Electrical Energy Consumption Pattern of Flour Mill in Nigeria.

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ABSTRACT

Virtually all manufacturing industries in Nigeria spend more than necessary on electrical power consumption just in an attempt to maximize productivity. The aim at maximizing productivity could as well be met without unnecessarily spending huge amount of money on electrical power consumed. This research is about the problems and solutions of maximum electrical power demand in Bendel Feed and Flour Mill Limited (BFFM), Edo State, Nigeria. We specified how high tariff could be attributed to high maximum demand. Also how maximum demand could be traced to some factors that includes, the use of employed non-professionals to operate machines/appliances, low power factor, and the use of overrated machines. The results of this study are capable of reducing the total annual amount spent on electric bills by more than 8.5% of the total amount spent on electrical power consumed annually by BFFM from Power Holding Company of Nigeria (PHCN) and about 18% from the use of standby generators.

(Keywords: flour mill, electrical power, power factor, tariff)

INTRODUCTION

In analyzing the maximum electrical load consumed in a manufacturing industry, we must be able to assess the maximum demand (M.D.) of all electrical installations. Maximum demand implies the greatest of all the demands that have occurred during a given specified period. The load requirement usually in kilowatt or kilovolt ampere (KW or KVA) is the average over a suitable and specified interval of time of short duration is called demand [1, 2, 3]. Most manufacturing industries in Nigeria spend more than necessary amount of money on their electrical power billing and thereby loosing millions of Naira annually. In BFFM limited, this wasted amount can be saved conveniently and at the same time to able to embark on maximum productivity, with increase in the life span of industrial machines and appliances.

MATERIALS AND METHOD

In this work data, from BFFM, for maximum demand on monthly electrical energy consumed from PHCN and standby generators, tariff paid, average time of electrical energy consumed monthly for five years were collated [4]. Figures 1 to 4 are graphs of maximum demand (KVA), electrical energy consumed (KWh), duration of power (hours), and tariff paid against months for the five years under consideration. Some utilities measure total power, (usually averaged over a 15 minutes load period) and charge a monthly fee or tariff for the highest fifteen minutes average loading in the month. This tariff is usually added to the energy charge or kilowatt-hour charge. This type of billing is called KVA demand billing and can be quite costly to an industrial facility. In this work piece, the causes of the above shortcoming are been critically analyzed and solutions carefully specified.

RESULTS AND DISCUSSION

In BFFM's maximum demand metering, if a new demand is more than the pervious level and this new demand remains sustain for say half an hour, it becomes the established maximum demand until some other demand crosses this limit and equally remain sustained. Figure 1 shows the monthly maximum demand for five years. Figure 2 shows the energy in KWh consumed by BFFM from both PHCN and industrial generators. While Figure 3 shows the monthly amount paid for the electrical energy consumed and Figure 4 shows the number of hours this power was supplied from PHCN and generators in each month.

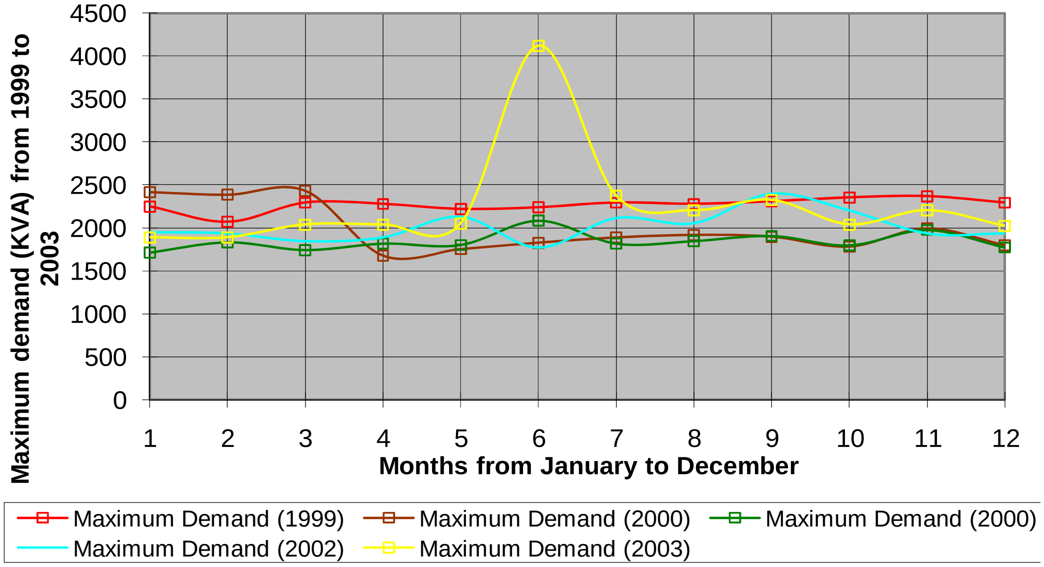

Figure 1: Graph of Maximum Demand versus the Months.

