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An Energy Audit of Hindustan Machine Tools, Pinjore - A Case Study

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Abstract**:** *The scope for electrical energy conservation is gigantic and if properly harnessed can take the organization to the path of opulence. Energy Audit becomes all the more important in the view of the energy conservation Act 2001 enacted by govt. of India. This paper contains the findings and analysis of the results obtained from energy audit program employed in an industrial unit "Hindustan Machine Tools". Electrical audit was carried out under two major heads, i) Motor load based energy audit, ii) Harmonic analysis at PCC. Readings were taken under these heads, analyzed to find the scope of electrical energy conservation opportunities in the selected test case industrial unit.*

Keywords: *Energy audit, point of common coupling, power harmonic analyzer, energy conservation.*

I. Introduction

An energy audit identifies where energy is consumed and how much energy is consumed in an existing facility, building or structure. Information gathered from the energy audit can be used to introduce energy conservation measures (ECM). An energy audit, therefore, is a detailed examination of a facility's energy uses and costs that generates recommendations to reduce those uses and costs by implementing equipment and operational changes [1]. The energy audit is an organized approach through which the energy wastage can be easily identified also determine how this waste can be eliminated at a reasonable cost and within a suitable time frame.

In developing countries like India, where electrical energy resources are scare and production of electricity is very costly, energy conservation studies are given great importance.

The primary objective of energy audit is to determine ways to reduce energy consumption per unit of product output or to lower operating costs. Energy audit gives a positive orientation to the energy cost reduction, preventive maintenance and quality control programs which are vital for production and utility activities [2].

Under the energy audit program the first head is the Electrical Motor Energy Audit, which is performed during the Facility Assessment process which involves a visit to the plant in order to identify eligible motors for the Energy Conservation process.

Second head under which the energy audit program was performed is harmonics analysis. Harmonics reflect the distortion of the wave form and detoriate the quality of the power this leads to increased transformer heating and transmission losses. Harmonics can be defined as periodic, steady-state distortion of voltage or may be current waveform in a power system. These distortions are produced by devices which exhibit non-linear relationship between current and voltage.

II. Electrical Motor Energy Audit

Normally, motors are operated more efficiently at 75% of rated capacity as compared to the motors operated lower than 65% of rated capacity, because they were chosen in big capacity, performing inefficiently, and due to reactive current increase, power factors are also decreased. These kinds of motors do not consume the energy efficiently because they have been chosen in big power, not according to the need.

Three phase, 4 pole, 1470 rpm induction motors of Kirloskar make are being used for various production processes in the plant. During the energy audit the focus area were the Light Machine shop and the Foundry. Motors having rated capacity above 5 HP were analyzed and assessed. Table 1 represents the motors which were under analysis during motor load based energy audit, table consists of the rated capacity of each motor, the rated voltage, rated power factor (PF), rated capacity i.e true power (KW), rated speed in rpm and the manufacturer of the respective motor.

Table 1: Motor load analysis

	Identity of motor	*Rated Power*	*Rated efficiency*	*Voltage*	*Curren t*	*PF*	*Output Power (kW)*	*Motor loading %*
1	FAY	45 (60)	92	396	55	.64	24	53
2	Riveting	30 (40)	92	398	45	.82	27	90
3	STC-02	30 (40)	92	398	28	.76	15	50
4	RTV	22 (30)	91	397	31	.71	16	72
5	FN2	18.5 (25)	90.5	398	23	.81	13	70
6	M900	12.5 (18)	88.4	396	15	.78	8	64
7	S-Pilot	11 (15)	88.4	398	15	.86	9	81
8	L200	7.5 (10)	87	398	14	.84	5.63	75

During the survey and measurement process it has been observed that some of the motors are under-loaded.

- Two 60 HP (45 kW) motors has been running at 53% of the rated capacity.
- Two 40HP (30 kW) motors has been running at 50% of the rated capacity.
- One 18HP (12.5 kW) motor running at 65% of the rated capacity.

There are some problems with under loaded motors, under- loading increases motor losses and reduces motor efficiency and the power factor. Under- loading is the most common cause of inefficiency of motor performance due to following reasons:

a) Equipment manufacturers tend to use a large safety factor when selecting the motor.
b) Equipment is often under-utilized. For example, machine tool equipment
c) Manufactures provide for a motor rated for the full capacity, resulting in under- loaded operation most of the time.
d)

1.1 Energy Efficient Motors

High efficiency electric motors have been designed especially to increase operating efficiency compared to standard electric motors. Efficiencies are 5% to 9% higher compared with standard motors. Figure1 describes the improvement opportunities that are often used in the design of energy efficient motors.

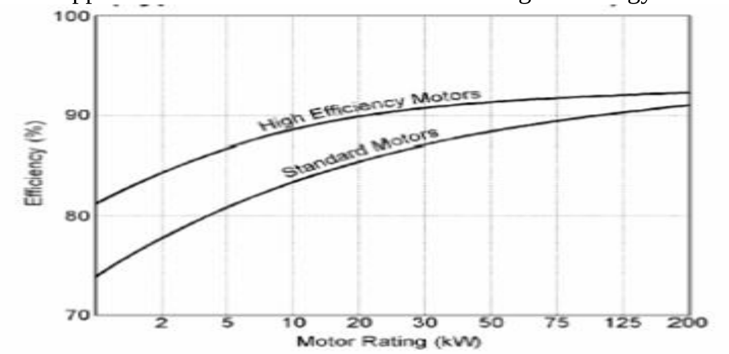

Fig 1: comparison between high efficiency and standard motor [6].

