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Analysis of Weekly/Monthly/Yearly Load Profile Generated in 10 Different Industries/Utility Companies/Research Papers

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Abstract

The report first provides an introduction to generating stations and their various types. It then briefly defines economic and technical parameters on which we have done the analysis of 10 practical load profiles. After discussing in detail 10 such real-world load profiles we have attached manual as well as MATLAB calculations for technical factors.

In such manner, the report proposes a plan for two creating stations including their 3D models, details and financial aspects for driving the two case profiles.

Introduction

The conversion of energy available in different forms in nature into electrical energy is known as generation of electrical energy.

Electricity has become an indivisible part of our life today. It is required for many domestic, commercial as well as industrial purposes, and the requirement is still increasing day by day. This bulk demand for electric power is supplied by huge electric power-generating stations or power plants. Some fuel source, such as coal, oil, natural gas, or nuclear fuel produces heat, which is then used to boil water to create steam. The steam under high pressure is used to spin turbine coupled with the shaft(s) of one or more alternators or generating units. Generators then provide electric power to the grid through a transmission and distribution system. Indeed, generating stations are the source of all power.

- **Technical Analysis**
  - ✓ **Base Load**: The minimum load that must always be supplied by a generating Station
  - ✓ **Maximum Demand**: It is the greatest demand of load on the power station during a given period.
  - ✓ **Load Factor**: The ratio of average load to the maximum demand during a given period is known as load factor i.e.,

    Load factor = Average load / Max. Demand

    The ideal load factor is 1 which represent load is drawing the maximum Possible Power from a generating station,
  - ✓ **Demand Factor**: It is the ratio of maximum demand on the power station to its connected load i.e.

    Demand factor = Maximum demand / Connected load
  - ✓ **Diversity Factor:** The ratio of the sum of individual maximum demands to the maximum demand on power station is known as diversity factor i.e., Diversity factor = Sum of individual max. demands / Max. demand on station
  - ✓ **Plant Capacity Factor:** It is the ratio of actual energy produced to the maximum possible energy that could have been produced during a given period

Plant capacity factor = Actual energy produced / Max. energy that could have been produced

  - ✓ **Plant Use Factor:** It is ratio of kWh generated to the product of plant capacity and the number of hours for which the plant was in operation i.e.

    Plant use factor = Station output in kWh / Plant capacity × Hours of use
  - ✓ **Average Load** = Maximum Demand × Load Factor
  - ✓ **Units Generated/Annum** = Average Load in kW × No. of Hours in a Year
  - ✓ **Units Generated/Annum** = Maximum Demand in kW × Load Factor × 8760

- **Economical Analysis**

For economic analysis of a power plant, the overall annual cost of electrical energy generated by a power station can be expressed in two forms i.e. three part form and two part form. In this report two-part form will be used.

Two-part form: In this case, the annual cost of energy is divided into two parts

Total annual cost of energy = Rs. (A kW + B kWh) *:* where A and B are constants

A = a constant which when multiplied by maximum kW demand gives the annual cost of the 1st part

B = a constant which when multiplied by the annual kWh generated gives the annual running cost

Interest and depreciation area unit the terms that has to be employed in the social science of power generation

Interest: The cost of use of money is known as interest.

Depreciation: The decrease in the value of the power plant equipment and building due to constant use is known as depreciation.

In this report 10% of interest and depreciation rate will be considered

$$\text{Fixed Charges} = \text{Peak Demand} \times \text{Installed Charges/kW}$$

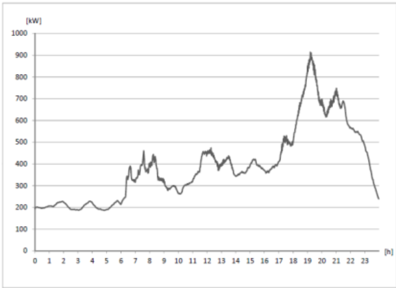
$$\text{Running Charges} = \text{Energy Generated} \times \text{Installed Charges / kWh}$$

$$\text{Per Unit Generation} = \text{Total Charges / Energy Generated}$$

LOAD PROFILES ANALYSIS

1. LOAD PROFILE #1:

Electric load at household level **(**kW**)** **[1]**



The data extracted from research paper is given below

TIME	kW
00:00	190
01:00	200
02:00	220
03:00	180
04:00	230
05:00	185
06:00	230
07:00	380
08:00	470
09:00	420
10:00	360
11:00	310
12:00	460
13:00	370
14:00	340
15:00	385
16:00	360
17:00	390
18:00	490
19:00	910
20:00	620
21:00	730
22:00	575
23:00	460

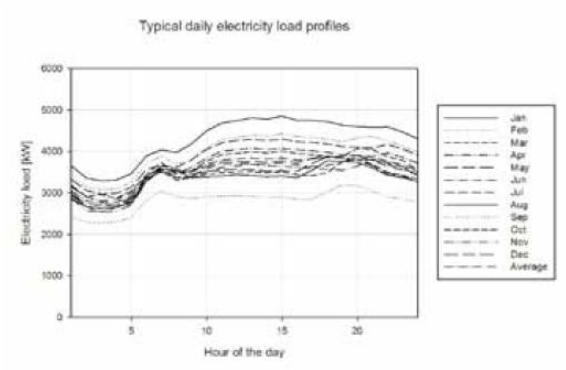
Units Consumed = 9705 kWh

Load Factor = 0.444 or 44%

Explanation: The demand increases during the night time (7 PM to 11 PM) because of lighting load. The demand stays capped at around 400 KW during the day time (6AM to 6 PM), with only occasional peaks. During the sleeping hours (after 12 AM to 5 AM) the demand is the lowest at 200 KW.

2. LOAD PROFILE #2:

Airport in Veneto Region Northern Italy **(**kW**)** **[2]**



The data extracted from research paper is given below

Time	kW
00:00	3700
01:00	3500
02:00	3520
03:00	3570
04:00	3580
05:00	3650
06:00	3680
07:00	3900
08:00	3950
09:00	4100
10:00	4500
11:00	4650
12:00	4580
13:00	4710
14:00	4750
15:00	4900
16:00	4700
17:00	4710
18:00	4400
19:00	4340
20:00	4200
21:00	4300
22:00	4600
23:00	4300

Units Consumed = 104990 kWh

Load Factor = 0.892 or 89.2%

Explanation: The demand during the (12 AM TO 9 AM) is almost around 400KW.
The peak demand of the airport is 4900KW which is at (3PM).the demand during the (9 AM to 12AM) is varies.

3. LOAD PROFILE #3:

Shopping Centers Building Indonesia (kW) [3]

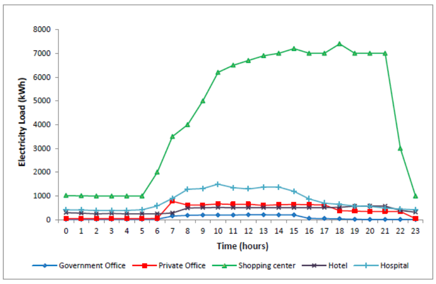


Figure 3 The electrical load profile of commercial buildings in Jakarta, Indonesia.

The data extracted from research paper is given below

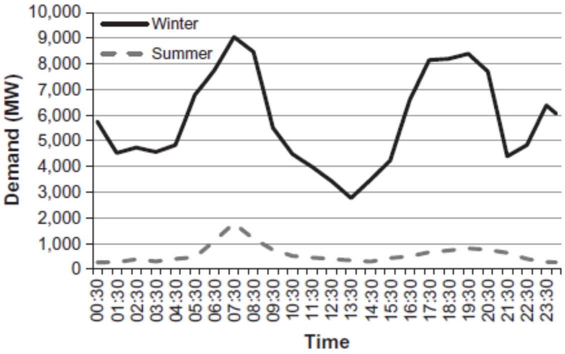
Time	kW
00:00	950
01:00	1020
02:00	980
03:00	970
04:00	975
05:00	1310
06:00	1700
07:00	3020
08:00	3800
09:00	4650
10:00	5650
11:00	6450
12:00	6590
13:00	6800
14:00	6900
15:00	7050
16:00	7100
17:00	7010
18:00	7200
19:00	7350
20:00	7020
21:00	7025
22:00	6130
23:00	2950

Units Consumed = 111600 kWh
Load Factor = 0.63 or 63%

Explanation: Shopping centers operate from 09:30 to 22:00 and their major utilities and lighting systems are started up at 07:00, after which the electrical load keeps rising until 22:00.

4. LOAD PROFILE #4:

UK Domestic Electricity (MW) [4]



The data extracted from research paper is given below

Time	MW
00:00	5900
01:00	5100
02:00	4700
03:00	4600
04:00	4750
05:00	6200
06:00	7300
07:00	8700
08:00	8800
09:00	6500
10:00	4900
11:00	4100
12:00	3600
13:00	3000
14:00	3200
15:00	4000
16:00	5150
17:00	7850
18:00	8200
19:00	8250
20:00	8000
21:00	5000
22:00	4750
23:00	5050

Units Consumed = 104990 kWh
Load Factor = 0.892 or 89.2%

Explanation: The peak demand of UK is achieved during the time (6AM to8AM) is 8800MW and then from (9AM to 4PM) is low. Then in the evening during the time (5PM to 8PM) again peak demand is achieved. The demand during the night time is lowest which moves around 6000MW.

