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OPTIMIZATION ECONOMIC POWER GENERATION USING MODIFIED IMPROVED PSO ALGORITHM METHODS

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ABSTRACT

Fuel consumption on operation of power generation is one of the things that need to get special attention because most of the operating costs incurred is fuel costs. The output of the power generation always strived to meet the needs of the loads. Economical optimization is an attempt to minimize the cost of power generation fuel. This research proposes the application of the Algorithm Methods of Modified Improved Particle Swarm Optimization (MIPSO) that are compared with the Lagrange method and the Improved Particle Swarm Optimization (IPSO) in the case of the IEEE 30-bus system as a validation, in which the results of the simulation of MIPSO method can minimize the cost to 575.28 $/hour compared to the Lagrange method at 575.32 $/hour and IPSO method at 575.29 $ /hour. Then MIPSO Algorithm Method applied to the SULSELBAR 150 kV interconnection system are compared with the cost of a real system, the results of the simulation showed that the MIPSO method algorithm can reduce the cost of power plant to *Rp*. 51,706,000.- per hour or decrease operating costs of around 13.73% per hour.

Keywords: *Optimization Economic, Modified Improved PSO Algorithm Methods, 150kv SULSELBAR Interconnection System*

1. INTRODUCTION

The main role of the electrical power system is to ensure that the electrical energy needs of customers can be served. But in doing so, the operation of the interconnection of electric power systems usually have a common problem, namely how to produce maximum output power with minimum operation cost of generating electric energy. There fore, it is necessary to have a power flow optimization function which can minimize the cost of electric energy generation that is affected by changes in the energy needs within a specified time.

Optimization Economic is a procedure to determine the electrical power generated by the plant is connected to the system's electrical interconnection so that the overall cost of operation isminimized simultaneously with the rise in the demand load.

Conventional optimization economic problems can be solved by the lagrange method multiplier, but this method is not effective and less than optimal to resolve problems, because in its development, the function of modern electric generation costs is non linear [5].

The development of techniques to solve the problem of optimization economic using the algorithms of artificial intelligence (AI) in improving settlement is more optimized. One method that is often used is the Particle Swarm Optimization (PSO) [1], [4].

Particle Swarm Optimization algorithm was introduced based on the intelligence of birds or fish behavior in search of food so that it can be applied to scientific or engineering research methods [1]. The main advantage of the PSO algorithm are the simplicity of its concept, easy implementation, robustness to control parameters, and computational efficiency than any other heuristic optimization techniques.

In next research, PSO is modified by applying the Inertia Weight (IW) to dampen the pace during the iteration so it can be balanced in keeping local and global search [2]. The repair of PSO using Contriction Factor (CF) [13] with the goal to ensure the convergence of the PSO algorithm and particle

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amplitude oscillation decreases over time without setting the maximum speed.

Another research on PSO is done by comparing the Inertia Weight (IW) with Contriction Factor Approach (CFA) and found that the use of the CFA has better convergence than the IW [6].

To resolve this problem, researchers proposed a Modified Improved Particle Swarm Optimization (MIPSO) method algorithm in solving the optimization economic by combining inertial weight and constriction factor with the aim of maintaining the balance of global and local search so as to avoid local solutions. By combining constriction factor it will guarantee the local solutions. To validate the excellence of the proposed method , it will first to be tested on the IEEE 30-bus power system and then compared with the Lagrange method and the Improved Particle Swarm Optimization (IPSO). After that, the method was tested on a real system that is 150 kV interconnection systems of South and West Sulawesi (SULSELBAR).

