Energy Audit of an Industry

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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 between demand and supply of electricity is also increasing day by day. To minimize this gap the best solution is to conduct is energy audit of all industries on regular bases. The energy audit will determine energy wastage and losses, and provide techniques and ways to minimize the losses. The energy consumption techniques suggested by the energy audit will not only minimize the losses but also reduce monthly electricity bill. This paper suggests ways and means to conduct an energy audit in an industry.

Index Terms: Energy Audit, Energy Consumption, Energy Conservation, Power Factor Surcharge, Payback Period, Energy Audit Phase, Energy Conservation Opportunities (ECOs).

1 INTRODUCTION

ENERGY Audit is defined as the verification, monitoring and analysis of energy use including submission of technical report containing all the recommendations for improving energy efficiency with cost analysis and an action plan to reduce consumption [1]. 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 [2].The energy audit was conducted at Globetech Engineers and Consultant Ltd, E-51, Vishvkarama industrial area, road no.4, Jaipur, Rajasthan, 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 complete transformer tanks and fabrication of protection boxes ranging from 25kVA to 100kVA.The daily production is about of 60 tanks with protection boxes. This industry has a sanctioned load at 400V, is 96.98 kW and it comprises of different sections like two floor office building, Workshop no.1,Workshop no.2, Workshop no.3 and an Open space. The total area of industry is 183.8 square meter and total staff strength 50 including clerical staff. It has many types of equipments and heavy machinery like Shearing machines, Power press, Traditional welding sets, Cutters, Air compressor, Air conditioners, Drill machines, Sheet rounding machine, Hand grinder shown in Fig.1

2 MAIN OBJECTIVES

The proposed work will cover following sections.

2.1 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

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Table.1
Schedule of Energy Audit Phase -1

S. 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-3
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
Machines and Equipments in Industry

S. no.	Name of Machine/ Equipment	Quantity	Capacity and Motors installed
1	Shearing Machines	3 Nos.	10hp,7.5hp and 3hp
2	Welding Sets	15 Nos.	8 kW each
3	Power Press	5 Nos.	50Ton(7.5hp),30Ton(3 hp),20Ton(3hp),10Ton(2 hp)
4	Cutters	2 Nos.	2 hp each
5	Air Compressor	1 Nos.	10 hp
6	Air conditioners	2 Nos.	2 Ton,1.5Ton
7	A.P.F.C	2 Nos.	80kVAr,30 kVAr
8	Drill machine	1Nos.	3hp
9	Sheet Rounding M/c	1Nos.	2hp
10	Hand Grinder	1Nos.	1hp

Table 3
Instruments Required for Energy Audit

Sno.	Name of Instruments
1	Digital Multimeter
2	Digital Techometer
3	Power Analyzer/Tong tester having kW,hp,kVA options/Clip on meter
4	Measuring tape of 100 meter
5	Lux meter
6	Power factor meter