5. LOAD PROFILE #5:

Singapore Commercial Building (kW) [5]

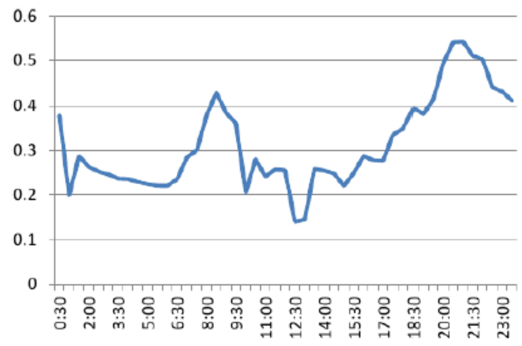


Fig. 1. Average load profile in NTU on February 26, 2012.

The data extracted from research paper is given below

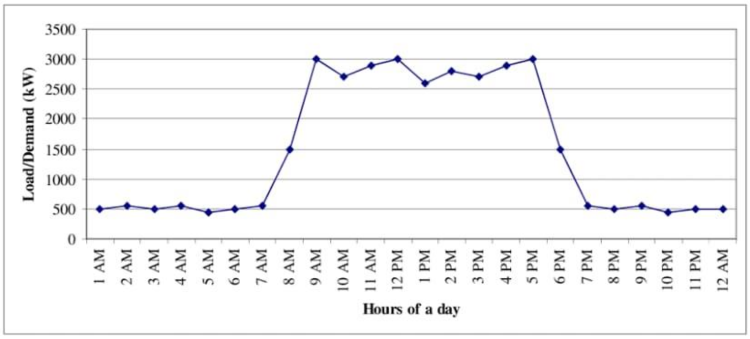
Time	kW
00:00	0.38
01:00	0.29
02:00	0.25
03:00	0.3
04:00	0.26
05:00	0.22
06:00	0.21
07:00	0.30
08:00	0.41
09:00	0.37
10:00	0.28
11:00	0.24
12:00	0.14
13:00	0.24
14:00	0.23
15:00	0.22
16:00	0.28
17:00	0.30
18:00	0.39
19:00	0.40
20:00	0.53
21:00	0.51
22:00	0.44
23:00	0.42

Units Consumed = 8.02 kWh
Load Factor = 0.63 or 63%

Explanation: The demand during the sleeping time is low which moves around 300W. The peak demand of the building is 530W (8PM) because of high lighting load.

6. LOAD PROFILE #6:

Industrial Load US (**k**W) **[6]**



The data extracted from research paper is given below

Time	kW
00:00	500
01:00	520
02:00	600
03:00	500
04:00	600
05:00	400
06:00	500
07:00	600
08:00	1500
09:00	3000
10:00	2700
11:00	2900
12:00	3000
13:00	2600
14:00	2800
15:00	2700
16:00	2900
17:00	3000
18:00	1500
19:00	400
20:00	500
21:00	600
22:00	400
23:00	500

Units Consumed = 35720 kWh
Load Factor = 0.496 or 49.6%

Explanation: The load between the night time (12AM to 7AM) is very low. The demand between the peak working hours of industry is around 3000KW. The demand of industry during the night is again low as the heavy industrial load is not working in night.

7. LOAD PROFILE #7:

Gujarat Household Electric Load (kW) [7]

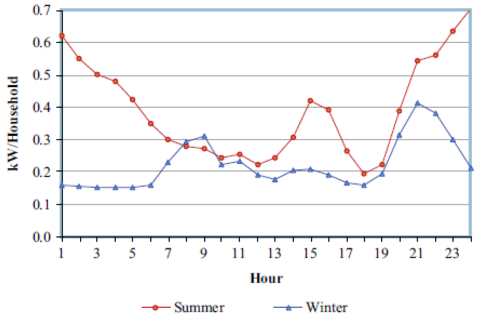


Fig. 7. Load curve for residential sector of Gujarat.
Sources: Authors' estimates.

The data extracted from research paper is given below

Time	kW
00:00	0.15
01:00	0.14
02:00	0.15
03:00	0.13
04:00	0.14
05:00	0.15
06:00	0.16
07:00	0.22
08:00	0.30
09:00	0.31
10:00	0.22
11:00	0.23
12:00	0.19
13:00	0.18
14:00	0.20
15:00	0.20
16:00	0.19
17:00	0.17
18:00	0.16
19:00	0.20
20:00	0.31
21:00	0.41
22:00	0.38
23:00	0.30

Units Consumed = 5.38 kWh
Load Factor = 0.546 or 54.6%

Explanation: The demand increases during the night time (8 PM to 11 PM) because of lighting load. The demand moves around 3100 W during the day time with only occasional peaks. During the sleeping hours (after 12 AM to 5 AM) the demand is the lowest at 150W.

8. LOAD PROFILE #8:

Load of Building Kenya (**k**W) [8]

The data extracted from research paper is given below

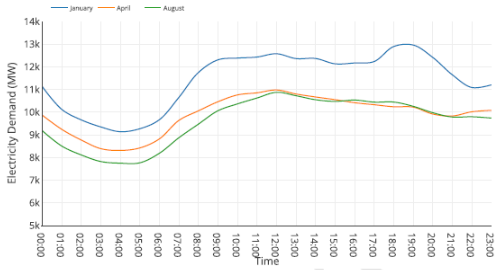
Time	kW
00:00	23
01:00	24
02:00	22
03:00	21
04:00	40
05:00	31
06:00	37
07:00	49
08:00	53
09:00	59
10:00	64
11:00	63
12:00	62
13:00	61
14:00	61
15:00	59
16:00	56
17:00	58
18:00	57
19:00	56
20:00	54
21:00	37
22:00	36
23:00	35

Units Consumed = 1151 kWh
Load Factor = 0.749 or 74.9%

Explanation: The peak demand of the building during the time (8AM to 8PM) is around 64KW. The demand during the night time (8PM to 7AM) moves around 49KW.

9. LOAD PROFILE #9:

Belgium Load Profile (MW) [9]



(a) Belgium.

The data extracted from research paper is given below

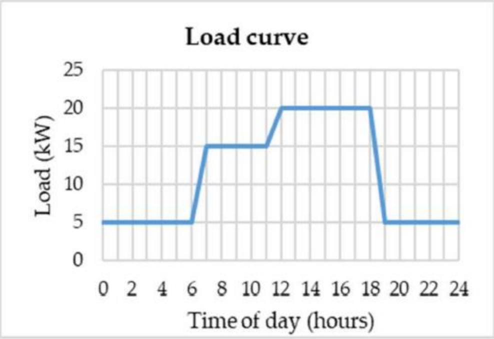
Time	MW
00:00	11100
01:00	10100
02:00	9700
03:00	9400
04:00	9200
05:00	9300
06:00	9700
07:00	10800
08:00	11900
09:00	12200
10:00	12250
11:00	12200
12:00	12500
13:00	12150
14:00	12100
15:00	12050
16:00	12150
17:00	12200
18:00	12900
19:00	12900
20:00	12300
21:00	11800
22:00	11100
23:00	11000

Units Consumed = 284200 kWh
Load Factor = 0.917 or 91.7%

Explanation: The peak demand of whole Belgium is moves around 12300MW during the day time or working hours. The demand during the night time is lowest around 97000MW.

10. LOAD PROFILE #10:

Building Load Profile (kW) [9]



The data extracted from research paper is given below

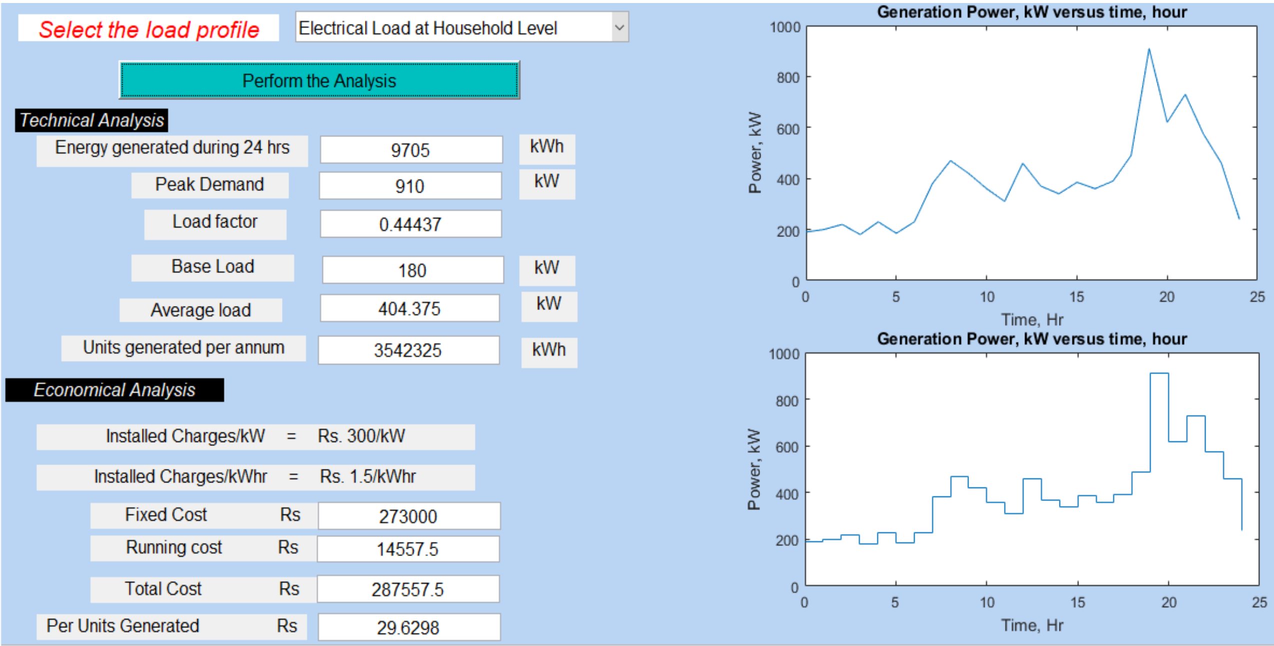
Time	kW
00:00	5
01:00	5
02:00	5
03:00	5
04:00	5
05:00	5
06:00	5
07:00	15
08:00	15
09:00	15
10:00	15
11:00	15
12:00	20
13:00	20
14:00	20
15:00	20
16:00	20
17:00	20
18:00	20
19:00	5
20:00	5
21:00	5
22:00	5
23:00	5

