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Determination of Load Demand Using Load Estimate Method (LEM) Suitable for Industrial Environment, A Preview of Load Demand Rate at Prototype Engineering Development Institute, Ilesa, Osun State

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Authors' contributions

This work was carried out in collaboration between all authors. Author SAJ designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript and managed literature searches. Authors SOF, KAA and AMY managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This paper presents the Load Demand Rate of Prototype Engineering Development Institute in the year 2009 when operation actually started and compares to the load demand in the year 2014 as the institute continues in its growth drive, since more electrical equipment have been procured by the institute for effective operation. The power rating, in watts, of the electrical equipment on ground in 2009 were taken and tabulated as well as those of equipment acquired after 2009 till year 2014. The loads demand of each unit were tabulated and ground total of load for the years under review were obtained in two separate tables from where conversion to KVA ratings of each year were obtained. This comparison shows that there is large difference between the load demands of the

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two years under consideration, of which the existing transformer may not be able to cope with the present load demand. This study illustrates the application of load estimate method to determining the maximum load demand of an installation with a view to planning against unexpected system's collapse that could arise from overloading of the substation's transformer. Load demand Rate for the year under review is 451.87 KVA compared to the Installed transformer rating of 300KVA meaning that load demand rate has increased by 50%. Having obtained the load demand rate of the years under review, conclusion reached was to upgrade the substation's transformer that supplies the Institute to be able to cope with the present load demand and for future expansion. This research work could be needed in holistic design of all industrial layouts.

Keywords: Load demand rate; maximum load; substation; KVA ratings; system's collapse.

1. INTRODUCTION

The load demand of an installation is the sum of maximum demand of the individual electrical equipment connected to a load source [1,2]. When maximum demand of a supply is being assessed, it is not sufficient to simply add together the ratings of all electrical equipment that could be connected to that supply; hence, a figure higher than the true maximum demand will be produced. This is because it is unlikely that all electrical equipment on a supply will be used simultaneously [3]. Therefore, there is need to de-rate the maximum load demand obtained from the nominal or rated power of the installed loads connected to a supply source.

"The concept of being able to De-rate a potential maximum load to an actual maximum demand is known as the application of a diversity factor". The load is time dependent as well as being dependent upon equipment characteristics. The diversity factor recognizes that the whole load does not equal the sum of its parts due to this time interdependence (i.e diverseness) [3]. In distribution network, the ratio of the sum of the peak demands of each connected loads to the peak demand of the source of supply is termed diversity factor [4,5]. According to this report, the source of supply is a sub-station installed in the premises of the institute.

Nigeria power system network, like all other power system, waves about the entire country and it is by far the largest interconnection of a dynamic system in existence to date. No matter how carefully the system is designed, losses are present. Electric power losses are wasteful energy caused by external factors or internal factors, and energy dissipated in the system [6,3,7]. Thus, affecting the load demand of the end user.

With the rising of electrical demand in industrial, agricultural, commercial and domestic sectors, all sources of generation namely; atomic, hydro, and thermal are required to be tapped. The location of power station is decided by factors such as the availability of water potential in the case of hydro power stations, the ease of access to coal pits and availability of water for cooling in the case of thermal power stations. Such sites are available only at selected places. As such, long high-voltage transmission lines to carry power to the consumers, situated all over the country, are inevitable. Bearing in mind the economics of power systems, huge blocks of power are stepped up to extra high voltage near generating stations for transmission to load centers and then stepped down in stages for sub-transmission and distribution so as to utilize the power finally at the consumer's end. Thus, between the generating stations and the consumers, a certain number of voltage transformations are required. Transformers are used for these purposes. The places where transformers are installed for such transformations are called substations. A substation may thus be defined as an assembly of electrical apparatus which transforms electrical energy (AC) from one voltage to another [8].

