ELECTRIC GENERATOR

Abstract

The model which is used for generation system planning and best-mix only considers cost minimization and total yearly or quarterly electricity demand every year. In a view point of one day power supply operation monitoring of the ramp up/down rate of total generation system, minimum up/down time are very important. Through the solution of this problem, energy provided will be in the most cost-efficient manner. This would save vital funds which can be used elsewhere by the government. This would also amount to lower cost of electricity being paid by the customers.

Problem Designing & Framework

The main aim of this project will be to minimize the cost of operating three types of electricity generators for meeting the demand of a particular city for a day which will be divided into four slots of six hours each as described in table 2.

Each type of generator has the following properties-

a) Cost per kilo watt of electricity produced(rupees)
b) Maximum capacity of Generator (megawatt)
c) Number of generators

The properties of each type of generator are explained through the following definitions.

a) Cost per megawatt hour of electricity produced – This is the cost of each type of generator for the energy being produced per hour which when multiplied by the given duration for which each generator was operated will give the total cost for the production of energy by a particular generator of each type.

b) Maximum capacity of Generator (megawatt) – The maximum capacity of each type of generator is the maximum amount of energy produced by a generator in one hour, hence the standard unit of measure, megawatt is being used to describe it.

c) Number of generators- There are three types of generators available in this situation and each type has an optimum number of availability.

Table 1

Types of Generators	Cost per MWh of Electricity (in Rs)	Max Capacity of Generator per hour (in MW)	No. of Generators
G-I	4000	2	8
G-II	3900	1	5
G-III	4100	3	3

Table 2

Time Slot	Demand (in MWh)
Morning (6AM – 12PM)	21
Afternoon (12PM – 6PM)	27
Evening (6PM – 12AM)	18
Mid-Night (12AM – 6AM)	12

All the details have been provided to produce electricity for different time slots for a given city. The energy in a particular time slot can be produced using different combinations of generators of each type but to make it cost efficient an optimization has to be done, which will provide the combination of generators which minimizes the cost for producing the amount of energy needed in a given time slot.

To optimize the most cost-efficient way of generating electricity choose the best suitable method of linear programming to solve it and then verify it with the help of MATLAB.

Problem Formulation

Optimization model is composed of objective function and constraints. Objective function will consist of the cost of generating electricity which can be formed with the help of rates of respective generators given in table 1. Constraints are described as the following considering technical aspects mentioned earlier.

Table 3

Objective Function(cost)
Minimize Σ (cost_per_MW_for_each_type_of_generator * capacity * number_of_required_generators_of_each_type)
Constraints
Σ {maximum_capacity(MW) * number_of_required_generators_of_each_type} ≥ demand
Number of required generators of each type ≤ Number of available generators of each type

Variables –

Variable x_1 = number of G-I generators used
Variable x_2 = number of G-II generators used
Variable x_3 = number of G-III generators used
Variable D = demand of electricity
Variable Z = cost of electricity per time slot

Equations -

As per the equations in table 3 and the given data in table 1 we will have the following equations.

Objective function $Z = 8000x_1 + 3900x_2 + 12300x_3$

Subject to constraints

a) $2x_1 + x_2 + 3x_3 \geq D$
b) $x_1 \leq 5$
c) $x_2 \leq 8$
d) $x_3 \leq 3$

Method used – The best method for solving this type of problem is **Dual Simplex.**

a) Solution for morning time slot-

Morning (6AM - 12 PM)

Minimize $z = 8000x_1 + 3900x_2 + 12300x_3$

Subject to constraints

→ $2x_1 + x_2 + 3x_3 \geq 21$

→ $x_1 \leq 5$

→ $x_2 \leq 8$

→ $x_3 \leq 3$

Adding slack variables

$$-2x_1 - x_2 - 3x_3 + 0S_1 = -21$$
$$x_1 + 0S_2 = 5$$
$$x_2 + 0S_3 = 8$$
$$x_3 + 0S_4 = 3$$

$(C_B)_j$	C_j	8000	3900	12300	0	0	0	0	Sol^n
	BV	x_1	x_2	x_3	S_1	S_2	S_3	S_4	
0	S_1	-2	-1	-3	1	0	0	0	-21 ← Key Row
0	S_2	1	0	0	0	1	0	0	5
0	S_3	0	1	0	0	0	1	0	8
0	S_4	0	0	1	0	0	0	1	3
	Z_j	0	0	0	0	0	0	0	
	$C_j - Z_j$	8000	3900	12300	0	0	0	0	

