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Energy Audit of an Industry & Solution on Energy Wastage According to Variable Load Analysis

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ABSTRACT: India is a developing country and electrical energy consumption by industries is about 60% of the total energy consumption. The industrial development in the country is progressing at a fast pace due to the increase in the number of industries, the gap among demand and supply of electricity is also increasing continuously. To minimize this gap the perfect solution is to conduct is energy audit of all industries on frequent bases. The energy audit will determine energy wastage and losses, and provide techniques and ways to minimize the losses. The energy consumption by different ways suggested by the energy audit will not only decrease the losses but also reduce monthly electricity bill. This paper suggests ways and means to conduct an energy audit in an industry.

KEYWORDS: Energy Audit, Energy Consumption (EAC), Energy Conservation, Power Factor Surcharge PFS, Payback Period(PBP), Energy Audit Phase(EAP), Energy Conservation Opportunities (ECOs).

I. INTRODUCTION

Energy Audit is the verification, monitoring and analysis of energy use including submission& calculation of technical report containing all the recommendations for improving energy efficiency with cost analysis and an action plan to reduce power usage . In general energy audit is the translation of conservation ideas into realities by lending technically feasible solutions with economics and other organizational considerations within a specified time frame.

The energy audit was conducted at DINANATH PRECISION CLAMPINGS, Plot no. 19-A, gut no. 53, Shajapur, MIDC Waluj, Aurangabad-431136 (MS), to identify the major areas of energy waste. The energy audit was conducted within a period of three months.The above industry is a manufacturer of Gear hobbing, Gear grinding, Gear Shaving(Machine mounted auto actuated by tailstock), Gear Shaving (Between centre type), Toolholders, Inspection Mandrels, Turning.

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II. DATA COLLECTION

The proposed work will cover following sections.

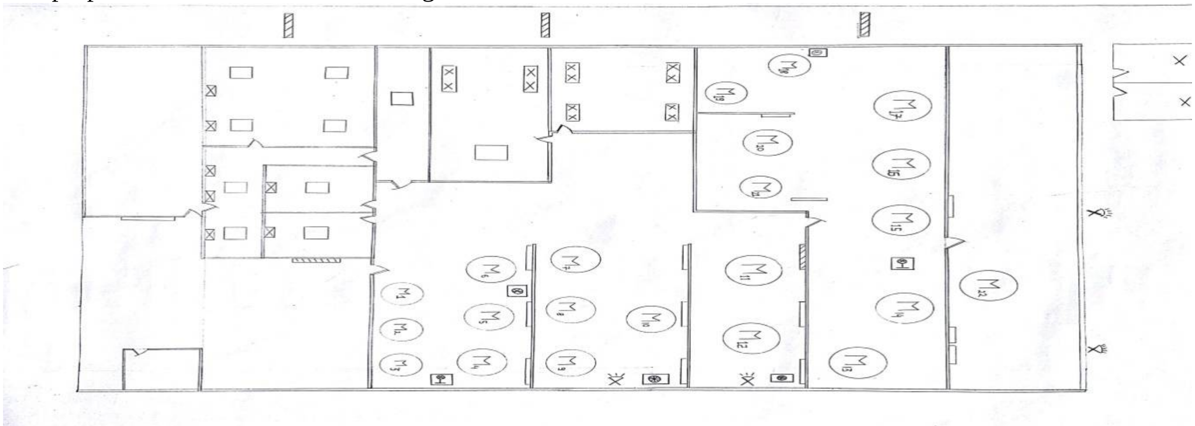

Fig.1 Plant Layout and Power Flow Diagram of Industry

A) Audit Phase- I (Pre-Audit Phase)

During pre-audit phase the following observations/inspection were complited within two days as per the schedule given in Table 1

