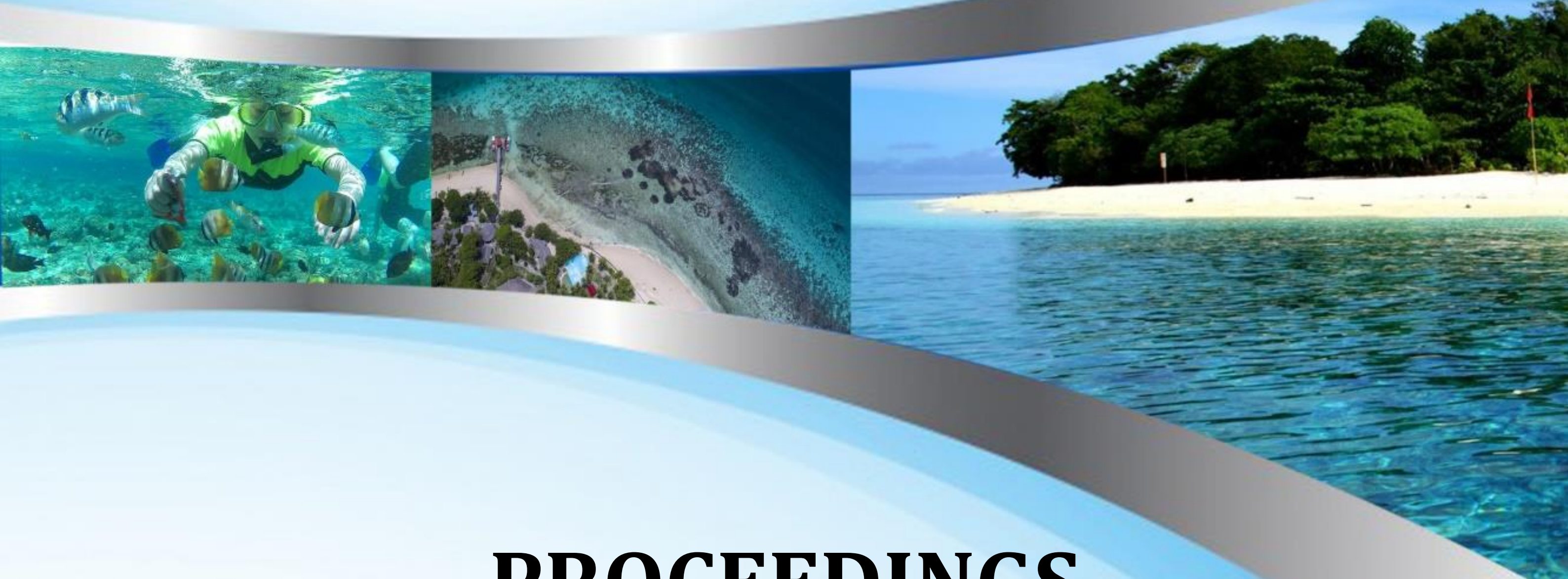

PROCEEDINGS

2018 International Conference on Applied Science and Technology
iCAST
Indonesian Polytechnics

2018 International Conference on Applied Science and Technology *for Engineering Science* (iCAST-ES)

October 26-27, 2018
Manado, Indonesia

2018 International Conference on Applied Science and Technology

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2018 International Conference on Applied Science and Technology (ICAST)

Optimization of Machine Operation Schedule in Diesel Power Plant System with Integer Programming Method

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***Abstract*-The operation of Diesel Power Plant Machines using fuel oil is diesel oil and this is a high cost usage, so in overcoming this, optimization is carried out in the operating schedule rather than the existing machines. This research was conducted to provide a new approach to the scheduling of power plant operations in North Sulawesi. First, the data in the form of power requirements used by consumers in the operating system were estimated by using a data distribution test in this case the Kolmogorov-Smirnov test was used for normal testing. In testing the data turned out to be normally distributed because for all time intervals the maximum value of the calculation is less than the same as the table value. By using the calculation formula for large samples, the power requirements must be generated by the system at each time interval, and this value is created in a mathematical model to find the combination of machines that is operated. As the aim of this paper is to use Integer Programming Zero-One Method and Additive Algorithm, it can be determined by a combination of machines that will be scheduled to be operated, so as to provide a very efficient contribution to the electricity company. Based on the results of this study, a combination of machines is scheduled to be operated at all time intervals.**

Keywords-Integer Programming Zero-One Method, Power Plants.

