Review on Industrial Audit and Energy Saving Recommendation in Aluminium Industry

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***Abstract*— Conservation and use of energy in an efficient manner is the fundamental goal of energy management. 78% of generated energy is used in the industrial area. The main aspect of energy conservation is to use the energy in an efficient manner. This paper presents the review on type of audit conducted in the industries and detailed energy audit in the aluminium industry. The audit processed through walk through audit, preliminary and detailed audit. The team observed online, offline and real time data. The valuable four types of recommendations are suggested for reduction in the power tariff with the implementation of energy efficient equipments.**

Keywords— Energy Audit, Motors, Power consumption, Heat, Vibrations

I. INTRODUCTION

From the global prospective data the production of electricity in 2009 was 20,053TWh. With the Indian prospective the utility electricity sector in India had an installed capacity of 302.833 GW as of 30 April 2016. India became the world's third largest producer of electricity in the year 2013 with 4.8% global share in electricity generation. Instead of that the energy consumption is increasing 1.6% annually due to growing populations, increasing incomes and the industrialization of developing countries. Due to these increment results to raise some issues like increasing scarcity of natural resources, the accelerating pollution of the environment, and the looming threat of global climate change. The electrical demand is increasing day by day due to the reason that the generation is not matching with the consumption in an effective manner. The difference between the generation and demand can be reduced by two manners, either we can improve the generation or we can save in the generated power. Today the central government, state government and the individual power producers are concentrating on more generation to meet the ever increasing energy demand. But all of these programs are based on generation only. No one is thinking about the decrement of consumption of energy. The generation and consumption can be matched by reducing the usage also. That is why now days the auditing is mandatory. Audit is defined as a systematic and independent examination of data statements, records, operations, and performance of an enterprise for a purpose. Energy audits can be defined as the first step towards understanding how energy is being used in given facility and a systematic study of survey to identify how energy is being used in an industry, building or plant, and identifies energy savings. In India 78% of the total electrical energy is used in industries. Industry having an energy consumption of above 30,000 tonnes of oil equivalent per year would be notified. Industrial energy audit has exploded as the demand to lower increasing expensive energy costs and moves towards a sustainable future have made energy audits greatly improvement. So the industrial audit is the most mandatory thing nowadays. Keeping these things in mind the audit team has managed to visit an aluminium industry in an industrial area of Chennai. There the audit team has managed to take the audit in two stages as: Walk-through or preliminary audit & Detailed Energy audit. The audit team has covered the factors during detailed audit of the industry are: PF Improvement study, Capacitor performance, Transformer optimization, Cable sizing & loss reduction, Motor loading survey, Lighting system, Electrical heating & melting furnaces, Electric ovens, Fans & Blowers, Exhaust & ventilation System, Pumps and pumping System, Compressed air System, Air Conditioning & Refrigeration System, Cooling Tower System. After completion of detailed audit the audit team has suggested some necessary recommendations as discussed below. After the implementation of these recommendations the particular industry got the outcome as energy savings, avoiding power factor penalties and environmental compliance cost, quality improvement, productivity improvement, reduced maintenance, fewer breakdown, better safety and protection.

The next section is the review about the several data collections and suggested recommendations about the industry.

II. LITRATURE REVIEW

The research team made an extensive study for the literature on the several industrial audit papers and the challenging problems facing by the industries now days. Literature was nice on the topic and awareness about the topic is very encouraging among the students as well as among the owner

of those industries who are thinking that they are paying high amount of electricity bill.

In the year 2001 [1] audit has been conducted in a textile industry. The selection, in particular, of a textile industry considered because of (i) The higher magnitude of electrical energy used in such industries and (ii) The large number of textile industries in this country. Since, the electricity cost in the total cost of the textile industry found to be around 65%. After finding the total energy cost some eight recommendations are recommended for the textile industries, (i) Reducing In-service transformers capacity, (ii) Running of parallel cables, (iii) change of motor connections, (iv) power factor improvement, (v) saving through peak shaving, (vi) changing air conditioned environment, (vii) By energy efficient motors, (viii) Through lighting. All recommendation were implemented then the 18.23% result achieved in electricity cost saving and also environmental benefits achieved. Reduction in emission 11.85% on the total energy cost. Cost investment ratio of 61.29% during the 1st year.

