Energy Audit: A Case Study at Medium Scale Industry

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Abstract- **Energy is one of the major inputs for the economic development of any country. In the case of the developing countries, the energy sector assumes a critical importance in view of the ever-increasing energy needs requiring huge investments to meet them. 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, Payback Period, Energy Audit Phase, Energy Conservation Opportunities (ECOs).**

I. INTRODUCTION

Energy audit concept is a measure of the efficiency of energy utilization in a manufacturing process, thus leading to interest in energy performance of machines and plants directly associated with production process (Aiyedun and Ologunye, 2001). Shrivastava et al. (2013), defined energy audit as the verification, monitoring and analysis of energy use including submission of technical report containing this also recommendations for improving energy efficiency with cost analysis and an action plan to reduce consumption. While, Ojo (1995), sees energy audit as an attempts to balance the total energy inputs with its use and serves to identify all the energy streams in the systems and quantifies energy usages according to its discrete function. 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 (Umesh, 1998). Energy audit is the fundamental and most significant step for implementation of any effective energy management program. It tries to answer how, where and how much energy is used in a system. It also provides an opportunity to look into energy use pattern and recommends way and mean of eliminating losses and improving the efficiency of the system. The immediate advantages obtained through energy audit are improved maintainability, reliability features coupled with reduction losses. Long term energy saving can be through the use of energy efficient equipment.

There are two types of Audits preliminary audit and detailed energy audit. The preliminary audit alternatively called a simple audit, screening audit or walk-through audit, is the simplest and quickest type of audit. It involves minimal interviews with site operating personnel, a brief review of facility utility bills and other operating data, and a walk-through of the facility to become familiar with the building operation and identify glaring areas of energy waste or inefficiency. Typically, only major problem areas will be uncovered during this type of audit. Corrective measures are briefly described, and quick estimates of implementation cost, potential operating cost savings, and simple payback periods are provided. This level of detail, while not sufficient for reaching a final decision on implementing a proposed measure, is adequate to prioritize energy efficiency projects and determine the need for a more detailed audit. Detailed energy audit on the other hand is a comprehensive audit which provides a detailed energy project implementation since it evaluates all major energy using systems. It is an accurate method for Energy saving and Audit. In this audit three phases are involved, Pre Audit Phase, Audit Phase and Post Audit Phase. The objective of Energy Audit is to promote the idea of Energy Conservation in the company.

The purpose of the energy audit is to identify, quantify, describe and prioritize cost saving measures relating to energy use in the office, workshops and premises of the company. The work eligible for Energy Audit Study should be directed towards the following. Identifying the areas of energy wastage and estimation of energy saving potential in the company facilities. And suggesting cost-effective measures that will improve the efficiency of energy use, estimating the costs and payback period. Others includes documenting results and information generated through these activities and Identifying the possible usages of co-generation, renewable sources of energy (say Solar Energy, Biogas plant) and recommendations for implementation, wherever possible, with cost benefit analysis. The increasing role of energy efficiency as a catalyst for sustainable industrial development is realism in the industrialized countries of the world. The whole purpose of energy efficiency is to minimize the amount of energy used to get a desired effect.

MATERIALS AND METHODS

The energy audit was conducted at CB Industry, MIDC Hingna ,Nagpur,Maharastra to identify the major areas of energy waste. The energy audit was conducted within a period of four months. The above industry is a manufacturer of Tanks Fabrication, Industrial Chimney Fabrication, Rod Gate, Heavy Fabrication Works, Sliding Gates, Compressed Air Storage Tank,Thermal Storage Tank, MS Tank, SS Tank, SS Air Receiver Tank, Horizontal Air Receiver Tank etc . This industry has a sanctioned load at 440V, is 50 kW and it comprises of different sections like two floor office building, Workshop area and an Open space. The total area of industry is 10,000 square feet and total staff strength is 20. It has many types of equipments and heavy machinery like hydraulic press, Traditional welding sets, Cutters, Air compressor, Air conditioners, Drill machines, Sheet rounding machine, Hand grinder and over hanging crane.

Procedure Adopted

The proposed work will cover following sections.

Audit Phase- I (Pre-Audit Phase)

During pre-audit phase the following observations/inspection were completed.