2. METHODS

2.1 Formulation Problems and Limitations

In general the function of the cost of power generation can be formulated mathematically as an objective function as given in the following equation:

$$F_T \qquad (1)$$

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

with :

F_T = total power generation cost (Rp)

$F_i(P_i)$ = input-output cost function of power generation *i* (Rp/hour)

a_i, b_i, c_i = cost coefficient of power generation *i*

P_i = output power generation *i* (MW)

N = the number of power generation units

i = index of dispatchable unit

Restrictions that must be met in the calculation are:

1. Limitation of Power Equilibrium

$$\sum_{i=1}^{N} P_i = P_D + P_L \qquad (3)$$

with

$$P_L = P_i^T B P_i \dots\dots\dots\dots\dots\dots (4)$$

where :

P_L = transmission Lost

P_i^T = power generation output *i transposable*

P_i = power generation output *i*

B = coefficient of transmission losses

P_D = power demand load

2. The limit of unit i ability with inequality:

$$P_{i,min} \le P_i \le P_{i,max} \dots\dots\dots\dots (5)$$

where :

P_i = output power generation unit *i*

$P_{i,min}$ = minimum power generation unit *i*

$P_{i,max}$ = maximum power generation unit *i*

2.2 Particle Swarm Optimization

Particle Swarm Optimization (PSO) is one of the evolutionary computation technique, in which a population on the search of algorithm is based on PSO and begins with a population that is random which is called particle [10]. The simplicity of the algorithm and a good perfomance make PSO attract much attention from researchers and has been applied in a variety of operating system power optimization problems[11].

2.2.1 Basic PSO

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In the PSO [8], each particle will move from the original position to a better position with a velocity. Velocity vector of PSO algorithm is updated for each particle and then summing the velocity vector to the particle position. Update velocity on the application of OPF is affected by both the global best solution that is associated with the lowest fee ever obtained by a particle and local best associated with the lowest costs in the initial populations. As for the equation of this basic algorithm is as follows:

$$v_{id}^{k+1} = v_{id}^{k} + c_1 r_1^k \left(Pbest_{id}^k - x_{id}^k\right) + c_2 r_2^k \left(Gbest_d^k - x_{id}^k\right) \quad (6)$$

and

$$x_{id}^{k+1} = x_{id}^{k} + v_{id}^{k+1} \quad (7)$$

with

v_{id}^k = Velocity of particle *i*, dimension *d* at iteration *k*

v_{id}^{k+1} = Velocity of particle *i*, *d* dimension at iteration *k + 1*

x_{id}^k = Position particle *i*, *d* dimension at iteration *k*

x_{id}^{k+1} = Velocity of particle *i*, *d* dimension at iteration *k+1*

r_1^k, r_2^k = Particle positions *i*, *d* dimensions at iteration *k*

c_1, c_2 = Coefficient acceleration

$Pbest_{id}^k$ = Local best position particle *i*, at iteration *k*

$Gbest_{id}^k$ = Global Best position particles *i*, at iteration *k*

2.2.2 IPSO

Inertial weight parameters is incorporated into the standard PSO algorithm. The dynamic equations of the PSO with inertia weigth (*w*) is modified or called with an Improved Particle Swarm Optimization (IPSO) to:

$$v_i^{k+1} = w v_{id}^{k} + c_1 r_1^k \left(Pbest_{id}^k - x_{id}^k\right) + c_2 r_2^k x \left(Gbest_d^k - x_{id}^k\right) \quad (8)$$

On the update process of this velocity, the values of parameters such as *w*, c_1 and c_2 must be determined in advance [7]. In general, the parameter of weigth *w* is obtained by using the following equation:

$$w(i) = w_{max} - \left(\frac{w_{max} - w_{min}}{i_{max}}\right) i \quad (9)$$

where

$w(i)$ = inertia weigth at iteration *i*

$w_{max} - w_{min}$ = initial and final inertia weigth

i_{max} = maximum iteration

i = iteration

2.2.3 MIPSO

Another Parameter is called the Construction Factor (CF) that is used to modify an existing IPSO algorithm known as Modified Improved Particle Swarm Optimization (MIPSO) [12].

