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Energy Audit of an Industry for Energy Conservation and Economical Operations

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Abstract

Energy today has become a key factor in deciding the product cost at micro level as well as in dictating the inflation and the debt burden at the macro level. Energy cost is a significant factor in economic activity based on factors of production like capital, land and labor. The imperatives of an energy shortage situation calls for energy conservation measure, which essentially mean using less energy for the same level of activity. As per Energy Conservation Act 2001, energy audit is mandatory for every commercial firm in India. Energy Audit 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. Energy Audit helps in energy cost optimization, pollution control, safety aspects and suggests the methods to improve the operating & maintenance practices of the system. It is instrumental in coping with the situation of variation in energy cost availability, reliability of energy supply, decision on appropriate energy mix, decision on using improved energy conservation equipment's, instrumentation's and technology.
Keywords: Diesel generator, economy, energy audit, energy conservation, harmonics, power factor, transformer

I. INTRODUCTION

An energy audit, also known as an energy assessment, is the first step to assess how much energy consumes and to evaluate what measures can take to make the industry/home more energy efficient. An assessment will show the problems that may, when corrected, save significant amounts of money over time.Energy audit is an inspection of energy using site to find out energy losses, wastage and inefficient apparatus or process by collection and detailed analysis of data related to energy usage and energy flow, comparison of collected results with set up standards to find out Energy Conservation Opportunities and suggests technically feasible energy saving measures to reduce or eliminate energy losses and wastage. Energy audit also helps building owners and industries to reduce their billing cost and implementing best possible and cost effective energy saving measure by analysis of payback period.

II. OBJECTIVES OF ENERGY AUDITING

The Energy Audit provides the vital information base for overall energy conservation program covering essentially energy utilization analysis and evaluation of energy conservation measures. It aims at:

- Identifying the quality and cost of various energy inputs.
- Assessing present pattern of energy consumption in different cost centers of operations.
- Relating energy inputs and production output.
- Identifying potential areas of thermal and electrical energy economy.
- Highlighting wastage's in major areas.
- Fixing of energy saving potential targets for individual cost centers.
- Implementation of measures for energy conservation & realization of savings.

An energy analysis or Energy Audit includes the following steps:

- Develop Single line diagram and analysis
- Collection and analysis of historical energy use.
- Study of the building and its operational characteristics.
- Identification of potential solutions that will reduce the energy use and/or cost.
- To perform an engineering and economic analysis of potential modifications.
- Preparation of rank-ordered list of appropriate modifications.

- Preparation of an audit report to document the analysis process and results

III. TYPES OF ENERGY AUDITS

The energy audit orientation would provide positive results in reduction energy billing for which suitable preventive and cost effective maintenance and quality control programmers are essential leading to enhanced production and economic utility activities. The type of energy audit to be performed depends upon the function or type of industry. There can be three types of energy audit.

- Preliminary energy audit
- General energy audit
- Detailed energy audit

A. *Preliminary Energy Audit*

The preliminary energy audit alternatively called a simple audit screening audit or walk through audit, is the simplest and quickest type of audit. It is carried out in a limited span of times and it focuses on major energy supplies and demands. It aims at taking steps which are necessary for implementation of energy conservation program in an establishment. It involves activities related to collection, classification, presentation and analysis of available data in arising at the most appropriate steps to be taken in establishing energy conservation. It involves collection of necessary data, minimal interviews with site operating personnel, a brief review of facility utility bills and other operating data and identifies glaring areas of energy waste or inefficiency.

Typically, only major problems area 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 searching a final decision on implementing proposed measures, is adequate to prioritize energy efficiency projects and determine the need for more detailed audit.