Table.1 Schedule of Energy Audit Phase -1

S.No	Observations/inspection	Result
1	A complete walk through in the industry	Done
2	Discuss advantages of energy audit	Done
3	Inspect various sections for any energy wastage	Done
4	Prepare a list of major energy consuming machinery with their ratings	See Table-2
5	Plant layout	See Figure 1
6	To identify instruments required for audit	See Table-3
7	Calculate lighting Load	See Table-4
8	Check any loose connection and leakage	loose connection and Leakages were found
9	Calculate Machine Load	See Table-5
10	Suggestion and ECOs for Pre-audit Phase-I	See Suggestions given Below

Table 2 Machines and Equipments in Industry

S. no.	Name of Machine/ Equipment	Quantity	Capacity and Motors Installed
1	Over Hanging Crane	1 Nos.	14.5 kW
2	Welding Sets	4 Nos.	5 kW each
3	Power Press	2 Nos.	11 kW, 8 kW
4	Cutters	1 Nos.	2 hp
5	Air Compressor	1 Nos.	4 hp
6	Air conditioners	1 Nos.	1 Ton (3.5 kW)
7	Bench Grinder	2 Nos.	0.37 kW
8	Drill machine	2 Nos.	1.5 kW, 0.75 kW
9	Sheet Rounding M/c	1 Nos.	7.5 kW, 3.7 kW
10	Hand Grinder	3 Nos.	2 hp

Table 3 Instruments Required for Energy Audit

Sno.	Name of Instruments
1	Digital Multimeter
2	Digital Tachometer
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

Plant Layout

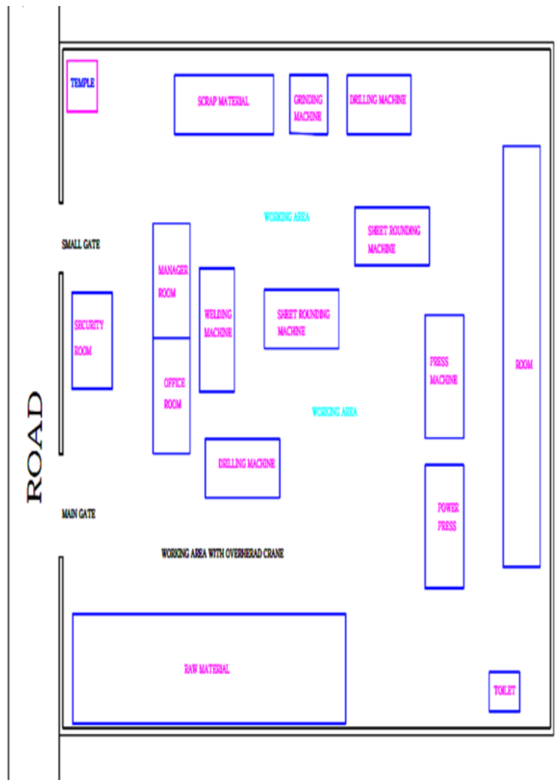

Fig.1 Plant Layout

DATA COLLECTION

In preliminary data collection phase, exhaustive data collection was made using different methods such as observation, interviewing key persons, and measurements. The following steps were taken for data collection: A visit to each of the workshops, offices and other entities of the institution. Information about the general electrical appliances was collected by observation and interviewing. The Site drawing of available building lay-out and Electricity distribution were collected. Electricity bill was collected from the personnel in-charge. The power consumption of appliances was measured using power analyzer in some cases (such as fans) while in other cases, rated power was used (CFL for example). Information was also collected on redundant / non-operational energy systems. The details of usage of the appliances were collected by interviewing key persons e.g. Electrician, caretaker (in case of departments) etc. and approximations and generalizations were done at places with lack of information.

Table 4 Lighting Load Calculation of CB Industry

Sr.No	Type Of Loads	Office Building	Store Room	Temple	House	Washroom	Work Area
01.	Halogen (500 W)	-----	----	----	----	----	03
02.	Ceiling Fan (53 W)	02	----	----	01	----	----
03.	Tube Light (55 W)	02	01	01	01	01	------
04.	Air Conditioner (3500W)	01	----	----	----	----	----
05.	Cooler (370 W)	01	----	----	----	----	----
06.	Printer (420 W)	01	----	----	----	----	----
07.	Computer (270 W)	02	----	----	----	----	----
08.	Incandescent Bulb (60 W)	----	----	----	----	----	02
	Total Load in Watt	5020	55	55	150	55	1620

Total Lighting Load = 6.955 Kilo Watt

Table 5 Machine Load (connected) Calculation of C.B. Industries

Sr.No	Name Of Machine	Qty	Rating	Qty*Rating
01.	Welding Set	04	8 KW,	32 kW
02.	Press Machine	02	8 KW,11 KW	19 kW
03.	Air Compressor	01	4 KW	4kW
04.	Drill Machine	02	1.5 KW, 0.75 KW	2.25 kW
05.	Bench Grinder	01	0.37 KW	0.37 kW
06.	Hand Grinder	03	2 KW	6 kW
07.	Over Hanging Crane	01	14.5 KW	14.5 kW
08.	Sheet Rounding Machine	02	3.7 KW, 7.5 KW	11.2 kW
09.	Water Pump	01	0.373 kW	0.373 kW