In the year 2007 [2] audit has been conducted in 91 industries of Malaysia. The audited factories are divided into 11 sectors according to the product they manufactured. Division has been done from international standard industrial classification (ISIS). In these sectors 48% of total energy is used in industrial motor. The audit team have to the visit 125 industries which are 5% of total 2500 industry but the audit team managed to visit and collect complete data for 91 industries. The strategies they applied include using highly efficient motor, variable speed drive (VSD) and capacitor bank to improve the power factor. By applying these methodologies it has been estimated that there can be total energy saving of 1765, 2703 and 3605MWh by utilizing the energy efficient motor for 50%, 75% and 100% loads respectively. It was also found that 115.93$, 173.019$ and 230.693$ bill can be saved similarly. The payback period after implementation of these recommendations is 1 to 3 years.

In the year 2011 [3] an audit has been conducted in an industrial area of Malaysia. From this paper several methodologies to improve the energy audit in an industrial site through data mining web application can be focused. Data mining is a process of applying one or more computer learning techniques to automatically analyse and extract knowledge from data contained within a database. The use of web application in this process enables users to access from remote location and guarantees the data security and integrity. This paper addresses the data mining web application in air-con and lightning energy audit of an industrial building. It consist of introduction, data mining process model, web application based data mining, energy audit methodology, a case study example of data mining web application in energy audit and the conclusion. The mandatory methodologies applied is preparation of worksheet, data collection calculation according to lumen method, comparison processes suggestion output, assembling of data and mining and web application of data mining.

In the year 2012 [4] audit has been conducted in a tobacco industry in Indore. The three mandatory expenses found in the particular industry energy (both electrical and thermal), labour and material. The audit team has focused on the saving of energy without investment by modification and proper tuning. During audit they have monitored about manufacturing process, leaf drying process, lamina process and taken these processes as primary manufacturing division operations. After the primary division they have monitored the secondary division operations. In this type the energy consumption and electricity bills, load factors, PF, SEC (specific energy consumption) has been considered and tabulated also. After monitoring they recommended to check the plant operations in a certain period of time at night and at weekend as well to ensure that nothing is overlooked. It is concluded that the total energy saving potential of 26271 kWh per year is possible by implementing the specific recommendations. Hence the total saving is of Rs3.49 lakh per year with initial investment of Rs1.67 lakh. Hence the payback period will be of 6 months.

This paper shows the survey study in an American industrial area conducted in year 2013 [5]. This paper brings the advantages of using energy audit to save future installation of power generation capacity and load reduction of distribution system. It also envisages the introduction of energy conservation techniques to eliminate substandard equipment. This paper deals about the mandatory terms for industrial energy audit like energy conservation management, load management, time of day metering electricity pricing and cogeneration efficient technologies which are the various methods to reduce system demand and save system capacity. After implementation of these recommendation the benefits is an efficient system, increasing plant capacity and a big save on financial resources. Through this paper one American case study also considered done in year 2011. The PG & E tool lending library helped to reduce the energy demand just by monitoring the equipments reduce energy demand by 157MW and saved 92.5 million KWh of electrical energy. The efficient use of lightning and motor is also considered in the titled paper.

A case study of 8 large industrial buildings of a famous car manufacturing industry in **Italy** in the year **2014** [6] is shown through this paper. The factory analysed in this paper is located in Emila Romagna and it occupies the area about 70,000m^2, corresponding to the total heated volume of 320000m^3. Preliminary energy audit has been carried out in all the 8 buildings. Places where the audit was mandatory taken as input data concern the factory layout, thermal and electrical plant, energy costs through the reading of bill, monitoring of indication of natural gas flow meter. The data required to develop the energy audit were collected over a period of six month from June 2012 to January 2013. The strategies they applied are thermal insulation of walls and roof tops, the replacement of old boilers & the use of heat recovery unit in HVAC system. By applying these recommendation can produce a saving of about 355000KWh, which is approx 100000$ per year. The investment in implementing these recommendations is about 580000$. Hence the total simple

payback time of the proposed thermal retrofitting is evaluated to be less than 6 years.

In the year 2016 [7] audit has been conducted in an industry of Brazil. This paper represents the new approach for improving energy efficiency. The international energy agency (IEA) countries as having a critical rate in addressing these are three types energy security, climate change and economic objectives. The agency recommended 25 energy efficiency policies to the G8 in Hokkaido - Toyako summit in 2008 in seven priority areas: Building appliances, lightning, Transport, industry, energy utility and cross- sectional issues. The aim of this paper is a review of Brazilian industrial energy policies. There are three ways to improve energy efficiency at site level: Employing more efficient technology, changing to more efficient behavior and connecting to alternative fuels or production/ transport/consumptions routes that provide the same service consuming less energy. The 1st systematic initiative to promote the efficient use of electricity in Brazil was the national program for electricity conservation.