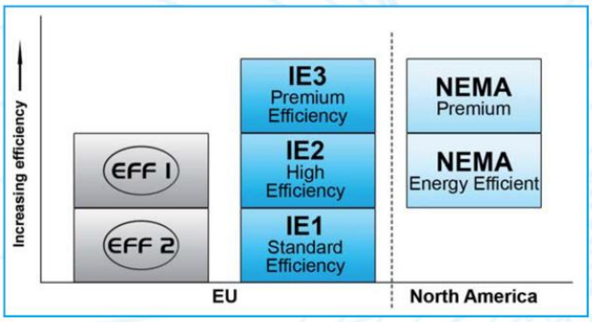

Fig 2 the new energy efficiency classes [4]

1.2 Energy **Efficient Motors performance**

Energy-efficient motors now available in India operate with efficiencies that are typically 5 to 7% points higher than standard motors. In keeping with the demand of the BIS, energy-efficient motors are designed to operate without loss in efficiency at loads between 75% and 100% of rated capacity. Energy-efficient motors have lower operating temperatures and noise levels, greater ability to accelerate higher-inertia loads, and are less affected by supply voltage fluctuation.

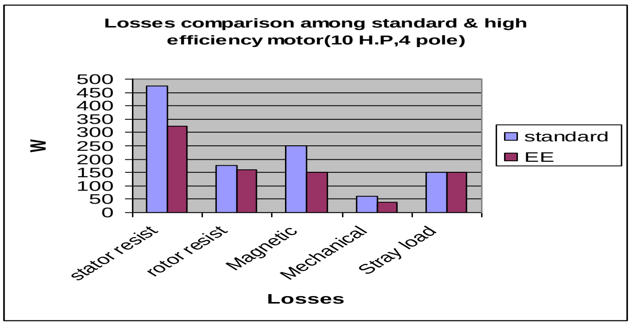

Fig 3 Losses comparison among standard & high efficiency motors [7]

1.3 Payback Period

Table 2: Payback period

No. of hrs of usage/ yr	*Std (45 kW) loss kWh/ yr*	*Std (30 kW) loss kWh/ yr*	*EE (30 kW) loss kWh/yr*	*Cost @ 5.77 std (45 kW)*	*Cost @ 5.77 std (30 kW)*	*Cost @ 5.77 EE (30 kW)*	*Savings for 30 kW std*	*Savings for 30 kW EE*	*Payback period (years)*	*Payback period (years)*
16 hr/ day	45,360	15840	11,520	2,61,727	91,397	66,470	1,70,330	1,95,257	0.5	0.4
12 hrs/ day	34,020	11,880	8640	1,96,295	68,548	49,853	1,27,747	1,46,442	0.7	0.6
10 hrs/day	28,350	9,900	7200	1,63,580	57,123	41,544	1,06,457	1,22,036	0.8	0.7
8 hrs/ day	22,680	7920	5760	1,30,863	45,698	33,235	85165	97,628	1.04	0.9

III. Harmonic Analysis

The usage of non-linear electric load and automation in industries is being increased as compared to the early days, with this increase poor power quality due to harmonics has come up as a serious issue.

To tackle the problem of increasing harmonic distortion in power distribution network government has issued guidelines for various large scale and medium scale industrial units of the state to get current and voltage harmonic content evaluated at their premises at the point of common coupling (PCC), and if the current and voltage harmonic content are not within the limits as stipulated by IEEE-519-1992Standard then it is under guidelines to undertake remedial filtering solutions.

The goal of harmonic studies is to quantify the distortion in current and voltage waveforms in the power system of industrial units. The results of the harmonic analysis are useful for evaluating corrective measures and troubleshooting harmonic related problems.

2.1 Effects of harmonics on the network [5]

- Overloading of neutral conductor
- Reduced efficiency of motors.
- Poor power factor of the total system due to introduction of distortion factor.
- Overloading of power factor capacitors
- Malfunctioning of control equipment

2.2 Harmonic Measurements at the industry under Energy Audit

The harmonic spectrum of LT currents in three phase distribution system of plant recorded with the help of Power and Harmonic Analyzer is indicated in table 3.

2.3 Verification of IEEE Limit Compliance.

From the data provided by the electrical division of the plant, per unit impedance of transformer is 0.103. The maximum demand current (I_L) is 980 amperes. The short circuit current (I_{SC}) calculated at Point of Common Coupling (PCC) is 4273.64 amperes and Short-Circuit ratio is 4.4 amperes [Table 3].
The industrial consumer under study falls in the category of short-circuit ratio lying in range<20 for which the maximum allowable THD value is 4% (up to 11^{th} harmonics).

It is seen that THD value at PCC of HMT,Ltd is within limit. Further calculations of TDD at PCC are also within limit as per IEEE-519-1992 Std.

Table3: Values of LT currents as shown by Harmonic Analyzer

$\frac{Isc}{Il}$	<11	$11 \leq h<17$	$17 \leq h<23$	$23 \leq h<35$	$35 \geq h$	TDD
<20	4.0	2.0	1.5	0.6	0.3	5.0
20-50	7.0	3.5	2.5	1.0	0.5	8.0
50-100	10.0	4.5	4.0	1.5	0.7	12.0
100-1000	12.0	5.5	5.0	2.0	1.0	15.0
>1000	15.0	7.0	6.0	2.5	1.4	20.0

Table 4 Current Distortion Limit of IEEE-519-1992 Standard [8]

Currents	***RMS Current (A)***	***Total Harmonic Distortion (THD)***	***Total Demand Distortion (TDD)***
I_1	750 A	4%	3%
I_2	486 A	4.5%	2.2%
I_3	469 A	4.6%	2.29%

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