Total Machine Load=89.693 kW

Factory Energy Consumption of Factory

The total load of factory = Lighting load+ Machine load

= 6.955+89.693

= 96.648 Kw

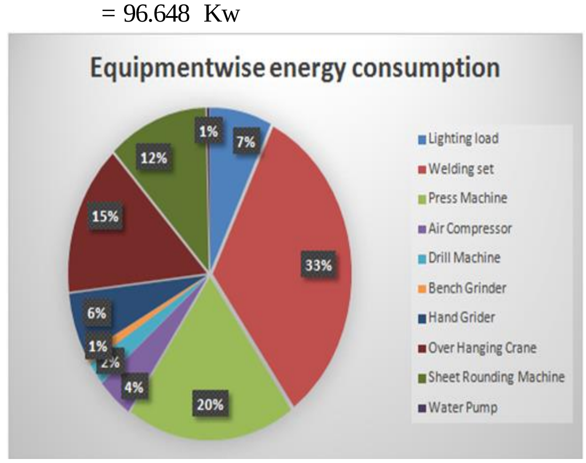

Fig 2: Equipment wise energy consumption

Visual Inspection Report of Pre-audit Phase-I

- All tube lights are of higher rating.
- Halogens (500W) are used
- Incandescent bulbs of high rating are used instead of LED bulbs

- Ceiling fans of high rating are used.
- No any control on scrap of M.S sheets they are spread on the whole sections. That could be dangerous.

Suggestion and ECOs for Pre-audit Phase-I

- Ceiling fans (53 W) should be replaced by Ceiling Fans (32 W).
- Halogens (500 W) in the work area should be replaced by LED Halogens (100 W) which has a luminance of 9000 same as that of previous halogens.
- Tube lights (22 W) should be used to reduce lighting load.
- LED Bulbs (15 W) should be used instead of Incandescent Bulbs (60 W).
- AC ventilation should be regularly cleaned.

Audit Phase- II

During audit phase II the following observations were completed. The summary of electricity bills of 12 months since Feb 2017 to Jan 2018 is shown in Table 6

Table 6Monthly power factor variation in a year

Sr.No	Month	Power Factor	Consumption
01.	Feb 2017	0.912	1589
02.	Mar 2017	0.902	1590
03.	Apr 2017	0.912	2136
04.	May 2017	0.899	1828
05.	June 2017	0.901	2125
06.	July 2017	0.900	2474
07.	Aug 2017	0.900	3012
08.	Sep 2017	0.904	1928
09.	Oct 2017	0.915	2730
10.	Nov 2017	0.905	1423
11.	Dec 2017	0.900	2138
12.	Jan 2018	0.910	1634
	Average	0.905	2050.58

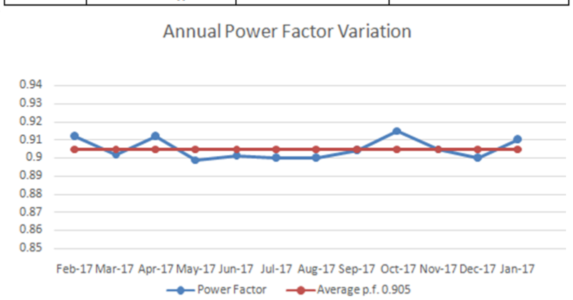

Fig 3: Power Factor v/s Months kVAr Calculation for Industry

According to the electrical data given below the required kVAr or capacitor bank can be calculated to maintain the power factor of 0.995 to reduce power factor surcharge and to increase incentive 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 kW

Average power factor (during the year Feb 2017 to Jan 2018)

= 0.905 (Referring Fig.2)

Required power factor = 0.995

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

$$(kVA)^2=(kW)^2+(kVAR)^2 \quad (1)$$

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

The required kVAr can be calculated from the above equation 2.If the power factor is improved from 0.905 to 0.995 this wills increase the power factor incentive. The required kVAr or capacitor bank can be calculated from the Fig.5 given below.

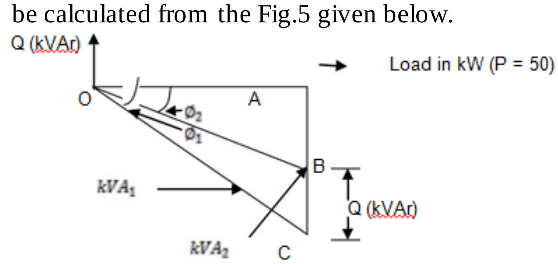

Fig.4 Power Factor Correction

The required kVAr will be calculated as under $\tan ø_1$ = AC/OA, OA = P (kW).