From the above literature survey the following can be inferred: It is found that the average energy savings which can be achieved on an average is 30%. It is also found that various methods for energy analysis, like controlling speed using VSD, implementation of high efficiency motors, operation of water pumps at the right operating point and the importance of enumerating of equipments use. It is also found that there is scope for more smart energy efficiency solutions. The post audit result is also key factor in energy analysis.

To support the initiative to reduce demand and create awareness to the general public Dr. M.G.R Educational & Research Institute, Chennai has taken initiative in the year 2014 called. **'MGR Vision 10 MW'** under the leadership of Dr. L Ramesh to save 10 MW in 10 years. The contributed research works under the pilot project-1 and pilot project- 2 were published in Scopus publications [8-12] and the reports are published by the Research Forum GREEN9 (Energy Efficiency Research Group).

This work is the pilot study work -3 and presents the detailed energy audit results including best energy saving recommendations at aluminum industry situated in Kodungyur industrial sector.

III. INDUSTRIAL DATA ANALYSIS

Audit team has conducted a detailed audit in an aluminum industry. The industry is placed in KVT oil mill industrial area, Kodungyur. The particular industry is connected to an 11Kv feeder named as Jambulee feeder. Two transformers of 500KVA and 250KVA are connected from the industry. 500KVA transformer is connected from the ground floor and first floor whereas the 250KVA transformer is connected to the second floor. The total load connected from each transformer is 149KW. Number of vessels produced in one day from the particular factory is 2000.

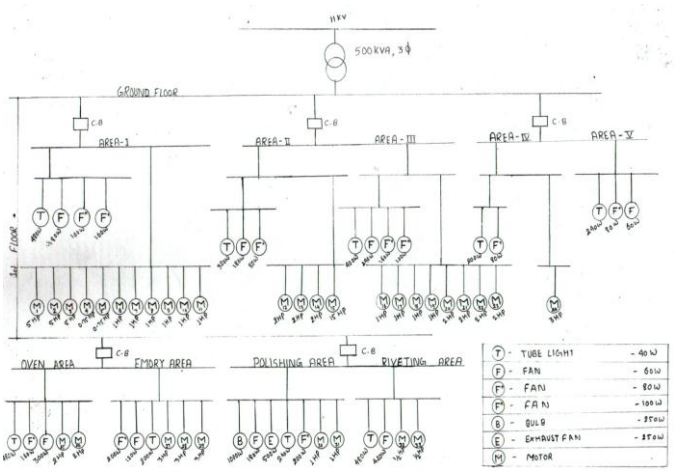

Fig. 1: SLD of the industry from 500KVA transformer

The figure (1) shows the single line diagram of the ground floor and first floor of the industry. 500KVA transformer is connected through these areas. The first floor and the ground floor entire connections are shown through the figure. All the equipment is taken as lumped load except motor. Each section is separated by area of the particular industry. Total of 5 circuit breakers are connected from both the floor. All the circuit breaker is of 25A. 1st, 2nd and 3rd circuit breakers are connected with ground floor whereas the 4th and 5th circuit breaker is connected through 1st floor. The circuit breaker 1st, 3rd, 4th and 5th are connected with the appropriate load. But the circuit breaker 2nd is having much more load than it can sustain. The particular issue is discussed briefly in the recommendation part. The ground floor is divided into 5 different areas. The first area having 11 motors connected from 1st circuit breaker. Area 2nd having 4 motors and area 3rd having 8 motors connected and both the areas are connected from the same circuit breaker. Area 4th having only one motor and area 5th having no motor connected because of official use and these both the areas are connected from one circuit breaker. The first floor is divided into four areas named as oven area, emory area, polishing area, riveting area. Here the oven area and the emory area having 5 motors connected with one circuit breaker. The polishing area and riveting area are having 4 motors which are connected from the same circuit breaker. Here the total power consumption by the lightings is 89.22KW which is taken in the lumped load. Power consumption by the different fans is 59.84KW is also connected in lumped load, and the power consumption from the motor is taken separately in the other section.