Table.1 Schedule of Energy Audit Phase -1

Sr. no.	Observations/inspection	Result
i	A complete walk through in the industry	Done
ii	Discuss advantages of energy audit	Done
iii	Inspect various sections for any energy wastage	Done
iv	Prepare a list of major energy consuming machinery with their ratings	See Table-2
v	Obtain drawings and electrical distribution	See Figure-1
vi	To identify instruments required for audit	See Table-2
vii	Calculate lighting and machine load	See Table-4
viii	Check any loose connection and leakage	No any loose connection and leakage
ix	Prepare a visual inspection report	See Table-5
X	Suggestion and ECOs for Pre-audit Phase-I	See Table-6

Table.2 Instruments Required for Energy Audit

S.no.	Name of Instruments
1	Digital Multimeter
2	Digital Tachometer
3	Power Analyser having kW,kVA options Clip on meter
4	Measuring tape of 100 meter
5	Lux meter
6	Power factor meter

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B) Audit Phase- II

During audit phase II the following observations were completed within 10 days. The summary of electricity bills of 12 months since Jan 2017 to Feb 2018 is shown in Table 8. Due to some technical reason the electricity bill for the month of Feburary-2017 and Aug 2017 was not added in the electricity bill .Therefore there were some irregularities found in electricity bills of Dinanath industry.

Table .3Summary of Annual Electricity Bills

S. no	Month	Power Factor	Energy Consumption in kwh	Power factor surcharge (in Rs.)
1	Feb 2018	0.807	3333	37195.45
2	Jan 2018	0.552	4235	55816.53
3	Dec 2017	0.570	2214	30389.96
4	Nov 2017	0.996	3329	31537.03
5	Oct 2017	0.995	3820	25388.23
6	Sep 2017	0.992	6215	27971.42
7	Jul 2017	0.951	3483	18216.59
8	Jun 2017	0.945	1778	8885.78
9	May 2017	0. 999	5780	17357.54
10	April 2017	0.997	2888	10602.81
11	March 2017	0.995	2438	9555.88
12	Jan 2017	0.997	4558	4179.24
Average		**0.899**	3672.58	23091.37

The Performance of different machines and appliances for Dinanath industry is shown in Table 9.This table shows that almost all machines were not being operated with their maximum capacity. It means that the motors used in these machines are higher rating or over size . This table also shows that all machines operated at average power factor of 0.8999 lag. Also traditional welding sets draw high current and operate at 0.8 lagging power factor that causes power factor low. Due to this reason the power factor of industry will be low and there is an average monthly power factor surcharge (Rs.23091.37) is added in electricity bill. It is an extra cost paid by consumer which needs to be reduced by energy auditing.