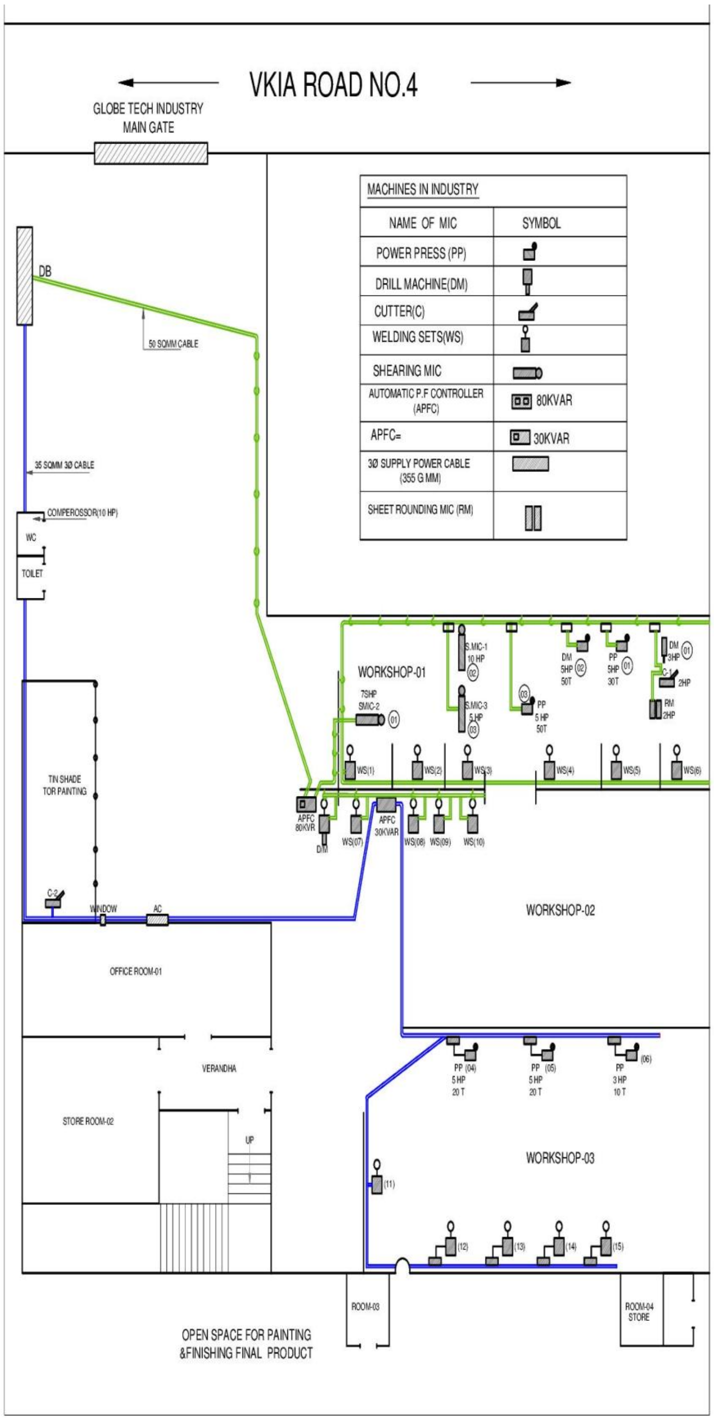

Fig.1 Plant Layout and Power Flow Diagram of Industry

Table 4
Lighting Load Calculation of Globtech Industry

S.no.	Department/type of load	Office building ground floor	Office building first floor	Workshop No.1	Workshop No.2	Workshop No.3	Open Space
1	CFL (18W)	-	2	-	-	-	-
2	CFL (25W)	-	2	-	-	-	-
3	CFL (35W)	-	-	3	-	2	5
4	CFL (85W)	-	-	3	-	1	-
5	Halogen (70W)	-	-	1	-	-	2
6	Halogen (150W)	-	-	3	2	-	4
7	Tube light (55W)	3	2	18	17	11	1
8	Ceiling fan(100W)	1	1	18	7	1	-
9	Table fan(150W)	-	-	2	-	6	-
10	Table fan(200W)	-	-	1	-	1	-
11	Total Load in watt	265 W	296 W	4170 W	1935 W	1960 W	970 W

Total lighting load = 265+296+4170+1935+1960+970
= 9596 W

Table 5
Machine Load (connected) Calculation of Globetech industry

S.no	Machine	Load in kW
1	Shearing Machines	16.787
2	Power Press	20.888
3	Cutters	2.984
4	Air compressor	7.460
5	Drill Machine	2.984
6	Sheet Rounding machine	1.492
7	Welding set	120
8	Air Conditioner	3.5
	Total Machine Load	**176.095**

Table 6
Visual Inspection Report of Pre-audit Phase-I

S. no	Deficiency found in the Industry
1	All tube lights connected with traditional chokes.
2	15 nos of T.L are switched on while not in use
3	A.C ventilation should be chocked due to painting of transformer tanks.
4	All ceiling fan are connected without fan regulator
5	No any control on scrap of M.S sheets they are spread on the whole sections. That could be dangerous.
6	There was lot of smoke of welding inside the Workshop no. 1 and Workshop no. 2.