$-(C_j - Z_j)$	-8000	-3900	-12300	0	0	0	0
S_1	-2	-1	-3	1	0	0	0
Ratio	4000	3900	4100	-	-	-	-

↑

X_2 entering S_1 leaving

Teacher's Signature

Morning (6AM - 12 PM)

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$(C_B)_j$	C_j	8000	3900	12300	0	0	0	0	Sol^n
	BV	X_1	X_2	X_3	S_1	S_2	S_3	S_4	
3900	X_2	2	1	3	-1	0	0	0	21
0	S_2	1	0	0	0	1	0	0	5
0	S_3	-2	0	-3	1	0	1	0	-13 ← Key Row
0	S_4	0	0	1	0	0	0	1	3
	Z_j	7800	3900	11700	-3900	0	0	0	
	$C_j - Z_j$	200	0	600	3900	0	0	0	

$-(C_j - Z_j)$	-200	0	-600	-3900	0	0	0
S_3	-2	0	-3	1	0	1	0
Ratio	100	0	200	3900	-	-	-

X_1 entering S_3 leaving

$(C_B)_j$	C_j	8000	3900	12300	0	0	0	0	Sol^n
	BV	X_1	X_2	X_3	S_1	S_2	S_3	S_4	
3900	X_2	0	1	0	0	0	1	0	8
0	S_2	0	0	-3/2	1/2	1	1/2	0	-3/2 ← Key Row
8000	X_1	1	0	3/2	-1/2	0	-1/2	0	13/2
0	S_4	0	0	1	0	0	0	1	3
	Z_j	8000	3900	12000	-4000	0	-100	0	
	$C_j - Z_j$	0	0	300	4000	0	100	0	

$-(C_j - Z_j)$	0	0	-300	-4000	0	-100	0
S_2	0	0	-3/2	1/2	1	1/2	0
Ratio	-	-	200	-8000	-	-200	

X_3 entering S_2 leaving

Teacher's Signature

Morning (6AM - 12 PM)

$(C_B)_j$	C_j / BV	8000 x_1	3900 x_2	12300 x_3	0 S_1	0 S_2	0 S_3	0 S_4	Sol^n
3900	x_2	0	1	0	0	0	1	0	8
12300	x_3	0	0	1	-1/3	-2/3	-1/3	0	1
8000	x_1	1	0	0	-1/6	1	0	0	5
0	S_4	0	0	0	1/3	2/3	1/3	1	2
	Z_j	8000	3900	12300	-5433	-8200	-4100	0	
	$C_j - Z_j$	0	0	0	5433	8200	4100	0	

Optimal Sol^n: $x_1 = 5$ $x_2 = 8$ $x_3 = 1$

$Z = 83500$

Code for morning time slot –

```
% Morning-slot optimization
%   Z = 8000*x1 + 3900*x2 + 12300x3
%   -2*x1 + -1*x2 + -3*x3 <= -21
%   1*x1 <= 5
%   1*x2 <= 8
%   1*x3 <= 3

f = [8000 3900 12300];
A = [-2 -1 -3; 1 0 0; 0 1 0; 0 0 1];
b = [-21 5 8 3];
Aeq = [];
beq = [];
lb = [0 0 0];
ub = [];
[x, z] = linprog(f,A,b,Aeq,beq,lb,ub);
statement = 'optimized data for morning slot';
disp(statement);
disp('Number of generators of g-I, g-II and g-III are as follows --> ');
disp(x);
disp('Total optimized cost for the production of given electricity demand is -->');
disp(z);
```

Output for morning time slot -

```
>> A1_G_17
Optimization terminated.
optimized data for morning slot
Number of generators of g-I, g-II and g-III are as follows -->
    5.0000
    8.0000
    1.0000

Total optimized cost for the production of given electricity demand is -->
   8.3500e+04
```

b) Solution for Afternoon slot-

Afternoon (12 PM - 6 PM)

