

## Investigation of Electrical Load Characteristics at Warri Refinery and Petrochemical Ltd., Warri

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**Abstract:** The electrical load characteristics are basic information needed by Electrical Consultant, when designing an electrical system for a refinery. In establishing such data like load density, demand factor and load factor, it was necessary to conduct a research so as to ascertain the parameters in an existing industry, where Warri refinery was taken as a case study. The research came out with the following useful data for: Load density =  $12.8 \text{ VA M}^{-2}$ , Load factor = 88.5%, Demand factor = 24.4%.

**Key words:** Load characteristics, electrical consultant, refinery, demand factor, load factor

### INTRODUCTION

In consultancy services, the client needs to be advised on the cost implication of a proposed project. He therefore, seeks professional information necessary for the successful implementation of his proposed project. A client embarking on an industrial outfit involving the use of electricity obviously needs an Electrical Consultant Engineer or firm. The Electrical Engineer in turn must be familiar or have records of data relating to the proposed industry. His consultancy services must recognize the need for a cost effective design of the whole power system, so that the client can realize adequate profit on a long-term basis. A petroleum refinery industry involves large capital out lay, which runs into billion of Nairas, hence a good and durable electrical design is essential (Usifo, 2000).

In view of the above, the consultant needs to know the electrical load characteristics which are mainly load density, maximum power demand, load demand and demand factor. These factors will help him a lot to carry out his functions properly (Usifo and Ehiwario, 2003).

Prior to this time, researches have been done to ascertain the electrical load characteristics for some industries in Nigeria viz a viz:

- Flour Mills, have demand factor, load density and load factor as 22.5%,  $13.9 \text{ VA M}^{-2}$  and 68.25%, respectively (Usifo and Ehiwario, 2003).

- Medical Hospitals, have demand factor, load density and load factor as 60%,  $9 \text{ VA M}^{-2}$  and 62%, respectively (Usifo and Idedia, 2004).
- Breweries, have demand factor, load density and load factor as 43%,  $37.8 \text{ VA M}^{-2}$  and 74.3%, respectively (Usifo and Okhuevbie, 2004).

The electrical load characteristic for Warri refinery is the focus of this study.

**History of electrical system in Warri refinery:** The Warri refinery, was commissioned in 1978 at Warri. The electrical generating system consists of three steam turbine driven generators of 15 MW rating each.

In 1988, the Petrochemical Company was added to the refinery, hence, the name Warri refinery and Petrochemical Ltd. By this time, more three gas turbines driven generator were installed, where two were of 30MW each and the other 20MW. In addition, for lighting loads, a diesel generator of 1.6MW was installed. On the whole, the total power of 126.6MW was the generating capacity of the new company as at 1988.

The distribution system consists of 24nos of sub-stations with four voltage levels of 33KV, 11KV, 6.6KV and 400V, respectively (Alsthom, 1990).

**Load density:** Load density is defined as the maximum power demand per unit area of a given industry. It is expressed in Volt-Amperes per square metre ( $\text{VA M}^{-2}$ ).

**Maximum demand:** This is the highest demand power over a duration of 15, or 30 or 60 min of electrical loads per day in a plant. It is expressed in Volt-Amperes (VA) (Theraja, 1997).

**Demand factor:** This is the ratio of maximum demand to the total connected loads in a plant. It is expressed in percentage or less than unity. The factor is very useful in determining the rating of transformers, switchgears and cables (Alsthom, 1990).

**Load factor:** This is the ratio of average demand to the maximum demand per day. It is less than unity. This factor is useful during plant operation.

## MATERIALS AND METHODS

The research was carried out at Warri refinery and Petrochemical Ltd., Warri.

The study involves:

- Determination of the built up area of the industry.
- Identification and computation of the total connected load in each section of the refinery.
- Measurement of the maximum load demand for 28 working days on a 24 h basis per day, when other utilities in the plant were working perfectly.
- Computation of the demand factor, load factor and load density.

## MEASUREMENTS

**Areas and connected loads:** The built up areas were physically measured in conjunction with the as built in factory drawings showing the connected loads. The results are shown in Table 1 for the industry.

**Maximum electrical load demand:** The maximum demand within 2 h interval reading was carried out on a daily basis for continuous 24 h operation (Nageth and Kothari, 1982).