Units Consumed = 280 kWh
Load Factor = 0.583 or 58.3%

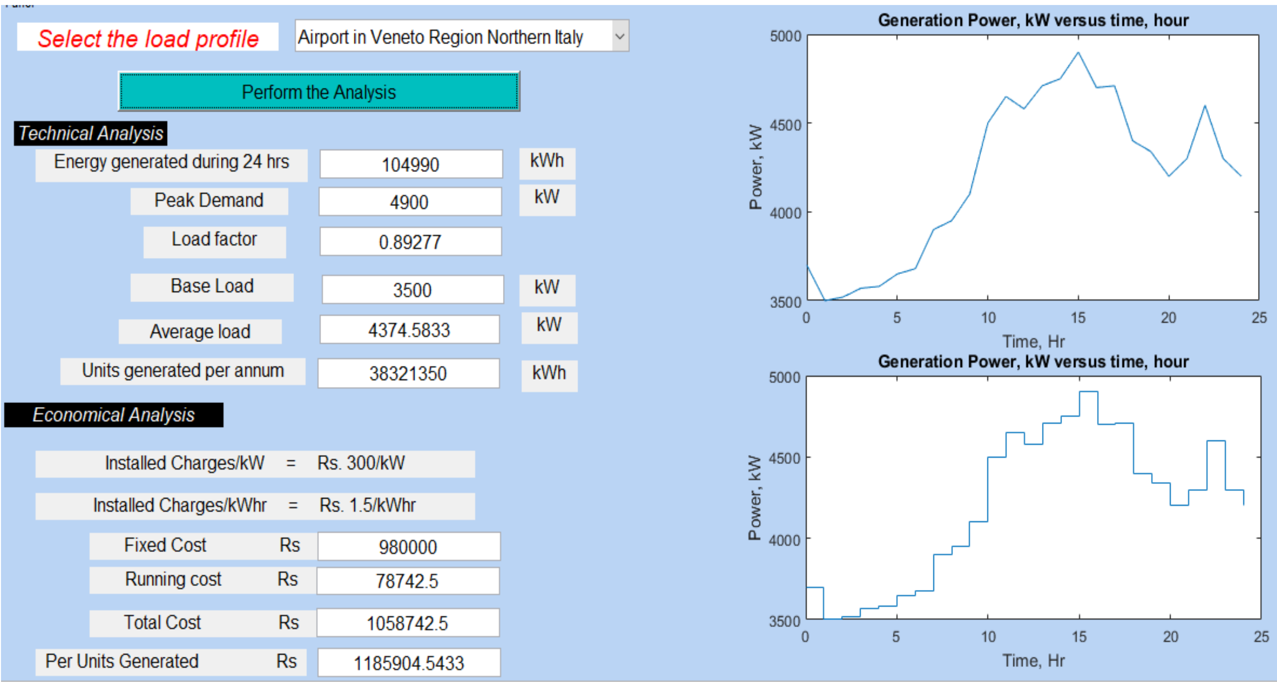
Explanation: The peak demand of the building is achieved during the time (12PM to 6PM) that is 20KW. The demand during the sleeping time is stays around 5KW. The demand during the time (7AM to 11AM) stays around 15KW.

GRAPHICAL USER INTERFACE ON MATLAB OF LOAD PROFILES

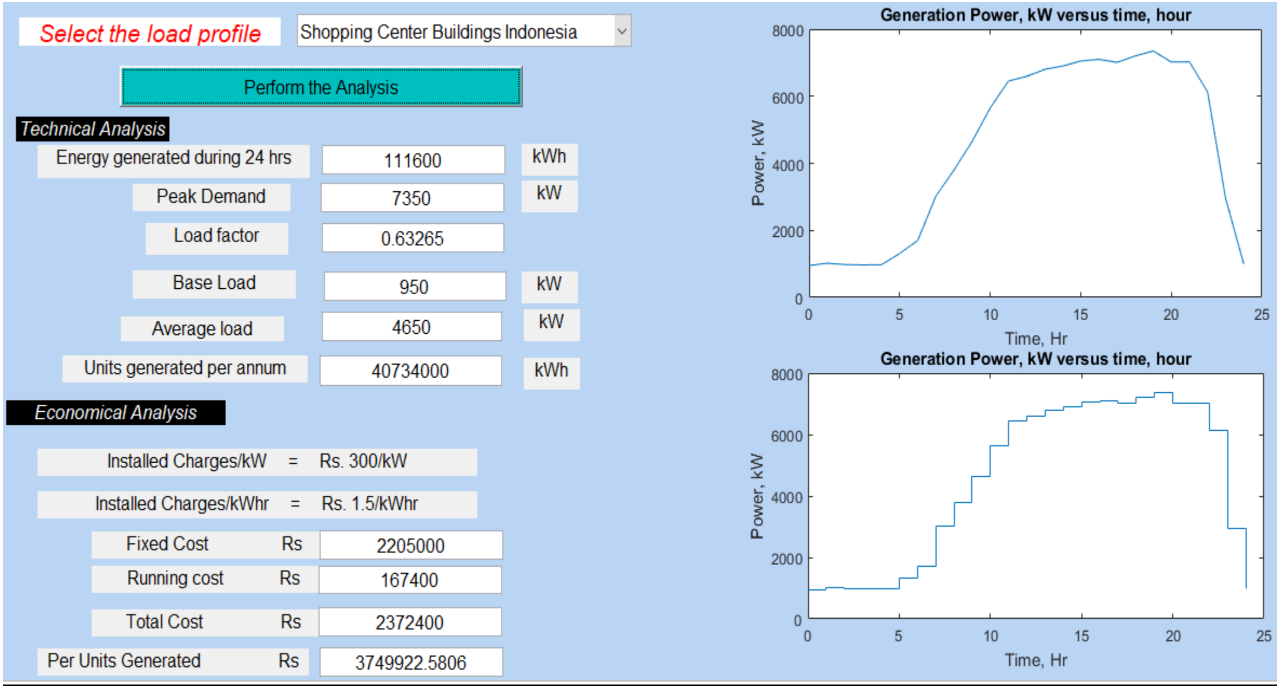
1. LOAD PROFILE #1:



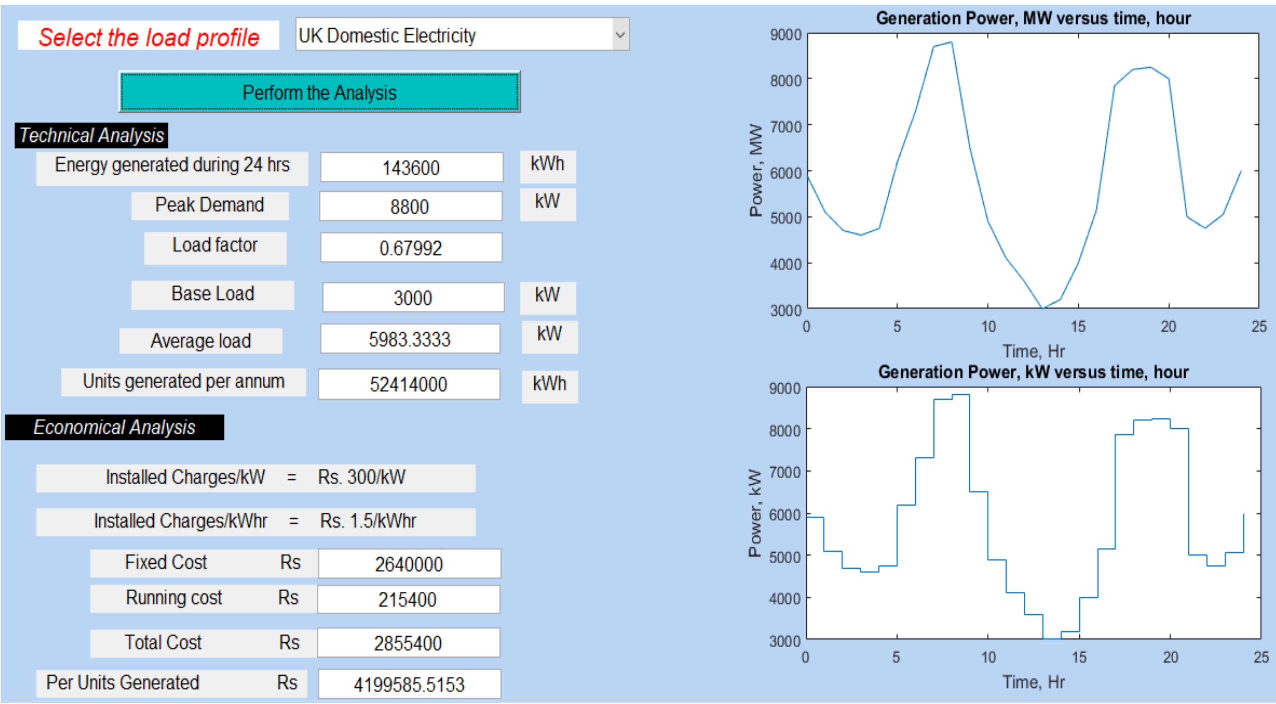
2. LOAD PROFILE #2:



