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Harmonic Analysis and Power Factor Correction For Food Processing Industry

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ABSTRACT

Harmonic analysis of the distribution system is essential to study the behavior of equipments connected in the non-sinusoidal system environment for designing and optimal location of filters. Harmonic distortion can have a significant impact on industrial customers such as additional losses and heating of certain network equipment, faulty operation of control equipment and interference in neighboring telecommunication system. In this case study harmonic analysis of food processing industry has done using harmonic analyzer 'YOKOGAVA'. The aim of the study was to improve the power factor, maintain harmonic distortion within acceptable levels and reduce possible resonance problem at the plant. Analysis of voltage and current harmonics is performed at distribution side point of common coupling before and after connecting APFC panel.

KEY WORDS: *APFC Panel, Energy Audit, Harmonics, Nonlinear load, Total Harmonic Distortion, Under loaded motors, Yokogava.*

I. INTRODUCTION

It is the objective of the electric utility to supply its customers with a sinusoidal voltage of fairly constant magnitude and frequency. To ensure compliance with the Grid Code [2] voltage and current distortion levels must satisfy limits set out by IEC 61000-3-6 [5]. In any industry, the three top operating expenses are often found to be on energy, labor and materials. If one were to find out the potential cost savings in each of the components, energy would invariably emerge at the top, and thus energy management function constitutes a strategic area for cost reduction. . Industries use a large amount of electrical energy, and that is why it is important to ensure a loss-free and energy-efficient system in industries [3]. In developing countries like India, where electrical energy resources are scarce and production of electricity is very costly, energy conservation studies are of great importance. Energy audit is the translation of conservation ideas into realities by blending technically feasible solutions with economic and other organizational considerations within a specified time frame [4]. An energy audit is a study of a plant or facility to determine how and where energy is used and to identify methods for energy savings. An energy audit was carried out under four major heads: (i) process section audit, (ii) Refrigeration section audit, (iii) power load audit (motors, compressor, etc.), and (iv) harmonic analysis. Readings were taken under these heads and analyzed to find the scope of energy conservation opportunities in the selected test case industrial unit.

II. AUDITING PROCEDURE

Energy audit cannot be successfully carried out without the commitment from the top management. Management must be firstly convinced of the necessity of implementing energy management and hence energy audit [7] . Energy audit consists of several tasks, which can be carried out depending on the type of the audit and the size and the function of the audited facility [8] . Therefore, an energy audit is not a linear process and is rather iterative. The audit described in this paper has been carried out based on the following functional activities:

- Walk-through survey
- Motor load survey used in various processes
- Harmonic analysis

III. FIELD VISITS AND MEASUREMENT WORK

Katraj Dairy is one of the oldest milk processing industry in Pune, Maharashtra. Readings for harmonic distortion and and for power factor improvement are taken with the help of YOKOGAWA(Harmonic Analyser) before and after connecting APFC Pannal.

3.1 Plant Electrical Energy Consumption

The energy consumption of the industry was identified in terms of the equipments and functional area wise. The results were obtained after measurements during the factory visits. Power analyzers, Harmonic Analyzer, clamp meters, etc. were used to measure the electrical energy consumption of the industry. The total load of the unit is approximately 1326.3 kW .

Sr.no	Sections	Connected load in HP
1	Air compressor section	182
2	Process section	349.5
3	Refrigeration section	882
4	Boiler section	120
5	E.T.P. section	180
6	Raw water sector	30
7	Ice cream plant	10
8	Illumination	15
	Total load in HP	1768.5
	Total load in KW	1326.3