B. *General Energy Audit*

The general energy audit is also called a mini audit or site energy audit or complete site energy audit. It expands on the preliminary audit by collecting more detailed information about facility operation and performing a more detailed evaluation of energy conservation measures identified. Utility bills are collected for a 12 to 36 months period to allow the auditor to evaluate the facility energy/demand rate structure and energy usage profiles. Additional metering of specific energy consuming systems is often performed to supplement utility data. In depth interviews with facility operating personnel are conducted to provide a better understanding of major energy consuming systems as well as insight into variations in daily and annual energy consumption and demand. This type of audit will be able to identify all energy conservation measures appropriate for the facility given its operating parameters. A detailed financial analysis is performed for each measures based on detailed implementation cost estimates, site specific operating cost savings and the customer's investment criteria. Sufficient detail is provided to justify project implementation.

C. *Detail Audit*

Detailed energy audit is also called comprehensive audit or investment grader audit. It expands on the general energy audit. It covers estimation of energy input for different processes, collection of past data on production levels and specific energy consumption. It is a comprehensive energy audit action plan to be followed effectively by the industry.

It provides a dynamic model of energy use characteristics of both the existing facility and all energy conservation measures identified. The building model is calibrated against actual utility data to provide a realistic baseline against which to compute operating savings for proposed measures.

Extensive attention is given to understanding not only the operating characteristics of all energy consuming systems, but also situations that cause load profile variations on both an annual and daily basis. Existing utility data is supplemented with sub metering of major energy consuming systems and monitoring of system operating characteristics.

Thus, the scope of this audit is to formulate a detailed plan on the basis of quantitative and control evaluation, to evolve detailed engineering for options to reduce total energy costs, consumption for the product manufactured. It should be at 8 to 10 percent savings, detailed audit study shall be completed in a period of three weeks from the date of commencement. After which, preparation of energy audit reports shall be completed in a period of three weeks. The major system that are encountered in industries with regard to which energy audit is to be carried out are: Boilers, furnaces, air conditioning systems, refrigeration or cold room etc., power generation and distribution systems, compressed air generation systems, pumping systems and electric motor driven systems.

IV. CASE STUDY

Detailed analysis carried out with the help of single line diagram of the plant

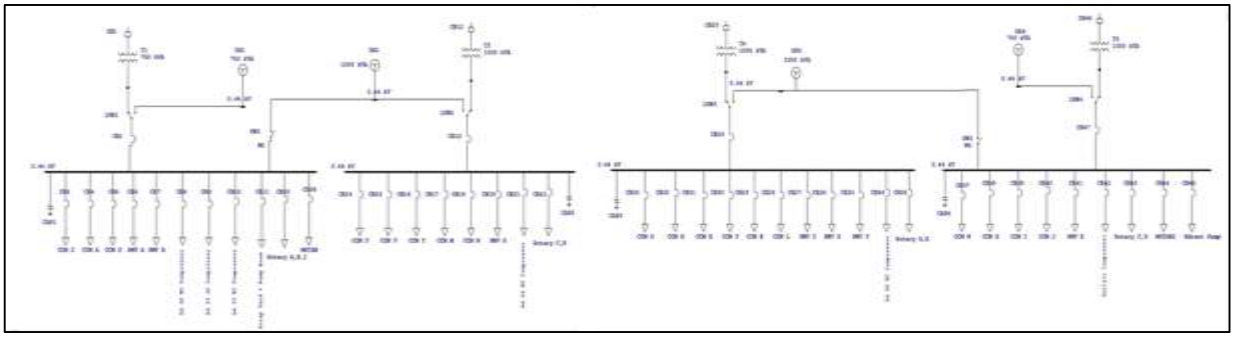

Fig. 1: Single line diagram of the plant

V. OBSERVATIONS AND ANALYSIS

In this the Observations and Analysis of Previous Bill DG Sets, Capacitor banks, Transformers has been done.

A. Bill

Collected and analyzed the previous bills of company from March 2014 to February 2015 has been done.