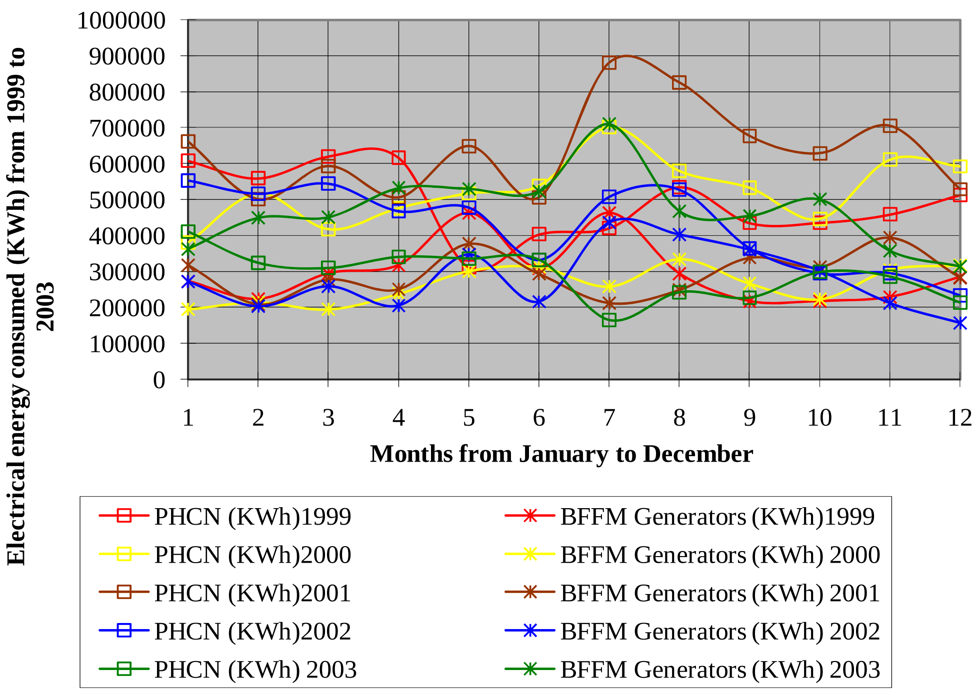

Figure 2: Electrical Energy Consumed in Five Years.

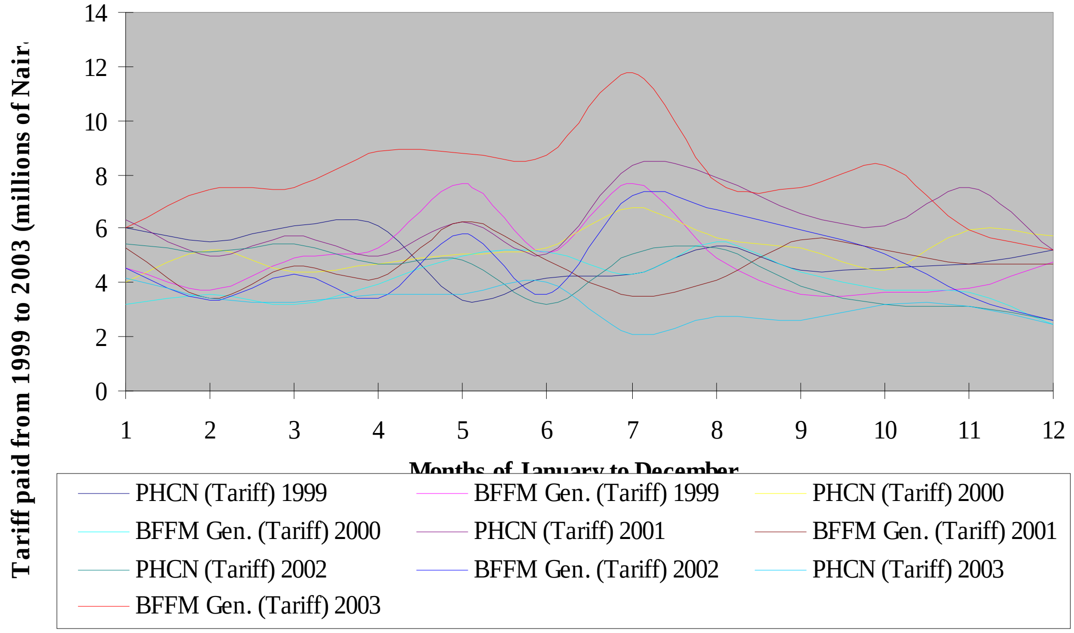

Figure 3: Tariff Paid Monthly for Five Years.