Table 7
Suggestion and ECOs for Pre-audit Phase-I

S. no	Suggestion for Pre-audit Phase 1
1	All tube lights chokes replaced with ballast chokes.
2	Install a automatic night light circuit along with a common off at dark circuit.
3	A.C ventilation should be regularly cleaned
4	All ceiling fans should be controlled by electronic fan regulators.
5	The scrap of M.S sheets are collected time to time and store in a proper place they may be use for make another material like Washers etc. Also the scrap of M.S sheets sold to earn money.
6	Workshop no.1 and 2 needs Exhaust fans to remove smoke of welding.

2.2 Audit Phase- II

During audit phase II the following observations were completed within 10 days. The summary of electricity bills of 12 months since July 2013 to July 2014 is shown in Table 8. Due to some technical reason the electricity bill for the month of Feburary-2014 was added in the electricity bill of March-2014.Therefore there were some irregularities found in electricity bills of Globetech industry.

TABLE 8
Summary of Annual Electricity Bills

S. no	Month	Power Factor	Energy Consumption in kwh	Power factor surcharge (in Rs.)
1	July 2013	0.87	11721	1846.08
2	Aug 2013	0.87	12257	1930.48
3	Sep 2013	0.88	13637	1431.89
4	Oct 2013	0.867	14379	2491.16
5	Nov 2013	0.845	17407	5026.27
6	Dec 2013	0.844	12196	3585.62
7	Jan 2014	0.874	13246	1808.08
8	Feb & March 2014	0.880	10280 & 9980	1431.89
9	April 2014	0.851	8405	2162.19
10	May 2014	0.871	10177	1549.45
11	June 2014	0.851	11578	2978.44
12	July 2014	0.853	10053	2480.58
Average		**0.863**	**11947.38**	**2361.51**

The Performance of different machines and appliances for Globetech 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 sized [3]. This table also shows that all machines operated at average power factor of 0.639352941 lag. Also traditional welding sets draw high current and operate at 0.6 lagging power factor that causes power factor low. Due to this reason the power factor of whole industry will be low and there is an average monthly power factor surcharge (Rs.2361.51) 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.