TABLE.1 Total load of Katraj Dairy

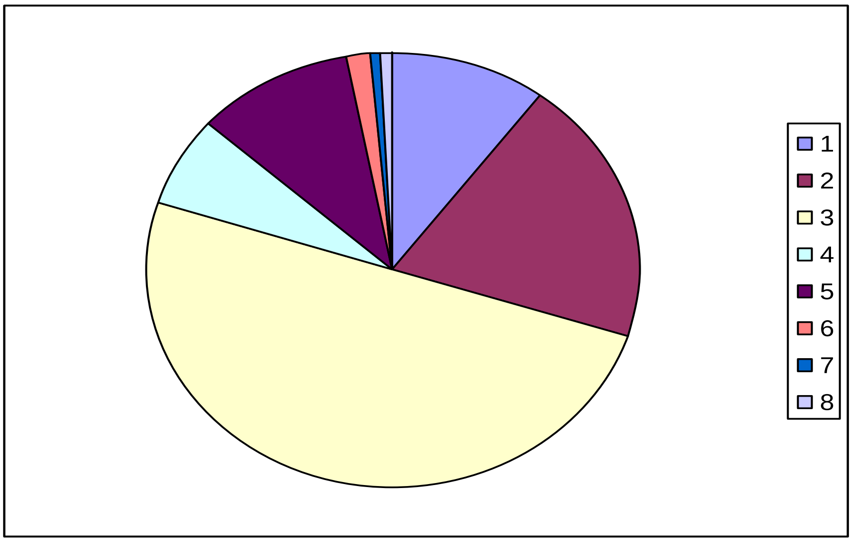

Fig.1Load division chart of Katraj Dairy

The following points can be observed from this survey:

- The major load in the plant is that of refrigeration, which constitutes approximately 66 % of the total load.
- Motor load constitutes approximately 38% of the total load.
- Total number of units consumed per month is 188380 after taking the average of 12 months.

3.3 Motor Survey

For most of the applications, three-phase, 4-pole, 1470- rpm induction motors of Kirloskar make have been used for various production processes in the plant. During survey and measurement process, it was observed that some of the motors are underloaded. And most of the motors used are energy efficient motors. Load on compressor where 45 KW,1460 rpm, 415V,80 amp,3ph,50 Hz motor is used is continuously varying between 40amp to 80 amp. Other motors have almost constant load on them.

3.4 Problems with Underloaded Motor

- An underloaded motor always runs at a low lagging power factor. If the motor is loaded around 50% of the rated load, power factor can be as low as 0.5 lagging. This means industry is utilizing only 50% of the power from the supply mains and paying for 100% if the billing is kVA based.
- Extra expenditure on installation of power factor improvement equipment to maintain the power factor within permissible limits set by the state electricity board needs to be done. Otherwise, penalty has to be paid.
- Efficiency of a standard induction motor is about 87-90% at the rated load and it reduces drastically at half of the rated load depending upon the size of the motor and loading (about 70-75% for 60 hp motor). This means motor will draw more current for the same mechanical output

IV. ENERGY-EFFICIENT MOTORS

More and more industries are switching to energy-efficient motors (EEMs) because EEMs lower the production costs. Just a small increase in motor efficiency can significantly lower the production costs. A motor can cost thousands of rupees a year to operate, so savings of even a few percent add up quickly. An EEM generates savings whenever it is running and as long as it lasts, which may be 20 years or more. EEMs cost more than the standard motors, but purchase price can be paled in comparison to a motor's operating costs. Since the annual operating cost of a motor is often 5-10 times its initial cost, the typical 3-5% higher efficiency of an EEM can more than offset its 15-20% higher initial cost over its life. In addition to costing less to operate, EEMs generally last longer, require less maintenance, and reduce system amperage draw. The efficiency curves of two EEMs are shown

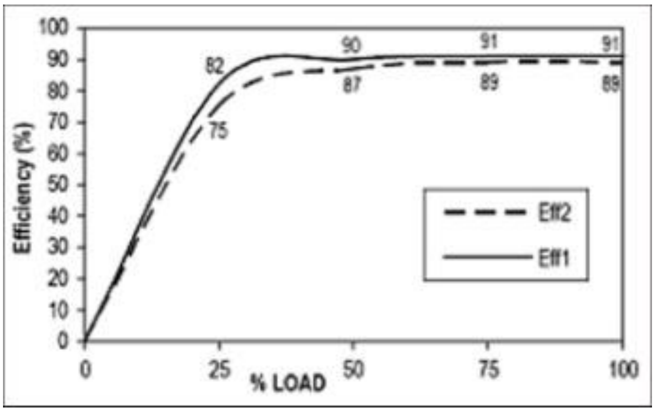

Figure 2: Efficiency of EEMs as per IS-12615 (Eff1 = 2-pole motor, Eff2 = 4-pole motor)

EEMs also offer other advantages, such as longer insulation life, longer lubrication interval, greater inertial acceleration, and higher service factors. In addition, they may be better equipped to handle heavy starting loads, large sustained loads, phase imbalances, voltage excursions, high ambient temperatures, and impaired ventilation. EEMs also do not add as much to air-conditioning loads as standard motors, since they do not give off as much heat.