Minimize $z = 8000 x_1 + 3900 x_2 + 12300 x_3$

Subject to constraints

→ $2x_1 + x_2 + 3x_3 \geq 27$

→ $x_1 \leq 5$

→ $x_2 \leq 8$

→ $x_3 \leq 3$

Adding slack variables

$-2x_1 - x_2 - 3x_3 + \textcircled{0} S_1 = -27$

$x_1 + 0 S_2 = 5$

$x_2 + 0 S_3 = 8$

$x_3 + 0 S_4 = 3$

$(CB)_j$	C_j / BV	8000 X_1	3900 X_2	12300 X_3	0 S_1	0 S_2	0 S_3	0 S_4	Sol^n
0	S_1	-2	-1	-3	1	0	0	0	-27 ← Ke
0	S_2	1	0	0	0	1	0	0	5 Ro
0	S_3	0	1	0	0	0	1	0	8
0	S_4	0	0	1	0	0	0	1	3
	Z_j	0	0	0	0	0	0	0	
	$C_j - Z_j$	8000	3900	12300	0	0	0	0	

$-(C_j - Z_j)$	-8000	-3900	-12300	0	0	0	0
S_1	-2	-1	-3	1	0	0	0
Ratio	4000	3900	4100	-	-	-	-

↑

X_2 entering S_1 leaving

Teacher's Signature

Afternoon (12 PM - 6 PM)

$(C_B)_j$	C_j / BV	8000 x_1	3900 x_2	12300 x_3	0 S_1	0 S_2	0 S_3	0 S_4	Sol^n
3900	x_2	2	1	3	-1	0	0	0	27
0	S_2	1	0	0	0	1	0	0	5
0	S_3	-2	0	-3	1	0	1	0	-19 ← key Row
0	S_4	0	0	1	0	0	0	1	3
	Z_j	7800	3900	11700	-3900	0	0	0	
	$C_j - Z_j$	200	0	600	3900	0	0	0	

x_1 entering S_3 leaving

$-(C_j - Z_j)$	-200	0	-600	3900	0	0	0
S_3	-2	0	-3	1	0	1	0
Ratio	100	-	200	-	-	-	-

$(C_B)_j$	C_j / BV	8000 x_1	3900 x_2	12300 x_3	0 S_1	0 S_2	0 S_3	0 S_4	Sol^n
3900	x_2	0	1	0	0	0	1	0	8
0	S_2	0	0	-3/2	1/2	1	1/2	0	-9/2 → Key Row
8000	x_1	1	0	3/2	-1/2	0	-1/2	0	19/2
0	S_4	0	0	1	0	0	0	1	3
	Z_j	8000	3900	1200	-4000	0	-100	0	
	$C_j - Z_j$	0	0	300	4000	0	100	0	

$-(C_j - Z_j)$	0	0	-3900	-4000	0	-100	0
S_2	0	0	-3/2	1/2	1	1/2	0
Ratio	-	-	200	8000	-	-200	-

x_3 entering S_2 leaving

Afternoon (12 PM - 6 PM)

$(C_B)_j$	C_j / BV	8000 x_1	3900 x_2	12300 x_3	0 S_1	0 S_2	0 S_3	0 S_4	Sol^n
3900	x_2	0	1	0	0	0	1	0	8
12300	x_3	0	0	1	-1/3	-2/3	-1/3	0	3
8000	x_1	1	0	0	0	1	0	0	5
0	S_4	0	0	0	1/3	2/3	1/3	1	0
	Z_j	8000	3900	12300	-4100	-8200	-4100	0	
	$C_j - Z_j$	0	0	0	4100	8200	4100	0	

Optimal sol^n: $x_1 = 5$ $x_2 = 8$ $x_3 = 3$

$Z = 108100$

Code for Afternoon slot-

```
% Afternoon slot optimization
%   Z = 8000*x1 + 3900*x2 + 12300x3
%   -2*x1 + -1*x2 + -3*x3 <= -27
%   1*x1 <= 5
%   1*x2 <= 8
%   1*x3 <= 3
f = [8000 3900 12300];
A = [-2 -1 -3; 1 0 0; 0 1 0; 0 0 1];
b = [-27 5 8 3];
Aeq = [];
beq = [];
lb = [0 0 0];
ub = [];
[x, z] = linprog(f,A,b,Aeq,beq,lb,ub);
statement = 'optimized data for Afternoon slot';
disp(statement);
disp('Number of generators of g-I, g-II and g-III are as follows --> ');
disp(x);
disp('Total optimized cost for the production of given electricity demand is -->');
disp(z);
```