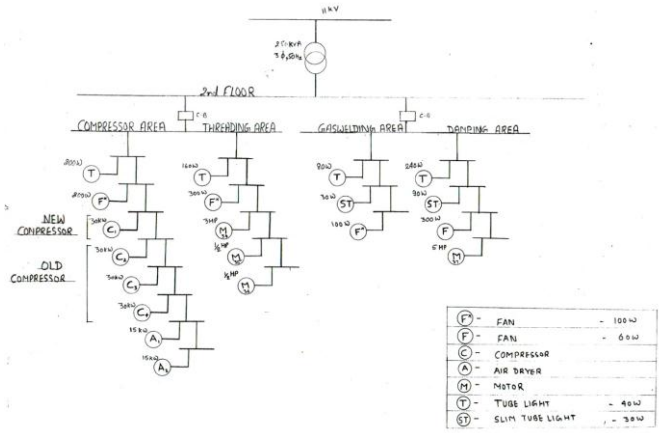

Fig. 2: SLD of the industry from 250KVA transformer

The figure (2) shows the single line diagram of the second floor of the industry. 250KVA transformer is connected through these areas. The second floor entire connections are shown through the figure. All the equipment is taken as lumped load except motor. Each section is separated by area of the particular industry. Total of 2 circuit breakers are connected from both the floor. All the circuit breaker is of 25A. 1st circuit breaker is connected with compressor area and threading area whereas the 2nd circuit breaker is connected through gas welding and damping area. Both the circuit breakers are connected with the appropriate load. Total of four compressors are connected in this floor. Among these four one is new compressor whereas the other three are old one. Two air dryer are also present in the compressor area. From the compressor area 6 motors are connected and threading area total of 3 motors are connected. No motors are connected in the gas welding area and only 1 motor is connected through the damping area. Here the total power consumption by the lightings is 39.82KW which is taken in the lumped load. Power consumption by the different fans is 23.68KW is also connected in lumped load, and the power consumption from the motor is taken separately in the other section as shown in the figure.

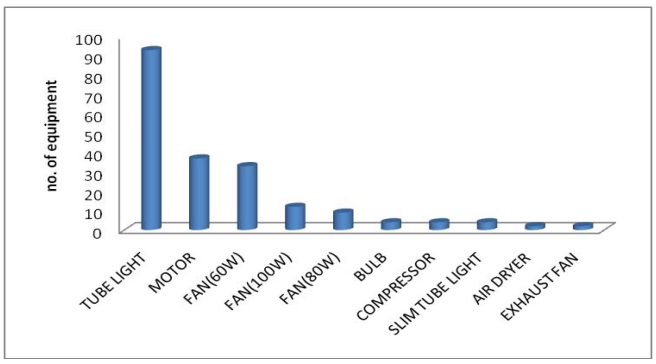

Fig. 3: Number of equipments graph

Fig-(3) represents the total number of equipments present in the particular industry. From the above mentioned graph it is concluded that the tube light is the most used equipment in the industry. Total 93 tube lights are present in the industry. Because of no proper natural lightning system most of the tube light is working for 12 hours. The motor and fans present are in average number taken as 37 and 54. Remaining all the equipments is negligible in number.

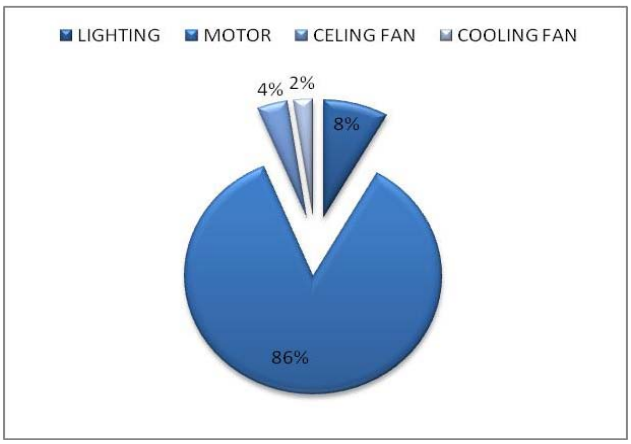

Fig. 4: Percentage of equipments in KWh

This pie chart represented in fig-(4) shows the percentage of power utilization of several equipments present in the industry. The motor is taking maximum power as 86% consumption throughout all the equipments. Fan and light are taking 4% and 8% respectively of the total power consumption. Cooling fans are taking the minimal amount of power.