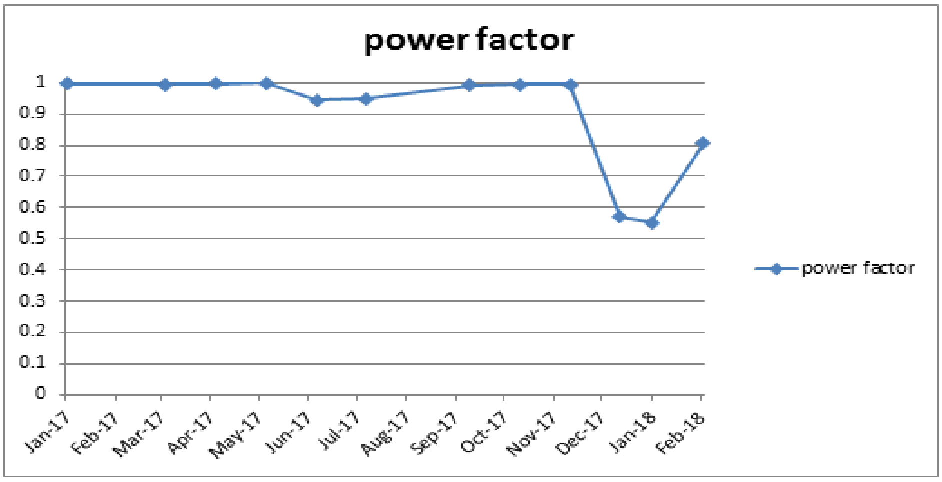

Fig.2 shows the monthly power factor variation in a year

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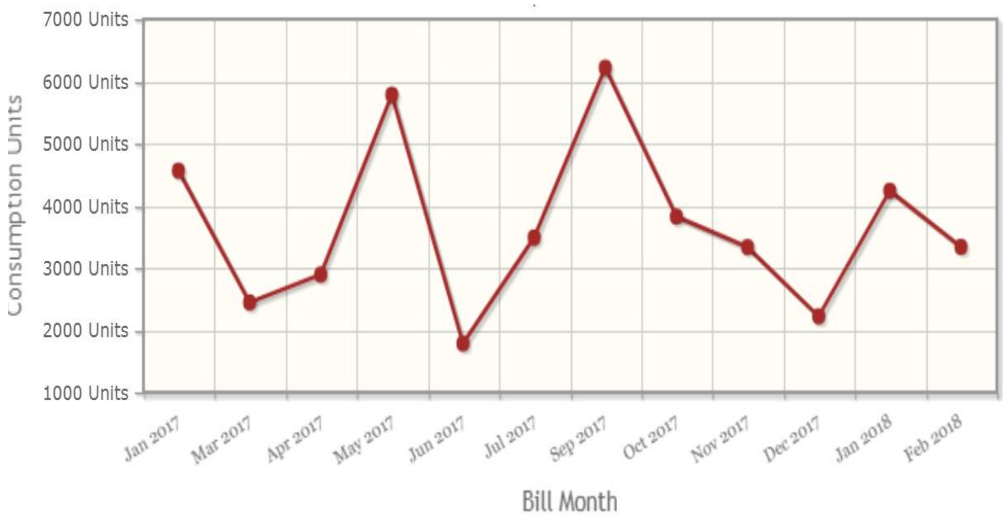

Fig.3 shows the monthly billing unit variation in a year

C) Line Graph Of Monthly Consumption Unit..

Fig.4 shows the monthly billing amount variation in a year

Line Graph OfMonthiy Billing Amount In Rs

Table4. Performance of Electrical Appliances/Machines for Dinanth Industry
Lighting load:

Sr. No.	Type Of Load	Block 1	Block 2	Block 3	Block 4	Block 5	Block 6	Block 7	Block 8	Block 9	Block 10	Block 11	Block 12
1	CFL(18W)	1	1	-	-	-	-	-	4	4	-	-	2
2	LED(36W)	-	-	-	2	1	2	4	1	-	-	-	-
3	TUBELIGHT(36W)	1	1	1	-	-	-	-	-	-	11	2	3

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4	TABLE FAN (55W)	-	-	-	-	-	-	-	-	-	-	4	-
5	COOLER (80W)	-	-	-	-	-	-	-	-	-	2	1	1
6	CFL TUBE(36w)	-	-	-	-	-	-	-	-	-	1	-	2
	TOTAL WATTAGE	54w	54w	36w	72w	36w	72w	144w	108w	72w	592w	372w	296w

Total lighting load =54w + 54w + 36w + 72w + 36w + 72w + 144w + 108w + 72w + 592w + 372w + 296w= 1908W

Table 5.Machine load : Workshop-1

Sr. no.	Name of Machine/ Equipment	Quantity	Capacity and Motors installed
1	Brown And Sharp	2	3.4 KW
2	Zhaho	1	0.75 KW
3	Archdale England	1	4.49 KW
4	G. Vernier	1	0.36 KW
5	LDC	1	1.2 KW
6	Cutter Machine	1	0.75 KW
7	Welding Machine	1	15 KVA
8	Turn Master 350	1	2.2 KW
9	Minar	1	2.2 KW
10	Turbo	1	2.2 KW
11	Grinder	2	0.74 KW

Workshop-2

Sr. no.	Name of Machine/ Equipment	Quantity	Capacity and Motors installed
1	Grinder	4	4.6KW(each)
2	Drilling	4	2.2 KW(each)

Total machinery load in industry(Workshop-1): 3.4+0.75+4.49+0.36+1.2+0.75+2.2+2.2+2.2+0.74=18.29KW
Total machinery load in industry (Workshop-2):(4.6*4)+(2.2*4)=27.2KW
Total load = (Workshop-1) + (Workshop-2) = 18.29+27.2 = 45.49KW = 4549W

Energy Consumption in industry

The total load of industry = Lighting load+ Machine load= 1908W +4549W=6457 kW
The equipment wise energy consumption is shown in Fig.3.