Output for Afternoon slot-

```
Optimization terminated.
optimized data for Afternoon slot
Number of generators of g-I, g-II and g-III are as follows -->
    5.0000
    8.0000
    3.0000

Total optimized cost for the production of given electricity demand is -->
   1.0810e+05
```

c) Solution for Evening slot-

Evening (6PM - 12 AM)

Minimize $Z = 8000x_1 + 3900x_2 + 12300x_3$

subject to constraints

→ $2x_1 + x_2 + 3x_3 \geq 18$ — ①

→ $x_1 \leq 5$ — ②

→ $x_2 \leq 8$ — ③

→ $x_3 \leq 3$ — ④

Adding slack variables

$$-2x_1 - x_2 - 3x_3 + 0S_1 = -18$$
$$x_1 + 0S_2 = 5$$
$$x_2 + 0S_3 = 8$$
$$x_3 + 0S_4 = 3$$

$(CB)_j$	C_j	8000	3900	12300	0	0	0		Sol^n	
	B.V	X_1	X_2	X_3	S_1	S_2	S_3	S_4		
0	S_1	-2	-1	-3	1	0	0	0	-18	← Key Row
0	S_2	1	0	0	0	1	0	0	5	
0	S_3	0	1	0	0	0	1	0	8	
0	S_4	0	0	1	0	0	0	1	3	
	Z_j	0	0	0	0	0	0	0		
	$C_j - Z_j$	8000	3900	12300	0	0	0	0		

$-(C_j - Z_j)$	-8000	-3900	-12300	0	0	0	0
Key Row	-2	-1	-3	1	0	0	0
Ratio	4000	3900	4100	0	0	0	0

↑ X_2 Entering

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Evening (6 PM - 12 AM)

$X_2 \rightarrow$ entering $\quad S_1 \rightarrow$ leaving

$(C_B)_j$	C_j	8000	3900	12300	0	0	0	0	
	BV	X_1	X_2	X_3	S_1	S_2	S_3	S_4	Sol^n
3900	X_2	2	1	3	-1	0	0	0	18
0	S_2	1	0	0	0	1	0	0	5
0	S_3	-2	0	-3	1	0	1	0	-10 ← key row
0	S_4	0	0	1	0	0	0	1	3
	Z_j	7800	3900	11700	-3900	0	0	0	
	$C_j - Z_j$	200	0	600	3900	0	0	0	

$-(C_j - Z_j)$	-200	0	-600	-3900	0	0	0
S_3	-2	0	-3	1	0	1	0
Ratio	100	-	200	-	-	-	-

↑

x_1 entering

$X_1 \rightarrow$ entering $\quad S_3 \rightarrow$ leaving

$(C_B)_j$	C_j	8000	3900	12300	0	0	0	0	
	BV	X_1	X_2	X_3	S_1	S_2	S_3	S_4	Sol^n
3900	X_2	0	1	0	0	0	1	0	8
0	S_2	0	0	-3/2	1/2	1	1/2	0	0
8000	X_1	1	0	3/2	-1/2	0	-1/2	0	5
0	S_4	0	0	1	0	0	0	1	3
	Z_j	8000	3900	12000	-4000	0	-100	0	
	$C_j - Z_j$	0	0	300	4000	0	100	0	

Optimal Sol^n: $X_1 = 5 \quad X_2 = 8 \quad X_3 = 0$

$Z = 71200$

Code for Evening slot-

```
% Evening slot optimization
%   Z = 8000*x1 + 3900*x2 + 12300x3
%   -2*x1 + -1*x2 + -3*x3 <= -18
%   1*x1 <= 5
%   1*x2 <= 8
%   1*x3 <= 3
f = [8000 3900 12300];
A = [-2 -1 -3; 1 0 0; 0 1 0; 0 0 1];
b = [-18 5 8 3];
Aeq = [];
beq = [];
lb = [0 0 0];
ub = [];
[x, z] = linprog(f,A,b,Aeq,beq,lb,ub);
statement = 'optimized data for evening slot';
disp(statement);
disp('Number of generators of g-I, g-II and g-III are as follows --> ');
disp(x);
disp('Total optimized cost for the production of given electricity demand is -->');
disp(z);
```

Output for Evening slot-

```
optimized data for evening slot
Number of generators of g-I, g-II and g-III are as follows -->
    5.0000
    8.0000
    0.0000

Total optimized cost for the production of given electricity demand is -->
   7.1200e+04
```

d) Solution for Mid-Night Slot-

Mid - Night (12 AM - 6 AM)