B. DG Set Data

Collected and analyzed the previous DG records of company from March 2014 to February 2015 has been done. Oriental Containers Ltd., using three DGs of two 1010kVA and two 750kVA.Effieciency is lies in between 27.16 to 32.34 in these months. From that Power factor, Maximum demand, Unit consumed, Diesel consumption, cumulative efficiency analyzed and plotted proper graph.

NOTE: The following graphs are in a cluster of three.

The first series is for the period – Mar'2012-Feb'2013.

The second series is for the period – Mar'2013-Feb'2014

The third series is for the period – Mar'2014-Feb'2015

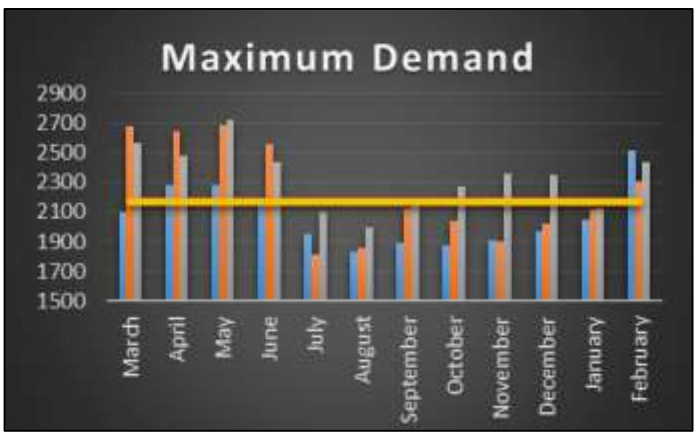

Fig. 2: Maximum Demand

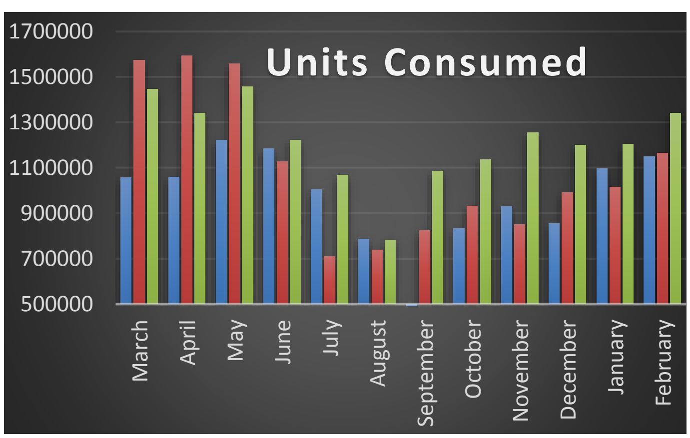

Fig. 3: Units Consumed

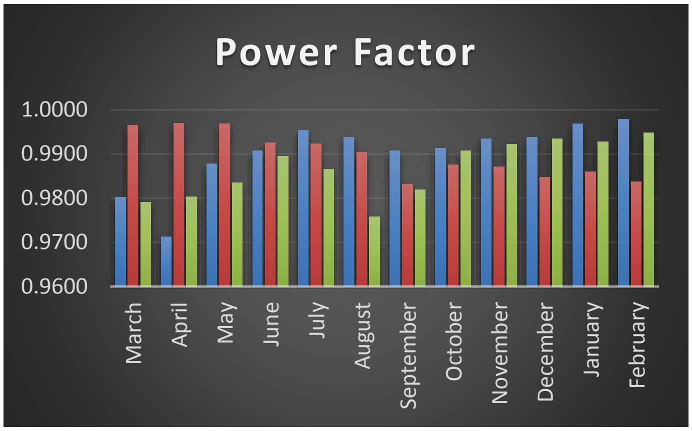

Fig. 4: Power Factor

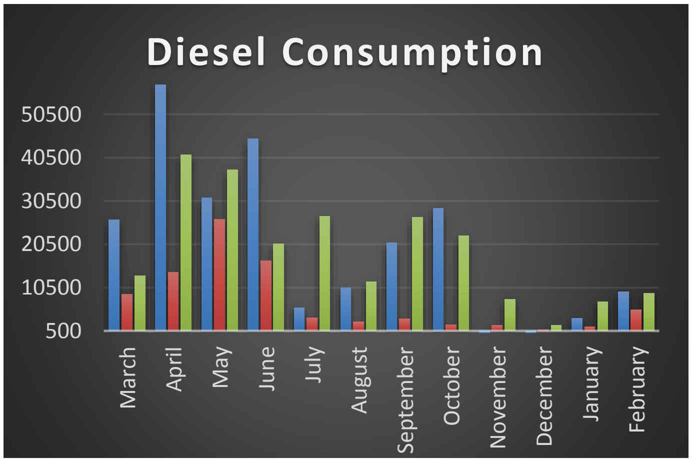

Fig. 5: Diesel Consumption

C. *Transformer data*

Transformer-1 is of 750 kVA. There are 10 machines which includes chiller and compressor comes here.DPF of various machine lies between -0.660 to 0.889. Here PMV-A chiller giving this -0.660 DPF has been noted and put forwarded for further studies.THD (Current) of PMV-A got 40.8, and also specially noted.