I. INTRODUCTION

Optimization problems are problems that are almost found in all aspects of life. A special form of the optimization problem is linear programming or linear programs so that this linear program has been widely used in industry, transportation, trade and so on. Integer programming model is part of the linear programming technique which requires an absolute assumption in linear programs except that specific variables do not have to be nonnegative integers of optimal solutions. Operational research approach is a scientific method that specifically begins this process by observing and formulating problems and then building a scientific model (mathematical model) that attempts to abstract the core of the real problem.

Linear Programming is one technique that can assist in making optimum and limited allocation of resources for the allocation of resources. These limited resources if in one industry or company include all production factors such as; machines, labor, raw materials, capital, technology and information. Linear Programming Problems have four things in general, namely:

1. The problem encountered is maximization or minimization as the goal
2. Having a "Constraint", or limiting function to achieve the goal to be achieved (objective function).
3. Alternatives must be available to solve the problem.
4. The mathematical relationship is linear. [2]

Integer programming models are part of linear programming techniques that require absolute assumptions in linear programming except that specific variables do not have to be integer non-negative values on optimal solutions. Operational research approach is a scientific method that specifically begins this process by observing and formulating problems and then building a scientific model (which is typically mathematical) that attempts to abstract the core from the real problem [2].

Scheduling problems in machine operation can be approximated by the Integer programming model which is a mathematical settlement model that allows the results of the completion of linear programming case in the form of real numbers converted into integers without leaving the optimality of the solution. The model expected in this study is the value 0 and 1 for the variable, this problem is called Zero-One Integer Programming and as a method of solving it with additive algorithms [6].

In choosing the machines that are operated, it is necessary to calculate in advance the alleged electrical power that must be generated by the system at a certain time interval so that the fuel spent on the operation of the machines can be reduced to a minimum, but the needs of consumers are still fulfilled. In this paper will search the optimization concept that is Integer Programming to combine the power generation machines that are operated in order to obtain optimal solutions so that it can reduce costs and reduce fuel usage in order to achieve minimum operating cost and to plan the optimal scheduling of power plant operations.

In the preparation of this paper is limited to:

- Data taken at the engine boundary Diesel Power Generator in Bitung city, North Sulawesi
- The influence of the parameters discussed is the engine power capacity, fuel and fuel expenditure costs of each machine in each intrerval time.
- Decision variables taken are zero and one, the Integer programming model used is Zero-One Integer with its solution through an additive algorithm.

The purpose of this paper is Implementing the Integer Programming concept in determining the optimal combination of machines to operate so that the fuel is used to a minimum, so that it can provide an efficient contribution to the State Electricity Company and plan the

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most optimal power plant operating schedule and can Plan the most optimal power plant operating schedule.

II. LITERATURE REVIEW

A. *Electrical Power*

The biggest part of the financing unit in operating the electric power system is energy, raw material (around 80%), besides that the ups and downs of its use are always related to the use of electrical energy by the load [7]. In general, the efficiency or efficiency of the machine can follow the following equation:

Efficiency = (output power) / (input power) X 100%

Output is the amount of power generated by the diesel engine, and input is the amount of fuel needed by the diesel engine. The efficiency of a diesel engine is at around 40%, while the losses that occur are in coolers of 30%, 24% exhaust gas, 4% other losses [3]

In a power generation system, the generation cost will become even greater in line with the distance between plants [5]. The cost of fuel and the power of electric power generating machines without neglecting the power losses in the transmission line can be stated as follows :

$$F_r = \sum_{i=1}^{N} F_i(P_i)$$

$$= F_1(P_1) + F_2(P_2) + \cdots + F_N(P_N) \qquad (1)$$

$$P_R = P_r$$

$$P_r = \sum_{i=1}^{N} P_i = P_1 + P_2 + \cdots + P_N \qquad \text{………………(2)}$$

F_r = total fuel cost (Rp / hour)
F_i = fuel costs on generator -i
P_r = total output power generator (MW)
P_R = load of the generating system optimal i
i = 1,2,3 ..... N (number of power generation machines)

The total power supplied by the N generating machine to the system is:

$$P_r = \sum_{i=1}^{N} P_{gi} = P_{g1} + P_{g2} + \cdots + P_{gN} \qquad \text{……………(3)}$$

P_r = Total power generated
P_{gi}= The total power generated by the i-generation.