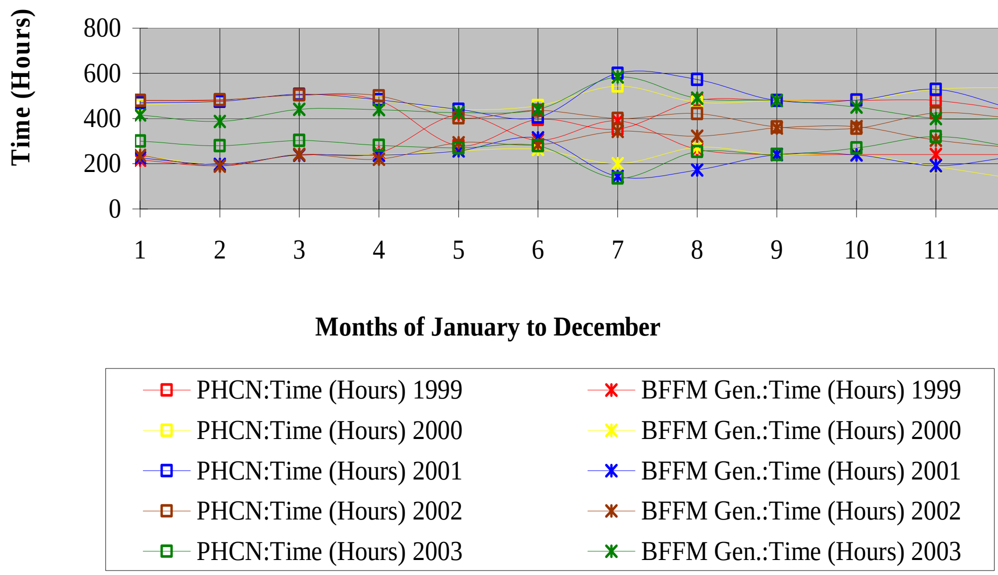

Figure 4: Duration of Power Consumed Monthly for Five Years.

Public utilities normally use the two-part method in computing industrial bills. The two-part tariff consists of: A fixed charge proportional to the maximum demand but independent of the units consumed and a low running charge proportional to the actual number of units consumed.

The rates for commercial and industrial consumers who uses large amount of electric energy are directly related to Kilowatt-hour (KWh) and Maximum demand (KW).

$$\text{Monthly bill} = ₦\,(\kappa \times KW + \partial \times KWh) \qquad \textbf{(1)}$$

where κ is the charge per KW or KVA of maximum demand and ∂ is the price per KWh. However, the method used by PHCN in computing BFFM's tariff is as follows:

Monthly bill = ₦ (κ x KVA + ∂ x KWh + C) **(2)**

where κ, ∂ and C are constants, ∂ is ₦ 8.50K (K = Kobo) which is the charge per KWh of energy consumed, κ is N230.00K which is the charge per KVA of maximum demand and,

C = VAT + ₦49, 000.00 **(3)**

where VAT is the value added tax and it is 5% of total amount obtained from the first two part (the right hand side) of equation 2. ₦49,000.00 is fixed charge that includes meter maintenance.

Table 1: Kilowatt Multiplier Table [5].

Original Power Factor	Desired Power Factor: 0.800	0.850	0.900	0.950	1.000
0.50	0.982	1.112	1.248	1.403	1.732
0.55	0.768	0.899	1.034	1.190	1518
0.60	0.583	0.714	0.849	1.005	1.333
0.65	0.419	0.549	0.685	0.840	1.169
0.70	0.270	0.400	0.536	0.692	1.020
0.75	0.132	0.262	0.398	0.553	0.882
0.80	0.000	0.130	0.266	0.421	0.750
0.85		0.000	0.135	0.291	0.620
0.90			0.000	0.156	0.484
0.95				0.000	0.329
1.00					0.000

REDUCTION OF MAXIMUM DEMAND USING THE SHUNT CAPACITOR BANK

If the reactive power component of a machine is decreased, the total power will also decrease. In order to decrease the reactive power (KVA_r) in BFFM, shunt capacitor banks were installed on each of the three relay frames in the three machines towers. Comparing the value of maximum demand within the years specified in Figure 1, it became apparent that these capacitor banks were no longer effective. In the year 2003 (for example in November 2003), the industry had maximum demand of 2206 KVA and consumed energy of 286340 KWh for 320 hours giving a bill of ₦ 3.137 million.