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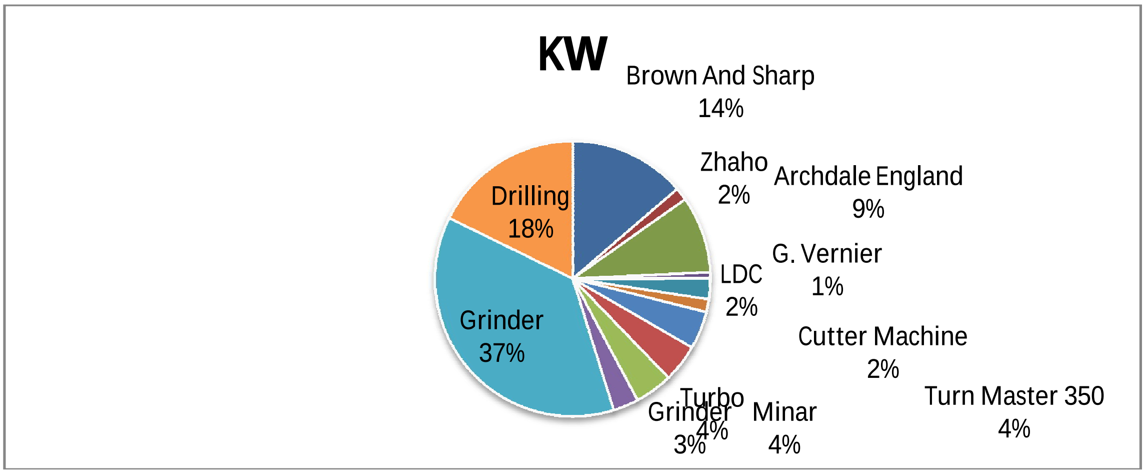

Fig.5 Equipment Wise Energy Consumption

Referring Fig.4, it can be seen that contract demand and billing demand of factory is 62 kVA , 24 kVA respectively but factory should be operated on low demand(recorded demand).

III. KVAR CALCULATION FOR INDUSTRY

According to the electrical data given below the required kVAr or capacitor bank can be calculated to maintain the power factor of 0.95 to reduce power factor surcharge because the electrical utility shall be apply a power factor clause for those consumers who have not maintain the average power factor of 0.90.In case the average power factor falls below 0.9(90%), a surcharge @1% of energy charges for every 0.01(1%) fall in average power factor below 0.90(90%), shall be charged. Also an incentive of 1% of energy charges shall be provided if power factor is above 0.95(95%) for each 0.01 (1%) improvement above 0.95(95%).

Sanctioned load = 67 hp, Load in KW = 50.25

Average power factor (during the year Jan 2017 to Feb 2018) = 0.899 (Referring Fig.2)

Required power factor = 0.95

The power factor is defined as the ratio of true or real power in kW to apparent power in kVA.

Therefore, Power factor ($\cos\Phi$) = kW/kVA (1)

The required kVAr can be calculated from the above equation 2.If the power factor is improved from 0.863 to 0.95 this wills reduces the power factor surcharge. The required kVAr or capacitor bank can be calculated from the given below.

Power Factor Correction

The required kVAr will be calculated as under tan= AC/OA, OA = P (kW).

