Dynamic optimal power flow calculates

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Submission date: 13-Sep-2022 03:40AM (UTC-0400)
Submission ID: 1898696515
File name: Dynamic_optimal_power_flow_calculates.pdf (514.85K)
Word count: 3388
Character count: 16342

IOP Conference Series: Earth and Environmental Science

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Dynamic optimal power flow calculates intermittent wind turbine using ant colony method

To cite this article: R P Siwi *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **926** 012108

Dynamic optimal power flow calculates intermittent wind turbine using ant colony method

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Abstract. Intermittent is electrical energy that is not available continuously due to uncontrollable external factors generated by a power plant which conditions vary in a reasonably short time scale. Intermittent can be limited or even mitigated by electricity storage, which is a rapidly growing area of research. In this research, the renewable energy used is the wind turbine. This study aims to schedule an economic generator by considering the intermittent wind turbine. Dynamic optimal power flow calculate Intermittent wind turbine uses ant colony method to determine the value of optimizing system operation with the integrated wind turbine. To determine the optimization value of the system operation, this study use a south sulawesi system consisting of 76 buses, 21 generators, and two wind power plant. From the results of the dynamic optimal power flow simulation, it is found that the generation costs are reduced from the real system costs using the ant colony method when the peak load time is 18.28% and the out peak load time is 18.08%, so that in only two times the ant colony optimization method, can reduce the cost of generation by Rp. 121,123,830.

1. Introduction

The demand for electrical energy is increased along with the development of the times, causing providers to be required to provide sufficient supply. With the development of science and technology, renewable energy is starting to become an option to reduce dependence on fossil energy [1].

In order to meet the increasing demand for electricity, it is necessary to have adequate power generation infrastructure and refer to economic principles [2]. In other words, the generator must meet the power required by consumers, and the generator is obliged to minimize the total cost of generation. When the Southern Sulawesi electricity system is interconnected, the Southern Sulawesi electricity system plays a role in increasing the reliability of the electricity system, so the supporting facilities for the electricity system are required to operate in optimal conditions, because this will affect the stability when operating [3].

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Renewable Energy is an alternative energy that can be used to replace natural energy on earth [4]. Natural fuels on earth cannot be obtained easily. This is caused by the process of formation of the earth's energy which lasts hundreds to thousands of years. Therefore, we need a new energy source that can be used without fear of running out. In Indonesia, it can be a very good place to develop alternative energy [5]. With Indonesia's rich nature, it is very easy to find various energy sources that are more environmentally friendly. In particular, areas located in the Southern Sulawesi electricity system have many potential renewable energy sources (RE), such as Biomass, Water, Wind and Solar Energy, which need to be developed in order to meet the long-term demand for electrical energy [6].

The existence of a wind power plant will cause a change in the flow of power in the existing system, and will be able to affect the overall cost of generation. With the wind turbine, an evaluation of the electrical system needs to be done to update the data system [7]. This data is useful in the operation of the system as well as design material for the development of the electricity system in the future, especially on the operating costs of the generation [8]. The existence of load variations and intermittent wind turbine power supply in the system will affect the electrical system as well. Therefore, an analysis of the system needs to be done to find out such effects [9].

Dynamic optimal power flow is a method for scheduling the online generator output with the required load demand over a certain time range, so that the system can be operated economically. The conventional optimal power flow is one of the important optimization problems in the electrical system. OPF aims to meet load demand with minimum production costs [10]. At this time, the price of fuel has increased, so the cost of generating electricity has also increased. It is salient to determine how to generate electricity with minimum costs in the electrical system but still meet these conditions, but only for one time.

This study aims to solve the problem of optimal power flow by considering the load over a certain time range. This study discusses the optimal dynamic power flow taking into account intermittent wind power plants using the ant colony method. With this ant colony method, it is hoped that the results can be used as a reference in the optimal power generation and distribution operation, especially regarding the cost of generation at any time.

2. Dynamic Optimal Power Flow

Dynamic Optimal power flow (DOPF) is a load scheduling optimization process that aims to determine the generator's active power schedule to serve fluctuating load requests without violating the predetermined limits and looking for the cheapest generation. In previous research, more optimization methods and algorithms were developed for use in DOPF, including; Lambda Iteration[6], Particle Swarm Optimization (PSO)[11], Biogeography-Based Optimization (BBO)[12], Krill Herd Algorithm (KHA)[13], Culture Algorithm (CA)[14], Charged System Search (CSS))[15], Novel Bat Algorithm (NBA)[16], Genetic Algorithm (GA)[17].