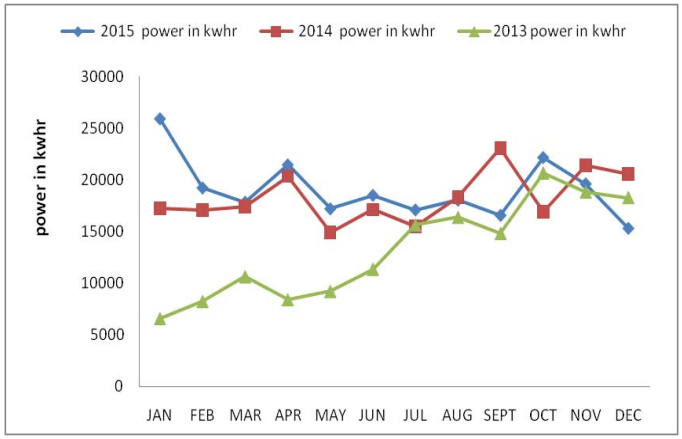

Fig. 5: Power Consumption in KWh (500KVA)

Fig-(5) represents the total power consumption unit of last three years from 500KVA transformer. The figure represents that the power consumption is maximum in the month of April, October and December due to increment of demand in the festive season. The industry is paying more than 1lakh 40 thousand in these months. Minimum load is in the month January and June due to less demand in off seasons. In these months the consumption is average, approx 1lakh only.

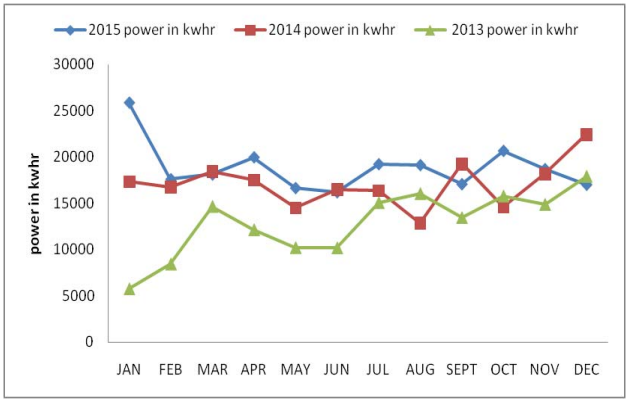

Fig. 6: Power Consumption in KWh (250KVA)

Fig-(6) represents the total power consumption unit of last three years from 250KVA transformer. The figure represents that the power consumption is maximum in the month of April, October and December due to increment of demand in the festive season. The industry is paying more than 1lakh 40 thousand in these months. Minimum load is in the month January and June due to less demand in off seasons. In these months the consumption is average, approx 1 lakh only.

IV. RECOMMENDATIONS

A. *Restructure the SLD*

It is observed that the Circuit breaker has more connected load than it can handle. It can be seen through the graphical representation. Hence two options are given. Option 1 is to remove some of the connected load and give it to a new circuit breaker. Option 2 is to have a dedicated circuit breaker for motors separately and one for lighting and fan loads. By applying these recommendations the risk of damage of the equipments can be reduced. The restructured layout presented to the industry.

B. *Lighting*

Light constitutes of an appreciable load and consist of an inefficient system of lamps and luminaries. Use of effective energy product will lead to savings of power as well as capitals. Total 101 lightning sources are using in the particular industry. The table given below is representing the number of light on the basis of used hour.

TABLE 1: - NUMBER OF REPLACEABLE LIGHTNING W.R.T KWH

EQUIPMENT	NUMBER	KWHr	Recommen
TUBE LIGHT	20	9.6	No
TUBE LIGHT	20	12	No
TUBE LIGHT	30	21.6	14.4
TUBE LIGHT	23	20.7	13.8
SLIM TUBE LIGH	4	1.32	No
BULB	4	24	12

According to the tabular column given above it is observed that the lighting recommendations are segregated into 3 parts. Among these parts bulb is having the maximum power consumption of 24 KWhr which can be immediately replaced by YELLOW LED bulb of same lumens. After replacement it is observed that 12 KWhr can be saved per day. Similarly the 2nd group and 3rd group also saving become as 14.4 and 13.8 respectively. In the remaining set of lighting no recommendations is required.