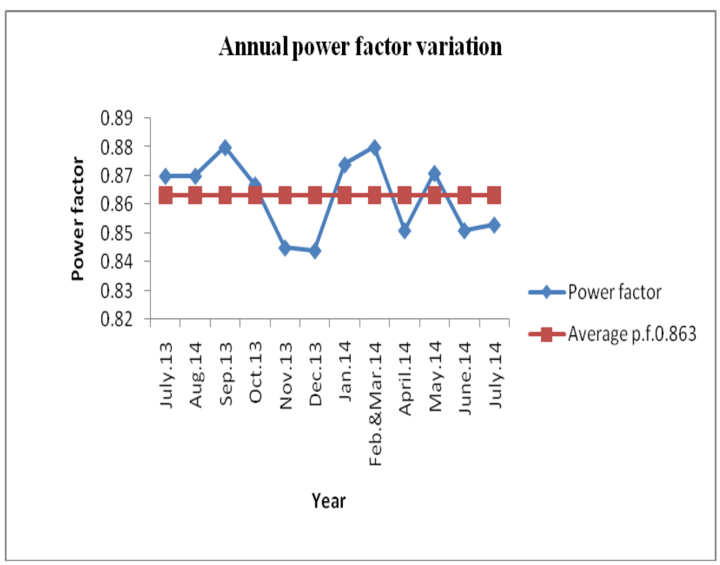

Fig.2 Power Factor v/s Months

Table 9
Performance of Electrical Appliances/Machines for Globe tech Industry

S. No	Machinery	Rating	Measured current/voltage/RPM							% load	Power factor
			Voltage(Volt)	Current(A)	RPM	hp	kW	kVA	kW/kVA		
1	Shearing M/c-1	10hp, 15A	426	6.87	1498	5.06	3.78	5.06	0.74	45.8	0.74
2	Shearing M/c-2	7.5hp,11.2 A	430	9.42	1460	4.6	3.20	7.01	0.45	83.7	0.45
3	Shearing M/c-3	5hp 7.5 A	427	4.8	1480	2.65	1.97	3.5	0.55	64	0.55
4	Welding sets (15 nos.)	8kw/each	430	150-268	-	-	8	-	-	-	0.60
5	Power Press-1	5hp,50 ton 7.5 A	430	3.87	1480	2.21	1.65	2.88	0.57	51.6	0.57
6	Power Press-2	5hp,50 ton 7.5 A	430	3.53	1480	1.85	1.39	2.62	0.52	47	0.52
7	Power Press-3	3 hp,30 ton 4.5 A	428	2.50	1460	1.27	1.10	1.85	0.59	55	0.59
8	Power Press-4	5hp,20 ton 7.5 A	427	4.06	1490	1.79	1.7	3.00	0.56	54	0.56
9	Power Press-5	5hp,20 ton 7.5 A	427	5.88	1480	2.44	2.02	4.34	0.46	57.9	0.46
10	Power Press-6	3hp,10 ton 4.5 A	430	2.32	1460	1.44	1.01	1.72	0.58	51.5	0.58
12	Cutters	2hp,6 A	230	3.5	2850	1	0.75	0.80	0.93	58.3	0.93
13	Sheet rounding M/c	2hp,3A	230	1.8	2850	0.5	0.37	0.41	0.9	60	0.9
14	Air conditioner-1	2 ton, 10 A	230	9.5	-	-	-	-	-	-	-
15	Air conditioner-2	1 ton, 10 A	230	8.5	-	-	-	-	-	-	-
16	Air compressor	10 hp,15A	230	11	1440	5.06	3.78	5.06	0.74	73	0.74

2.3 Factory Energy Consumption of Factory

The total load of factory = Lighting load+ Machine load
= 9.596 +176.095= 185.691 kW

The equipment wise energy consumption is shown in Fig.3.