In this study, the Ant Colony method was used to solve DOPF in the Southern Sulawesi electricity system, consisting of 76 bus, 21 generators. Optimal power flow includes various optimization variables such as power balance and generator capacity limits. The mathematical equation in solving the optimal power flow is as follows:

$$F(P_g) = \sum_{n}^{n} = 1(a_i P_{gi}^2 + b_i P_{gi} + c_i) \quad (1)$$

The Economy Shipping Limits are as follows.
Power balance limit:

$$\sum_{n=1}^{n} P_i = P_d + P_L \quad (2)$$

Optimal Active Power Formula:

$$P_{Ga} - P_{Da} = V_a \sum_{n=1}^{NB} V_b (G_{ab} \cos(\theta_a - \theta_b) + B_{ab} \sin(\theta_a - \theta_b)) \quad (3)$$

Information:
$F(P_g)$ = Total generation costs

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$a_i, b_i, c_i,$ = The coefficient of fuel costs
P_d = Power Load
$P_L,$ = Losses
G_{ab}, B_{ab} = Admittance of line a,b

In general, power losses as in the following formula.

$$P_L = I^2 R \quad (4)$$

Where:
P_L = Power losses
I^2 = current flowing on line (ampere)
R = resistance on line (ohm/ Ω)

2.1 Intermittent

Intermittent electricity is electrical energy that is not available continuously due to uncontrollable external factors, generated by power generating sources which conditions vary in a fairly short time scale. Intermittent power sources include solar power, wind power, tidal power, and wave power. Although solar and tidal power are quite predictable (length of days, weather patterns, tidal cycles), they are still intermittent because the duration of electricity can be made limited[18]. Due to this variable power generation, these sources are considered non-deliverable, which means that their electricity output cannot be used at any given time to meet the community's fluctuating electricity demand[19].

Intermittent can be limited or even overcome by the use of electricity storage, which is a rapidly growing area of research. These intermittent sources can store their electricity for later use, and once this setup is perfected, the possibilities are truly endless. Tesla Motors is already mass-producing such energy storage devices, which can harness the sun's intermittent energy by connecting to solar panels, allowing homeowners to use their solar power during non-usable hours. Owners of these storage devices can avoid paying peak time prices for electricity, and have a reliable source of power at all times even in the event of a power outage. The most common and highest contributing intermittent source is wind.

Wind speed determines the amount of electricity generated by the turbine. Higher wind speeds produce more power because stronger winds allow the blade to rotate faster. Faster rotation means more mechanical power and more electrical power from the generator [20].

2.2 Wind Power Plant

With the existence of a wind turbine, wind energy can be used as a wind power plant. Now more wind turbines are used to accommodate the electricity needs of the community by using the principle of conversion and using renewable natural resources, namely wind. Conventional power plants such as diesel power plants and steam power plants, wind turbines are still being developed by scientists because in the near future humans will be expected to face the problem of lack of non-renewable natural resources as the basic material for generating electricity. With the presence of wind energy as unconventional, wind energy can replace fossil fuel energy as an energy resource on earth [21].

The basic differences from the Wind Power Plant in southern Sulawesi:

• Tolo Wind Power Plant:
  a) capacity : 144 MW
  b) Wind turbine : 20 Unit
  c) Tower height : 132 m
  d) Length of propeller : 64 m
  e) Total production : 142.86 MWh

• Sidrap Wind Power Plant:
  a) Capacity : 75 MW
  b) Wind turbine : 30 Unit

c) Tower height : 80 m
d) Length of propeller : 57 m
e) Total production : 35,000 MWh

2.3 Ant Colony Optimization
This method was first discovered by Marco Dorigo (1991) which is a technique to determine the shortest path between a source point and a destination area. At first, the ants are looking for a random trajectory. When the ants find a food source, the ant will walk back to the nest by leaving a trail of pheromones that show the way to the food source. When other ants find the pheromone trail, the other ants will follow the pheromone trail to the food source. The ants then direct the colony to the pheromone trail. When the ants bring food back to the nest, the pheromone trail gets thicker. The pheromone trail will be thicker because so many ants pass through the same trajectory. The pheromone traces in the distant trajectory will gradually evaporate and disappear [22], as shown in Figure 1.