Transformer-2 is of 1010kVA. There are 16 machines Capacitors, plant for air conditioners, plant for lights and chillers comes here. DPF of various machine lies between -0.999 to 0.906. Here Capacitor (manual) giving the -0.024 DPF and -0.999 DPF has been noted and put forwarded for further studies. THD (Current) of PVM-G got 25.0, and also specially noted.

Transformer-3 is of 1010 kVA. There are 20 machines which includes chiller and capacitors comes here. DPF of various machine lies between -0.001 to 0.961.Here PMV-C, D, F giving comparatively high THD (Current) as 28.3, 29.1, 26.5 respectively.

Separately studied about PMV-A and plotted graph which showing the harmonics current and voltage.

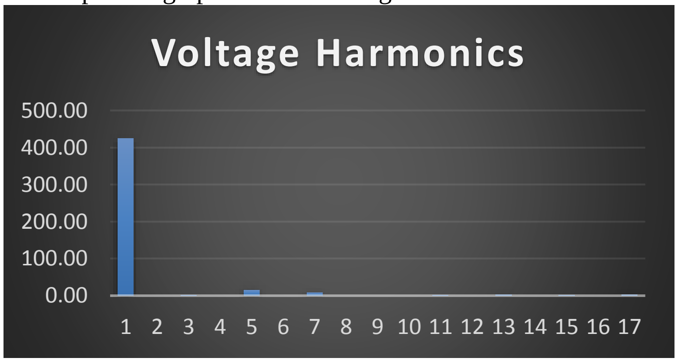

Fig. 6: Voltage Harmonics

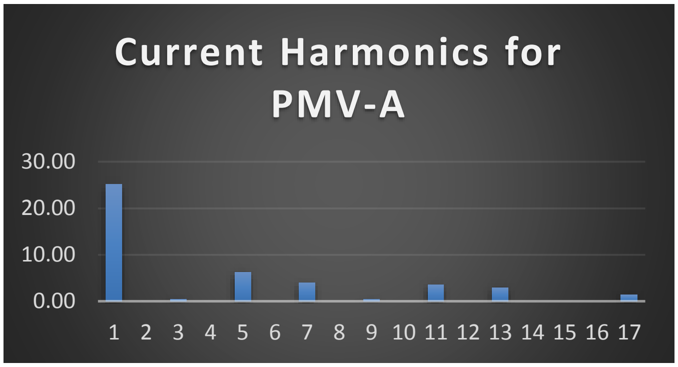

Fig. 7: Current Harmonics for PMV-A

The Voltage and Current Harmonics observed on PQ analyzer are shown in Figure 6 and Figure 7

