Optimizing Three Power Plants' Output Power Using Firefly Method

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***Abstract*—**Continuing the previous article that use merit order, the simplest method in economic dispatch, this article pursue to optimize the output of three power plants using more advanced algorithm, the firefly. The plants used are similar to the previous paper which are three generators used to supply a load of 975 MW. Simulation is used by taking into account losses. The results show that in spite of having higher losses, firefly algorithm managed to calculate a better result than merit orders did by 0,15%.

Keywords—Economic dispatch, firefly, merit order

I. Introduction

Managing power plant output has become an interesting issue for electric and power plant companies as it will reduce the total cost of the electric they use. The amount of power every power plant produce can be engineered easily without sacrificing the other parameters such as the load. This engineering process is called economic dispatch of power plants.

There are several methods to determine the power plant produced power that already used widely, and the most popular one is merit order method. This method was already used in the previous article [9] to determine the power of three power plants. This method offers a very simply algorithm as it only make an order of the existing power plant based on the heat rate and function cost of the particular power plants. Moreover, this method is also widely used especially in Perusahaan Listrik Negara, the Indonesian electric company, to determine the output of each power plant. However, there is one disadvantage of this method which is its inability to represent the real valid order because it simplifies the main function cost into an average number.

This paper tries to implement firefly algorithm to solve the same problem as the initial article. The total cost and total losses between the proposed method and merit order will be compared in this article.

II. Methods

This paper combined firefly algorithm and power flow equation. The firefly algorithm is used to determine the best output power of the power plant, and the losses, voltage, and other parameters is calculated using power flow equation.

A. Power Plants Parameters

There are three power plants that are used in this article. Each of the power plant share a different parameter such as minimum and maximum power capacity and cost function. Table 1 depicts the parameters of each power plant.

Table 1. Power plant parameters

Index	Pmin (MW)	Pmax (MW)	Cost Function (Rp/h)
Power plant 1	200	450	$500 + 5.3P + 0.004P^2$
Power plant 2	100	225	$200 + 5.8P + 0.009P^2$
Power plant 3	150	350	$400 + 5.5P + 0.005P^2$

B. Line Parameters

The simulation that considers the losses uses a 4 bus configuration consisting of 3 generator buses and 1 load bus. Network configuration and data can be seen in table 2. To obtain the value of losses, the power flow equation is used, which in this simulation uses software from Hadi Saadat's book [10].

Table 2. Power plant parameters

Initial Bus	Destination Bus	R (pu)	X(pu
1	2	0.0012	0.0013
2	4	0.0017	0.0017
3	3	0.0007	0.0011
4	1	0.0015	0.0018

C. Firefly Algorithm

A basic firefly algorithm is inspired from firefly behavior in the nature. Each firefly will fly into particular direction, based on the brightness of the other fireflies. The less bright firefly will move to brighter firefly whereas the brightest firefly will move randomly. Basic of firefly movement can be calculated using following equation [7]:

$$X_i^{t+1} = X_i^t + \beta e^{-\gamma r_{ij}}(X_j - X_i) + \alpha\epsilon \quad (1)$$

X_i and X_j represent a less bright firefly of i and a brighter firefly j position, respectively. β represent firefly attractiveness factor or firefly speed movement. Light absorption coefficient is represented by γ coefficient. The parameter α represent random coefficient, and ϵ represent random vector. In this article, each firefly represents the power of power plant, and the objective function that represent firefly brightness is total cost of the power plant.

Fig. 1 Firefly movement illustration

B. Proposed Method

The main idea of the proposed method is use the firefly algorithm to determine the power output instead of using

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merit order method. There are two parameters in a single firefly used in this simulation which represent power plant 2 and 3. The first power plant will be selected as the slack bus. The proposed firefly then will be applied in power flow calculation that will produce both total generations cost as well as losses. The total generation cost will be used as the firefly brightness or the objective function of this simulation.

The next step is firefly movement step using equation (1). The less bright firefly will move towards the brighter one whereas the brightest will move randomly. This step will take place in maximum 200 iterations. The flowchart of proposed algorithm is presented in fig 2 followed by the source code.