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Minimize $Z = 8000x_1 + 3900x_2 + 12300x_3$

Subject to constraints

$\rightarrow \quad 2x_1 + x_2 + 3x_3 \geq 12$

$\rightarrow \quad x_1 \leq 5$

$\rightarrow \quad x_2 \leq 8$

$\rightarrow \quad x_3 \leq 3$

Adding slack variables

$-2x_1 - x_2 - 3x_3 + 0S_1 = -12$

$x_1 + 0S_2 = 5$

$x_2 + 0S_3 = 8$

$x_3 + 0S_4 = 3$

$(C_B)_j$	C_j / B.V	8000 x_1	3900 x_2	12300 x_3	0 S_1	0 S_2	0 S_3	0 S_4	Sol^n	
0	S_1	-2	-1	-3	1	0	0	0	-12	← Key Row
0	S_2	1	0	0	0	1	0	0	5	
0	S_3	0	1	0	0	0	1	0	8	
0	S_4	0	0	1	0	0	0	1	3	
	Z_j	0	0	0	0	0	0	0		
	$C_j - Z_j$	8000	3900	12300	0	0	0	0		

$-(C_j - Z_j)$	-8000	-3900	-12300	0	0	0	0
S_1	-2	-1	-3	1	0	0	0
Ratio	4000	3900	4100	0	-	-	-
		↑					

x_2 entering $\quad S_1 \rightarrow$ leaving

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Mid-Night (12AM – 6AM)

$(C_B)_j$	C_j	8000	3900	12300	0	0	0	0	Sol^n
	BV	x_1	x_2	x_3	S_1	S_2	S_3	S_4	
3900	x_2	2	1	3	-1	0	0	0	12
0	S_2	1	0	0	0	1	0	0	5
0	S_3	-2	0	-3	1	0	1	0	-4 ← Key Row
0	S_4	-2	0	1	0	0	0	1	3
	Z_j	7800	3900	11700	-3900	0	0	0	
	$C_j - Z_j$	200	0	600	3900	0	0	0	

$-(C_j - Z_j)$	-200	0	-600	-3900	0	0	0
S_3	-2	0	-3	1	0	1	0
Ratio	100	–	200	–	–	–	–
	↑ Entering						

$(C_B)_j$	C_j	8000	3900	12300	0	0	0	0	Sol^n
	BV	x_1	x_2	x_3	S_1	S_2	S_3	S_4	
3900	x_2	0	1	0	0	0	1	0	8
0	S_2	0	0	-3/2	1/2	1	1/2	0	3
8000	x_1	1	0	3/2	-1/2	0	-1/2	0	2
0	S_4	0	0	4	-1	0	-1	1	7
	Z_j	8000	3900	12300	-4000	0	-100	0	
	$C_j - Z_j$	0	0	0	4000	0	100	0	