Substations thus form a vital link between the generating stations and the consumers in delivering electric power. There are many types of substations, but of concern is the distribution sub-station, which is the main source of energy supply to Prototype Engineering Development Institute. "The distribution substation is the system from which electrical energy is distributed to domestic, industrial and commercial consumers". The distribution substation is a place where the 11kV primary distribution voltage is stepped down to the secondary distribution voltage of 415v, three –phase or 250-v single phase for use by consumers. The power to the consumers is fed from the distribution substations through a network of LT. overhead lines, cables mains and sub-mains and service lines [8]. Distribution transformers above 100kVA are installed on the ground with a protective fence around it. The distribution transformer installed in the premises of the institute is rated 300KVA. This work was embarked upon with the aim of knowing the load demand of the institute in the year 2014 and upgrading the existing substation, if necessary, in order to avoid system collapse in the event of overload.

2. METHODOLOGY

The first phase of the work was to capture the electrical loads that were in existence in the year 2009 in order to estimate the load demand for that year and relate it to the capacity of the installed transformer; this was carried out by going into the review of the equipment on ground in that year. Then, estimation of the electrical loads installed after year 2009 till date were also taken and added to the existing loads of 2009. Comparison was then made between the years concerned from where conclusion and recommendation were highlighted. It is worthy of note to know that the institute was sub-divided into units to make the work easy for the authors; these sub-division include mechatronics laboratory, smt laboratory, machine shops, fabrication workshop, server room, foundry workshop, cmm laboratory, old administrative building and new administrative building.

3. LOAD ESTIMATE IN 2009

The institute started its operations in 2009; many electrical machines were acquired and installed. Construction of administrative block and other workshops were undertaken within the year. Tables 1 to 6 show the load estimates of each sub-division for the year under review.

4. LOAD ESTIMATE IN 2014

Prototype Engineering Development Institute is growing in leaps and bounds; this growth drive has brought about the erection of fabrication and foundry workshops. Therefore, various machines, both heavy and light duty, were installed in the workshops between 2010 and the year under review. Also, new machines were installed in the existing workshops. The load estimates for the sub-divisions are shown in Tables 7-14.

5. LOAD DEMAND RATE CALCULATION IN KVA

From Table 15, the total load estimate in 2009 is 157,671 W or 157.671 KW
Then,
Real power = Apparent Power x power factor [9]

$$KW = KVA \times \cos\phi \qquad \text{------------------ (1) [10]}$$

But, apparent power = real power/power factor

$$KVA = KW/\cos\phi \qquad \text{------------------ (2)}$$

Where Cos ϕ is power factor
But real power = 157.671;
let the power factor = 0.8 [11]
Apparent power (KVA) = 157.671/0.8
= 197.09KVA
Taken diversity factor of 70% (Users to Transformer) [12]

Load demand = 197.09 X 0.7
= 137.96 KVA

Hence comparing, load demand rate of 137.96 KVA to the substation's transformer capacity of 300 KVA, it is obvious that the transformer was far from overloading since less than 50% of its capacity would probably be in use at any point in time.

Also, the total load estimate in 2014, as shown in Table 16, is 516,428W
= 516.428KW
From equation 1,
Apparent power (KVA) = 516.428/0.8
= 645.535 KVA
Taken diversity factor of 70%,
Load demand = 645.535 X 0.7
= 451.87 KVA

Comparing the KVA rating obtained in 2014 to the capacity of the sub-station's transformer; it is obvious that the load demand rate has exceeded this capacity by 50%.

6. RESULTS

The Table 15 and Table 16 show the grand total of load estimates in 2009 and 2014 respectively.

Table 1. Mechatronics laboratory

S/N	Electrical equipment	Power rating (W)	No	Total (W)
1	Air conditioner	7913	2	15826
2	Ceiling fan	70	4	280
3	2ft Fluorescent	20	10	200
4	Computer System	60	16	960
5	Laptop	65	4	260
6	Mechatronics gadget	300	1	300
7	Compressor	550	1	550
	Total			**18376**

Table 2. Surface mount technology laboratory (SMT)

S/N	Electrical equipment	Power rating (W)	No	Total (W)
1	Air conditioner	7913	2	15826
2	Ceiling fan	70	3	210
3	2FT Fluorescent	20	8	160
4	Computer System	60	10	600
5	Laptop	65	5	325
6	SMT equipment	10050	1	10050
	Total			**27171**

Table 3. Server room

S/N	Electrical Equipment	Power Rating (W)	No	Total (W)
1	Air conditioner	1500	1	1500
2	2FT Fluorescent	20	8	160
3	Computer System	60	4	240
4	Laptop	65	4	260
5	HPC	1200	6	7200
	Total			**9360**