B. *Integer Programming*

The general model of an integer program is as follows:

Maximize or minimum [4] :

$$z = f(x_1, x_2, \dots, x_n)$$

With restrictions

$$g_i(x_1, x_2, \dots, x_n) \leq, =, \geq b_i$$

$$\text{and } x_j \geq 0, \qquad i = 1, 2, \dots m$$

$$x_j \text{ integer} \qquad j = 1, 2, \dots, n \qquad \text{… ………….. (4)}$$

C. *Integer Zero - One problem*

All decision variables are required to be the same as Zero-One.

$$Min\ Z = \sum_{i=1}^{n} c_i x_i \qquad \text{…………………(5)}$$

with restrictions

$$\sum_{i=1}^{n} a_{ij} x_i = b_i \qquad \text{……………………..(6)}$$

With i = 1, 2, ...nj=1,2,...,m
$x_i = 0, 1$ (binary) [1]

D. *Additive Algorithm*

This algorithm is a solving method of zero-one problem that must be started dual worthy is an inappropriate and optimal solution to be a viable solution. All constraints must be of type less than equal to (≤), thus getting rid of the explicit equation [6] . In this case it is considered that the problem is minimum type and the definition of minimizing is:

$$Minimum\ Z = \sum_{j=1}^{n} C_j X_j \qquad \text{…………………..(7)}$$

C_j = fuel for the engine to-*j*

$$obstacles \quad \sum_{j=1}^{n} a_{ij} X_j + S_i = b_i, \quad i = 1, 2 \dots, m$$

$$X_j = 0 \ or\ 1, \qquad j = 1, 2, 3, \dots\dots, n$$

$$S_i \leq 0, \qquad i = 1, 2, 3, \dots\dots, m \qquad \text{…………(8)}$$

b_i = power generated by the engine
at the i-interval
S_i = slack variable to-i
a_{ij} = coefficient of constraints

The definition for each independent variable is X_j in the form:

$$V_j = \sum_{semua\ i} min\{0, S_i - a_{ij}\} \qquad \text{………...(9)}$$

S_i = slack to-i
a_{ij} = element in row- i column-i

Steps in step determining partial breakdown:

Test 1: For each independent variable X_j if $a_{ir} \geq 0$ for all i that corresponds to $S_i^t < 0$, then X_j cannot correct the invalidity of the problem and must be removed as non-promising.

Test 2: For each independent variable X_j if $C_r + Z^t \geq Z$, then X_j cannot lead to a better solution and therefore must be removed.

Test 3: Consider the limit of i

$$a_{i1} X_1 + a_{i2} X_2 + \cdots + a_{in} X_n + S_i = b_i$$

$$\text{With, } S_i^t < 0. \qquad \text{………(10)}$$

If N_t defines all improper sets of independent variables removed by testing 1 and 2. None of the independent variables in N_t promise for at least one $S_i^t < 0$, this condition is fulfilled if:

$$\sum_{j \in N_t} min\{o, \ a_{ij}\} > S_i^t \qquad \text{……………(11)}$$

Test 4: If $N_t \neq \emptyset$, the branching variable X_k is chosen as the corresponding variable

$V_k^t = \max\{V_j^t\}\ d\ engan\ j \in N_t$, where

$$V_j^t = \sum_{i=1}^{m} \min\{0, \quad S_i^t - a_{ij}\}$$

$S_i \le 0$, $i = 1,2,3, \ldots \ldots m$ ……………..(12)

b_i = power generated by the engine at the i-interval

S_i = slack variable to-i

a_{ij} = coefficient of constraints

The definition for each independent variable is X_j in the form:

$$V_j = \sum_{semua\ i} min\{0, S_i - a_{ij}\}$$ ……………………(13)

S_i = slack to-i

a_{ij} = element in row- i column-i

Steps in step determining partial breakdown:

Test 1: For each independent variable X_j if $a_{ir} \geq 0$ for all i that corresponds to $S_i^t < 0$, then X_j cannot correct the invalidity of the problem and must be removed as non-promising.

