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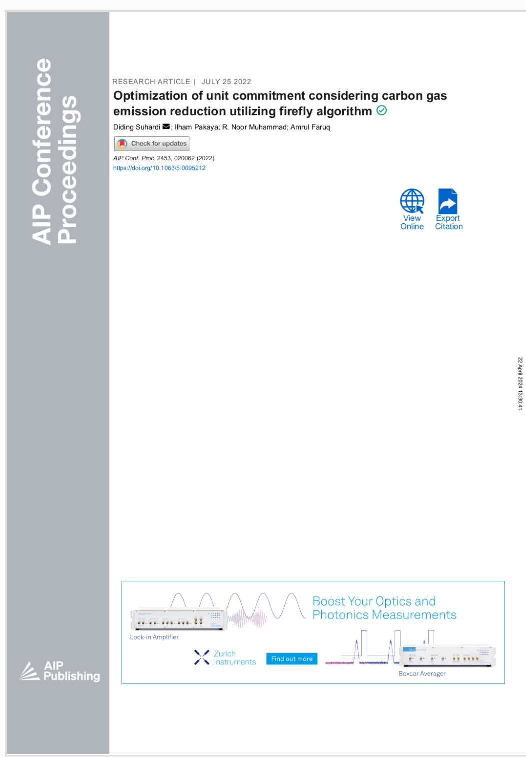
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Optimization of Unit Commitment Considering Carbon Gas Emission Reduction Utilizing Firefly Algorithm

Diding Suhardi[a)], Ilham Pakaya, Muhammad Noor R, Amrul Faruq

Department of Electrical Engineering, Universitas Muhammadiyah Malang, Malang, Indonesia

[a)]Corresponding author: diding@umm.ac.id

Abstract. The necessity for electrical energy has been currently significant to support economic growth in Indonesia, expected to annually increase every year. The increasing demand for electricity denotes that the electrical energy supplied by the generator is relatively large. In general, electricity generation in Indonesia utilizes fossil fuels in the generation process thus it creates emissions in the form of carbon dioxide (CO2), which are released into the air in large quantities. Therefore, planning is deemed instrumental, thereby encouraging that generation scheduling at an economical cost is required in the generation of each unit in order to adjust the load that changes every time. This final project discusses the problem of unit commitment (UC) with the addition of a carbon capture and storage (CCS) system in the generator. The Carbon Capture and Storage (CCS) process refers to a technology capturing up to 85% of carbon dioxide (CO2) emission as, the result of utilizing fossil fuels in electricity generation and industrial processes to prevent carbon dioxide from entering the atmosphere. The optimization algorithm utilized in this final project is the Firefly Algorithm (FA). The objective function that will be optimized lies in the cost of generation, scheduling on and off for each generator and carbon dioxide (CO2) emissions. The data used in this optimization includes the IEEE of 30 bus system and the addition of Carbon Capture and Storage Plants. The test results indicate that the FA method is able to perform UC calculations considering Carbon Capture and Storage.

INTRODUCTION

Electrical energy currently serves as an important requirement to support economic growth in Indonesia, expected to annually increase [1]. The increasing demand for electricity denotes that the electrical energy supplied by generators is enormous. In general, electricity generation in Indonesia utilizes fossil fuels; thus, the generation process creates emissions in the form of carbon dioxide (CO2), released into the air in very large quantities [2].

Currently, it is necessary to plan generation scheduling with economical costs required in generating each unit to adjust the load that changes every time, thereby controlling each unit or commonly called unit commitment (UC)[3]. There are several important factors in addition to regular scheduling, one of which is the emission content resulting from the generation. The emission content of the generation is Sulfur oxide (SO2), Carbon Oxide (CO2) , therefore optimization is required between generation costs, scheduling and emissions by adding a Carbon Capture Storage (CCS) system [4].