Therefore, AC = P tanØ1 And AB = P tanØ2, BC =AC –AB, put the values

we get,BC = P tanØ1 - P tanØ2

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and BC = Q (kVAr)- Q (kVAr) = P (tanØ1 – tanØ2) (3)

where,

cosØ1 = 0 .899 (existing power factor), Ø1=25.97

cosØ2 = 0.95 (required power factor) Ø2 = 18.194

Put the values of P = 50.25 Q (kVAr) = 50.25 [tan (25.97) – tan (18.194)

Q (kVAr) = 7.960, say 30 kVAr (approximately) (4)

IV. THREE PHASE CABLE SIZE CALCULATION

The load 50.25 KW in Dinanath industry is divided in two power circuits, hence the full load input current at average power factor of 0.899 and at 440 V supply voltage will be

I = P/ V cosΦ
I = (50.25 x1000)/1.732x 440 x 0.899 = 73.34 A. (5)

The power circuits uses two sized cables in these circuits,the first power circuit has 50sqmm,1100V, PVC, multi core Aluminum cable, while second power circuit has 35 sq mm,1100V, PVC, multi core Aluminum cable Comparing these three phases of current, hence it can be observed that the three phases of load of industry is almost balanced. The verification of above cable sizes can be determined as under shown in Table 10

Table 6. Load Calculation for Power Circuit no.1

Sr. no.	Name of Machine/ Equipment	Quantity	Capacity and Motors installed
1	Brown And Sharp	2	3.4 KW
2	Zhaho	1	0.75 KW
3	Archdale England	1	4.49 KW
4	G. Vernier	1	0.36 KW
5	LDC	1	1.2 KW
6	Cutter Machine	1	0.75 KW
7	Welding Machine	1	15 KVA
8	Turn Master 350	1	2.2 KW
9	Minar	1	2.2 KW
10	Turbo	1	2.2 KW
11	Grinder	2	0.74 KW
	TOTAL	13	18.29KW

We know that, Actual load in kW = Connected load x Demand Factor (6)
Taking demand factor for industry = 0.75 (7)
Therefore, actual load of circuit no.1 will be = 18.29 x 0.75= 13.71 kW

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Length of power circuit no.1= 38meters (measured).The full load current for this circuit is at 440V, 0.863 power factor will be, I = (13.71 x 1000) /(√3 **x** 440x0.899) =20.01 A. Now we can select 50 sq mm, 1100V, PVC, 3.5 core, Aluminum cable Havells[5]. Its current carrying capacity is 155 amperes and resistance per kilometer is 0.443 ohms . The resistance of 38 meter length cable = (0.443x 38)/1000 R = 0.01683 ohms

The permissible voltage drop = (440x5)/100= 22V (8)

Actual voltage drop in cable of circuit no.1 =√3. I R=√3 x 13.71 x 0.01683 = 0.39 V . (9)

Referring Equation 8 and Equation 9, it can be seen that the actual voltage drop for 50 sq mm, Aluminum cable is less than permissible voltage drop .Hence 50 sq mm, PVC, Aluminum cable is suitable for circuit no.1which is already installed at Dinanath industry.

Table7. Load calculation For Power Circuit 2

Sr. no.	Name of Machine/ Equipment	Quantity	Capacity and Motors installed
1	Grinder	4	4.6KW(each)
2	Drilling	4	2.2 KW(each)
	Total	8	45.49 KW

Actual load of circuit no.2 = 45.49 x 0.75 (Refer equation 7)= 34.11 kW
Length of power circuit no.2 = 38meters (measured).The full load current for this circuit is at 440V, 0.899 power factor will be,I = (34.11 x 1000) /(√3 x440x0.899) = 49.78 A. Now we can select 35 sq mm, 1100V, PVC, 3.5 coreAluminum cable Havells [5]. Its current carrying capacity is 130 amperes and resistance per kilometer is 0.320 ohms at 20 °c
Therefore,
The resistance of 38 meter length cable = (0.320x 38)/1000

R = 0.01216 ohms

The permissible voltage drop = (440x5)/100 = 22V (10)

Actual voltage drop in cable of circuit no.2 =√3 × I R =√3 x 49.78 x0.01216= 1.048 V (11)

Referring Equation 10 and Equation11, It can be seen that the actual voltage drop for 35 sq mm, Aluminum cable is less than permissible voltage drop. Hence 35 sq mm, PVC, Aluminum cable is suitable for circuit no.2 which is already installed at Dinanath industry.