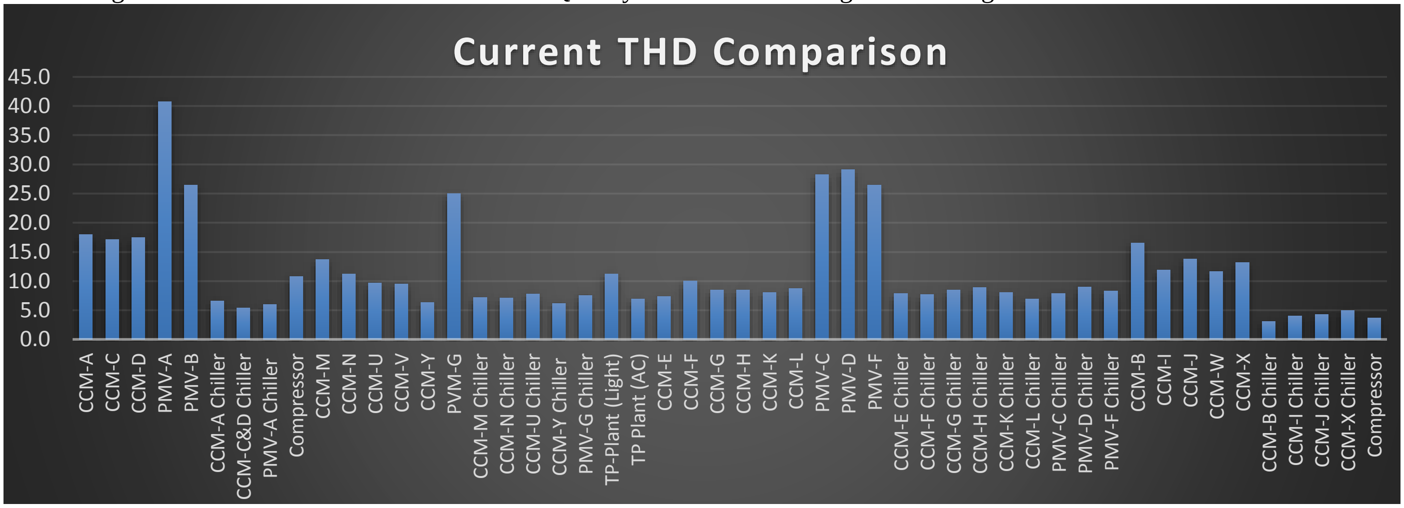

Fig. 8: Current THD Comparison

D. Losses

Based upon the observations calculated the losses are as follows,
Total Power Wasted including capacitor banks = 81.87kW
Total Energy Wasted per year for the working hours of 7000=573090kWh
Monetary Loss at the rate of 3.30/kWh =Rs.1891197
With the help of measured and calculated data detailed analysis carried out and graphs were plotted as mentioned abve.

Table – 1
Wasted Power calculation for Transformer 1

Machine	Measured Parameters		Fundamental Parameters		Higher Order Parameters		DPF	Power Drawn (kW)		
	Voltage (V)	Current (A)	Voltage (V)	Current (A)	Voltage (V)	Current (A)		Considering Total Current	Considering Fundamental Component	Wasted Power
CCM-A	424.36	62.86	424.00	61.80	0.36	1.06	0.889	23.71	23.29	0.42
CCM-C	424.36	65.04	424.00	64.10	0.36	0.94	0.864	23.85	23.48	0.37
CCM-D	424.36	60.37	424.00	59.50	0.36	0.87	0.864	22.13	21.80	0.33
PVM-A	424.36	26.62	424.00	25.10	0.36	1.52	0.686	7.75	7.30	0.45
PMV-B	424.36	30.27	424.00	29.40	0.36	0.87	0.727	9.34	9.06	0.28
CCM-A Chiller	424.36	53.71	424.00	53.60	0.36	0.11	0.846	19.28	19.23	0.05
CCM-C&D Chiller	424.36	65.09	424.00	65.00	0.36	0.09	0.688	19.00	18.96	0.04
PMV-A Chiller	424.36	16.18	424.00	15.70	0.36	0.48	0.660	4.53	4.39	0.14
Compressor	424.36	97.76	424.00	97.20	0.36	0.56	0.851	35.31	35.07	0.24

Table 1 shows the wastage of power from transformer 1 and its connected equipments in detail.Also the calculation has been done as like this for other transformers.