Test 2: For each independent variable X_j if $C_r + Z^t \geq \underline{Z}$, then X_j cannot lead to a better solution and therefore must be removed.

Test 3: Consider the limit of i

$$a_{i1} X_1 + a_{i2} X_2 + \cdots + a_{in} X_n + S_i = b_i$$

With, $S_i^t < 0$ ……………….(14)

If N_t defines all improper sets of independent variables removed by testing 1 and 2. None of the independent variables in N_t promise for at least one $S_i^t < 0$, this condition is fulfilled if:

$$\sum_{j \in N_t} min\{o, \ a_{ij}\} > S_i^t$$ …………(15)

Test 4: If $N_t \neq \emptyset$, the branching variable X_k is chosen as the corresponding variable

$V_k^t = \max\{V_j^t\}$ $d\ engan\ j \in N_t$, where

$$V_j^t = \sum_{i=1}^{m} \min\{0, \quad S_i^t - a_{ij}\}$$ ………...(16)

III. RESULT

From the data about the power generated by the system for 150 days (n = 150), the normality of each distribution interval was tested by the Kolmogorov-Smirnov test can be obtained Most Extreme Differences absolute which is a statistical value from the table of 1.64 and it turns out that for all time intervals the value is L≤Lα. This means that the decision-making criteria is H_0 accepted, in this case the distribution spreads normally.

By using SPSS Windows Version 17, the Z test is obtained for large samples:

For the upper limit of the interval: $\bar{X} + \frac{Z\alpha_{/2}\ S}{\sqrt{n}}$

For the lower limit of the interval: $\bar{X} - Z\alpha_{/2}\ S/\sqrt{n}$

So with a 95% confidence interval, the power forecast must be generated at each time interval as follows:

at time 00 - 03: $14.951 < \mu < 15.722$

at time 03 – 06: $15.509 < \mu < 16.308$

at ime 06- 09: $23.837 < \mu < 24.903$

at time 09 – 12: $24.458 < \mu < 25.429$

at time 12 – 15: $23.661 < \mu < 24.312$

at time 15 - 18: $25.091 < \mu < 25.754$

at time 18– 21: $33.739 < \mu < 34.268$

at time 21 - 24 : $14.864 < \mu < 15.43$

Mathematical Model and the Solution

Assumed that if the engine is operating the fuel usage is constant as it operates with 100% power. So if the machine is alive / operating, the fuel spent per hour is:

- For a power capacity of 4,040 KW, fuel is needed: 4,040 x 0.27 = 1,091 liters / hour.
- For a 5,000 KW power capacity, fuel is needed: 5,000 x 0.27 = 1,350 liters / hour.
- For 5,400 KW of power capacity, fuel is needed: 5,400 x 0.27 = 1,458 liters / hour.
- For a power capacity of 8,800 KW, fuel is needed: 8,800 x 0.27 = 2,376 liters / hour.
- For a power capacity of 11,000 KW, fuel is needed: 11,000 x 0.27 = 2,970 l / hour.

At each interval consists of 3 hours so that the total fuel needed in each power capacity is obtained. So the mathematical model .