A modified velocity equation on each particle by using the construction factor can be expressed with the following equation [9], [15]:

$$v_{id}^{k+1} = CF\, v_{id}^{k} + c_1 r_1^k \left(Pbest_{id}^k - x_{id}^k\right) + c_2 r_2^k \left(Gbest_d^k - x_{id}^k\right) \quad (10)$$

with coefisient constriction :

$$CF = \frac{2}{\left|2 - \varphi - \sqrt{\varphi^2 - 4\varphi}\right|} \quad (11)$$

and

$$\varphi = c_1 + c_2 \text{ and } \varphi > 4 \quad (12)$$

In general, the researchers applied a constriction with a value of φ = 4 then the value of $c_1$dan $c_2$to be set equal to 2:05 and so the value of the CF = 0.729 [3].

2.3 Implementation MIPSO

This section outlines the implementation of Modified Improved Particle Swarm Optimization algorithm method in calculation of the cost of an economic generation [15].

2.3.1 Initialization

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On initialization process, groups or populations is randomly generated. In this study, the structure of an individual on the issue of economic dispatch consists of a set of elements such as generation output. Therefore, the position of individual i at iteration 0 can be represented as a vector X_i^0=(P_{i1},….,P_{in}) where n is the number of power generation in the calculation of economic dispatch.

2.3.2 Update Velocity

To modify the position of each individual so that the positions of particles transported from its original position then needs to be calculated velocity on satge here that have been modified using inertial weigth as given equation (12).

2.3.3 Update Particle Position

The position of each particle can be modified by using the equation (7), and thus obtained the position of a new particle. Because of the position of the particle are obtained with the results of these modifications can not provide guarantee to fulfill the inequality constraint due to the over/under of velocity, then the position of the individual that has been modified will be set back by using the equation (13). At the same time equality constraint [14] equation (3) must also be met. (13)

$$P_{ij}^k = \begin{cases} P_{ij}^k & if\ P_{ij,min} \le P_{ij}^k \le P_{ij,max} \quad i \\ P_{ij,min} & if\ P_{ij}^k < P_{ij,\min} \quad i \\ P_{ij,max} & if\ P_{ij}^k > P_{ij,\max} \quad i \end{cases}$$

2.3.4 Update P_{best} and G_{best}

P_{best} of each particle on the iteration $k + 1$ was modified by using the following equation [3] :

$$P_{best}{}_i^{k+1} = X_i^{k+1}\ if\ TC_i^{k+1} < TC_i^k$$
$$P_{best}{}_i^{k+1} = P_{best}{}_i^{k}\ if\ TC_i^{k+1} \ge TC_i^k \quad (14)$$

with,

TC_i is the objective function evaluated at the position of the particle i.

X_i^{k+1} is the position of the particle i at iteration k+1

$P_{best}{}_i^{k+1}$ is the best position of particle i until iteration k + 1

The optimal solution is obtained by comparing the value of the objective function for all combinations of power generation [16]. Operating costs are dominated by the cost of fuel on the evocation is used as an objective function. As shown on the Flowchart of MIPSO Algorithm which is proposed in this study is indicated in the following:

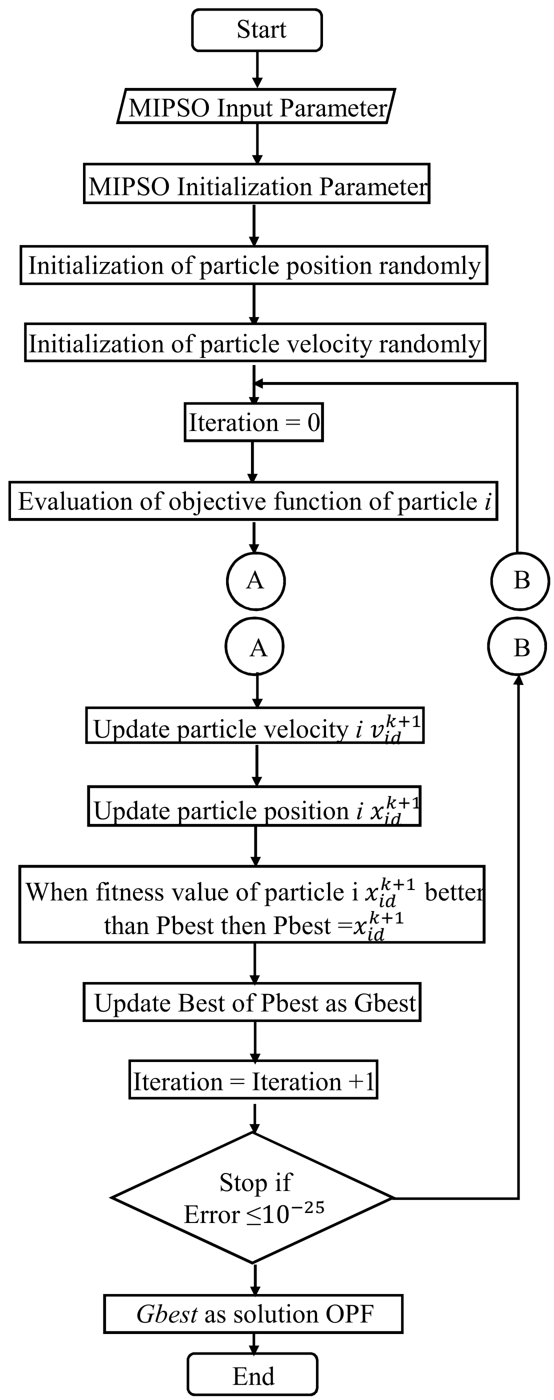

Figure 1 : MIPSO Algorithm Flowchart

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3. SIMULATION AND RESULT

In the simulation of the application of the MIPSO Algorithm method is performed in 2 system cases:

1. Case IEEE 30 Bus system, and
2. Case 150 kV Interconnection System SULSELBAR.

3.1 Case IEEE 30 Bus System

Electric power systems of IEEE 30-Bus with 189.2 MW load consists of 6 generating unit on bus 1, bus 2, bus 13, bus 22, bus 23, and bus 27, where bus 1 as slack bus. Data used in the simulation are shown in table 1, table 2 and Table 3. Each shows a data bus, data line and data cost functions as well as the limitations of the generation.

Table 1. Bus Data

No	Bus Type	Vm	Load		Generation	
			MW	MVar	MW	MVar
1	1	1	0	0	23.54	0
2	2	1	21,7	12,7	60.97	0
3	0	1	2,4	1,2	0	0
4	0	1	7,6	1,6	0	0
5	0	1	0	0	0	0
6	0	1	0	0	0	0
7	0	1	22,8	10,9	0	0
8	0	1	30	30	0	0
9	0	1	0	0	0	0
10	0	1	5,8	2	0	0
11	0	1	0	0	0	0
12	0	1	11,2	7,5	0	0
13	2	1	0	0	37	0
14	0	1	6,2	1,6	0	0
15	0	1	8,2	2,5	0	0
16	0	1	3,5	1,8	0	0
17	0	1	9	5,8	0	0
18	0	1	3,2	0,9	0	0
19	0	1	9,5	3,4	0	0
20	0	1	2,2	0,7	0	0
21	0	1	17,5	11,2	0	0
22	2	1	0	0	21.59	0
23	2	1	3,2	1,6	19.2	0
24	0	1	8,7	6,7	0	0
25	0	1	0	0	0	0
26	0	1	3,5	2,3	0	0
27	2	1	0	0	26.91	0
28	0	1	0	0	0	0
29	0	1	2,4	0,9	0	0
30	0	1	10,6	1,9	0	0

