 25.73 MW. The Particle Swarm Optimization (PSO) method is able to reduce the cost of generating the Sulselrabar system by Rp. 34,382,857.58,-/hour or 26.89%. From the results of generation optimization using the Ant Colony method, it resulted in a total generation cost of Rp. 94670335.98,-/hour to generate power of 270,309 MW with losses of 25.91 MW. The Ant Colony method is able to reduce the cost of generating the Sulselrabar system by Rp. 33,211,437.70,-/hour or 25.98%. From the results of generation optimization using the lagrange method, it resulted in a total generation cost of Rp. 117,121,631.08,-/hour to generate power of 339.4 MW with losses of 25,016 MW. The lagrange method is able to reduce the cost of generating the Sulselrabar system by Rp. 10,760,142.60,-/hour or 8.41%..

V. REFERENCES

[1] N. Rajaei, M. Ahmed, and M. Salama, "A novel Newton-Raphson algorithm for power flow analysis in the presence of constant current sources," in 2016 IEEE/PES Transmission and Distribution Conference and Exposition (T&D), 2016, pp. 1-5: IEEE.

[2] A. Eltamaly, A. A. Elghaffar, Y. Sayed Mohamed, and A.-H. M. El-Sayed, "Optimum Power Flow Analysis by Newton Raphson Method, A Case Study," 12/04 2018.

[3] Sirad, M. A. H. (2017). Analysis of the potential of renewable energy in South Sulawesi as power electrical needs. Journal of Electrical Technology UMY, 1(4), 196-201.

[4] Sakti, F. P., Sarjiya, S., & Hadi, S. P. (2017). Optimal power flow using flower pollination algorithm: A case study of 500 kV java-bali power system. IJITEE (International Journal of Information Technology and Electrical Engineering), 1(2), 45-50..

[5] S. S. Reddy and P. Bijwe, "An efficient optimal power flow using bisection method," Electrical Engineering, vol. 100, no. 4, pp. 2217-2229, 2018.

[6] D. Serhat, G. Uğur, M. S. Yusuf, and Y. Nuran, "Optimal power flow using gravitational search algorithm," Semantic Scholar, 2012.

[7] S. Makmur, Y. Y. Muhammad, Y. Yusmar, and M. Muhakkir, " Analisis Aliran Daya dan Gangguan pada Jaringan Transmisi Sistem Interkoneksi Sulselbar 2015 Menggunakan Power World Simulator," Jurnal Teknik Mesin SINERGI, vol. 13, no. 2, pp. 145-147, 2015.

[8] M. R. Djalal, M. A. Haikal, T. M. P. N. U. Pandang, and T. E. I. P. Aceh, "Penyelesaian Aliran Daya 37 Bus Dengan Metode Newton Raphson (Studi Kasus Sistem Interkoneksi 150 kV Sulawesi Selatan)," 2014.

[9] R. D. Muhammad and F. Faisal, "Studi Kestabilan Generator Sistem Sulselrabar (Stability Study of Sulselrabar System Generator)," JEEE-U Journal of Electrical and Electronic Engineering-UMSIDA, vol. 3, no. 1, pp. 82-119, 2019.

[10] T. Taqiyuddin and S. P. Hadi, "Studi Optimal Power Flow pada Sistem Kelistrikan 500 kV Jawa-Bali dengan Menggunakan Particle Swarm Optimization (PSO)," Jurnal Nasional Teknik Elektro dan Teknologi Informasi (JNTETI), vol. 2, no. 3, pp. 59-64, 2013.

[11] Sirad, M. A. H., Rais, M., Djalal, M. R., & Putri, A. N. (2018, March). Optimization of grounding resistance to minimize transient currents at 150 kV SULSELRABAR system. In 2018 International Conference on Information and Communications Technology (ICOIACT) (pp. 572-578). IEEE.

[12] Putri, A. N., Penangsang, O., & Sirad, M. A. H. (2020, September). Power Flow Based Monitoring Of State Estimation Using The

Weighted Least Square. In 2020 International Seminar on Application for Technology of Information and Communication (iSemantic) (pp. 408-411). IEEE.

[13] J. Kennedy, "Particle swarm optimization," Encyclopedia of machine learning, pp. 760-766, 2010.

[14] Sirad, M. A. H. (2018, December). Performance Optimazation Of 150 KV Transmission Tower In Jeneponto Steam Power Plant Using GIS Analysis. In 2018 2nd Borneo International Conference on Applied Mathematics and Engineering (BICAME) (pp. 203-206). IEEE.

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