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Cooperation between power plant in East Kalimantan by integrating renewable energy power plant

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Cooperation between power plant in East Kalimantan by integrating renewable energy power plant

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Abstract. Government power plants cannot supply all electricity demand in East Kalimantan Province especially if there is damage to the power plant with the largest production capacity, so cooperation with other suppliers needs to be done. There are four stakeholders that can supply electricity, namely State Electricity Company (SEC), Independent Power Producer (IPP), Rent, and Excess Capacity (EC). Each supplier has different power generation characteristics that lead to differences in fuel costs and emissions. This research proposes 4 mathematical models. The models are scenarios 4 forms of cooperation between electrical stakeholders in East Kalimantan taking into consideration the potential of renewable energy (RE) power plants. This mathematical model is solved with a heuristic algorithm solver excel. The result, the best scenario by integrating three power plants owned by SEC, IPP and RE. Whereas collaboration with the smallest emissions is SEC + Rent + RE.
Keywords: Electricity supply chain, Power Plant, Optimization, Renewable Energy, Supplier cooperation

1. Introduction

East Kalimantan is still experiencing a power outage. This is due to the unbalanced between supply and demand. There are 4 power suppliers in East Kalimantan: State Electricity Company (SEC), Independent Power Producer (IPP), Rent, and Excess Capacity (EC). While the center of demand spread over 12 different locations.

Each supplier has a different power plant. This difference leads to differences in costs and emissions. Costs and emissions are heavily dependent on the fuel used, where in this case there are still many who use oil and coal. Coal-fired power plants are usually cheaper but have a negative impact on the environment [1].

Costs and emissions can be reduced in various ways, one with the appropriate allocation of loads to each power plant using economic dispatch as in [2], [3]. Alternatively, using a renewable energy-fueled power plant as in [4]. Economic dispatch was originally used to minimize the cost of power plants in the interconnected system [5], [6]. Furthermore, economic dispatch is developed into economic dispatch, which also minimizes emissions [7] - [10].

Economic Dispatch has been widely used for power plant allocation with various constraints and solutions with various methods. However, ED has not been able to provide a detailed allocation for implementation in collaboration among suppliers. Therefore, this study proposes 4 types of a collaboration of power suppliers that have different power plant characteristics. Collaboration is modeled mathematically with the approach of the transport-economic dispatch model as in [3].

Computing is done with an excel solver. The combination between economic dispatch and transportation makes the computational outreach more detailed than the usual economic dispatch.

2. Methods

This research was conducted using 5 stages: Problem formulation, Literature review, modeling, Experiment, and Analysis (Figure 1).

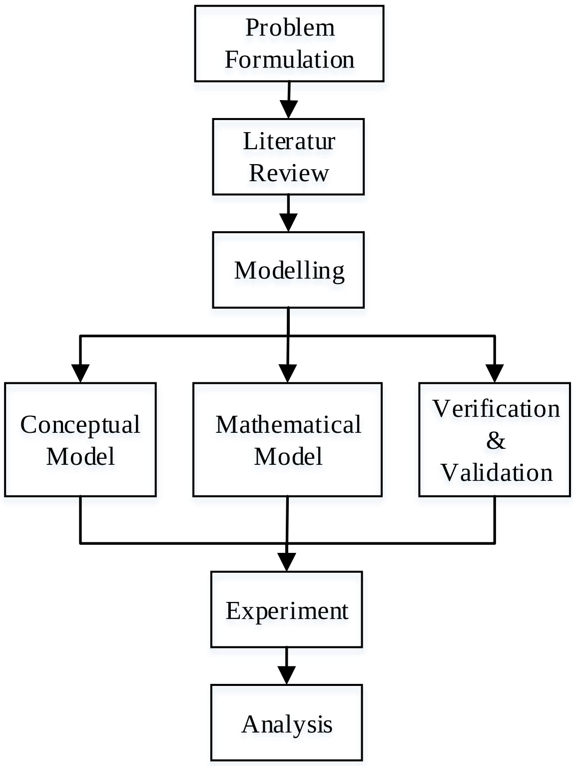

Figure 1. Research methodology

Formulation of the problem. How is the best collaboration of power suppliers in East Kalimantan to get the smallest total cost and emissions.
Literature study. Literature uses a journal published by Elsevier. Topics about economic dispatch, optimization, collaboration.
Modelling. There are 3 stages of modeling. First, the conceptual model to facilitate in designing the details of mathematical models. Second, a mathematical model to illustrate supplier collaboration. There are 4 mathematical models in this research: SEC + RE, SEC + IPP + RE, SEC + Rent + RE, and SEC + EC + RE.