Table 2. Line Data

from bus	to bus	R	X	1/2B
		pu	pu	pu
1	2	0.02	0.06	0.015
1	3	0.05	0.19	0.01
2	4	0.06	0.17	0.01
3	4	0.01	0.04	0
2	5	0.05	0.2	0.01
2	6	0.06	0.18	0.01
4	6	0.01	0.04	0
5	7	0.05	0.12	0.005
6	7	0.03	0.08	0.005
6	8	0.01	0.04	0
6	9	0	0.21	0
6	10	0	0.56	0
9	11	0	0.21	0
9	10	0	0.11	0
4	12	0	0.26	0
12	13	0	0.14	0
12	14	0.12	0.26	0
12	15	0.07	0.13	0
12	16	0.09	0.2	0
14	15	0.22	0.2	0
16	17	0.08	0.19	0
15	18	0.11	0.22	0
18	19	0.06	0.13	0
19	20	0.03	0.07	0
10	20	0.09	0.21	0
10	17	0.03	0.08	0
10	21	0.03	0.07	0
10	22	0.07	0.15	0
21	22	0.01	0.02	0
15	23	0.1	0.2	0
22	24	0.12	0.18	0
23	24	0.13	0.27	0
24	25	0.19	0.33	0
25	26	0.25	0.38	0
25	27	0.11	0.21	0
28	27	0	0.4	0
27	29	0.22	0.42	0
27	30	0.32	0.6	0
29	30	0.24	0.45	0
8	28	0.06	0.2	0.01
6	28	0.02	0.06	0.005

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Tabel 3. The Generation cost function and Limits

Unit	Data Power Generation		
	Cost Function (\$/Jam)	MW Limits	
		Min (MW)	Max (MW)
1	$0 + 2\,P_1 + 0.02\,P_1^2$	20	80
2	$0 + 1.75\,P_1 + 0.0175\,P_1^2$	20	80
3	$0 + 1\,P_1 + 0.0625P_1^2$	15	50
4	$0 + 3.25\,P_1 + 0.0083P_1^2$	10	55
5	$0 + 3\,P_1 + 0.025P_1^2$	10	30
6	$0 + 3\,P_1 + 0.025P_1^2$	12	40

The case of the IEEE 30-bus system used a parameter that is used to implement the MIPSO algorithm methods to complete generation optimization system of the IEEE 30-bus that is the value of the inertia weight (0.9-0.2) [11] total swarm = 50, maximum iterations = 1000, acceleration Coefficient ac_1=ac_2= 2.05, with total load of 189.2 MW.

Table 4. Comparison of results of IEEE 30 Bus System Simulation

Unit	Metodh		
	Lagrange	IPSO	MIPSO
1	44.124	42.397	44.051
2	57.650	56.772	57.511
3	23.015	22.570	22.975
4	32.856	35.891	36.818
5	16.702	17.265	15.222
6	17.493	16.876	15.266
Power Load (MW)	189.200	189.200	189.200
Total Load (MW)	191.839	191.772	191.844
cost (\$/h)	575.32	575.29	575.28
Power Loss (MW)	2.648	2.580	2.644

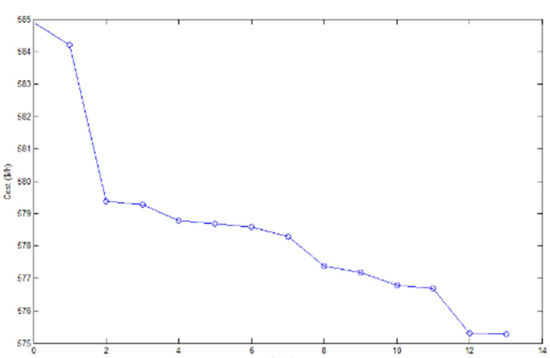

Figure 2. The curve of MIPSO minimum cost solution search

Simulated results on Table 4 showed that the most optimal solution obtained by MIPSO method with minimum fuel costs at 575.28 \$/hour. The search curve solution cost is reached at 13 number of iterations which is shown in Figure 2.

3. Case 150 kV Interconnection System SULSELBAR

In the case 150 kV Interconnection System SULSELBAR which consists of 7 thermal power generation and 3 water power generation, 28 bus and 34 channels. Table 5 shown a list of bus names and Type in the system.