Table – 2
Capacitive Losses

Capacitive Losses			
Type	kVAr	kVA	kW
Xmer - 1 (manual)	28.56	28.37	0.62
Xmer - 1 (APFC)	113.70	112.70	0.50
Xmer - 2 (manual)	104.10	106.20	2.20
Xmer - 2 (APFC)	129.70	130.10	6.70
Xmer - 2 (manual)	0.72	18.72	18.75
Xmer - 3 (manual)	115.80	115.60	3.20
Xmer - 3 (APFC)	196.20	196.20	0.30
Xmer - 4 (manual)	87.90	88.70	10.90
Xmer - 4 (APFC)	251.30	253.70	32.50

Table 2 shows the measured capacitive losses for all type of equipments seperately,which is occurred in the plant.

In the final stage mark out the main problems and remedies were suggested to the plant in the Audit report,also mentioned other preventive measures and precautions.

VI. CONCLUSION

A famous quote "Energy saved is Energy generated", shows that apart from increasing the generation capacity at higher cost, one must go for the energy audit to save the electricity at much lower cost. Because the demand for electricity is continuously growing and it is putting stress on the power utilities to increase the capacity to meet the load demand. With this aim the authors have undertaken a case study of an industrial unit because industries are the major power consumers. The data provided in this paper after a deep analysis based on collected and measured data ,shows that how we can save electric energy by incorporating some changes in the installation and making it energy efficient. The government should make it mandatory for every industrial house in the country for energy audit.

VII. SUGGESTIONS

Suggestions based upon the analysis that we carried out in the industry are as follows:

1) As can be seen from the graphs, the THD is very high. Filters have to be employed to reduce the harmonics.
2) The Capacitor banks give out waste power, and since they are continuously used, the magnitude is quite high. This waste power damages the dielectric of the capacitor and further deteriorates it. The faulty banks have to be replaced and other banks need to be tuned well.
3) The monetary loss per year amounts to around 19 lakhs, with proper corrective measures this loss can be reduced to a minimum.
4) Use of NCES or Hybrid systems to provide power to a part of the load to save on electricity bills and also the environment.
5) Increase the production during off-peak period and store for the peak period, as the bottle-caps are non-perishable items.

Some General Suggestions:

1) Capacitors Banks should be Δ-connected to reduce power usage.
2) LED lamps should be used for lighting to reduce consumption.
3) Proper Training to Employees should be given to make judicious use of power.
4) Temperature of the compressor room has to be reduced for optimum performance.
5) Minimise maximum demand by tripping loads through a demand controller.
6) Properly size the motors to the load for optimum efficiency. High efficiency motors offer of 4 - 5% higher efficiency than standard motors.
7) Operate pumping near best efficiency point & modify pumping to minimize throttling.
8) Use variable-speed drives for large variable loads.
9) Change the Compressor Oil Filter regularly.
10) Use waste heat from compressors & DG-sets to power an absorption chiller or preheat process or utility feeds.
11) For a Chiller, use the lowest temperature condenser water available that the chiller can handle. Reducing condensing temperature by 5.50C, results in a 20 - 25% decrease in compressor power consumption.
12) For HVAC systems, balance the system to minimize flows and reduce blower/fan/pump power requirements.
13) Use air-to-air heat exchangers to reduce energy requirements for heating and cooling of outside air.

14) Insulate exhaust pipes to reduce DG set room temperatures.
15) Temperature of ACs should be kept closer to the ambient temperature.

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