Optimal Sol^n: $x_1 = 2$ $x_2 = 8$ $x_3 = 0$

$Z = 47200$

Code for Mid-Night Slot-

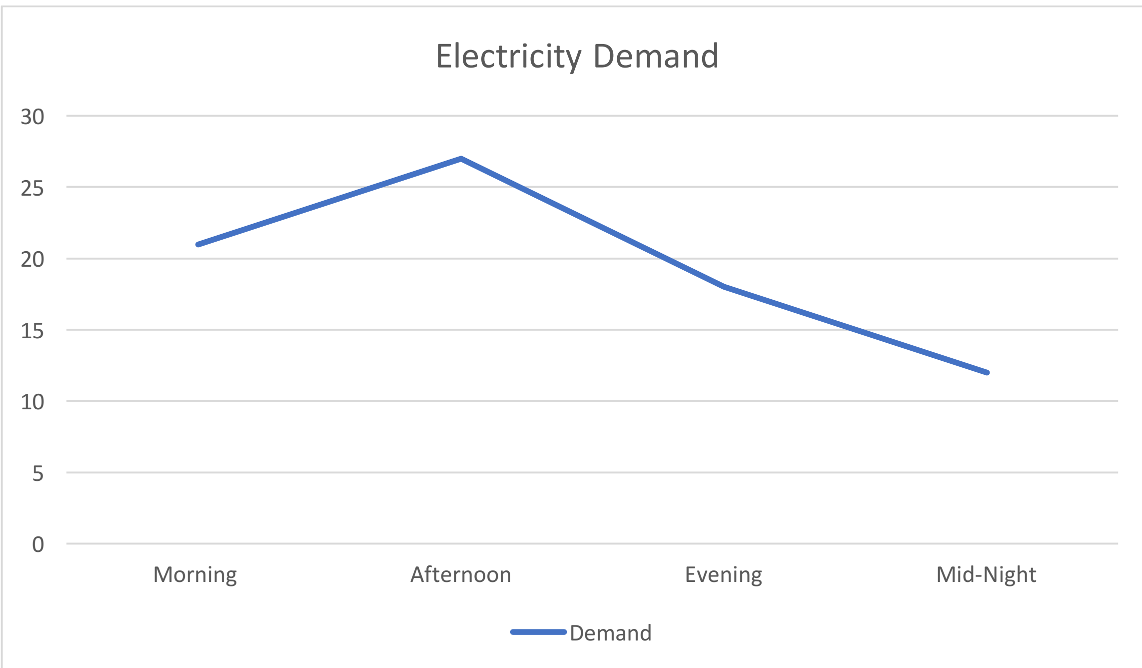
```
% Mid-night slot optimization
%   Z = 8000*x1 + 3900*x2 + 12300x3
%   -2*x1 + -1*x2 + -3*x3 <= -12
%   1*x1 <= 5
%   1*x2 <= 8
%   1*x3 <= 3
f = [8000 3900 12300];
A = [-2 -1 -3; 1 0 0; 0 1 0; 0 0 1];
b = [-12 5 8 3];
Aeq = [];
beq = [];
lb = [0 0 0];
ub = [];
[x, z] = linprog(f,A,b,Aeq,beq,lb,ub);
statement = 'optimized data for mid-night slot';
disp(statement);
disp('Number of generators of g-I, g-II and g-III are as follows --> ');
disp(x);
disp('Total optimized cost for the production of electricity demand is -->');
disp(z)
```

Output for Mid-Night Slot-

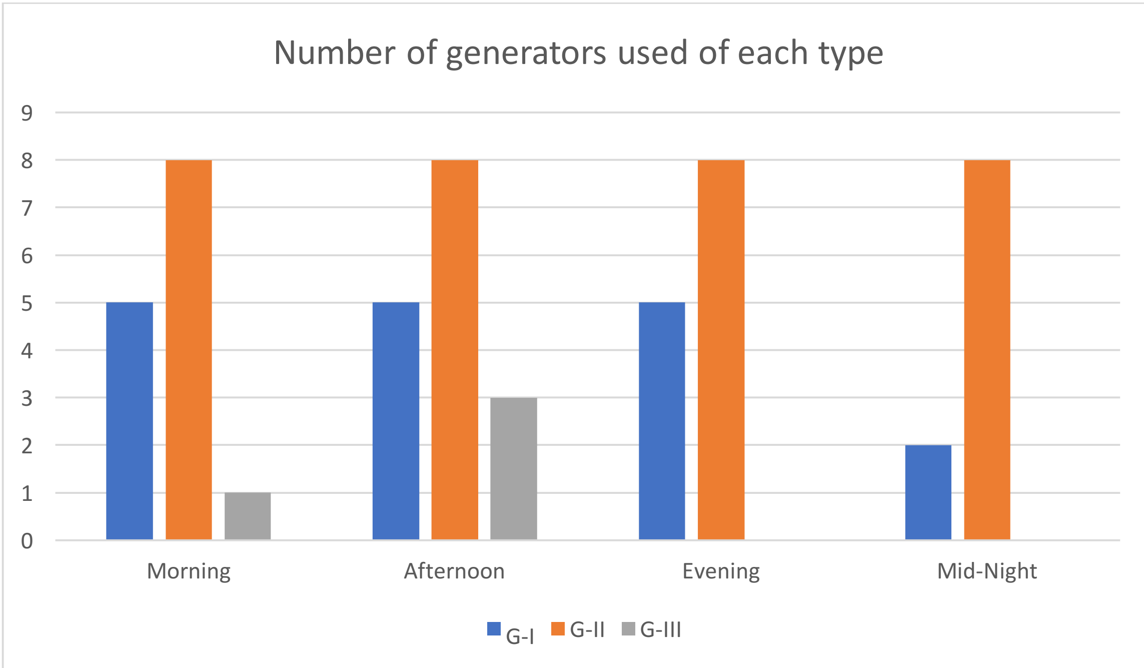
```
Optimization terminated.
optimized data for mid-night slot
Number of generators of g-I, g-II and g-III are as follows -->
     2.0000
     8.0000
     0.0000

Total optimized cost for the production of electricity demand is -->
   4.7200e+04
```