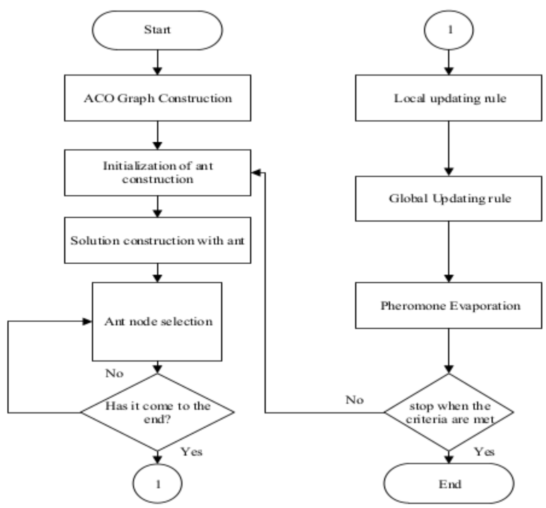

Figure 1. ACO Algorithm Flowchart

This starts to stop when the ants find another food source. Each ant is a simple agent that has the following characteristics:

a. Ants choose the vertices to visit by considering probabilities. The probability here is a function that is affected by the node distance and the amount of pheromone contained in an arc.
b. So that ants do not get stuck in the same path, visits to nodes that have been visited are not allowed.
c. The ant leaves a trail in an arc it passes through.

3. Result and Discussion
This study offers a method to determine the economic operating costs of a wind power plant using the ant colony optimization (ACO) method. Then test the results of the Dynamic Optimal Power Flow (DOPF) simulation using ACO meeting the equality and inequality limits. This simulation was carried out to test the

application of the ACO method to the DOPF problem. This test is carried out to find out whether the ACO method is good or not to be implemented in DOPF problems.

For testing the simulation case, the southern Sulawesi electricity system has 21 generators at Peak Load Time (PLT) at 19.00 WITA and Outside Peak Load Time (OPLT) at 11.00 WITA as shown in Figure 3.1. The results of the simulation of Dynamic Optimal Power Flow obtained from the Ant Colony method with wind power plant data seen in Table1.

Table 1. Simulation Results of DOPFPLTP at 19.00 WITA and OPLT at 11.00 WITA using the ant colony optimization (ACO) method

Unit Bus	Peak Load Time 19.00 WITA				Outside Peak Load Time 11.00 WITA			
	Real System		ACO		Real System		ACO	
	MW	Rp/hour (x1000)	MW	Rp/hour (x1000)	MW	Rp/hour (x1000)	MW	Rp/hour (x1000)
1	173.93	74404	148.944	63715.184	294.295	125890	152.798	65364.099
5	7.08	175	10.736	265.072	0	0	0	0
6	5.53	137	6.164	152.189	5.4	130	7.36	181.718
8	18.7	32360	15	25957.500	0	0	0	0
10	2	49	9.68	238.999	2	50	7.04	173.818
16	0	0	0	0	0.4	630	13.44	21319.872
17	162.05	70127	138.24	59823.36	112.76	48800	73.44	31781.160
18	180.53	78124	186	80491.500	114.05	49360	202	87415.500
19	180.56	78137	112	48468	182.46	78960	88	38082.000
29	0	0	0	0	0	0	0	0
34	14.9	119	19.135	153.082	16.9	140	19.939	159.514
43	33.91	14493	52	22224.800	30.36	12980	56.8	24276.320
45	0	0	0	0	0	0	0	0
46	0.36	3	1.455	11.642	2.29	20	1.51	12.077
49	122	976	126	1008	122	980	120.96	967.680
52	40.2	17181	35.2	15044.480	25.54	10920	31.2	13334.880
60	0	0	0	0	0	0	0	0
62	144	2392	184.08	3057.569	25.5	420	185.64	3083.480
63	30.6	508	118.08	1961.309	110.2	1830	120	1993.200
75	13.51	5774	7.488	3200.371	12.98	5550	17.856	7631.654
76	90.51	38684	56	23934.400	86.14	36820	48	20515.200
PLT 19.00 WITA			Real	ACO	OPLT 11.00 WITA		Real	ACO
Losses (MW)			18.211	24.042	*Losses* (MW)		20.995	23.703
Total Beban (MW)			1202.160	1202.160	Total Beban (MW)		1122.280	1122.280
Total Pembangkitan (MW)			1220.370	1226.202	Total Pembangkitan (MW)		1143.275	1145.983
Total Biaya(Rp/h x1000)			413643	349707.46	Total Biaya(Rp/h x1000)		373480	316292.17