Table 4. Old administrative building

S/N	Electrical equipment	Power rating (W)	No	Total (W)
1	Air conditioner	1500	6	9000
2	2FT Fluorescent	20	30	600
3	Computer System	60	5	300
4	Laptop	65	2	130
5	Fire Alarm	2	1	2
6	Photocopier	1200	1	1200
7	Refrigerator	120	1	120
8	Printer	60	1	60
9	Perimeter lighting	20	20	400
	Total			**11812**

Table 5. Machine Shop

S/N	Electrical equipment	Power rating (W)	No	Total (W)
1	Security Light	100	10	1000
2	Discharge lamp	500	8	4000
3	4FT Fluorescent	40	4	160
4	Pumping machine	1100	1	1100
5	Compressor	3580	1	3580
7	CNC milling machine	1000	3	3000
8	CNC Lathe machine	1840	1	1840
9	VMC machine	8324	2	16648
10	ENC Lathe machine	1840	1	1840
11	Shaping machine	21384	1	21384
12	Surface grinding machine	37500	1	37500
	Total			**90952**

Table 6. Mechatronics laboratory

S/N	Electrical equipment	Power rating (W)	No	Total (W)
1	Air conditioner	7913	2	15826
2	Ceiling fan	70	4	280
3	2ft Fluorescent	20	10	200
4	Computer System	60	16	960
5	Laptop	65	10	650
6	Mechatronics gadget	300	3	900
7	Compressor	550	3	1650
	Total			**20466**

Table 7. Surface mount technology (SMT) laboratory

S/N	Electrical equipment	Power rating (W)	NO	Total (W)
1	Air conditioner	7913	2	15826
2	Ceiling fan	70	3	210
3	2FT Fluorescent	20	8	160
4	Computer System	60	10	600
5	Laptop	65	12	780
6	SMT equipment	10050	1	10050
8	CNC Router	200	2	400
	Total			**28026**

Table 8. Server room

S/N	Electrical equipment	Power rating (W)	No	Total (W)
1	Air conditioner	1500	1	1500
2	2FT Fluorescent	20	8	160
3	Computer System	60	4	240
4	Laptop	65	4	260
5	Standing fan	135	1	135
6	HPC	1200	6	7200
	Total			**9495**

Table 9. Old administrative building

S/N	Electrical equipment	Power rating (W)	No	Total (W)
1	Air conditioner	1500	6	9000
2	2FT Fluorescent	20	30	600
3	Computer System	60	5	300
4	Laptop	65	8	520
5	Standing fan	135	4	540
6	Fire Alarm	2	1	2
7	Photocopier	1200	1	1200
8	Refrigerator	120	1	120
9	Printer	60	1	60
10	Perimeter Lighting	20	30	600
	Total			**12942**

Table 10. Machine shop

S/N	Electrical equipment	Power rating (W)	No	Total (W)
1	Security Light	100	10	1000
2	Discharge lamp	500	8	4000
3	4FT Fluorescent	40	4	160
4	Pumping machine	1100	1	1100
5	Compressor	3580	1	3580
6	Surface grinding machine	37500	1	37500
7	CNC milling machine	1000	3	3000
8	CNC Lathe machine	1840	1	1840
9	VMC machine	8324	2	16648
10	ENC Lathe machine	1840	1	1840
11	Shaping machine	21384	1	21384
12	Grinding Machine	2500	1	2500
13	Welding machine	10000	1	10000
	Total			**104552**

Table 11. New administrative building

S/N	Electrical equipment	Power rating (W)	No	Total (W)
1	Air conditioner(1.5 H.P)	1125	4	4500
2	Air conditioner(8.8 H.P)	6600	3	19800
3	2FT Fluorescent	20	26	520
4	Computer System	60	25	1500
5	Laptop	65	8	520
6	Photocopier	1200	1	1200
7	Refrigerator	120	1	120
8	Printer	60	1	60
	Total			**28220**