Model 1: SEC+RE

This model is a collaboration of SEC and RE power plants. The mathematical model is as follows:

$$Minimize \sum_{i=1}^{N} F_i\,(P_i) = a_i P_i^2 + b_i P_i + c_i + C_{RE} \quad (1)$$

Constraints

$$\sum_{i=1}^{N} P_i + P_{RE} = PD \quad (2)$$

$$Pmin_i \leq P_i \leq Pmax_i \quad (3)$$

$$P_{REmin} \leq P_{RE} \leq P_{REmax} \quad (4)$$

Model 2: SEC+IPP+RE

This model is a collaboration of the SEC, IPP and RE power plants. The mathematical model is as follows:

$$Minimize \sum_{i=1}^{N} F_i\,(P_i) + \sum_{i=1}^{N} F_{iIP}\,(P_{iIP}) = a_i\,P_i^2 + b_i P_i + c_i + a_{iIP}\,P_{iIP}^2 + b_{iIP} P_{iIP} + c_{iIP} + C_{RE} \quad (5)$$

Constraints

$$\sum_{i=1}^{N} P_i + \sum_{i=1}^{N} p_{iIP} + P_{RE} = PD \quad (6)$$

$$P_{imin} \le P_i \le P_{imax} \quad (7)$$

$$P_{iIPmin} \le P_{iIP} \le P_{iIPmax} \quad (8)$$

$$P_{REmin} \le P_{RE} \le P_{REmax}$$

Model 3: SEC+Rent+RE

This model is a collaboration of the SEC, Rent and RE power plants. The mathematical model is as follows:

$$Minimize \sum_{i=1}^{N} F_i\,(P_i) + \sum_{i=1}^{N} F_{iR}\,(P_{iR}) + P_{RE} = a_i\,P_i^2 + b_i P_i + c_i + a_{iR}\,P_{iR}^2 + b_{iR} P_{iR} + c_{iR} + C_{RE} \quad (9)$$

Constraints

$$\sum_{i=1}^{N} P_i + \sum_{i=1}^{N} p_{iR} + P_{RE} = PD \quad (10)$$

$$P_{imin} \le P_i \le P_{imax} \quad (11)$$

$$P_{iRmin} \le P_{iR} \le P_{iRmax} \quad (12)$$

$$P_{REmin} \le P_{RE} \le P_{REmax}$$

Model 4: SEC+EC+RE

This model is a collaboration of SEC, EC and RE power plants. The mathematical model is as follows:

$$Minimize \sum_{i=1}^{N} F_i\,(P_i) + \sum_{i=1}^{N} F_{iE}\,(P_{iE}) + P_{RE} = a_i\,P_i^2 + b_i P_i + c_i + a_{iE}\,P_{iE}^2 + b_{iE} P_{iE} + c_{iE} + C_{RE} \quad (13)$$

Constraints

$$\sum_{i=1}^{N} P_i + \sum_{i=1}^{N} p_{iE} + P_{RE} = PD \quad (14)$$

$$P_{imin} \le P_i \le P_{imax} \quad (15)$$

$$P_{iEmin} \le P_{iE} \le P_{iEmax} \quad (16)$$

$$P_{REmin} \le P_{RE} \le P_{REmax} \quad (17)$$

Description of the formula:

$F_i\,(P_i)$: SEC fuel costs
$F_{iIP}\,(P_{iIP})$: IPP fuel costs
$F_{iR}\,(P_{iR})$: Rent fuel costs
$F_{iE}\,(P_{iE})$: Excess Capacity fuel costs
P_{RE} : Total production of renewable energy power plants
PD : Demand
P_i : total the i-power plant production
P_{imin} : The minimum amount that the i-power plant must produce
P_{imax} : Maximum capacity that can be produced by i-power plant
P_{RE} : Total production of renewable energy
P_{REmin} : The minimum amount that must be produced by renewable energy
P_{REmax} : Maximum production capacity of power plant renewable energy
P_{iIP} : Total IPP production
P_{iIPmin} : The minimum amount that must be produced by the IPP power plant
P_{iIPmax} : Maximum production capacity that IPP can produce
P_{iR} : Total Rent production
P_{iRmin} : The minimum amount that must be produced by the Rent power plant
P_{iRmax} : Maximum production capacity that Rent can produce

P_{iE} : Total Excess Capacity production
P_{iEmin} : The minimum amount that must be produced by the EC power plant
P_{iEmax} : Maximum production capacity that EC can produce

Analysis
The analysis was based on experiments on four scenarios (mathematical models). The result is a comparison of different types of collaboration between suppliers. The parameters used are cost and emission.

3. Result and Discussion

3.1. Results
This study yielded 2 main comparisons, ie supplier collaboration without integration with renewable energy, and collaboration between suppliers with renewable energy integration.

3.1.1. Collaboration of suppliers without renewable energy. When collaboration is done without involving renewable energy, the result is as follows:

Table 1. Collaboration of suppliers without RE

No	Scenario	Peak Load		Low Load	
		Cost (Rp)	Emission (kg)	Cost (Rp)	Emission (kg)
1	SEC	1,159,917.5	173.7	671,491.6	105.3
2	SEC+IPP	273,136.5	161.8	153,746.1	99.8
3	SEC +Rent	634,620.1	155.9	227,274.5	86.5
4	SEC +EC	753,529.9	166.7	332,655.4	98.5

Experiments were conducted on 4 scenarios. Each scenario consists of 2 conditions: Peak Load and Low Load. Scenario 1: Only use PLN power plant. Scenario 2: PLN + IPP, Scenario 3: PLN + Rent, and scenario 4: PLN + Excess capacity.