Therefore, AC = P $\tan ø_1$ And AB = P $\tan ø_2$, BC =AC –AB, put the values we get BC = P $\tan ø_1$ - P $\tan ø_2$ and BC = Q (kVAr)

$$Q\ (kVAr) = P(\tan ø_1 - \tan ø_2) \quad (3)$$

Where, $\cos(ø_1) = 0.905$ (existing power factor)

$ø_1 = \cos^{-1}(0.905)$

$= 25.177^\circ$

$\cos(ø_2) = 0.995$ (Required power factor)

$ø_2 = \cos^{-1}(0.995)$

$= 5.732^\circ$

Put the values of P = 50 kW

Q (kVAr) = 50 [tan (25.177) –tan (5.732)]

Q (kVAr) = 18.48, say 25 kVAr (approximately) (4)

PLANT LAYOUT STUDY

1. To study the current flow pattern and relation of overall plant layout and develop a new plant layout.
2. 2. Relocating the workstations for simpler flow and reduction in check points.
3. To improve the efficiency of the plant layout using simulation.

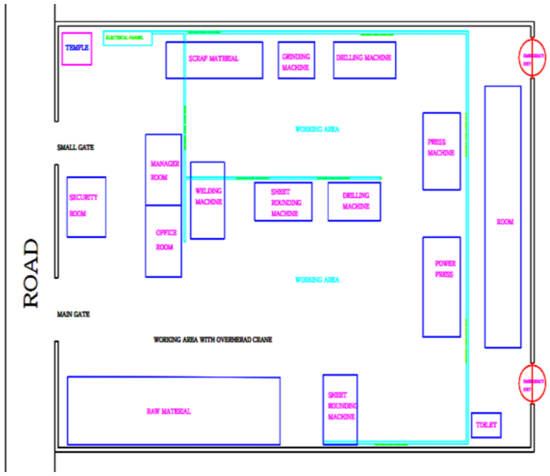

Fig 5: Suggested plant layout

Suggestion and ECOs for audit phase-II

1. Referring equation 4, to improve power factor from 0.905 to 0.995 the additional capacitor bank of 25 kVAr (APFC) should be connected across the load
2. According to the Electricity Distribution board, for maintaining power factor above 0.995 incentive of 7% of monthly electricity bill is rewarded to the company.

Audit Phase-III

1. Implementing the suggestions given in audit phase 1 and payback period calculation.
2. Also the additional capacitor bank is to be installed in the factory.

Table7 Calculation of payback period for Implementation of ECOs

Sr.No	Equipment to be installed	Quantity	Rate in Rs	Cost in Rs
1.	Capacitor Bank (25 kVAr)	1	36,000	36,000
2.	Tube light (22 W)	6	499	2,994
3.	Fan(32 W)	3	2291	6,873
4.	Led Bulb(12 W)	2	198	396

Annual energy savings (due to replacement of tubelight (55W))

=0.033 (kW)x 6(Qty) x 8(hrs) x 25(days) x 12 (months) x6.39(Rs)

= 3036.53 Rs……………… (1)

Annual energy saving (due to replacement of fan(53W))

= 0.021 x 3(Qty) x 10(hrs) x 25(days) x 12 (months) x 6.39(Rs)

= 1207.71 Rs……………… (2)

Annual energy saving (due to replacement of incandescent bulb(60W))

= 0.048 x x 2(Qty) x 4(hrs) x 25(days) x 12 (months) x 6.39(Rs)

= 736.13 Rs……………… (3)

Incentives rewarded due to installation of Capacitor Bank (25kVAr)

Average Energy consumption per month = 2050 units

Rate per unit = Rs 6.39

Average electricity bill = Rs 14000

Total electricity bill = Demand Charge + Energy Charge

= 14000 + 3740

= Rs 17740

Incentives rewarded for maintaining the power factor above 0.995 = 7% of total electricity bill

= 7% of 17740

= Rs 1242 per month

= Rs.14904 per year……………… (4)

Total investment will be = Total investment on hardware (as per Table7) - Income from selling old equipments

Total investment= 36,000+2,994+6,873+396- 3300

= Rs 42,969……………… (5)

Net Savings = (1) + (2) + (3) + (4)

= 3036 + 1207 + 736 +14904

= Rs.19, 883……………… (6)

We know that Payback period in year will be given as

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

Referring Equation12 and Equation13
Total investment = Rs 42969
Net annual savings= Rs 19,883
Therefore the Payback period will be = 42969/19,883
= 2.16 year
Payback period in months = 2.16x 12
= 25 months

CONCLUSION

1) The payback period of the energy audit programmed for C.B. Industry will be 25 months.
2) The sources of electrical energy wastage were identified and assessed the effectiveness of the strategies for electrical energy savings in the industries.
3) The work shows that replacing the conventional tube lights with energy saving LED tube lights reduces the energy consumption drastically.
4) It also shows that installing the fans suggested in the paper also reduces energy consumption.
5) Installing Capacitor Bank of 25 kVAr improves the power factor of the industry.
6) 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 not cost effective are not often implemented.

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