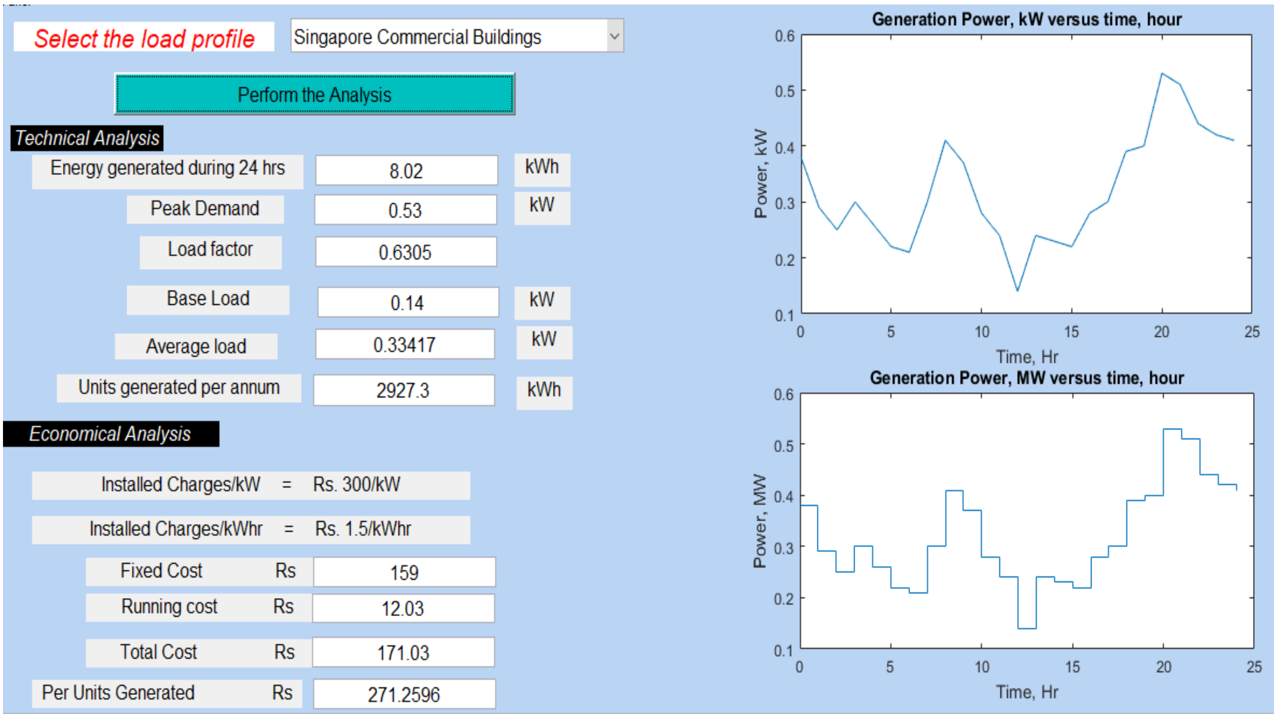
3. LOAD PROFILE #3:



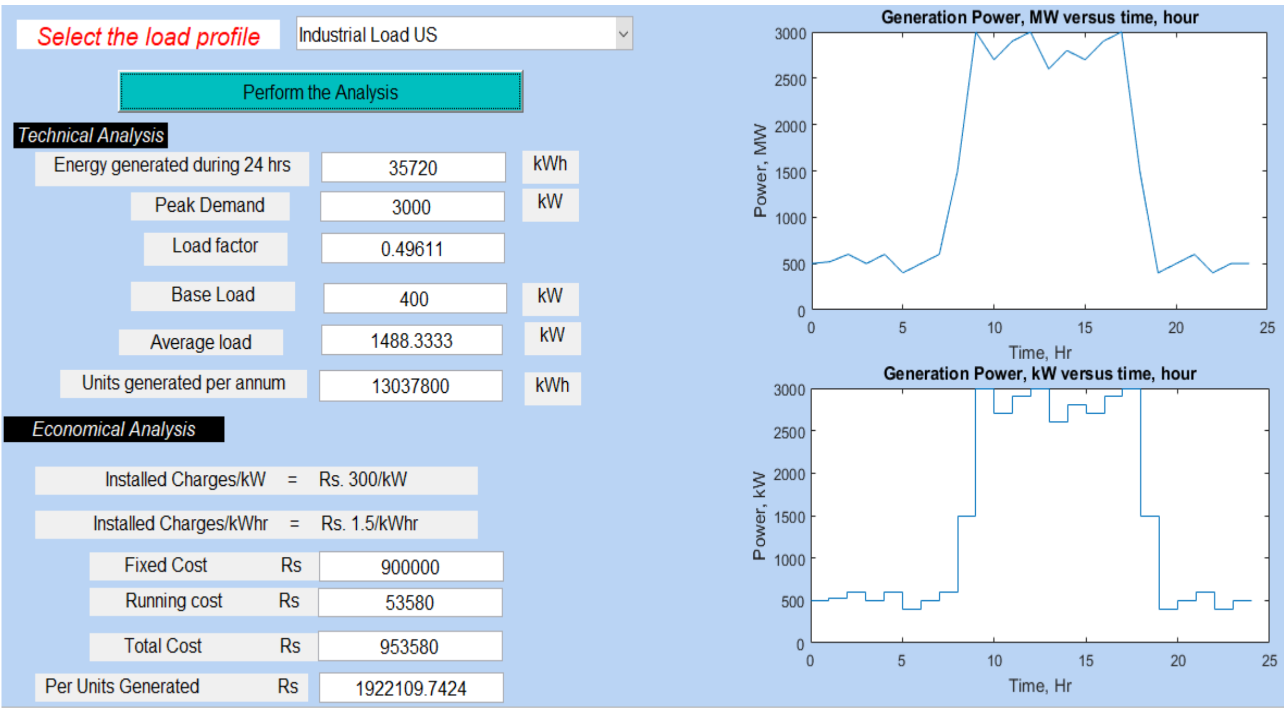
4. LOAD PROFILE #4:



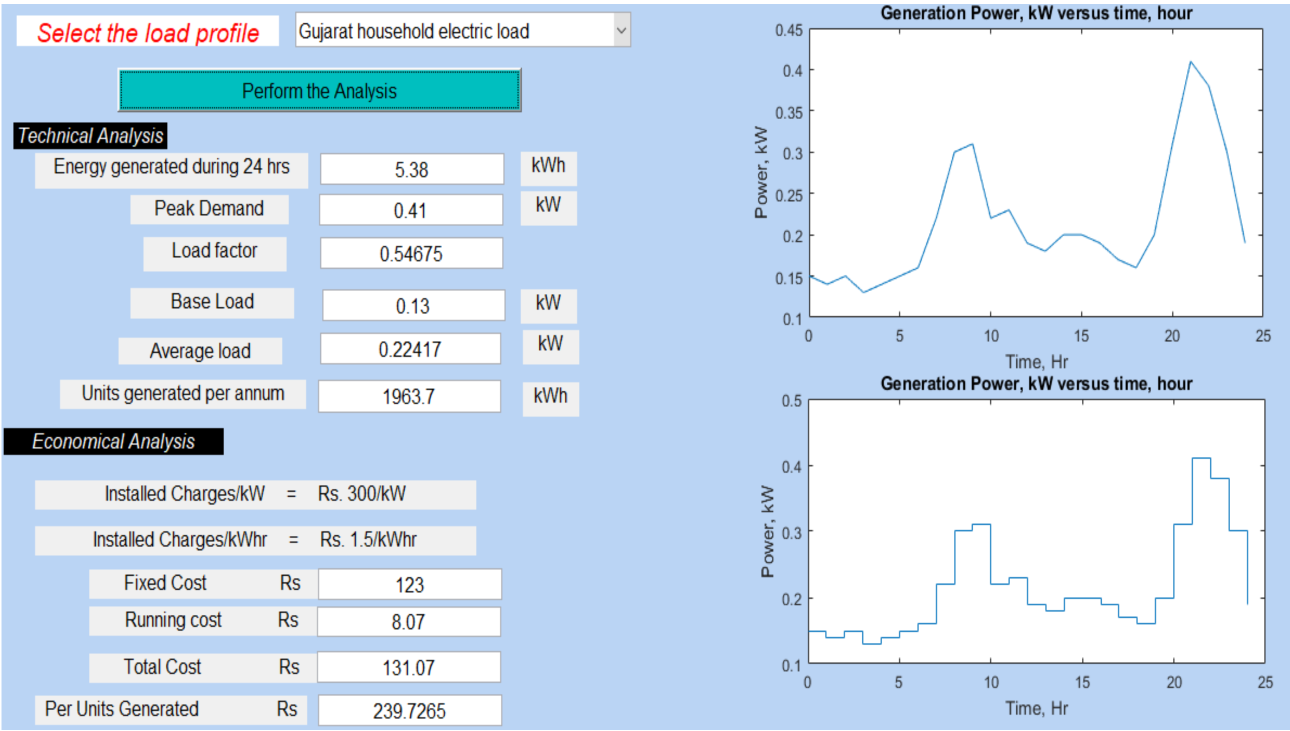
5. <u>LOAD PROFILE #5:</u>



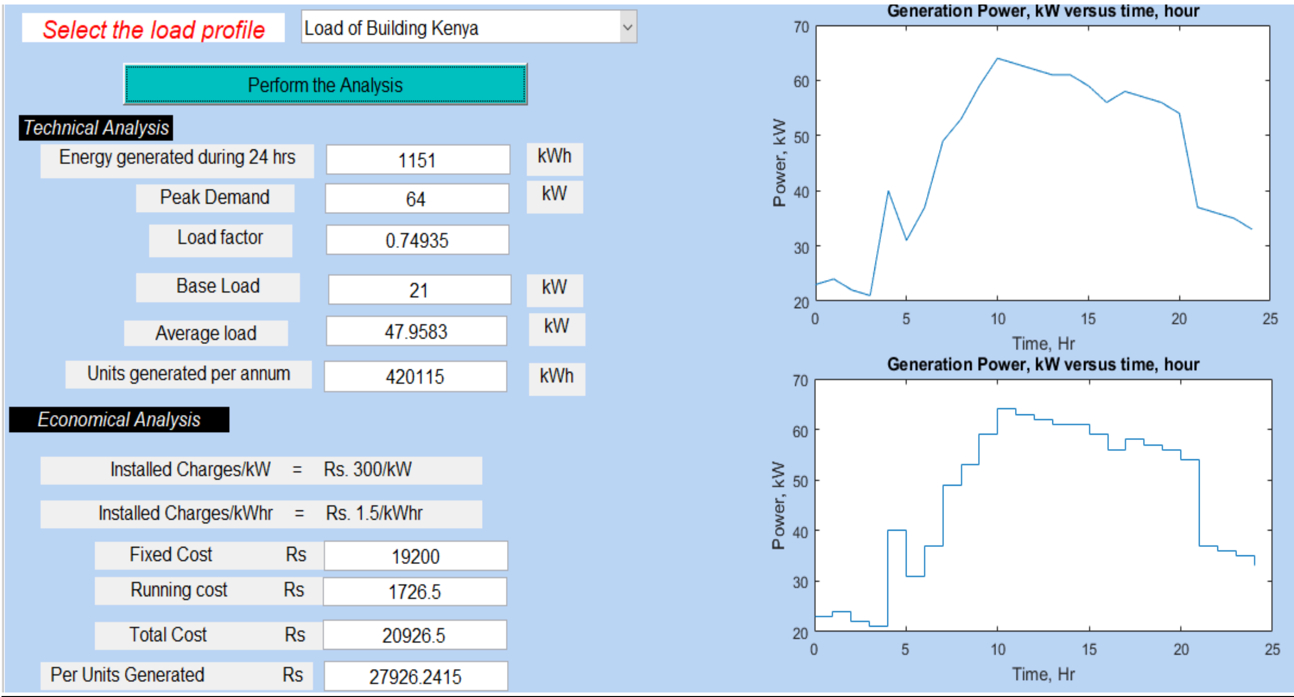
6. <u>LOAD PROFILE #6:</u>



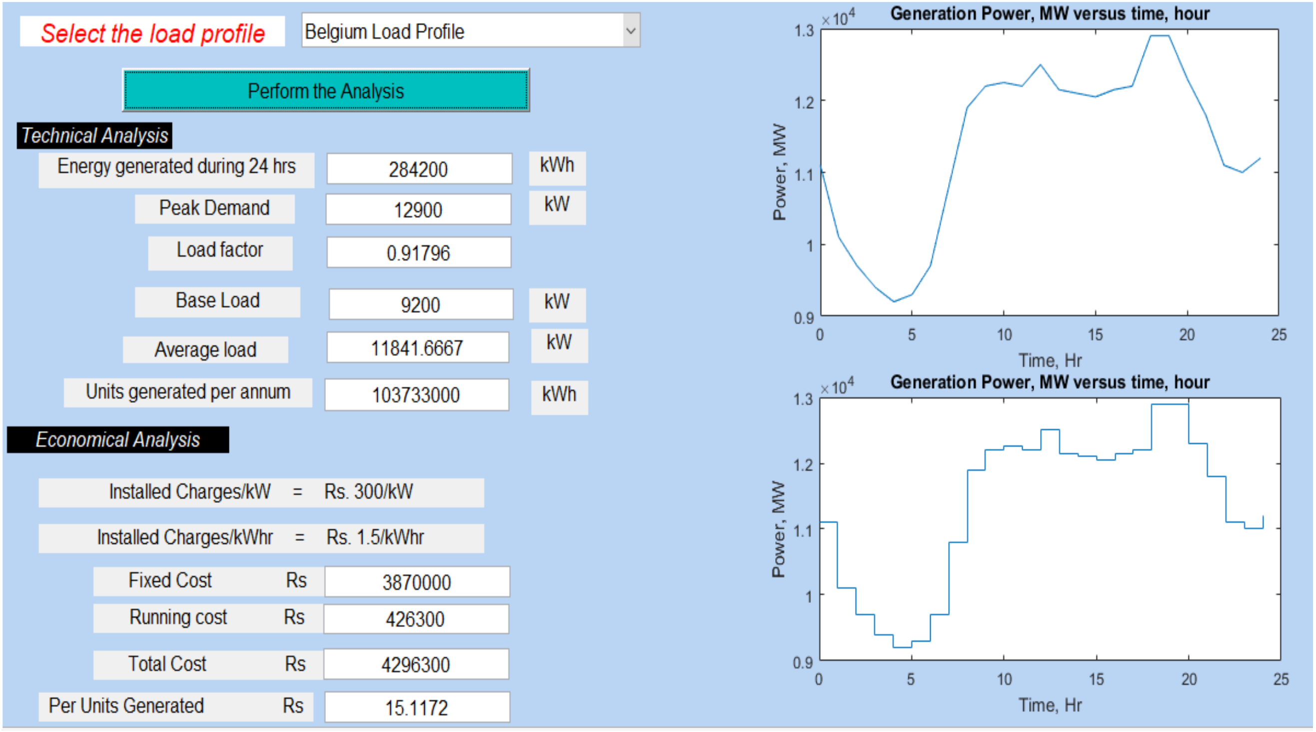
7. LOAD PROFILE #7:



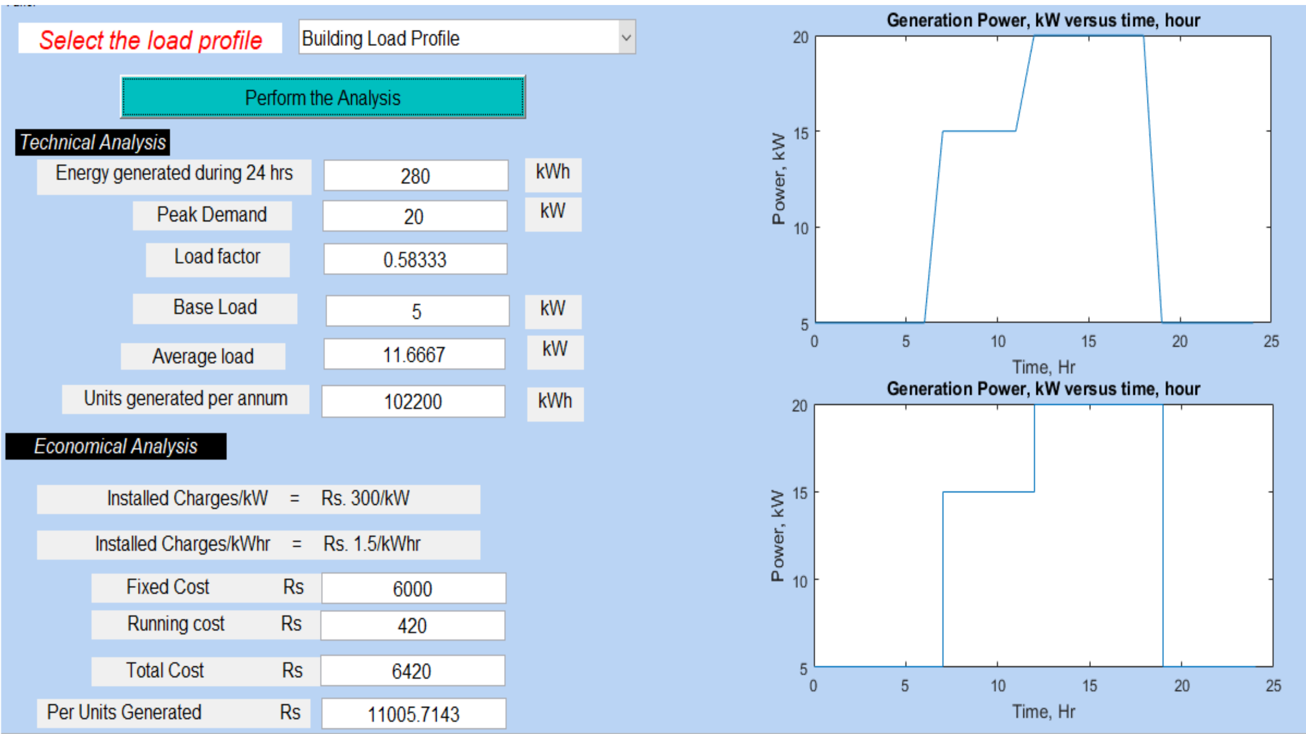
8. LOAD PROFILE #8:



9. LOAD PROFILE #9:



10. LOAD PROFILE #10:



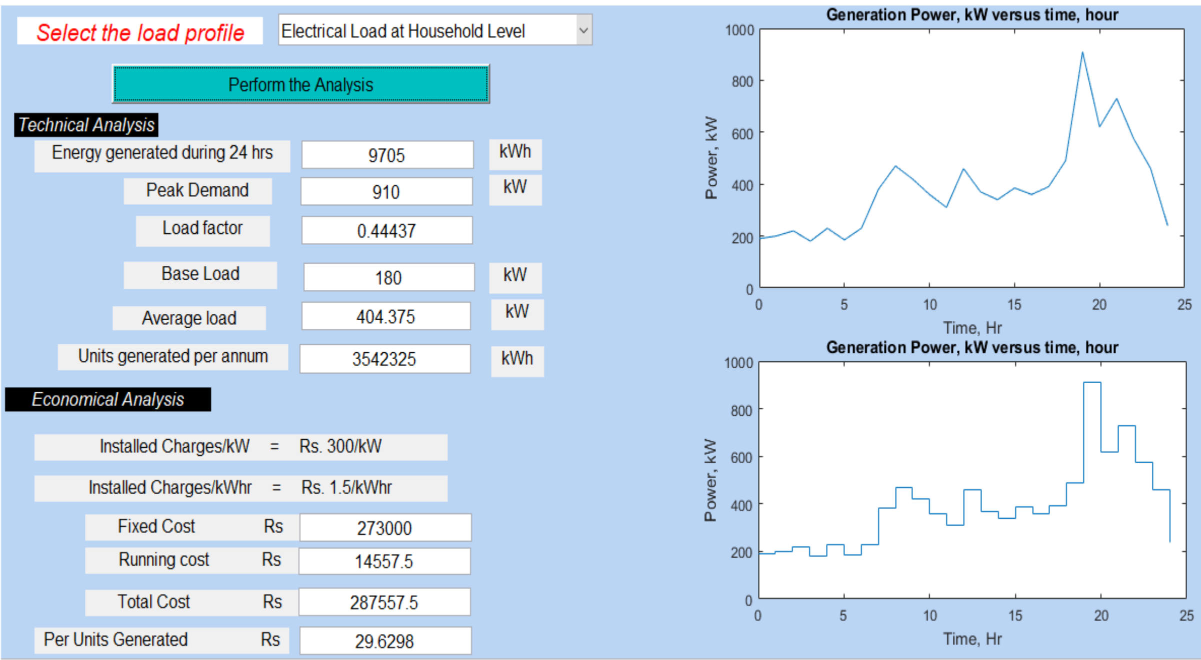
LOAD FACTOR COMPARISON

Load Profile	Average Load (kW)	Maximum Demand (kW)	Load Factor (%)
Electric load at household level	404.375	910	44.4
Airport in Veneto Region Northern Italy	4374.8	4900	89.2
Shopping Centers Building Indonesia	4650	7350	63.2
UK Domestic Electricity	5893.3	8800	67.2
Singapore Commercial Building	0.334	0.53	63.2
Industrial Load US	1488.3	3000	49.6
Gujarat Household Electric Load	0.224	0.41	54.6
Load of Building Kenya	47.95	64	74.9
Belgium Load Profile	11841.6	12900	91.7
Building Load Profile	11.66	20	58.3

The Blue shaded region show the load profile with most poor load factor ***worst scenario)*** and we will be considering it for proposing it more efficient power generating station design for them.

POWER PLANT DESIGNING AND ECONOMIC ANALYSIS FOR TWO WORST CASES

CASE 1: ELECTRICAL LOAD AT HOUSEHOLD LEVEL



Current Load factor =44.4%

Average Load= 404.37kW

Maximum Demand= 910kW

Energy generated in 24 hours=9705k kwh

Generator Sizing

Proposed number of units and values of generators are as

- Number of units: 5
- Values of Units: 250 kW (as base load) + 150 kW + 100 kW + 100 kW
- Plant Reserve capacity = 250 kW
- Plant installed capacity = 600 kW + 250 kW = 850 kW

Improvement Method

For this Load profile, we have adopted peak shifting method. The peak which was occurring at 7 pm is evenly distributed from 4 pm to 11 pm. In this way average load increases which lead to increase the load factor which ultimately reduces per unit generation cost of the electricity. The improved load factor is beneficial for both customer and utility.

Plant Running Sequence

Hour	Load (KW)	Generator (values in KW)
00(Mid night)	190	250
1	200	250
2	220	250
3	180	250
4	230	250
5	185	250
6	230	250
7	380	250 +150
8	470	250 +150 + 100
9	420	250 +150+ 100
10	460	250 +150 + 100
11	360	250 + 150

Running schedule for noon

12 (noon)	310	250 +150
01	370	250 +150
02	340	250 +150

03	385	250 +150
04	600	250 +150+100+100
05	600	250 +150+100+100
06	600	250 +150+100+100
07	600	250 +150+100+100
08	600	250 +150+100+100
09	600	250 +150+100+100
10	600	250 +150+100+100
11	600	250 +150+100+100

CALCULATION OF PCF & PUF

After optimizing the peak the improved load factor = 67.3%

PCF (Plant Capacity Factor) = Average Load / Plant installed capacity
= 404.375 / 850 = 0.47 OR 47 %

PUF (Plant Use Factor) = Required KWh / Actual KWh generated
Required KWhr = 9705
Actual KWh generated = 9730
PUF = 9705/ 9730= 99.7 %

ECONOMIC ANALYSIS OF THE POWER PLANT

Total annual cost of energy = Rs. (A kW + B kWh)

Capital cost / kW= Rs 10,000

Total capital cost for 9730 kW= Rs 97,300,000

Interst and Dep = 10%

Total fixed annual cost = 0.10 x 97,300,000

So A= 9,73,000

Operating cost/ kWh = Rs 3

Units generated per year = Max demand x LF x hours in year

=600 x 0.67 x 8760 = 3,521,520

So Total operating cost = 3521520 x 3 = Rs 10,564,560

Total annual cost = Rs (A+B)

= Rs 11,537,560

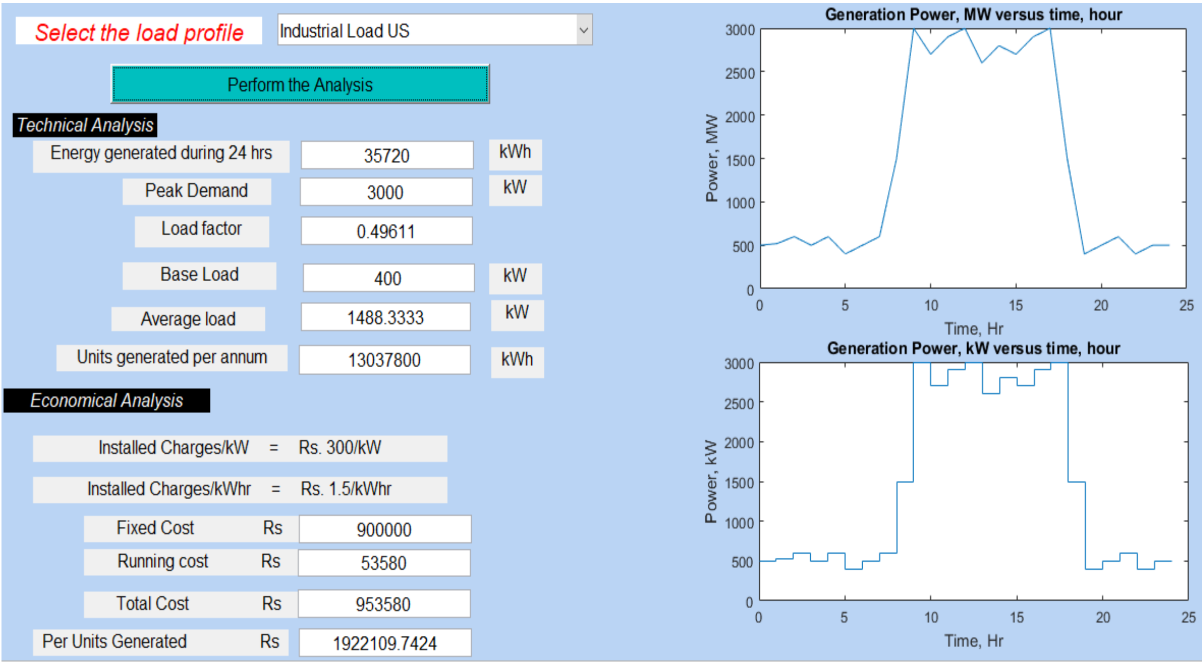
Total cost per kWh = 11537560 / 3521520

Total cost per kwh= Rs 3.27

The above is the cost per unit generated which is much more optimized and economical than the original one

Comment: *We have used Diesel Power Plant for Electrical Load at Household Level.*

CASE 2:



Current Load factor = 49.6%

Average Load= 1488.33 kW

Maximum Demand= 3000kW

Energy generated in 24 hours=35720 kWh

Generator Sizing

Proposed number of units and values of generators are as

- Number of units: 5
- Values of Units: 600kW (as base load) + 600 kW + 600 kW + 500 kW
- Plant Reserve capacity = 600 kW

Plant installed capacity = 2300 kW + 600 kW = 2900 kW

Improvement Method

For this Load profile of industrial load, we have adopted peak shaving method. The peak demand of 3000kW is shaved and is shifted to the time where there is less electric demand. Industry is advised to increase its working hour so that demand gets evenly distributed.. In this way average load increases which lead to increase the load factor which ultimately reduces per unit generation cost of the electricity.