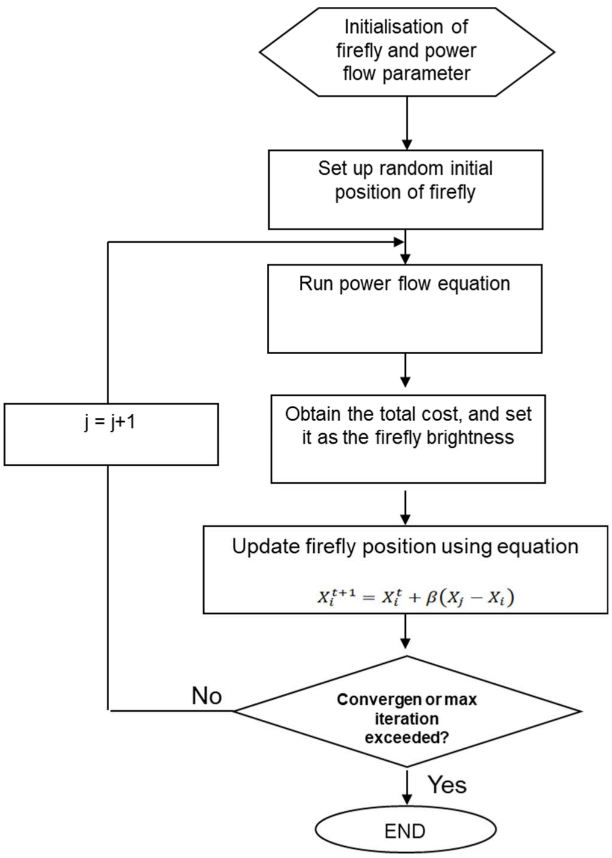

Fig. 2 Firefly movement illustration

```
clc
clear

basemva = 100; accuracy = 0.001; accel = 1.2;
maxiter = 900;

Load=975;

Lb=[200; 100; 150];
Ub=[450; 225; 350];
Mb=(Lb+Ub)/2;


% aP^2 + bP + c
CF=[ 0.004 5.3 500
 0.009 5.8 200
 0.006 5.5 400];

IC=[2*CF(1,1) CF(1,2)
 2*CF(2,1) CF(2,2)
 2*CF(3,1) CF(3,2)];


Rp(1)=(IC(1,1)*Mb(1))+IC(1,2);
Rp(2)=(IC(2,1)*Mb(2))+IC(2,2);
Rp(3)=(IC(3,1)*Mb(3))+IC(3,2);


betaff = 0.01;
alphaff = 0.01;
jff = 50;
error = 1000;
errorm = 0.001;
itermff = 200;
iterff=0;


for iff=1:jff
 ff(iff,1) = round(rand*(Ub(2,1)-
Lb(2,1)))+Lb(2,1);
 ff(iff,2) = round(rand*(Ub(3,1)-
Lb(3,1)))+Lb(3,1);
end

while iterff<itermff
 iterff = iterff+1
 ff;
 for iff=1:jff
 iff;


busdata=[1 1 1.0 0.0 0.0 0.0 0.0  0.0 0 0 0
  2 2 1.0 0.0 0.0 0.0 ff(iff,1) 0.0 0 0 0
  3 0 1.0 0.0 Load 0.0 0.0  0.0 0 0 0
  4 2 1.0 0.0 0.0 0.0 ff(iff,2) 0.0 0 0 0];


linedata=[1 2 0.0012 0.0013 0  1
  2 4 0.0017 0.0017 0  1
  4 3 0.0007 0.0011 0  1
  3 1 0.0015 0.0018 0  1];



LFYBUS
LFNEWTON


Totallosses=Pgt-Pdt;

cost(1)=(CF(1,1)*(Pg(1)^2))+(CF(1,2)*Pg(1))+(
CF(1,3));
cost(2)=(CF(2,1)*(Pg(2)^2))+(CF(2,2)*Pg(2))+(
CF(2,3));
cost(3)=(CF(3,1)*(Pg(4)^2))+(CF(3,2)*Pg(4))+(
CF(3,3));
Totalcost=sum(cost);
```


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```
fit(iff,1)=Totalcost;
 end

 if iter == 1
 fflama = ff;
 fitlama = fit;
 end

 for iff=1:jff
 for kff=1:jff
  if fit(iff,1) <= fit(kff,1)
  ff(kff,1) = ff(kff,1)+betaff*(ff(iff,1)-
ff(kff,1));
  ff(kff,2) = ff(kff,2)+betaff*(ff(iff,2)-
ff(kff,2));
  end
 end
 end
 min(fit(:,1))

end

if sum(Pg)<=sum(Ub)
 fprintf('------------------------------------
-----------')
 fprintf('\n')
 BUSOUT
 Totallosses
 Totalcost
 fprintf('\n')
 fprintf('------------------------------------
-----------')
 fprintf('\n')
end

if sum(Pg)>sum(Ub)
 fprintf('------------------------------------
-----------')
 fprintf('\n')
 fprintf('overload')
 fprintf('\n')
 fprintf('------------------------------------
-----------')
 fprintf('\n')
end
```

III. Results and Discussion

The simulation is taken to verify the performance of proposed method, and compare it to the previous result. The simulation result is depicted in the fig 3 whereas the previous merit order is depicted in fig 4.

Maximum Power Mismatch = 5.05853e-06
No. of Iterations = 3

Bus No.	Voltage Mag.	Angle Degree	------Load------ MW	Mvar	---Generation--- MW	Mvar	Injected Mvar
1	1.000	0.000	0.000	0.000	481.599	-123.713	0.000
2	1.000	0.004	0.000	0.000	186.566	-185.186	0.000
3	0.995	-0.612	975.000	0.000	0.000	0.000	0.000
4	1.000	-0.352	0.000	0.000	313.583	317.456	0.000
Total			975.000	0.000	981.748	8.557	0.000

Totallosses =

6.7485

Totalcost =

8.2903e+03

Fig. 3 The result of proposed method simulation

Power Flow Solution by Newton-Raphson Method
Maximum Power Mismatch = 3.84816e-006
No. of Iterations = 3

Bus No.	Voltage Mag.	Angle Degree	------Load------ MW	Mvar	---Generation--- MW	Mvar	Injected Mvar
1	1.000	-0.021	0.000	0.000	450.000	-98.122	0.000
2	1.000	0.000	0.000	0.000	181.330	-179.213	0.000
3	0.995	-0.600	975.000	0.000	0.000	0.000	0.000
4	1.000	-0.322	0.000	0.000	350.000	285.472	0.000
Total			975.000	0.000	981.330	8.137	0.000

Totallosses =

6.3304

Totalcost =

8.3026e+003

Fig. 4 The result of the merit order simulation

From the simulation result above, the comparison between proposed method and merit order can be presented. Despite having higher losses, the proposed algorithm produces a better solution in terms of total cost without scarifying the load. It means that the power plants success to supply the load with a lower cost. The total cost has been lowered from 8.3026e+03 to 8.2903e+03, which is 0,15 % from the initial total cost.

. IV. Conclusion

Ensure that the conclusion is related to the title, purpose, and contribution of the paper.

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