From the simulation results of Dynamic Optimal Power Flow by considering intermittent 2 wind turbines, the ant colony method can provide economical scheduling results at low cost. As shown in Table 1, Peak Load Time at 19.00 WITA, the real system wind turbine on bus 16 is not active, but the wind turbine on bus 8 supplies 18.7 MW of power with the total power supplied by the entire generator is 1220.370 MW at a cost of Rp. 413,643,000. After optimizing the ACO method, it can reduce the generation cost to Rp. 349,707,460 with a total generated power of 1226,202 MW, so that the difference in the total cost of generation is Rp. 63,936,000 or 18,28%. The DOPF solution search curve by the Ant Colony Optimization Method is shown in Figure 2 and Figure 3.

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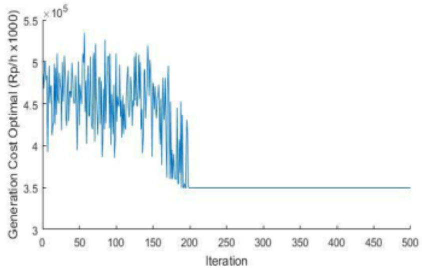

Figure 2. Results of the cost generation optimization graph with ACO Peak Load Time 19.00 WITA

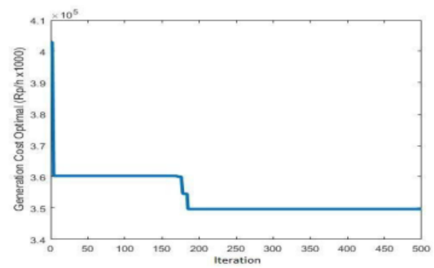

Figure 3. Global Best Tour graph with ACO Peak Load Time 19.00 WITA

Out Peak Load Time 11.00 WITA in Table 1 the real system wind turbine on bus 18 is not active, but the wind turbine on bus 16 only supplies 0.4 MW of power with the total power supplied by the entire generator, which is 1143,275 MW at a cost of Rp. 373,480,000. After optimizing the ACO method, it can reduce the generation cost to Rp. 316,292,170 with a total generated power of 1145,983 MW, so the difference in the total cost of generation is Rp. 57,187,830 or 18.08%. The DOPF solution search curve by the Ant Colony Optimization Method is shown in Figure 4 and Figure 5.

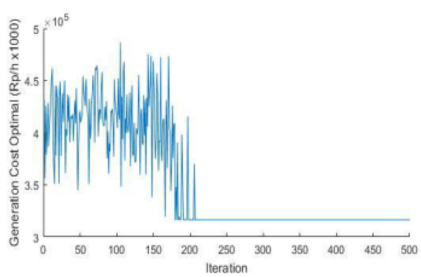

Figure 4. Results of the cost generation optimization graph with ACO Out Peak Load Time 11.00 WITA

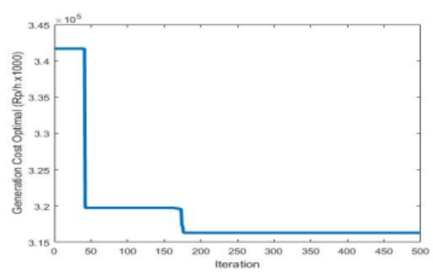

Figure 5. Global Best Tour graph with ACO Out Peak Load Time 11.00 WITA

4. Conclusions

In this study, wind power plants are used to accommodate the electricity needs of the community by using the principle of conversion and using renewable natural resources, namely wind. Optimal power flow includes various optimization variables such as power balance and generator capacity limits. The method that can be used to calculate the DOPF intermittent wind turbine is the ant colony method, the simulation is carried out in two times, namely Peak Load Time at 19.00 WITA and Out Load Peak Time at 11.00 WITA Rp. 63,936,000 and out peak load time of 18.08% or Rp. 57,187,830, so that in just two times the ant colony optimization method can reduce the generation cost of Rp. 121,123,830.

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