4.1 Energy-efficient Motor's Performance

The efficiency of a motor is the ratio of the mechanical power output to the electrical power input. Design changes, better materials, and manufacturing improvements reduce motor losses, making premium or EEMs more efficient than the standard motors [Figure 2]. Reduced losses mean that an EEM produces a given amount of work with less energy input than a standard motor. In 1989, the National Electrical Manufacturers Association (NEMA) developed a standard definition for EEMs [10] . The definition was designed to help users identify and compare electric motor efficiencies on an equal basis.

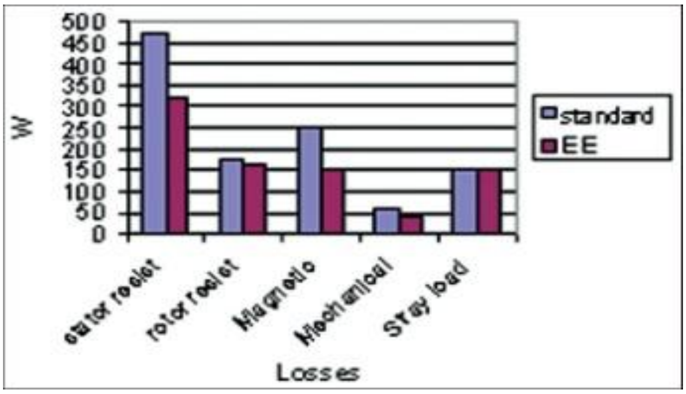

Figure 3: Losses comparison among standard and high efficiency motors [14]

V. Harmonic Analysis

Harmonics are one of the major concerns in a power system. Harmonics cause distortion in current and voltage waveforms resulting into deterioration of the power system. The first step for harmonic analysis is the harmonics from non-linear loads. The results of such analysis are complex. Over many years, much importance is given to the methods of analysis and control of harmonics. Harmonics present in power system also has non-integer multiples of the fundamental frequency and have aperiodic waveform. The harmonics are generated in a power system from two distinct types of loads.

First category of loads are described as linear loads. The linear time-invariant loads are characterized such that application of sinusoidal voltage results in sinusoidal flow of current. A constant steady-impedance is displayed from these loads during the applied sinusoidal voltage. As the voltage and current are directly proportional to each other, if voltage is increased it will also result into increase in the current. An example of such a load is incandescent lighting. Even if the flux wave in air gap of rotating machine is not sinusoidal, under normal loading conditions transformers and rotation machines pretty much meet this definition. Also, in a transformer the current contains odd and even harmonics including a dc component. More and more use of magnetic circuits over a period of time may get saturated and result into generation of harmonics. In power systems, synchronous generators produce sinusoidal voltages and the loads draw sinusoidal currents. In this case, the harmonic distortion is produced because of the linear load types for sinusoidal voltage is small.

Non-linear loads are considered as the second category of loads. The application of sinusoidal voltage does not result in a sinusoidal flow applied sinusoidal voltage for a non-linear devices. The non-linear loads draw a current that may be discontinuous. Harmonic current is isolated by using harmonic filters in order to protect the electrical equipment from getting damaged due to harmonic voltage distortion. They can also be used to improve the power factor. The harmful and damaging effects of harmonic distortion can be evident in many different ways such as electronics miss-timings, increased heating effect in electrical equipments, capacitor overloads, etc. There can be two types of filters that are used in order to reduce the harmonic distortion i.e. the active filters and the passive filters. Active harmonic filters are electronic devices that eliminate the undesirable harmonics on the network by inserting negative harmonics into the network. The goal of harmonic studies is to quantify the distortion in voltage and current waveforms in the power system of industrial units. The results are useful for evaluating corrective measures and troubleshooting harmonic related problems.