At interval time 00.00-03.00

Destination function:

$$Min\ Z = 3.272X_1 + 3.272X_2 + 3.272X_3 + 4.050X_4 + 4.374X_5 + 4.374X_6 + 7.128X_7 + 8.910X_8$$

Obstacles:

$$4.040X_1 + 4.040X_2 + 4.040X_3 + 5.000X_4 + 5.400X_5 + 5.400X_6 + 8.800X_7 + 11.000X_8 \geq 14.859$$

$$4.040X_1 + 4.4040X_2 + 4.040X_3 + 5.000X_4 + 5.400X_5 + 5.400X_6 + 8.800X_7 + 11.000X_8 \leq 15.509$$

From this equation is obtained simplex table 1

Tabel I. Table Simplex On Time 00.00-03.00

X_1 **3.272**	X_2 **3.272**	X_3 **3.272**	X_4 **4.050**	X_5 **4.374**	X_6 **4.374**	X_7 **7.128**	X_8 **8.910**	S_1S_2 **0 0**	**RHS** **Z**
4.040	4.040	4.040	5.000	5.400	5.400	8.800	11.000	1 0	15.509
-4.040	-4.040	-4.040	-5.000	-5.40	-5.400	-8.800	-11.000	0 1	-14.869

Because the additive algorithm requires all signs in inequality in the form ≤, the mathematical model becomes:

$$Min\ Z = 3.272X_1 + 3.272X_2 + 3.272X_3 + 4.050X_4 + 4.374X_5 + 4.374X_6 + 7.128X_7 + 8.910X_8$$

Obstacles:

$$-4.040X_1 - 4.040X_2 + 4.040X_3 - 5.000X_4 - 5.400X_5 - 5.400X_6 - 8.800X_7 - 11.000X_8 \leq -15.509$$

$$4.040X_1 + 4.4040X_2 + 4.040X_3 + 5.000X_4 + 5.400X_5 + 5.400X_6 + 8.800X_7 + 11.000X_8 \leq 16.308$$

With the independent variable initially at the zero level, it is obtained:

$Z^0 = 0$ with (S_1^0, S_2^0) = (15.509, -14.869).

This shows that the settlement is not feasible because there is still a negative value, so it is necessary to raise one or more variables at level one as long as it is headed to a feasible settlement. In this case raising the independent variable to level one, and testing as follows:

In accordance with the first test, there are no variables removed so that they are obtained:

V_1=min(0,15.509-4.040+min(0,-14.869 +4.040) = (-11.465)

V_2=min(0,15.509-4.040+min(0,-14.869 +4.040) = (-11.465)

V_3=min(0,15.509-4.040+min(0,-14.869 +4.040)= (-11.465)

V_4=min(0,15.509-5.000+min(0,-14.869 +5.000) = (-10.505)

V_5=min(0,15.509-5.400+min(0,-14.869 +5.400) = (-10.105)

V_6=min(0,15.509-5.400+min(0,-14.869 +5.400) = (-10.105)

V_7=min(0,15.509-8.800+min(0,-14.869 +8.800)= (-6.705)

V_8=min(0,15.509-11.000+min(0,-14.869 + 11.000)= (-3.869)

We see that the machine that must be raised to level one is a machine that has the greatest variable value, so here we have to increase it

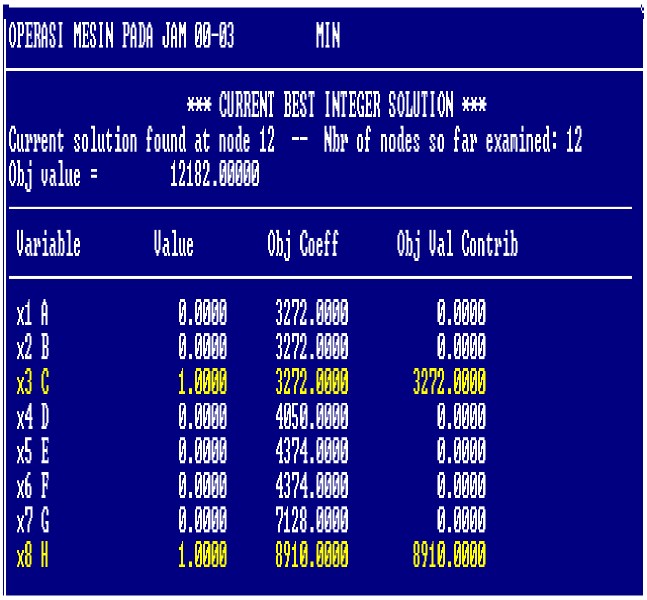
X_8 get it Z^1 = 8.910 with $(S_1^1, S_2^1) = (4.509, -3.869)$.