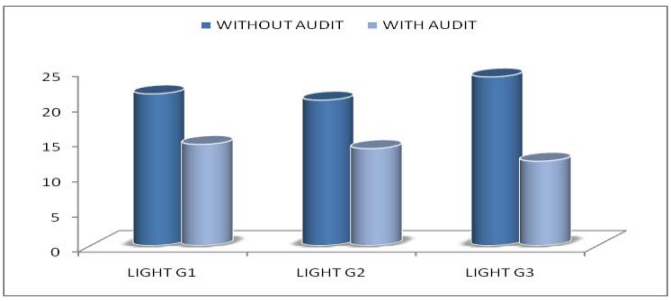

Fig. 7: Power consumption of light

Fig-(7) represents that how much energy can be saved in lightning section after implementation of the recommendation discussed above. Before audit the unit consumption is approx 25 KWhr but after the implementation of suggested recommendations it reduced to approx 15KWhr only. Hence we can see that the difference is just half in with audit and without audit.

C. *Fan and Exhaust fan*

Use of effective energy product will lead to savings of power as well as capitals. Total 56 fans sources are using in the particular industry. The table given below is representing the number of fans on the basis of used hour.

TABLE 2: - NUMBER OF REPLACEABLE FANS W.R.T KWH

EQUIPMENT	NUMBER	KWHr	Recommen
CELING FAN	10	9	No
CELING FAN	12	14.4	3.6
CELING FAN	11	11.88	3.6
CELING FAN	4	2.56	No
CELING FAN	5	4	No
COOLING FAN	4	3.2	No
COOLING FAN	4	4	No
COOLING FAN	4	4.8	No
COOLING FAN	2	6	No

According to the tabular column given above it is observed that the fan recommendations are segregated into 2 parts. Among these parts the fan used for 10 hrs is having the maximum power consumption of 14.4 KWhr which can be replaced by 45 watt high efficiency fan. After replacement it is observed that 3.6 KWhr can be saved per day. Similarly the 2nd group also saving will become as 3.6 KWhr per day. In the remaining sets of fan no recommendations is required.

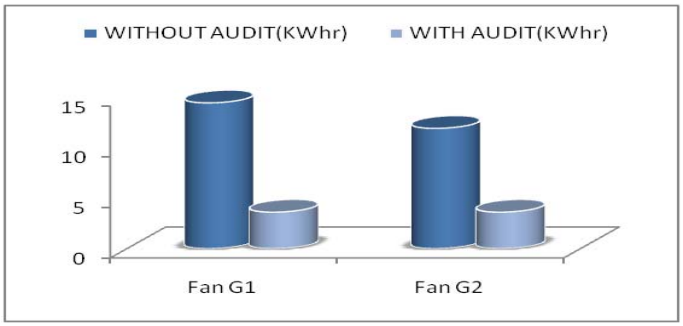

Fig. 8: Power Consumption of fan and exhaust fan

Figure (8) represents that how much energy can be saved in fan and exhaust fan section after implementation of the recommendation discussed above. Before audit the unit consumption is approximately 15 KWhr per day but after the implementation it reduced to approx 5 KWhr only per day.

D. Motor

Motor is one of the very important parts of the particular industry. In this industry 86% of total energy is used in motors. There are total of 43 motors are used. In these motors almost motors are in good conditions but some motors was taking more current as per required. The audit team has suggested replacing these motors with high efficiency motors.

TABLE- 3: -CONSUMED KWH PER DAY and MOTOR EFFICIENCY

MOTOR NO.	KWHr/day	EFFICIENCY	MOTOR NO.	KWHr/day	EFFICIENCY
M1	41.03	50%	M23	16.418	55%
M2	41.03	50%	M24	22.38	58%
M3	41.03	50%	M25	14.92	65%
M4	5.595	52%	M26	14.92	65%
M5	5.595	52%	M27	17.9	70%
M6	5.968	65%	M28	22.38	65%
M7	5.968	65%	M29	22.38	65%
M8	5.968	52%	M30	5.968	75%
M9	7.46	50%	M31	5.968	75%
M10	7.46	50%	M32	3.73	65%
M11	7.46	50%	M33	2.98	70%
M12	14.92	65%	M34	22.38	65%
M13	19.92	65%	M35	3.73	65%
M14	11.93	70%	M36	3.73	65%
M15	123.09	50%	M37	29.84	75%
M16	7.46	60%	M38	29.48	78%
M17	7.46	65%	M39	37.3	65%
M18	7.46	65%	M40	37.3	65%
M19	7.46	58%	M41	37.3	65%
M20	16.412	52%	M42	17.9	78%
M21	16.412	52%	M43	17.9	78%
M22	16.412	52%			

From the table given above it is observed that some motors having very high heat and very high vibration. Due to these factors the motor is giving very low efficiency and having very high power consumption. The audit team has recommended changing these motors immediately with the high efficiency motors. The list of all the motors affected is given in the next column.