Readings were taken from maximum demand meter in the control room at the power house. Readings were carried out for twenty eight working days when productions were uninterrupted. Results are recorded in Table 2-5 for load performances. The demand factors and load factors were calculated using the data in the Tables by applying the related formulae in Eq. 1-4.

Table 1: Connected loads in the refinery

Location	Total load connected (MVA)	Coverage area (M <sup>2</sup> )
Steam plant area	10.316	70,000
Power plant area	17.55	62,500
CB plant area	10.524	62,500
PP/CD plant	11.3	40,000
GT plant	3.4	80,000
Laboratory/Kero unit	5.34	120,000
Tank farm	5.18	800,000
Admin/workshops/Warehouse/clinic	1.99	50,000
WWT, FCC Feed/H <sub>2</sub> O pumps	1.36	10,000
Total	66.96	1,295,000

Table 2: Load demand performances in Warri refinery for wk 1

S/N	Time (GMT)	16/11/03 Sun power (MVA)	17/11/03 Mon power (MVA)	18/11/03 Tues power (MVA)	19/11/03 Wed power (MVA)	20/11/03 Thurs power (MVA)	21/11/03 Fri power (MVA)	22/11/03 Sat power (MVA)
1	0600	13.54	12.75	11.79	12.68	13.26	10.78	14.79
2	0800	14.91	13.02	12.20	13.36	14.10	10.88	15.60
3	1000	14.59	12.81	12.81	14.04	15.12	10.94	15.06
4	1200	14.86	13.12	13.10	14.37	16.57	10.91	9.43
5	1400	14.72	13.48	13.38	14.59	16.49	11.18	10.85
6	1600	13.87	13.45	14.30	13.87	16.49	10.83	13.08
7	1800	13.60	13.10	16.02	14.36	15.97	10.96	13.08
8	2000	13.14	12.86	15.78	13.60	15.26	11.09	12.35
9	2200	13.04	12.73	15.88	13.97	15.25	11.54	12.21
10	2400	12.27	12.27	15.14	13.28	14.87	11.24	12.21
11	0200	11.89	12.2	14.84	13.21	14.91	11.26	12.07
12	0400	11.72	11.98	14.60	13.07	13.59	10.92	11.88
	Total	162.15	153.77	169.84	164.40	181.88	132.53	152.61
	Average	13.51	12.81	14.15	13.70	15.15	11.04	12.72
	Maximum demand	14.91	13.48	16.02	14.59	16.57	11.54	15.60
	Load factor	0.906	0.950	0.883	0.939	0.914	0.957	0.815
	Total connected load	66.96	66.96	66.96	66.96	66.96	66.96	66.96
	Demand factor	0.223	0.201	0.132	0.218	0.247	0.172	0.233

Table 3: Load demand performances in Warri refinery for week 2

S/N	Time (GMT)	23/11/03 Sun power (MVA)	24/11/03 Mon power (MVA)	25/11/03 Tues power (MVA)	26/11/03 Wed power (MVA)	27/11/03 Thurs power (MVA)	28/11/03 Fri power (MVA)	29/11/03 Sat power (MVA)
1	0600	14.25	13.11	11.89	14.11	13.26	11.78	14.94
2	0800	15.70	14.40	14.20	13.36	14.10	11.88	15.60
3	1000	14.59	13.52	14.81	14.04	15.12	11.94	15.06
4	1200	14.86	13.12	18.10	11.80	14.17	10.91	14.43
5	1400	14.03	13.48	14.38	14.59	15.86	11.28	11.85
6	1600	13.87	14.24	11.30	14.11	15.24	11.83	14.08
7	1800	13.70	13.30	18.02	14.86	15.97	11.96	14.08
8	2000	13.20	12.84	10.78	13.00	15.45	11.09	14.57
9	2200	13.50	12.76	10.88	14.22	15.25	12.54	14.15
10	2400	13.04	12.28	10.14	13.21	14.90	12.24	14.21
11	0200	12.84	12.30	12.84	13.24	15.21	11.48	14.07
12	0400	11.88	12.21	14.80	13.77	13.59	11.42	12.88
Total		165.46	157.56	162.14	164.31	178.12	140.35	169.92
Average		13.78	13.13	13.51	13.69	14.84	11.70	14.16
Maximum demand		15.7	14.4	18.10	14.22	15.97	12.54	15.60
Load factor		0.877	0.911	0.746	0.962	0.930	0.933	0.907
Total connected load		66.96	66.96	66.96	66.96	66.96	66.96	66.96
Demand factor		0.234	0.215	0.27	0.212	0.238	0.817	0.233