Average power = $286340/320$ = 894.81KW

Power factor (p.f.) = $\dfrac{Average\ power}{Active\ power}$

$$= \frac{894.81}{2206} = 0.41 \qquad [6].$$

Assuming this power factor (0.41) is improved or compensated to about 0.90. the M.D. will be;
M.D. = $894.81/0.9 = 9994.233\,KVA$.

Using Equation 2 we shall have a new bill as follow;

Bill = ₦ (k x KVA +∂ x kWh + C)

where C = ($5/100$) x ₦ (230 x 994. 236 + 8.5 x 286340) + ₦ 49, 000.00 = ₦182, 128.214

Therefore, Bill = ₦ (230 x 994.236 + 8.5 x 286340 + 182,128.214) = ₦ 2.845 Million.

It represents 9.32% reduction and saving the sum of ₦ 292, 307.50k for the month of November. Assuming the initial power factor angle is Φ_1 and we desired a new improved or compensated power factor angle of Φ_2, the rating of the shunt capacitor bank required to effect this change is given as follows [5].

KVA_{rs} = KW (Tan Φ_1 = Tan Φ_2) **(4)**

where KW is the peak power demand and which is 2.4 MW for BFFM.

From Figures 2 and Figure 4 we observed that the average power factor is 0.5 and we desired to improve on it to 0.9.

Let cos Φ_1 = 0.5 and cos Φ_2 =0.9, then, $\Phi_1 = 60^0$ and $\Phi_2 = 25.84^0$

Therefore, MVA_r = 2.4 (Tan 60^0 – Tan 25.84^0), such that the shunt capacitor bank needed is equal to 2995.6 KVA_{rs}. The kilowatt multiplier can also be use in calculating the amount of KVA_{rs} required to raise the original power factor to a desired power factor. The kilowatt multiplier is shown in Table 1. Thus, to raise the power factor of 0.5 to 0.9, the multiplying factor of 1.248 is specified in the kilowatt multiplier table, and it is equal to 2400 x 1.248 = 2995 KVA_r. This amount of KVA_r rating will be shared proportionally among the relay frames in the three machine towers.

REDUCTION OF MAXIMUM DEMAND (KVA) USING LESSER RATED EQUIPMENT

Most electrical equipment in BFFM is over rated. Obvious examples are the electric motors use in operating the Roller Millers in flourmill and the two electric motors (90KW, 0.92 p.f. each) use in operating the two *hammer mills* in feed mill tower. The later are virtually the highest rated electric motors in the factory. These *hammer mills* can however be conveniently run using electric motors of 75KW (0.90 p.f.) each.

Assuming the two *hammer mills* are run in full capacity using the recommended electric motors (75KW), the industry stands at savings power of 30KW. If they are tentatively run for about 320 hours, as in November 2003, then the electrical energy that will be save per month is given as; 30 x 320 = 9600 KWh. Amount saved per month if PHCN is used is 9600 x ₦ 8.50K = ₦ 81, 600.00. This amount does not include the amount charged per KVA of maximum demand.

The factory has about 195 air conditioner sets of which about 120 are 2.0hp. Detailed investigation showed that 95 of the 120 2.0hp air conditioners are overrated as compared to the purpose and areas they were installed. 1.5hp air conditioners can conveniently be employed for these same purposes. If these 2.0hp air conditioners are replaced with 1.5hp the industry stands at saving a monthly energy of: 2.0hp – 1.5hp = 375 W = Power saved.

Total power saved = power saved multiplied by quantity of set is equal to 35.625KW.