Plant running sequence from 12am to 11am

Hour	Load (KW)	Generator (values in KW)
00(Mid night)	500	600
1	520	600
2	600	600
3	500	600
4	600	600
5	400	600
6	500	600
7	600	600
8	2300	600+600+600+500
9	2300	600+600+600+500
10	2300	600+600+600+500
11	2300	600+600+600+500

Plant running sequence from 12pm to 11pm

Hour	Load (KW)	Generator (values in KW)
00(Noon)	2300	600+600+600+500
1	2300	600+600+600+500
2	2300	600+600+600+500
3	2300	600+600+600+500
4	2300	600+600+600+500
5	2200	600+600+600+500
6	2200	600+600+600+500
7	2200	600+600+600+500
8	2200	600+600+600+500
9	600	600
10	600	600
11	600	600

CALCULATION OF PCF & PUF

After optimizing the peak the improved load factor = 64.7%

PCF (Plant Capacity Factor) = Average Load / Plant installed capacity
= 1488.33 / 2900= 0.51 OR 51 %

PUF (Plant Use Factor) = Required KWh / Actual KWh generated

Required KWh = 35220

Actual KWh generated = 35520

PUF = 35220 / 35520= 99.1 %

ECONOMIC ANALYSIS OF THE POWER PLANT

Total annual cost of energy = Rs. (A kW + B kWh)

Capital cost / kW= Rs 10,000

Total capital cost for 35520 kW= Rs 355,200,000

Interest and Dep = 10%

Total fixed annual cost = 0.10 x 355,200,000

So A= 35,520,000

Operating cost/ kWh = Rs 3

Units generated per year = Max demand x LF x hours in year

=2300x 0.64 x 8760 = 12,894,720

So Total operating cost = 12,894,720 x 3 = Rs 38,684,160

Total annual cost = Rs (A+B)

= Rs 74,204,160

Total cost per kWh = 74204160 / 12,894,720

Total cost per kwh= Rs 5.758

The above is the cost per unit generated which is much more optimized and economical than the original one

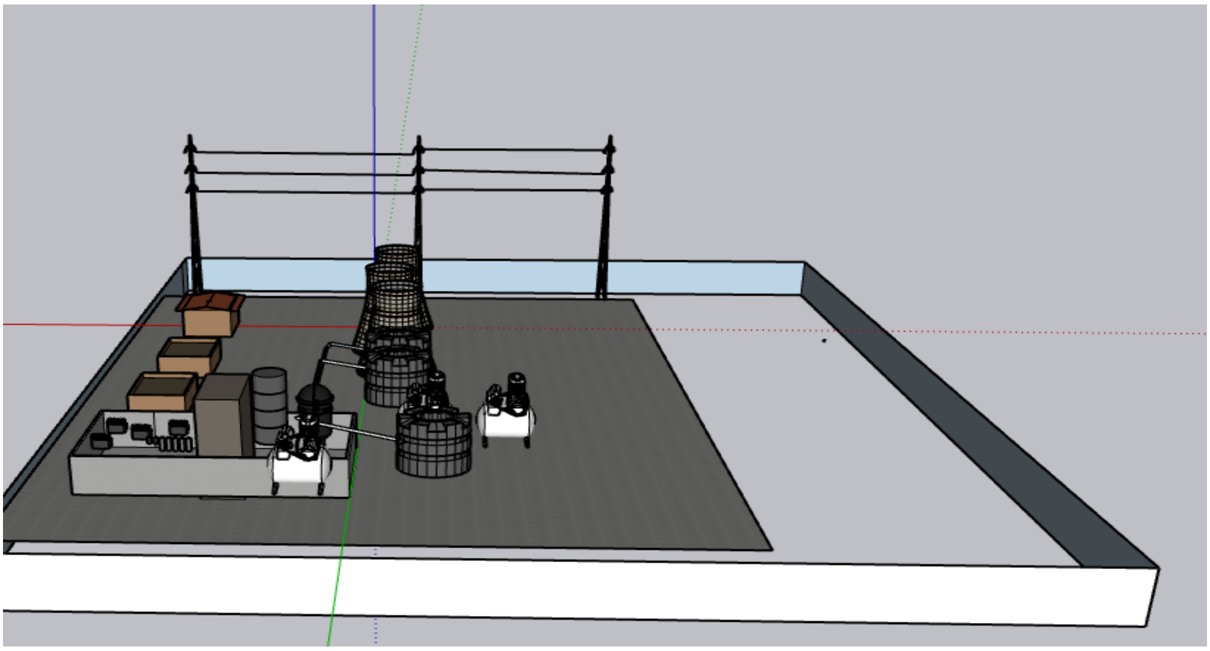
Comment: ***We have used Nuclear Power Plant for US Industrial Load.***

MODELLING OF POWER STATIONS

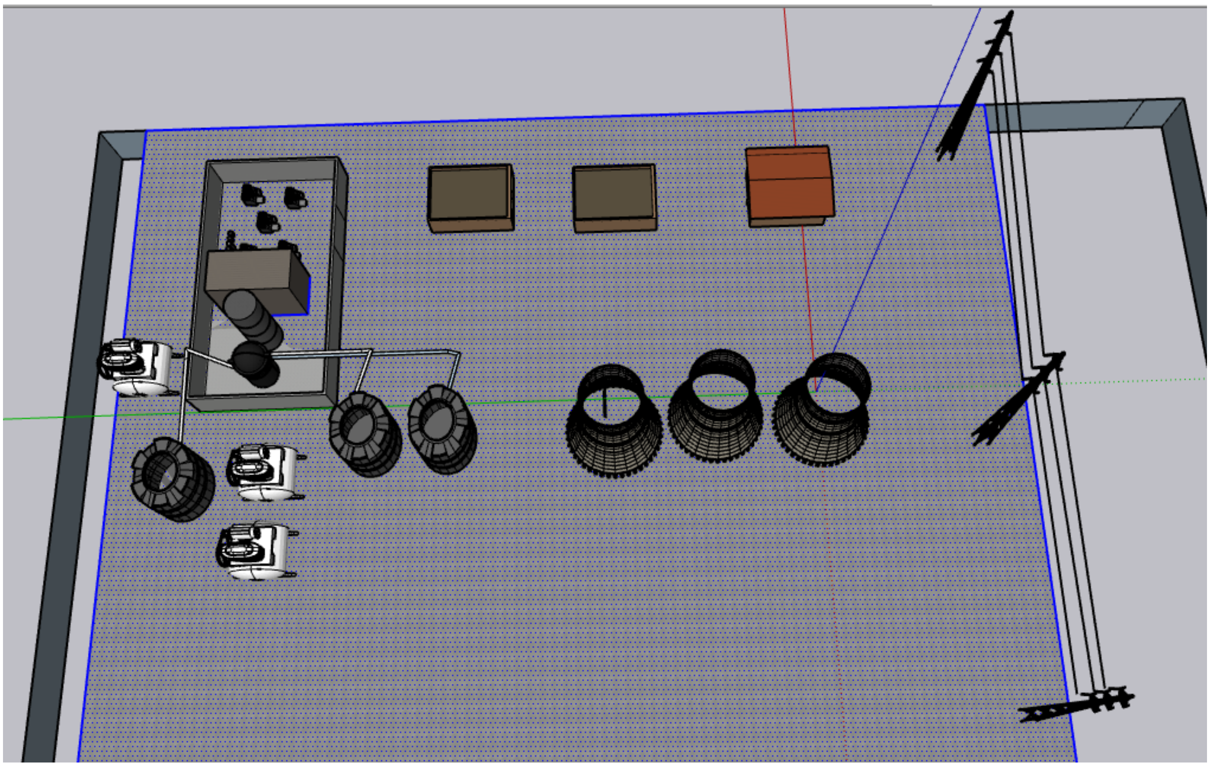
NUCLEAR POWER PLANT 3D VIEW (SKETCHUP)

We have used Nuclear Power Plant for US Industrial Load.