V. SUGGESTION AND ECOS FOR AUDIT PHASE-II& III

(i) Referring Table 9, it can be seen that the all over sized motors must be replaced by energy efficient motors for maintain power factor high.

(ii) Referring Fig.3, the maximum electrical energy consumed by traditional welding sets(64%) and also they operates at 0.6 lagging p.f. hence they must be replaced by the 300 Amp IGBT inverter welding sets for maintain p.f.

(iii) Referring Fig.4, it is advice to industry to reduce their contract demand and billing demand so that the tariff charged by RVVNL will be reduced.

(iv) Referring equation 4, to improve power factor from 0.899 to 0.95 the additional capacitor bank of 30 kVAr (APFC) should be connected across the load

(v) The average surcharge of Rs.23091.37 as per Table 8 can be eliminated in electricity bill by adopting above mentioned suggestions.

AUDIT PHASE-III

(i) Implement ECOs suggested in Table 7.
(ii) Install hardware in factory like automatic night light Off at dark circuit at a required place in factory.
(iii) It is advice to management that replaces old oversized motors or traditional welding sets in five phases.

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(iv) Also the additional APFC or capacitor bank has been installed in factory.

CALCULATION OF PAYBACK PERIOD FOR IMPLEMENTATION OF ECOS

The total investment on hardware shown in Table 12

Table 12. Investment on Hardware

S.no	Hardware to be installed with specification	Rate in Rs	Qty	Cost in Rs
a	Electronic ballast,40W, 230 V, Phillips.	200	18	3600
b	Capacitor bank(APFC),30KVAr	48000	1	48000
c	Annual interest and depreciation on cap. installation	15%per annum		7200
d	Investment			**58800**

(I) Annual energy savings (due to replacement of ballast)

= [18 (T.L) x36(W) x08(hr) x365(d) x7.5 (Rs/Kwh)] / 1000 = Rs 14191.2

where, T.L = tube lights

W = wattage of each traditional chokes

hr = no. of hours in a day

d = total no. of days in a year

Rs/Kwh = rate of each unit

(II) Average annual saving in power factor surcharge= 2274.121x 12(months) =Rs 27289.452

(III) Income from selling of old traditional chokes= 18x @Rs50 = Rs 900

Total investment will be = Total investment on hardware (as per Table 12) - Income from selling old Chokes

= [58800-900]

Total investment = Rs 57900 (12)

Net savings will be = (I) + (II)

Net savings = [14191.2 +27289.452] =Rs 41480.652 (13)

We know that Payback period in year will be given as

Referring Equation12 and Equation13

Total annual investment = Rs 57900

Net annual savings = Rs 41480.652

Therefore the Payback period will be = 57900/41480.652 = 1.3958 Years

Payback period in months= 1.3958 x 12=16.75 =Rs 17

VI. CONCLUSION

The payback period of the energy audit programmed for Dinanath industry will be 13 months; implementation of ECOs is being carried out and will be completed by late year 2015. It is believed that energy audit is one of the most comprehensive methods in achieving energy savings in industry thus reducing excessive energy consumption if all private sector participates while applying the energy audit programmes in their industry so that, wasteful consumption of energy will be minimized. The replacement of traditional welding sets with IGBT welding sets is not beneficial to the factory, no doubt they operates at good p.f. and small initial current but their cost and the maintenance cost is also very high that increases in the payback period. The implementation of energy saving measures suggested in this paper

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is solely dependent upon the decision of the management of the factory. Several ECOs that are cost saving are not often implemented due to lack of internal funding such as installation of IGBT welding sets.

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