Table 12. Foundry workshop

S/N	Electrical equipment	Power rating (W)	No	Total (W)
1	Air conditioner	1125	4	4500
2	2 ft Fluorescent	20	70	1400
3	Computer System	60	4	240
4	Laptop	65	18	1170
5	Induction Furnace	153000	1	153000
6	Rotary Furnace	5500	2	11000
7	Blower	2200	2	4400
8	Muffle Furnace	4000	1	4000
9	Electroplating Machine(1 phase)	1125	1	1125
10	Electroplating Machine(3 phase)	2150	2	4300
11	MOCVD	2300	1	2300
12	Spectrometric machine	4000	1	4000
13	Embedding machine	650	1	650
14	Polishing machine	550	2	1100
15	Sectioning machine	250	1	250
16	Air conditioner	1500	1	1500
17	Micro-Hardness Testing m/c	480	1	480
18	Metallographic microscope	480	1	480
19	Friction Co-efficient testing m/c	480	1	480
20	Die-casting machine	25000	1	25000
21	Muffle furnace	6500	1	6500
22	Friction wear tester	300	1	300
	Total			**228175**

Table 13. Fabrication workshop

S/N	Electrical equipment	Power rating (W)	No	Total (W)
1	Air conditioner(2 H.P)	1500	7	10500
2	Air conditioner(1.5 H.P)	1125	2	2250
3	2FT Fluorescent	20	20	400
4	Computer System	60	15	900
5	Laptop	65	23	1495
6	Standing fan	135	4	540
7	Energy saving bulb	105	4	420
8	Hydraulic press brake	19551	2	39102
9	Plasma cutting machine	10125	1	10125
10	Table top lathe	1000	3	3000
11	Laser cutting machine	300	2	600
12	Laser welding machine	300	2	600
13	Rapid Prototyping machine	1500	1	1500
14	Compressor	2000	1	2000
15	3D Printer and Dryer	2400	1	2400
	Total			**75832**

Table 14. Coordinate measuring machine (CMM) laboratories

S/N	Electrical equipment	Power rating (W)	No	Total (W)
1	Air conditioner	1500	2	3000
2	2ft Fluorescent	20	7	140
3	Computer System	60	2	120
4	Laptop	65	4	260
5	CMM	1200	1	1200
6	Compressor	4000	1	4000
	Total			**8720**

Table 15. Grand total of load demand for 2009

S/N	Sub-division	Sub-Total Power (W)
1	Mechatronics Laboratory	18376
2	SMT Laboratory	27171
3	Server Room	9360
4	Old Administrative Building	11812
5	Machine Shop	90952
	Grand Total	**157671**

Table 16. Grand total of loads demand till year 2014

S/N	Sections	Sub-total power (W)
1	Mechatronics Laboratory	20466
2	Surface Mount Technology Laboratory	28026
3	Server Room	9495
4	Old Administrative Building	12942
5	Machine Shop	104552
6	New Administrative Building	28220
7	Foundry Workshop	228175
8	Fabrication Workshop	75832
9	Coordinate Measuring Machine Laboratory	8720
	Grand Total	**516428**

7. CONCLUSION

This study illustrates the application of load estimate method to determining the maximum load demand of an installation with a view to planning against unexpected system collapse that could arise from overloading of the substation’s transformer.

It was observed from Table 16 that there was astronomical increase in the load demand of the institute after year 2009 because two new workshops, one laboratory and new administrative block were built and equipped with electrical equipment of different power ratings. It was also worthy of note that the loads demand of each unit in 2009 also increased when they were re-evaluated in 2014 as observed in Table 15 and 16; it is therefore not surprising that the load demand in 2014 rose to 387.32KVA as compared to 137.96 KVA in 2009.Conclusively, there is no way the installed transformer in the institute could conveniently cope with the present load demand of 2014. There is need, therefore, to upgrade the substation’s transformer that supplies the institute to be able to cope with the present load demand and give room for future expansion.

8. RECOMMENDATION

In order to take care of the present and future load demand of the institute, another 300KVA, 11KV/0.415KV transformer was recommended, procured and installed at a strategic place to complement the one on ground so that the loads could be shared between the two transformers. 500KVA, 33KV/0.415KV transformer may be procured and installed since a 33KV-distribution line passes the premises of the institute; this would even bring about regular supply of electricity.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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