Table 5. List of the name and bus type

No	Bus Type	Bus Name	No	Bus Type	Bus Name
1	2	Bakaru	15	0	Tallo Lama
2	0	Polmas	16	0	Sungguminasa
3	0	Majene	17	0	Tanjung Bunga
4	0	Mamuju	18	2	Tallasa
5	0	Pinrang	19	0	Maros
6	2	Parepare	20	1	Pagaya
7	0	Sidrap	21	0	Jeneponto
8	2	Balusu	22	0	Bulukumba
9	0	Barru	23	2	Sinjai
10	0	Pangkep	24	0	Bone
11	0	Bosowa	25	0	Soppeng
12	0	Kima	26	2	Sengkang
13	2	Tello	27	2	Makale
14	0	Panakukang	28	2	Palopo

Data of bus, line and cost function as well as the limitation of generation in the case of SULSELBAR 150 Kv Interconnection system is obtained from the data in field through PT. PLN (Persero) UPB region SULSELRABAR on March 11, 2015 At 19.30.

In table 6, The data bus in which the total load is at 655,580 MW, the data channel and the function of the cost of fuel thermal power generations is indicated in table 7 and table 8. For the data of the power generations (Bus 1 Bakaru - bus 23 Sinjai - bus 27 makale) in economic optimization simulation using MIPSO follow PT.PLN generation (Persero) is 126 MW for Bakaru, 9.7 MW for Sinjai and 13.1 MW for Makale. This is due to the operator of hydropower did not look at in terms of fuel costs, but the look of the pattern of water reserves in dams and reservoirs.

MIPSO parameters used in the simulation SULSELBAR 150 Kv Interconnection system is similar to the one simulated in the case of the IEEE

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30 Bus system with the total swarm = 50, Maximum iterations = 1000, acceleration coefficient $ac1$=$ac2$= 2.05, with a total load of 655,580 MW.

Table 6. Bus Data

No	Bus Type	Vm	Load		Generation	
			MW	MVar	MW	MVar
1	0	1.01	4.30	0.20	126.00	0.40
2	0	1.00	14.90	3.80	0.00	0.00
3	0	0.97	11.10	2.20	0.00	0.00
4	0	0.97	16.70	3.00	0.00	0.00
5	0	1.00	23.50	7.00	0.00	0.00
6	2	1.00	17.20	4.60	60.00	19.00
7	0	1.00	25.30	9.00	0.00	0.00
8	2	1.00	0.00	0.00	22.93	9.41
9	0	0.98	9.40	2.40	0.00	0.00
10	0	0.95	22.10	8.00	0.00	0.00
11	0	0.94	40.78	13.35	0.00	0.00
12	0	0.95	14.10	4.50	0.00	0.00
13	2	0.95	48.50	15.50	8.00	5.00
14	0	0.90	69.20	18.40	0.00	0.00
15	0	0.95	37.70	9.70	0.00	0.00
16	0	0.95	35.70	8.40	0.00	0.00
17	0	0.94	41.50	12.80	0.00	0.00
18	2	0.98	23.20	5.30	8.00	3.30
19	0	0.99	16.40	4.00	0.00	0.00
20	1	1.00	0.00	0.00	221.10	71.20
21	0	0.99	20.00	4.30	0.00	0.00
22	0	0.96	28.80	7.30	0.00	0.00
23	0	0.95	14.90	6.90	9.70	-1.51
24	0	0.96	28.80	8.20	0.00	0.00
25	0	1.00	13.10	4.20	0.00	0.00
26	2	1.03	25.00	9.20	216.50	2.30
27	0	1.03	8.80	2.10	13.10	2.89
28	2	1.03	44.60	7.30	5.00	1.80