Table 4: Load demand performances in Warri refinery for week 3

S/N	Time (GMT)	30/12/03 Sun power (MVA)	1/12/03 Mon power (MVA)	2/12/03 Tues power (MVA)	3/12/03 Wed power (MVA)	4/12/03 Thurs power (MVA)	5/12/03 Fri power (MVA)	6/12/03 Sat power (MVA)
1	0600	18.54	17.75	14.79	18.68	18.26	16.78	14.79
2	0800	14.91	18.02	17.20	18.36	14.10	16.88	16.60
3	1000	14.59	17.81	17.81	14.04	18.12	16.94	16.06
4	1200	14.86	18.12	18.10	16.37	18.57	16.91	18.43
5	1400	14.72	18.48	18.38	16.59	16.49	14.18	16.85
6	1600	18.87	18.45	14.30	18.87	16.49	16.83	18.08
7	1800	18.60	18.10	16.02	16.36	16.97	16.96	18.08
8	2000	18.14	17.86	16.78	18.60	16.26	14.09	14.35
9	2200	18.04	17.73	16.88	18.97	16.25	14.54	14.21
10	2400	12.27	17.27	16.14	18.28	16.87	14.24	14.21
11	0200	14.89	17.2	14.84	18.21	16.91	14.26	14.07
12	0400	14.72	14.98	14.60	18.07	18.59	16.92	17.88
Total		193.19	211.77	195.84	211.4	203.88	189.53	193.61
Average		16.1	17.65	16.32	17.61	17	15.8	16.13
Maximum Demand		18.87	18.48	18.38	18.97	18.57	16.96	18.43
Load factor		0.85	0.95	0.887	0.928	0.915	0.931	0.875
Total connected Load		0.28	66.96	66.96	66.96	66.96	66.96	66.96
Demand factor		0.223	0.276	0.274	0.283	0.277	0.253	0.275

Table 5: Load demand performances in Warri refinery for week 4

Time (GMT)	7/12/03 Sun power (MVA)	8/12/03 Mon power (MVA)	9/12/03 Tues power (MVA)	10/12/03 Wed power (MVA)	11/12/03 Thurs power (MVA)	12/12/03 Fri power (MVA)	13/12/03 Sat power (MVA)
0600	13.64	11.75	14.79	11.68	18.24	16.78	18.79
0800	14.91	18.02	14.28	18.36	11.10	14.88	16.60
1000	14.69	14.81	17.81	14.14	15.14	14.94	18.06
1200	15.86	18.12	17.10	16.17	16.54	16.91	10.43
1400	15.72	11.48	18.38	16.69	18.49	14.18	10.85
1600	18.87	11.45	17.30	18.87	18.49	16.83	18.08
1800	18.60	12.10	16.02	14.86	18.07	16.96	18.04
2000	14.14	12.86	17.78	18.30	18.26	11.09	11.35
2200	16.04	14.73	16.88	18.97	15.25	14.54	11.21
2400	14.27	14.27	16.14	18.28	14.87	11.24	14.21
0200	14.89	14.26	11.84	18.24	11.91	14.26	14.07
0400	17.72	13.98	11.60	18.07	18.59	14.92	17.88
Total	177.35	167.83	189.92	199.13	195.85	177.53	179.57

Table 5: Continue

Time (GMT)	7/12/03 Sun power (MVA)	8/12/03 Mon power (MVA)	9/12/03 Tues power (MVA)	10/12/03 Wed power (MVA)	11/12/03 Thurs power (MVA)	12/12/03 Fri power (MVA)	13/12/03 Sat power (MVA)
Average	14.77	13.99	15.82	16.59	16.32	14.79	14.96
Maximum demand	18.87	18.02	18.38	18.97	18.59	16.96	18.79
Load factor	0.782	0.776	0.86	0.870	0.881	0.872	0.796
Total connected Load	0.28	66.96	66.96	66.96	66.96	66.96	66.96
Demand factor	0.282	0.269	0.274	0.283	0.277	0.253	0.2806