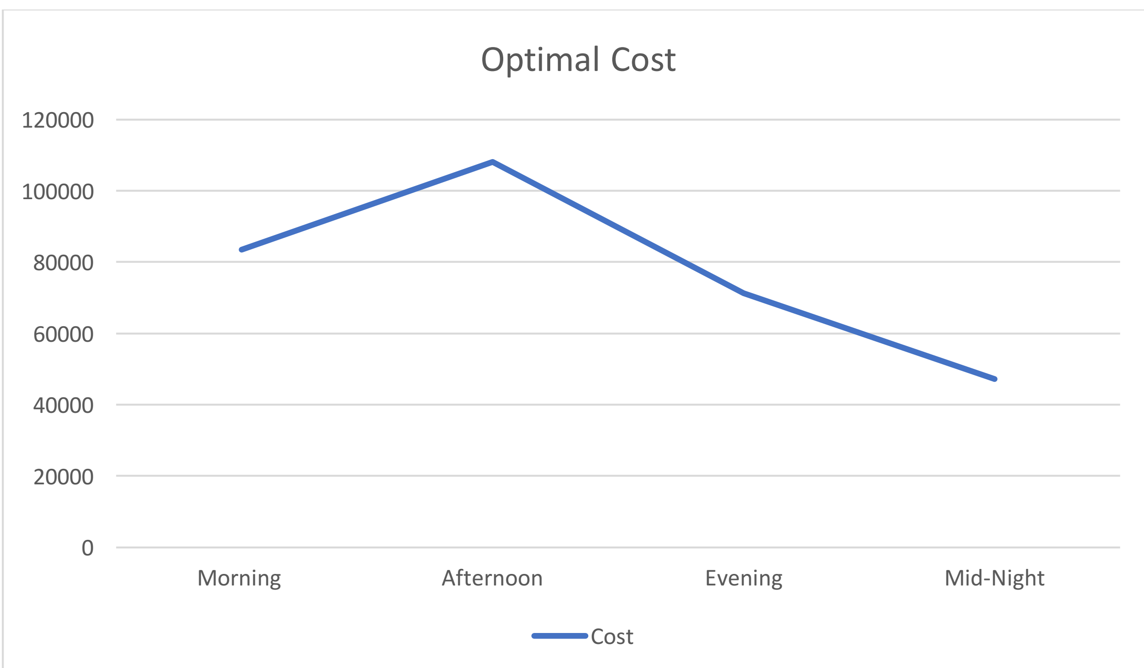
Conclusion

In this research, best mix is analyzed and presented. Best mix is the result of cost minimization that satisfies daily dispatch safety using the most advanced optimization modeling technique. Using this analysis method would allow adoption of best mix for easy and prompt power supply operation.



Result


Number of generators used of each type
9
8
7
6
5
4
3
2
1
0
Morning
Afternoon
Evening
Mid-Night
G-I
G-II
G-III


Optimal Cost
120000
100000
80000
60000
40000
20000
0
Morning
Afternoon
Evening
Mid-Night
Cost

ACKNOWLEDGEMENT

This project of Optimization Techniques and Advances has taught us a great deal about working and coordinating with our collogues. We would like to thank all our friends and mentors who have helped us to come over the obstacles that we faced in solving the given problem. We would also want to show our gratitude toward our distinguished faculty and mentor Dr. Jayaprakash Kar who assigned us such a task which would add to our experience in different aspects such as knowledge, group coordination etc. and also for the continuous support that has provided to guide us onto the right path during the project.

The LNM Institute of Information Technology
Jaipur, India

CERTIFICATE

This is to certify that this project submitted by Group -17 of A1 batch in requirement of Optimization Technique And Advances course of Computer Science Engineering, is a Bona fide record of work carried out by them at the Department of Computer Science Engineering, The LNM Institute of Information Technology, Jaipur, (Rajasthan) India, during the 3rd semester under my supervision and guidance and the same has not been submitted elsewhere.

________________ ____________________

Date Dr. Jayaprakash Kar