Heat and Vibration

Analysis of heat and vibrations was done during the detailed audit. The table given below is stating that how much KWhr each motor is using per day. It has been observed that the most effected motor by heat and vibrations are taken up for replacement.

TABLE 4: - HIGH HEAT AND VIBRATIONS MOTORS

MOTOR	OLD MOTOR (KW)	HIGH EFFICIENCY(KW)
2HP MOTOR	52%	91%
15HP MOTOR	50%	84%
2HP MOTOR	52%	84%

The audit team has selected three motors M20, M15, M22 which having very high heat and high vibrations due to the year of purchasing and lack of proper maintenance. Due to these factors these motors are taking more current than the current consumption given in the name plate detail and in a very dangerous condition. Due to these factors these motors have to be replaced very immediately. The table shown above is the increment in the efficiency after replacement of these three motors.

TABLE 5: MODERATE HEAT AND VIBRATIONS MOTORS

MOTOR	OLD EFFICIENCY	ENERGY EFFICIENT MOTOR
M17	65%	82.50%
M18	65%	82.50%
M19	58%	82.50%
M35	65%	84.00%
M36	65%	80.00%
M37	75%	87.50%

In the next set of motor the audit team has observed that still some motor having heat and vibrations but in moderate manner. On this basis six more motor have been selected as M17, M18, M19, M35, M36, M37 which having moderate heat and vibrations due to the year of purchasing and lack of proper maintenance. Due to these factors these motors are taking some more current than the current consumption given in the name plate detail. Due to these factors these motors should be replaced with high efficiency motor. The table shown above is the increment in the efficiency after replacement of these motors

E. Compressor

The plant consists of number of air compressor for instrumentation and process air requirement. Electrical parameters and pressure measured during the energy audit study are tabulated in Table- (6). The data obtained during the above measurement is utilized to calculate the efficiency of the air compressor and given below in the table.

TABLE 6: -COMPRESSOR ANALYSIS

Column1	OnLoad KW	UnLoad KW	Load Time	Unload Time	Power Consumption(kWh)	Unload	Total Power Consumption
Present Conditio	28	7	30	30	14	3.5	17.5
Leak Arrested	28	7	20	40	9.3	4.7	14

Though this table it is observed that the total power consumption is 17.5 KWhr per hour before recommendation. But it becomes 14 KWhr per hour only after the arresting of leaks. It is recommended to arrest the leaks at the tail end (consuming area). Saving due arrest the leaks is 7350KWhr (considered 7 hours per day).

V. COST AND SAVING ANALYSIS

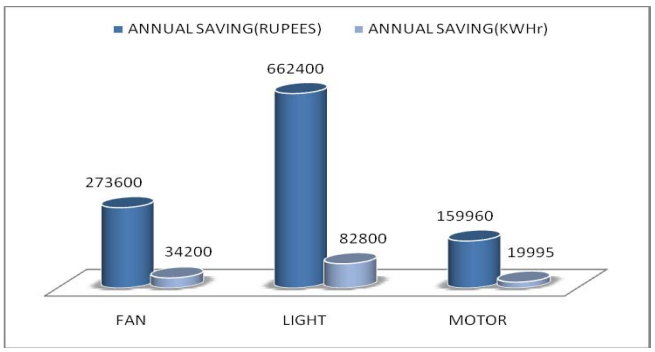

Fig. 9: Cost and saving analysis by different recommendations

After implementation of these recommendations the power saving with the mandatory investment is 136995kwhr per annum. The calculated cost of savings is Rs 1095960 per annum.

CONCLUSION

The preliminary and detailed audit is conducted for the aluminum industry in industrial sector of Chennai. The appropriate recommendation to operate the existing system with optimal energy saving is suggested. The recommendations suggested are to restructure the SLD, replacement of lighting and fan based on KWhr, replacement of motors on the basis of heat and vibrations, arrest the leaks of the compressor. After implementation of the suggested recommendations the power consumption reduction achieved is of 29.54%.

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