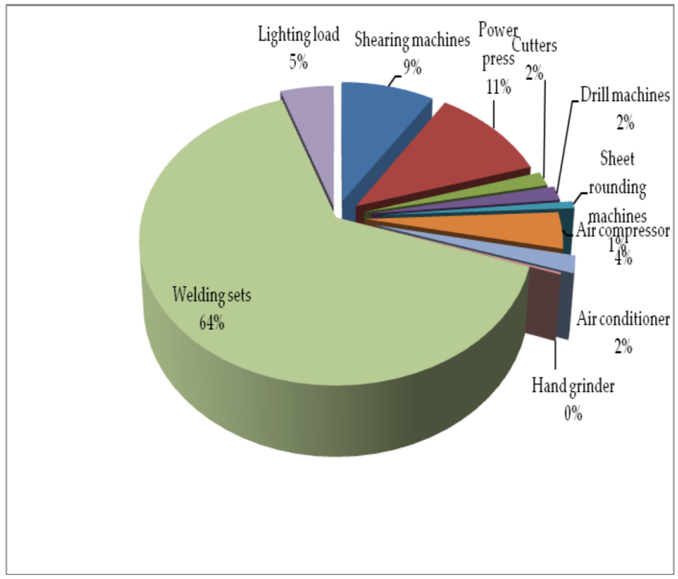

Fig.3 Equipment Wise Energy Consumption

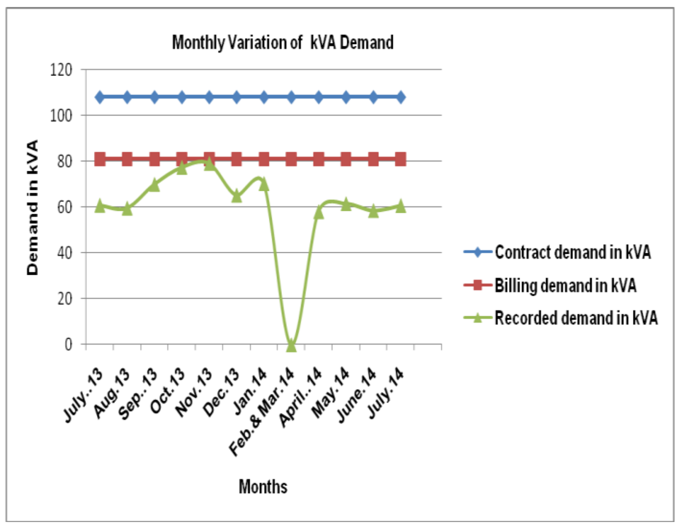

Fig.4 Demand v/s Months

Referring Fig.4, it can be seen that contract demand and billing demand of factory is 108 kVA , 81 kVA respectively but factory should be operated on low demand(recorded demand)[4].

2.4 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%) [5].

Sanctioned load = 130 hp
Load in KW = 96.98

Average power factor (during the year July 2013 to July 2014) = 0.863 (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 (cosΦ) = kW/kVA (1)

$$(kVA)^2 = (kW)^2 + (kVAR)^2$$

$$\text{kVAr} = \sqrt{(kVA)^2 - (kW)^2} \quad (2)$$

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 Fig.5 given below.

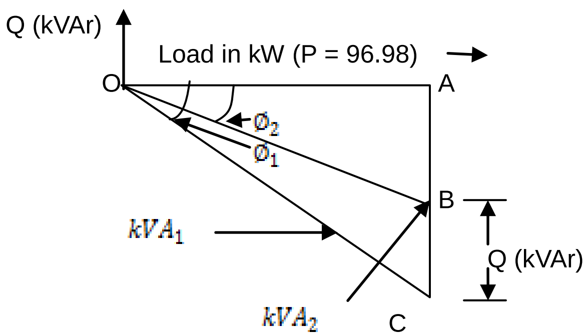

Fig.5 Power Factor Correction

The required kVAr will be calculated as under $\tan\phi_1$= AC/OA, OA = P (kW).
Therefore, AC = P $\tan\phi_1$ And AB = P $\tan\phi_2$, BC =AC –AB, put the values we get BC = P $\tan\phi_1$- P $\tan\phi_2$ and BC = Q (kVAr)
Q (kVAr) = P ($\tan\phi_1$ - $\tan\phi_2$) (3)

where, $\cos\phi_1$= 0.863 (existing power factor),
$\phi_1 = \cos^{-1}(0.863)$
= 30.088
$\cos\phi_2$= 0.95 (required power factor)
$\phi_2 = \cos^{-1}(0.95)$ = 18.194
Put the values of P = 96.98
Q (kVAr) = 96.98 [tan (30.088) – tan (18.194)]
Q (kVAr) = 24.316, say 30 kVAr (approximately) (4)
.

2.5 Three Phase Cable Size Calculation

The load 96.98 KW in Globetech industry is divided in two power circuits, hence the full load input current at average power factor of 0.863 and at 440 V supply voltage will be

I = P/ $\sqrt{3}$ V cosΦ

I = (96.98 x1000)/1.732x 440 x 0.863 = 147.458 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. The average full load current measured in second power circuit on dated 6/9/2014 at 3.30pm was found at 0.867 power factor as under,

R phase current = 19 Amps
Y phase current = 25 Amps
B phase current = 20 Amps

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 10
Load Calculation for Power Circuit no.1

S. no.	Name of machine	Capacity in horse power	Load in KW
a	Shearing Machine 1	10	7.46
b	Shearing Machine 2	7.5	5.59
c	Shearing Machine 3	5	3.73
d	Power Press,50 ton	5	3.73
e	Power Press,50 ton	5	3.73
f	Power Press,30 ton	5	3.73
g	Sheet Rounding Machine	2	1.492
h	Welding sets 7 no's 8KW each	75.06	56
i	Air Compressor	10	7.46
j	Drill Machine 1	3	2.238
k	Cutter 1	2	1.492
l	Lighting load	6.431	4.798
	Total	**135.991**	**101.45**

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 = 101.45 x 0.75
= 76.08 kW
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 = (76.08 x 1000) /($\sqrt{3}$ **x** 440x0.863) =115.680 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 at 20 ℃
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 = $\sqrt{3}$ I R
= $\sqrt{3}$ **x**115.680 x 0.01683
= 3.37 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 Gobetech industry.