Table 6: Average load characteristics in the refinery

Date	Max. demand MVA	Load factor MVA	Demand factor	Connected load	Area occupied M <sup>2</sup>	Load density VA/M <sup>2</sup>
16-11-03	14.91	0.906	0.223	66.96	1,295,000	11.51
17-11-03	13.48	0.905	0.201	66.96	1,295,000	10.40
18-11-03	16.02	0.883	0.132	66.96	1,295,000	12.36
19-11-03	14.59	0.939	0.218	66.96	1,295,000	11.26
20-11-03	16.57	0.914	0.247	66.96	1,295,000	12.80
21-11-03	11.54	0.957	0.172	66.96	1,295,000	8.90
22-11-03	15.60	0.815	0.233	66.96	1,295,000	12.04
23-11-03	15.7	0.877	0.234	66.96	1,295,000	12.12
24-11-03	14.4	0.911	0.215	66.96	1,295,000	11.11
25-11-03	18.10	0.746	0.27	66.96	1,295,000	13.97
26-11-03	14.22	0.962	0.212	66.96	1,295,000	10.98
27-11-03	15.97	0.930	0.238	66.96	1,295,000	12.32
28-11-03	12.54	0.933	0.187	66.96	1,295,000	9.68
29-11-03	15.60	0.907	0.233	66.96	1,295,000	12.04
30-11-03	18.87	0.85	0.28	66.96	1,295,000	14.57
1-12-03	18.48	0.95	0.276	66.96	1,295,000	14.27
2-12-03	18.38	0.887	0.274	66.96	1,295,000	14.19
3-12-03	18.97	0.928	0.283	66.96	1,295,000	14.64
4-12-03	18.57	0.915	0.277	66.96	1,295,000	14.33
5-12-03	16.96	0.931	0.253	66.96	1,295,000	13.09
6-12-03	18.43	0.875	0.276	66.96	1,295,000	14.23
7-12-03	18.87	0.782	0.282	66.96	1,295,000	14.57
8-12-03	18.02	0.776	0.269	66.96	1,295,000	13.91
9-12-03	18.38	0.860	0.214	66.96	1,295,000	14.19
10-12-03	18.97	0.870	0.283	66.96	1,295,000	14.64
11-12-03	18.59	0.881	0.277	66.96	1,295,000	14.35
12-12-03	16.96	0.872	0.253	66.96	1,295,000	13.09
13-12-03	18.79	0.796	0.2810	66.96	1,295,000	14.50
Average	16.66	0.885	0.244	66.96	1,295,000	12.8

$$\text{Average daily load demand} = \frac{\text{Total max.daily demand}}{\text{No of readings (12)}} \quad (1)$$

$$\text{Load factor} = \frac{\text{Average daily demand}}{\text{Maximum daily demand}} \quad (2)$$

$$\text{Load density} = \frac{\text{Maximum daily load demand}}{\text{Built up area}} \quad (3)$$

$$\text{Demand factor} = \frac{\text{Max. daily load demand}}{\text{Total connected load}} \quad (4)$$

The average load characteristics of results emanating from Table 2-5 are shown in Table 6.

## RESULTS AND DISCUSSION

Table 1 shows the connected load in the refinery. The coverage areas in square meters are shown for each connected load.

Table 2-5 shows the weekly load demands in the refinery.

Finally, the average load characteristics are computed in Table 6 on the 28-working days period (4 weeks).

Table 6 enables us to find the maximum demand of 16.66MVA, the Load factor of 88.5%, Demand factor of 24.4 and, the load density of 12.8VA M<sup>-2</sup> applicable in the refinery. The load density is a factor enabling a consultant to compute the total load demand necessary for a factory, with the availability of the architectural drawings, showing the areas of equipment involved.

Invariably, the electrical power system's cost can also be computed at the on set of the project. The load density forestalls a situation for an over or under designed project work. The knowledge of the maximum demand also enables the consultant to pin point the diversity factor needed in that plant. The load factor and demand factor are essential for operational purposes.

### **CONCLUSION**

The maximum demand, load density, load factor and demand factor have been established for Warri refinery. These data are ingredients for good electrical engineering consultancy services in the area of refinery operations and establishment.

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