Because the value of the slack still has a negative value so that the settlement is not feasible then the variable that needs to be raised is level one as in the initial step. In this step the variables which are independent variables are:

V_1 = min(0,4.509-4.040+min(0,-3.869 +4.040) = (0)
V_2 = min(0, 4.509-4.040+min(0,- 3.869 +4.040) = (0)
V_3 = min(0, 4.509-4.040+min(0,- 3.869 +4.040) = (0)
V_4 = min(0, 4.509-5.000+min(0,- 3.869 +5.000) = (-491)
V_5 =min(0, 4.509-5.400+min(0,- 3.869 +5.400) = (-891)
V_6 = min(0, 4.509-5.400+min(0,- 3.869 +5.400) = (-891)
V_7 = min(0, 4.509-8.800+min(0,- 3.869 +8.800) = (-4.291)
V_8 = min(0, 4.509-11.000+min(0,- 3.869 +11.000) = (-6.491)

Get it $Z^2 = 12.960$ with $(S_1^2, S_2^2) = (308, 495)$. Because the value of the slack is non-negative, in this case the settlement is feasible and this is the biggest value that can be accepted, and the most optimal value is to operate one machine with a capacity of 11,000 Kw and one engine with a capacity of 4,040 Kw with the use of as much fuel 12,182 liters. With the help of tora softwere, an optimal machine is available to operate at a predetermined hour.

Tora Sofware:



```
OPERASI MESIN PADA JAM 00-03          MIN

            *** CURRENT BEST INTEGER SOLUTION ***
Current solution found at node 12  --  Nbr of nodes so far examined: 12
Obj value =        12182.00000

 Variable        Value       Obj Coeff      Obj Val Contrib

 x1 A            0.0000      3272.0000         0.0000
 x2 B            0.0000      3272.0000         0.0000
 x3 C            1.0000      3272.0000      3272.0000
 x4 D            0.0000      4050.0000         0.0000
 x5 E            0.0000      4374.0000         0.0000
 x6 F            0.0000      4374.0000         0.0000
 x7 G            0.0000      7128.0000         0.0000
 x8 H            1.0000      8910.0000      8910.0000
```

Fig.1. Machine Operation on time 00-03

By using Tora softwere in Figure 1, the optimal combination of machines operates at 00.00-03.00, namely engine C (variable x3) and engine H (variable x8), with the amount of fuel needed on engine C is 3,272 liters and engine H is 8,910 liters. The total fuel is 12,182 liters.

IV. CONCLUSION

From the results of the discussion, it can be concluded that:

1. With a system load data for 150 days (n = 150) at all time intervals the data are normally distributed where the statistical value is calculated less than the same of table value (Lα) with α = 0.05.
2. With the Integer Programming Method approach, machines are operated at each time interval. Where on the machine operation scheduler at:

   - 00-03 hours, 03-06 hours and 21-24 hours there are 2 machines that are optimally operated. At 00-03 and 21-24 hours, the optimal engine combination is operated with a power capacity of 4,040 KW and 11,000 KW, while at 03-06 the optimal engine combination operates with a capacity of 5,000 KW and 11,000 KW.
   - 06-09 hours, 09-12 hours, 12-15 hours, and 15-18 hours there are 3 machines that are optimally operated. At 06-09,
   -09-12 hours have an optimal engine combination operated with a capacity of 5,000 KW, 8,800 KW and 11,000 KW, at 12-15 hours have an optimal engine combination operated with a power capacity of 4,040 KW, 8,800 KW, 11,000 KW and 15-18 hours have a combination of engine which is optimally operated with a power capacity of 5,400 KW, 8,800 KW, 11,000 KW.
   -18-21 hours there are 5 optimal engines operated with a power capacity of 4,040.5,000 KW, 5,400 KW, 8,800 KW, 11,000 KW.

   By looking at the operation of the machine at each time interval, where at 18-21 more machines are operated because at this time the power consumption increases than the other hours.

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