Scenario 1: In peak load condition, fuel cost Rp. 1,159,917.5 with emissions of 173.7 kg, whereas in low load conditions required fuel costs Rp. 671,491.6 with emission of 105.3 kg. Scenario 2: In peak load condition, fuel cost Rp. 273,136.5 with emission of 161.8 kg, whereas in low load condition required fuel cost Rp. 153,746.1 with emission of 99.8 kg. Scenario 3: In peak load condition, fuel cost Rp. 634,620.1 with emission of 155.9 kg, whereas in low load condition it takes fuel cost Rp. 227,274.5 with emission 86.5 kg. Scenario 4: In peak load condition, fuel cost Rp. 753.529.9 with emission 166.7 kg, whereas in low load condition required fuel cost Rp. 332,655.4 with an emission of 98.5 kg.

3.1.2. Supplier collaboration with renewable energy. When suppliers collaborate with renewable energy, the results are as follows:

Table 2. Supplier collaboration involves renewable energy

No	Scenario	Peak Load		Low Load	
		Cost (Rp)	Emissions (kg)	Cost (Rp)	Emissions (kg)
1a	SEC+RE	1,111,121.8	171.0	176,827.0	90.9
2a	SEC +IPP+RE	266,252.0	160.1	113,411.4	93.6
3a	SEC +Rent+RE	606,778.9	148.1	161,356.3	79.0
4a	SEC +EC +RE	718,084.0	163.7	117,237.6	89.8

Scenario 1a: In peak load condition, fuel cost Rp. 1,111,121.8 with emission 171 kg, whereas in low load condition needed fuel cost Rp. 266,252.0 with emission of 105.3 kg. Scenario 2a: In peak load condition, fuel cost Rp. 273,136.5 with emission 160.1 kg, whereas in low load condition required fuel cost Rp. 113.411.4 with emission of 93.6 kg. Scenario 3a: In peak load condition, fuel cost Rp. 606,778.9 with emissions of 148.1 kg, whereas in low load conditions required fuel costs Rp. 161,356.3 with emission of 79.0 kg. Scenario 4a: In peak load condition, fuel cost Rp. 718,084.0 with the emission of 163.7 kg, whereas in low load condition required fuel cost Rp. 117.237.6 with emissions of 89.8 kg. Graphically can be seen in Figure 2.

Figure 2. Cost and emission of 4 types of scenarios under peak and low load conditions.

3.2. Discussion

The entry of Renewable Energy into supplier collaboration has reduced total costs and emissions. Costs and emissions reductions can be seen in Table 3.

Table 3. Reduced costs and emissions due to Renewable Energy

Scenario	Peak Load		Low Load	
	Cost (Rp)	Emissions (kg)	Cost (Rp)	Emissions (kg)
SEC+RE	48,795.7	2.7	494,664.6	14.4
SEC +IPP+RE	6,884.5	1.7	40,334.7	6.2
SEC +Rent+RE	27,841.1	7.8	65,918.3	7.4
SEC +EC+RE	35,445.9	2.9	215,417.8	8.8

Collaboration SEC + IPP + RE resulted in decreased cost Rp. 6,884.5 (2.52%) during peak load, whereas when low load resulted decreased cost Rp. 40,334.7 (26.23%). Similarly, emissions, when peak load dropped 1.7 kg (1.02%), while when low load down 6.2 kg (6.2%) as in Table 4.

Table 4. Percentage reduction in costs and emissions due to Renewable Energy

Scenario	Peak Load		Low Load	
	Cost (Rp)	Emissions (%)	Cost (Rp)	Emissions (kg)
SEC+RE	4.21	1.54	73.67	13.71
SEC +IPP+RE	2.52	1.02	26.23	6.20
SEC +Rent+RE	4.39	5.01	29.00	8.61
SEC +EC+RE	4.70	1.77	64.76	8.88

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The SEC + Rent + RE collaboration resulted in a decrease in the cost of Rp. 27,841.1 (4.9%) during peak load, while when low load resulted decreased cost Rp. 65,918.3 (29%). Similarly, emissions, when peak load down 7.8 kg (4.39%), while when low load down 7.4 kg (8.61%).

4. Conclusion

Collaboration among suppliers in East Kalimantan is absolutely necessary. The best collaboration is SEC + IPP + RE. This collaboration yields the smallest total fuel cost to meet all demands. In addition to providing the smallest total cost, this collaboration also generates greater energy reserves than any other collaboration, making it safer from the point of view of continuity of power supply in the event of damage to one of the power plants, whereas collaboration produces the smallest emissions when combining SEC, Rent and RE power plants. However, if there is damage to the power plant with the largest capacity, all existing scenarios were not able to anticipate it.

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