Front Layout



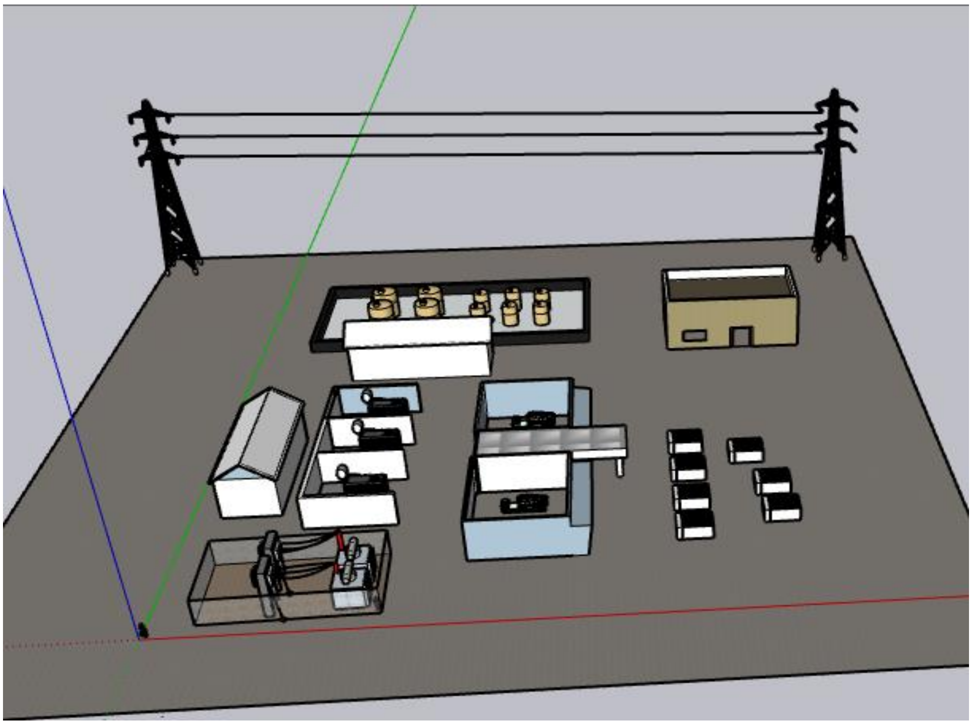
Top View



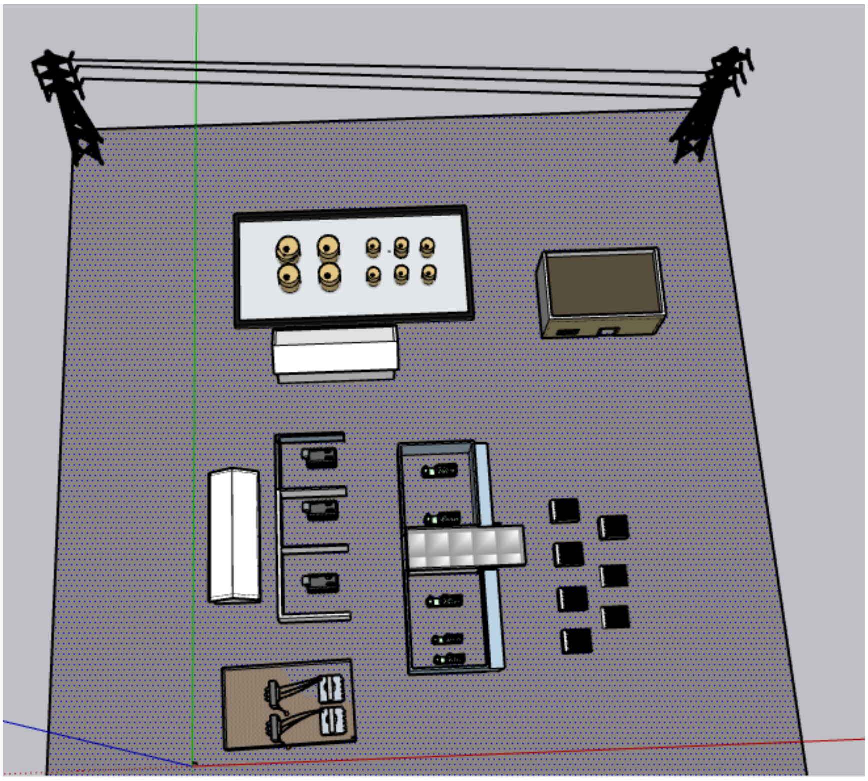
DIESEL POWER PLANT 3D VIEW (SKETCHUP)

We have used Diesel Power Plant for Electrical Load at Household Level .

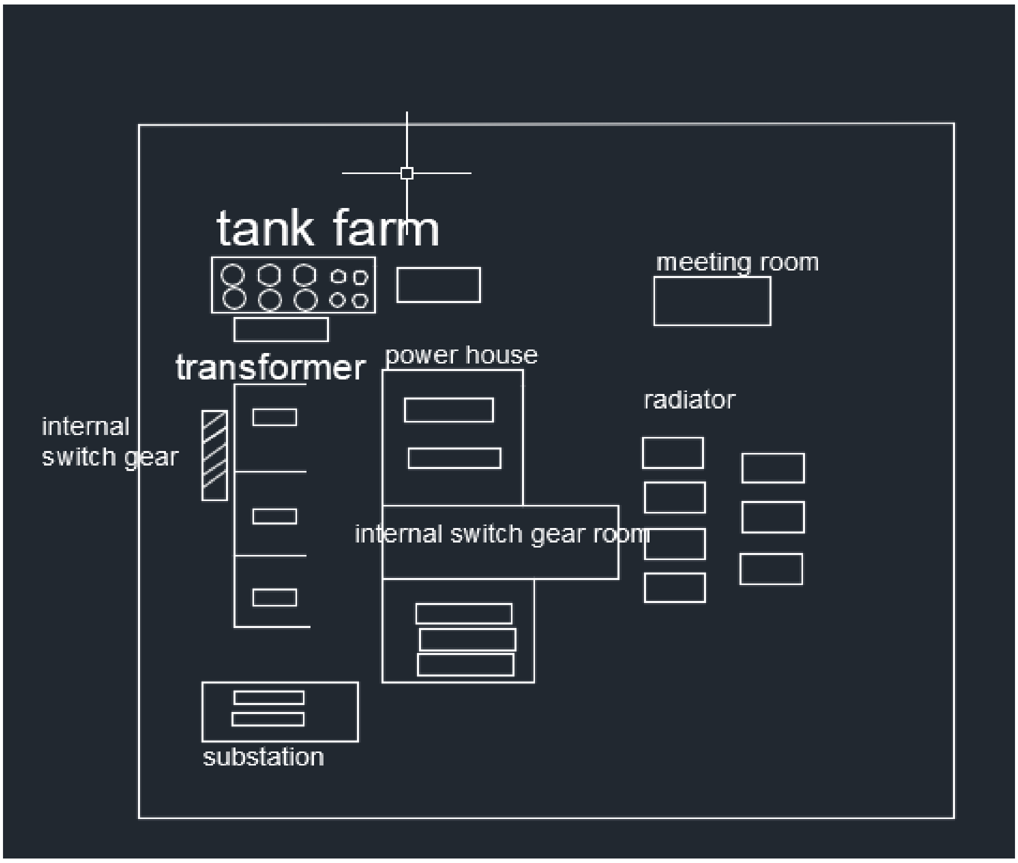
Front Layout



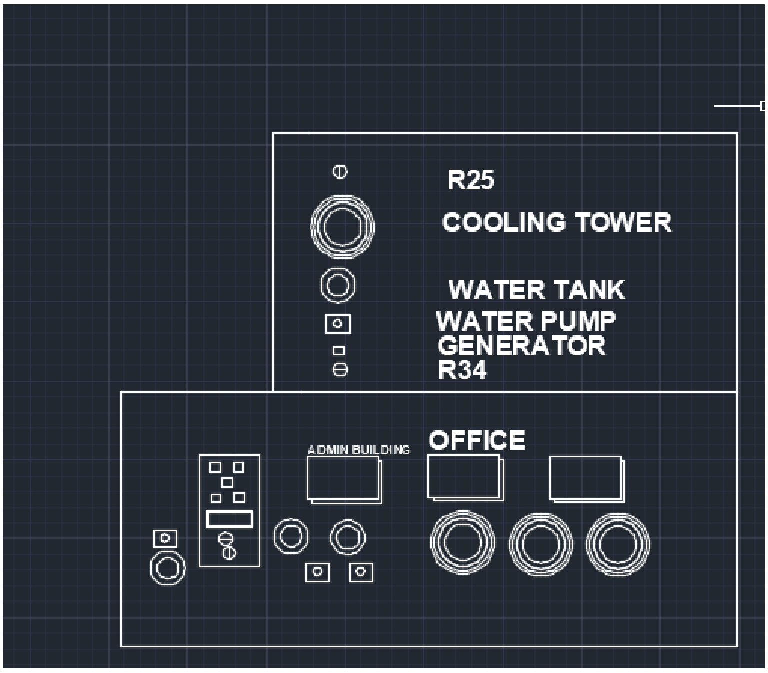
Top View



DIESEL POWER PLANT 2D VIEW (AUTOCAD)



NUCLEAR POWER PLANT 2D VIEW (AUTOCAD)



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