Table 11
Load Calculation for Power Circuit no.2

S. no	Name of machine	Capacity in horse power	Load in kW
a	Power press,20 ton	5	3.73
b	Power press,20 ton	5	3.73
c	Power press,10 ton	3	2.238
d	Cutter 2	2	1.492
e	Drill machine 2	1	0.746
f	Welding sets 8 no's 8KW each	85.79	64
g	Lighting Load	6.431	4.798
h	A.C	4.6916	3.5
	Total	**112.9126**	**84.234**

Actual load of circuit no.2 = 84.234 x 0.75 (Refer equation 7)
= 63.17 kW

Length of power circuit no.2 = 38meters (measured).The full load current for this circuit is at 440V, 0.863 power factor will be,I = (63.17 x 1000) /($\sqrt{3}$ **x**440x0.863)=96.05 A. Now we can select 35 sq mm, 1100V, PVC, 3.5 core Aluminum cable Havells [5]. Its current carrying capacity is 130 amperes and resistance per kilometer is 0.320 ohms at 20 ℃

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 = $\sqrt{3}$ I R
= $\sqrt{3}$ x 96.05 x0.01216
= 2.02 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 Globetech industry.

2.6 Suggestion and ECOs for Audit Phase-II

- **(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 0.863 to 0.95 the additional capacitor bank of 30 kVAr (APFC) should be connected across the load
- **(v)** The average surcharge of Rs.2361.51 as per Table 8 can be eliminated in electricity bill by adopting above mentioned suggestions.

2.7 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 over sized motors or traditional welding sets in five phases.
- (iv) Also the additional APFC or capacitor bank has been installed in factory.

2.8 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	52	10400
b	Automatic night light,5amp,230V	200	15	3000
c	Off at dark light circuit,5 amp,230V	150	5	750
d	Capacitor bank(APFC),30KVAr	48000	1	48000
e	Annual interest and depreciation on cap. installation	15%per annum		7200
f	**Investment**			**69350**

(I) Annual energy savings (due to replacement of ballast)
= [52 (T.L) x15(W) x12(hr) x365(d) x7.5 (Rs/Kwh)] / 1000
= Rs 25623

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) Annual energy savings (due to Automatic night light and Off at dark light circuit)
= [15 (T.L) x 40(W) x 6(hr)x365(d)x7.5(Rs/Kwh)]/1000
= Rs 9855

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

(IV) Income from selling of old traditional chokes
= 52x @Rs50 = Rs 2600

Total investment will be = Total investment on hardware (as per Table 12) - Income from selling old Chokes
= [69350-2600]
Total investment = Rs 66750 (12)
Net savings will be = (I) + (II) + (III)
Net savings = [25623+9855+27289.452]
= Rs 62767.452 (13)

We know that Payback period in year will be given as

$$= \frac{Total\ annual\ investment}{Net\ annual\ savings}$$

Referring Equation12 and Equation13

Total annual investment = Rs 66750

Net annual savings = Rs 62767.452

Therefore the Payback period will be = 66750/62767.452
= 1.06345 Years
Payback period in months = 1.06345 x 12

$$= 12.76$$

$$= 13 \qquad (14)$$

3 CONCLUSIONS

(1) The payback period of the energy audit programmed for Globetech industry will be 13 months; implementation of ECOs is being carried out and will be completed by late year 2015.
(2) 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 in the implementation of the energy audit programmes in their industry so that, wasteful consumption of energy will be minimized.
(3) 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.
(4) The implementation of energy saving measures suggested in this paper is solely dependent upon the decision of the management of the factory. Several ECOs that are cost effective are not often implemented due to lack of internal funding such as installation of IGBT welding sets.

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