Many optimization techniques are available in the literature which can be further subdivided as classical and stochastic techniques, the classical technique currently commonly used is the Lagrange Relaxation (LR) method [5]. The stochastic or metaheuristic method that mainly used in optimization such as Particle Swarm Optimization[6][7], Differential Evolution [8], and Genetic Algorithm [9].This study hence offers a solution by discussing the problem of unit commitment (UC) with the addition of a carbon capture and storage (CCS) system at the plant. The Carbon Capture and Storage (CCS) process contains a technology that can capture up to 85% of carbon dioxide (CO2) emissions, resulting from the use of fossil fuels in power generation and industrial processes to prevent carbon dioxide from entering the atmosphere. The optimization algorithm used in this research is Firefly Algorithm (FA). The objective function to be optimized regards the cost of generation, scheduling of each generator's on and off and carbon dioxide (CO2) emissions. The data used in this optimization is the IEEE 30 bus system and the addition of Carbon Capture and Storage Plants. The test results indicate that the FA method is able to calculate UC considering Carbon Capture and Storage.

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METHODS

The data in this research involves the IEEE 30 bus data. The data on generation contains data on fuel production, data on the minimum and maximum power that can be obtained by each production unit, data on the cost factor function of each production unit, as well as data on the emission factor function in each production unit.

In the IEEE 30 bus system there are 6 units of thermal generator and has 41 channels. The unit cost function of generating units is presented utilizing a non-smooth cost function. The following Table 1, Table 2, and Table 3 presentations illustrate the data that will be the main program input [10].

TABLE 1. IEEE 30 Bus System Generating Unit Limit

Unit	P max (MW)	P min (MW)	On min (hour)	Off min (hour)
1	200	50	4	4
2	80	20	3	2
3	50	15	2	3
4	35	10	2	2
5	30	10	2	2
6	40	12	2	2

Source: Journal (processed)

TABLE 2. IEEE 30 Bus System Operating Costs

Unit	Operating Cost Coefficient					On Cost ($)		Off Cost ($)
	A	B	C	E	f	Hot	Cold	
1	0,00375	2,00	0	18	0,037	70	176	50
2	0,01750	1,75	0	16	0,038	74	187	60
3	0,06250	1,00	0	14	0,400	110	113	30
4	0,00834	3,25	0	12	0,045	50	267	85
5	0,02500	3,00	0	13	0,042	72	180	52
6	0,02500	3,00	0	13,25	0,041	40	113	30

Source: Journal (processed)

TABLE 3 Load Data 1 Day

Hour Time-	Load (MW)	Hour Time-	Load (MW)
01	162.540	13	209.790
02	153.090	14	207.90
03	149.310	15	204.120
04	158.760	16	198.450
05	170.10	17	219.240
06	166.320	18	230.580
07	177.660	19	232.470
08	190.890	20	226.80
09	194.670	21	213.570
10	194.670	22	200.340
11	179.550	23	190.890
12	183.330	24	179.550

FA or commonly called the firefly algorithm because this algorithm is inspired by the behavior of fireflies. Firefly Algorithm becomes one of the methods used in calculating Unit commitment. Fireflies are animals that fly in a pattern. The pattern of light, the number of flashes and the timing of the flashes, are set as some kind of tool used to attract the opposite sex. The light intensity as a result of flashing at a certain distance from the light source corresponds to the inverse square law. The intensity of the light will continue to decrease along with the increasing distance. In addition, the air factor could absorb light, which means longer distances. Of the two factors, the distance between fireflies is limited when combined. The firefly algorithm has 3 main firefly factors including [11]:

1. All fireflies are unisex, thus one firefly will avoid the other fireflies' perception of their gender

2. The attraction of fireflies to one another according to the level of brightness. Fireflies will be attracted to other fireflies when the light is brighter. It is one obstacle in emitting light fireflies, including the distance and absorption of light by the surrounding air environment. Thus, with that the fireflies will move randomly.
3. The brightness or intensity of light on fireflies is affected by the distance and absorption in the air, therefore it is proportional to the value of the objective function.