Tabel 7. Line Data

From bus	To bus	R	X	1/2B
		pu	pu	pu
1	2	0.03	0.09	0.01
2	3	0.05	0.19	0.00
3	4	0.03	0.11	0.01
1	5	0.03	0.11	0.01
2	6	0.04	0.13	0.02
5	6	0.01	0.05	0.00
6	7	0.02	0.07	0.00
6	8	0.01	0.08	0.00
8	9	0.01	0.04	0.00
9	10	0.02	0.09	0.01
10	11	0.01	0.04	0.00
10	12	0.01	0.03	0.00
12	13	0.01	0.03	0.00
11	13	0.05	0.17	0.01
13	15	0.01	0.03	0.00
13	14	0.04	0.08	0.00
13	16	0.00	0.03	0.00
16	17	0.01	0.04	0.00
16	18	0.01	0.07	0.00
16	19	0.05	0.37	0.02
18	20	0.02	0.05	0.00
18	21	0.03	0.14	0.02
20	21	0.01	0.07	0.00
21	22	0.05	0.17	0.00
22	23	0.03	0.11	0.01
23	24	0.01	0.15	0.01
22	24	0.03	0.11	0.01
24	25	0.05	0.16	0.00
7	25	0.02	0.20	0.00
25	26	0.02	0.13	0.00
7	26	0.01	0.07	0.00
7	27	0.06	0.38	0.01
7	19	0.01	0.08	0.00
27	28	0.04	0.14	0.00

Tabel 8. Cost Function Thermal Generation

Unit	Cost Function (Rp/hour)x1000
1	-2.5302e-14 + 1908.44 P_1 + 1.8497e-11P_1^2
2	-2.4144e-14 + 427.4P_1 - 1.1182e-11P_1^2
3	1.3736e-12 + 2240.9 P_1 + 7.1332e-11P_1^2
4	-3.6365e-14 + 1917.8 P_1 - 4.5984e-11P_1^2
5	6.346e-15 + 432.75 P_1 + 1.9212e-10P_1^2
6	-4.7539e-15 + 427.78 P_1 - 1.0608e-10P_1^2
7	1.587e-13 + 2634.3P_1 + 1.3227e-11P_1^2

Tabel 9. Limits Thermal Power Generation

Unit	Min (MW)	Max (MW)
1	15.00	60.00
2	9.68	38.73
3	2.00	8.00
4	5.00	8.00
5	55.59	222.35
6	54.88	219.50
7	1.25	5.00

Tabel 10. Result of Simulation of SULSELBAR 150 kv System

Unit	Real System (MW)	MIPSO (MW)
1	126	126
2	60	44.67
3	22.93	34.42
4	8	2
5	8	5
6	221.1	222.1
7	9.7	9.7
8	216.5	219.5

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9	13.1	13.1
10	5	1.25
Power Load (MW)	655.580	655.580
Total Load (MW)	690.33	677.74
Cost (Rp/hour) x1000	376549	324842
Power Loss (MW)	27.408	28.308
Diference in cost (Rp/hour) x1000	-	51.707

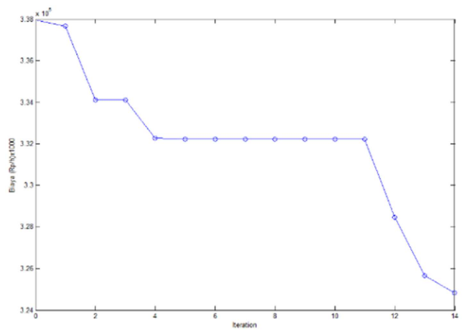

Figure 3. the curve of MIPSO search of minimum cost solution

The results of MIPSO simulations that are compared with real system data of PT. PLN (Persero) indicated in table 10. Economical optimization solutions that are visible by the method of MIPSO with the total cost per hour of Rp.324,842,000.- compared with real data sytem with total cost at Rp. 376,549,000.-per hour, so the costs that can be reduced by MIPSO method is at Rp.51,707,000.-. A search of the optimal solution of the economy reached at the 14th iteration as shown in Figure 3.

4. CONCLUSION

Based on the results of simulations using MIPSO method, the result simulated in IEEE 30 bus system as a form of validation showed minimum of 575.28 ($/hour) as compared to the Lagrange method at 575.32 ($/hour) and the IPSO at 575.29 ($/hour), and then MIPSO method is simulated in the SULSELBAR 150 Kv Interconnection system which compared to the real system operating costs amounting to Rp. 376,549,000,- per hour decreased to Rp. 324,843,000,- per hour, so there is a cost savings at about Rp. 51,706,000.- or around 13.73%.

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