5.1 Effects of Harmonics on Networks [10]

- Overloading of neutral conductor
- Reduced efficiency of motors
- Malfunctioning of control equipment
- Poor power factor of the total system due to introduction of distortion power factor
- Overloading of power factor capacitors
- Increase in kVA demand of the plant due to increase in rms current drawn

VI. RESULTS:

Following results are obtained before after connecting APFC panel.
Total consumption for FEB- 2013 is 139300.
KVA demand is 419. MSEB charges 190Rs. Per KVA for industrial load.
Total electricity bill including (TOD tariff, Electricity Duty and other charges) is 10,36,033.06 Rs.
They are getting power factor incentive 67,848.40Rs.
Total current bill is 9,68,184.66 Rs.

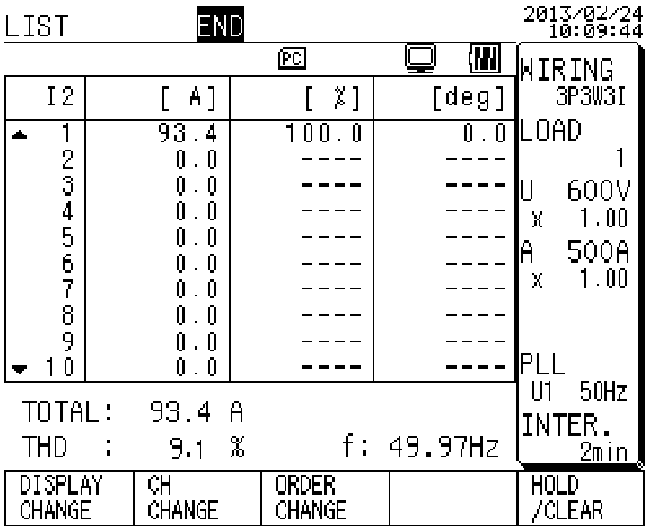

Figure (4) Without APFC panel connected THD = 9.1 %

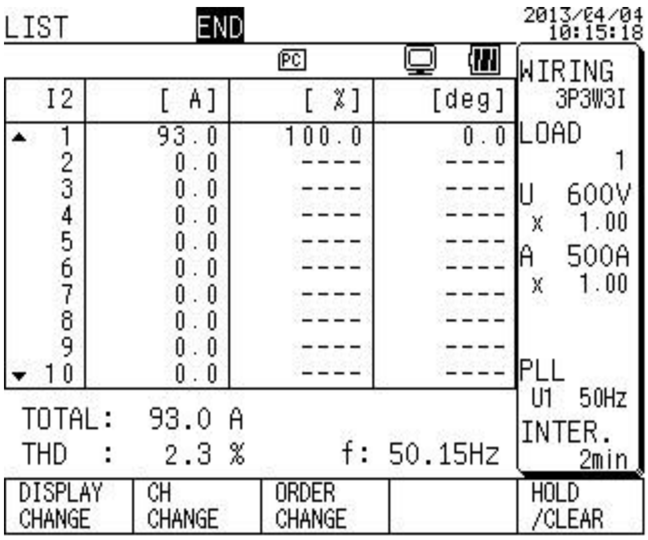

Figure (5) With APFC panel with the system THD = 2.3 %

VII. CONCLUSION

On the basis of Harmonic analysis study & electrical energy audit conducted, the following recommendations have been suggested to the consumer:

- In due course of time, if any motor gets damaged or some new motor is to be purchased, EEMs should be purchased.
- Harmonic components at PCC are greater than the permissible limits. Therefore, the consumer must install harmonic filter to improve the power quality and save the penalty on harmonic emission.
- Harmonic component across individual loads is much higher where variable frequency drives are used, which reflects at the PCC, so a more in-depth analysis is required and a harmonic filter can be designed.
- It is also shown in this paper that the proposed PFC capacitor banks can be tuned to act as harmonic filters and operate to reduce the harmonic distortion to acceptable levels. It is recommended that the PFC capacitor banks be tuned to act as harmonic filters and also that upon completion of the plant expansion harmonic measurement are taken to meet the grid code requirement. Proper size of motor should be used, as per the rated load. If possible, motor should be replaced with a proper size motor in a phased manner.

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