Assuming the air conditioners are put 'ON' for about 580 hours monthly, energy that will be save per month is given as; 35.625 KW x 580 =20662.5 KWh. If this energy is supplied by PHCN, we have, ₦ 175, 631. 25K. These amount does not include the charge for saved maximum demand in KVA. Finally, 80 of these 95 air conditioners are installed in the staff quarters and the occupants are expected to be in their factory office during eight working hours in the five working days in a week. It was however discovered that these air conditioners are always ON for virtually 24 hour every day. Assuming they are OFF when the house occupants are out for work, the industry stands at saving power as follows: If 1air conditioner = 2.0hp ≡ 750W x 2 = 1.5KW. Then 80 air conditioners ≡ 1.5 x 80 = 120KW. Energy to be saved per day is; 120KW x 8hours = 960KWh. Energy to be saved per week is; 960 KWh x 5 = 4800KWh. Energy to be saved per month is; 4800 KWh x 4 = 19200KWh. Assuming this energy is to be supplied by PHCN, we have, 19200 KWh x ₦ 8.50K = ₦ 163, 200.00K.

The above amount is besides the amount charge per KVA saved. The respective saved amount calculated above will eventually double if power is supplied by the industrial generating set (plants). This is mainly due to the amount per KWh of power supplied by the industrial generators is estimated to be ₦ 16.60K as compared to ₦ 8.50K for PHCN. We observed that the increase in maximum demand in BFFM is also caused by the following factors; (i) Using of over rated equipments/machines. (ii) Operating on very poor power factor, (iii) High mean time to repair (MTTR) of the industry, (iv) Un-professional operators are employed to operate the machines, and nonchalant attitude of the staff in operating their appliances.

After careful analysis of the above effects solution were specifically profound. In the end, the industry stands at saving about 17% from the annual sum of N130m spent on utility supplied electrical energy. From Figure 1, we observed that the company experienced a very high M.D in 1999 and first quarter of 2000. This was due to the fact that the formally installed shunt capacitor banks were no longer effective. In March 2000, the shunt capacitor banks were however rehabilitated though not totally replaced. This development led to the M.D. to drop in June and for the rest part of 2000 through 2001 to the first quarter of 2002. From the second half of 2003 to December 2003, the capacitor banks did not function.

From Figure 3, it is very obvious that the company spent huge sum of money on electrical energy consumed and this does not in any way affect the corresponding unit of products produced. This is because greater proportion of the power consumed was generated by the BFFM standby generators whose price per unit of electrical energy is virtually twice that supplied by the public utility.

From Figure 1, in the month of June 2003, the company experienced the highest M.D. within the period under consideration. Investigation shows that on the 22nd of this month, the two milling plants and central silo where operating in full capacity, all of a sudden there was power failure from PHCN and it was restored back within a period of 30 seconds. The operators in these milling plants switched ON their equipment almost simultaneously without getting clearance from the technicians in the powerhouse. This resulted to high reactive current being demanded by all the induction motors for starting at the same time. With improved power factor, the use of lesser rated equipments and the reduction in time of switching 'ON' of air condition in residential homes it was estimated that BFFM stands to save ₦ 10.256 million annually. It should however be noted that the above estimation was made with the assumption that the power is supplied by the public utility. The estimated amount doubled when the BFFM generators supply the power.

CONCLUSION

In view of the fact that BFFM stands at savings an annual amount of about ₦ 10 million, about 8.5% of the total amount paid on electrical power consumed (from public utility power supply), there is therefore need to improve on their power system, thus the following recommendations: BFFM power factor should be improve upon using at least a new shunt capacitor banks of rating of about 9995.6 KVAr. This shunt capacitor bank should be proportionally installed on the relay frames of the three major plants in the industry (feed mill, flour mill and central silo).

All over-rated machines should be replaced with machines of normal rating and types that can perform the same function i.e. the two 90 KW induction motors use in operating *hammer mills* feed mill section should be replaced with induction motors of 75kW each. Moreover, electric motors use in operating roller millers in flour millers in flourmill section should be replaced with lower rated types that can handle the capacity of the roller millers. Finally, the 95 over rated 2.0 hp air conditioners should be replaced with types of 1.5hp. The house occupants and office users should however be properly oriented on the need to put OFF their appliance when they are not at home or in the office (especially the AC users).

The three major plants must not commence operation or production at the same time, a minimum of 5 minutes interval must be given to start a plant if one had been started previously. This will help in reducing maximum demand. Because of PHCN's high mean time to repair (MTTR), I strongly recommend that the company should be assisting the local sub-station with some financial or material support when ever any major fault is developed on their transmission lines that may lead to failure in power supply to the factory. In order to reduce the MTTR in the factory, spare parts must be made readily availably and effort should be made to encourage local production of this spare parts.

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