In its simplest form, the light intensity I (r) varies according to the inverse square law as Equation 1[11].

$$I(r) = \frac{Is}{r^2} \tag{1}$$

In which: *Is* denotes the intensity originating from the source, for a particular medium with a fixed light absorption coefficient. The intensity of light I varies with distance r, including as Equation 2.

$$I = I0e^{-yr} \tag{2}$$

In which, I_o denotes the original light intensity, to avoid the singularity at r = 0 in the expression $\frac{Is}{r^2}$ the effect The combination of an inverse square law and absorption is in accordance with Gaussian, including as Equation 3.

$$I(r) = I0e^{-yr^2} \tag{3}$$

The gap between the fireflies is initiated, and the position of the fireflies is created by placing them at random distribution points in the Cartesian diagram with the formula for the difference between the fireflies and the distance between the two fireflies as Equation 4 [13].

$$rij = \sqrt{(xi - xj)^2 + (yi - yj)^2} \tag{4}$$

The movement of the firefly, attracted to the light produced by the firefly as Equation 5, determined by

$$xi = xa + \beta_0 e{-}yr^2(xi - xj) + \alpha\epsilon \tag{5}$$

RESULTS AND DISCUSSION

This study utilizes the IEEE 30 bus system, having 6 thermal generator units, performed by considering carbon capture storage (CCS) and utilizing the firefly algorithm (FA) method.

FIGURE 1. Hourly generating comparison of cost

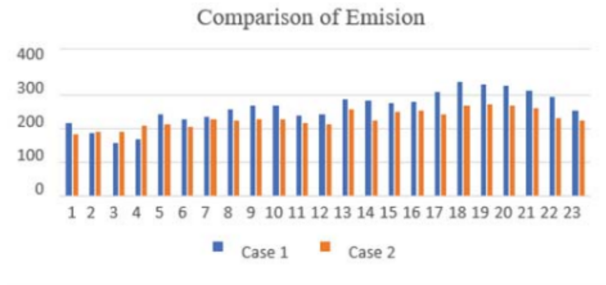

FIGURE 2. Hourly emission comparison

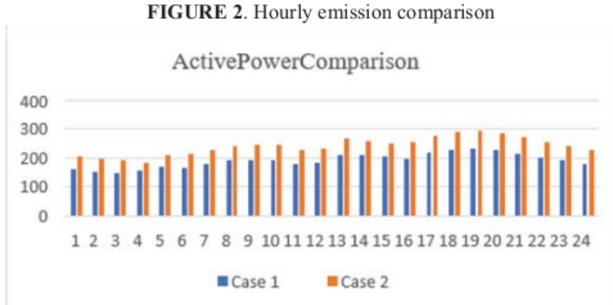

FIGURE 3. Hourly active power comparison

The results of the analysis of the cost of generation indicates the problem of 1 unit commitment with emissions without utilizing CCS is $134,049,841 and total emissions are 62,957,346 Tons/hr. Meanwhile, in the problem of 2-unit commitments with emissions utilizing CCS, the total generation cost is $171,680,633 and the total emissions produced are 55,267,495 Tons/hr. In the analysis of problem 1, the resulting generation costs look much different from problem 2 where the comparison can be seen in Figure 1. Inversely proportional to the emissions produced in problem 1, it appears bigger than problem 2, due to the CCS in problem 2, where the emissions generated in each unit, are actively absorbed. Figure 2 depict the comparison of emission in hourly. However, the power generated is not in accordance with the existing load demand, because the CCS system itself requires power when activated. Thus, the power to activate the CCS system is charged to each generating unit which Figure 3 is shows the comparison of the active power in both case. There are also differences where problem 1 without utilizing CCS and problem 2 utilizing CCS, cautilizing a difference in generation costs of 37,630,792 $ and emissions of 209,222 Ton/hr.

CONCLUSIONS

The FA algorithm has been applied to optimize unit commitments that consider reductions in carbon gas emissions. The simulation results indicate that with the installation of carbon capture storage (CCS); the total generation cost will increase but the amount of carbon dioxide produced is small or can reduce the carbon dioxide emissions produced by the plant. The total cost value in the 1unit commitment problem with emissions without utilizing CCS is $ 134,049.841 and a total emission is of 62,957,346 Tons/hr. Meanwhile, in the problem of 2unit commitments, emissions utilizing CCS are $171,680,633 and total emissions are 55,267,495 Tons/hr. In sum, the iteration value affects the simulation results in the research; for the generator data used, the 200th iteration reaches a convergent value.

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