INDUSTRIAL ENERGY AUDIT

Simon Shiney [1] , Akash Chauhan [2] , Abhishek Singh[3] , Arun Nair [4] , H.V. Rupareliya [5]

[1]Dept. of Electrical Engineering, ITM Universe Vadodara, Gujarat, India,
[2]Dept. of Electrical Engineering, ITM Universe Vadodara, Gujarat, India
[3]Dept. of Electrical Engineering ITM Universe Vadodara, Gujarat, India
[4]Dept. of Electrical Engineering, ITM Universe Vadodara, Gujarat, India
[5] Asst. professor, Dept. of Electrical Engineering, ITM Universe Vadodara, Gujarat, India

---***---

Abstract

 "Industrial Energy Audit was conducted at R.R. Industries, 815, GIDC, Makarpura Vadodara.
During this industrial audit, we monitored the entire production and process system through systematic analytical and statistical approach *and technical calculations of both the industries.*
This analysis and calculations helped us to identify and minimize the overall energy losses/waste in the entire industry and also, reduction in energy bills, without effecting the production and quality of the service. Consequently we were able to maximize the overall power factor to unity value and thus increase in the efficiency of the system through inclusion of power capacitors."

Key words: System monitoring, loss Identification, analytical approach, Technical Calculation, energy losses, Cost reduction, improved Power Factor System Efficiency.

1.0.   INTRODUCTION

1.1.   ENERGY AUDIT :

Energy audit is the key to a systematic approach for decision making in the area of energy management. It attempts to balance the total energy input with its use, and serves to identify all energy streams in a facility. It quantifies energy usage according to its discrete functions.
Industrial energy audit is fundamental to a comprehensive energy management program and is defined in EC Act 2001 as follows:
"Energy Audit" means the verification, monitoring and analysis of use of energy including submission of technical report containing recommendation for improving energy efficiency with cost benefits analysis and an action plan to reduce energy consumption.

1.2.   OBJECTIVE :

The main Objective of this Energy Audit is to make "Divine Industries-Vadodara" an energy efficient industry through:
- Minimizing the energy losses/waste without affecting the production and its quality
- Optimum utilization of the energy
- Reduction in energy utility bill / cost
- To minimize the environment effects, if any.

1.3.   AUDIT METHODOLOGY:

Energy is one of the major inputs for the economic development of any country. In the case of the developing countries such as INDIA, the energy sector assumes a critical importance in view of the ever-increasing energy needs requiring huge investments to meet them.

In India, 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.
Accordingly, it can be said that Energy Audit is the key to a systematic approach for decision-making in the area of energy management. It attempts to balance the total energy inputs with its use, and serves to identify all the energy streams in a facility.

Thus, we can conclude that Energy audit is the 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.

1.4.   TYPES OF ENERGY AUDIT:

The type of energy audit to be performed depends on the types of industry, the depth to which final audit is needed, and the potential and magnitude of cost reduction desired. Thus energy audit can be classified into following types:
1.   Preliminary Audit
2.   Targeted audit

3.   Detailed audit

1.5.   APPROACH TOWARDS THE ENERGY AUDIT:

Detailed energy audit is a comprehensive audit and results in a detailed energy project implementation plan for a facility, since its accounts for the energy use of all major equipment. It includes detailed energy cost saving calculation and project implementation costs.

One of the key elements in a detailed energy audit is the energy balance. This is based on an inventory of energy-using systems, assumption of current operating conditions, measurement and calculations of energy use.

Detailed energy auditing is carried out in three phases:
1.   Pre Audit Phase
2.   Audit Phase
3.   Post Audit Phase

1.6.   PRE-AUDIT PHASE:

During the initial site visit following actions were taken:
- Discussion with the site's senior management about the aims of the energy audit.
  - Explain the purpose of the audit and indicate the kind of information needed during the facility tour.
  - Obtain site drawing where available- plant/building layout, steam distribution, compressed air distribution, electricity distribution etc.
  - Tour the site accompanied by site representative.

1.7.   DETAILED AUDIT PHASE:

The information collected during the detailed audit includes:
- Sources of energy supplies (e.g. electricity from the grid or self-generation).
- Energy cost and tariff data.
- Energy consumption by type of energy, by department, by major process equipment, by end-use.
- Generation and distribution of site services.
- Process and material flow diagram.
- Material balance data.(raw material, final product, recycled materials, use of scrap etc)
- Review of ongoing energy management procedures and energy awareness training programs.

1.8.   POST AUDIT:

Data Collection: In preliminary data collection phase, exhaustive data collection was prepared using different methods such as observation, discussion with key persons, and measurements.

Information about the general electrical appliances was collected by observation and interviewing.

The Site drawing and details of building Lay-out and Electricity Distribution system were collected. Electricity bill was collected from the personnel in-charge. 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.

Data analysis: Detailed analysis of data collected was performed.

The analysis of data was done in following manner:

Review of Power Flow diagram, Evaluation of collected data, Reasons for the Variance of power flow between connected load and actual consumption was evaluated. Additionally, the database prepared was further scrutinized and the results are presented graphically, this helped to identify the areas with maximum energy saving potential.

On the basis of results of data analysis and observations, some steps, for reducing power consumption are provided herewith in this audit report. The recommended measures will NOT affect the present working conditions and at the same time substantial energy savings will arise.

Following steps are involved in this process:

The capital cost involved in recommended replacement of an appliance and/or process is estimated, the energy saving by the move is calculated in terms of price of energy per year. These two costs are compared to calculate the capital cost recovery time which is defined as the Payback-Period by which the saving in energy bill balances the capital cost involved.

1.9.   INSTRUMENTS USED DURING DETAILED AUDIT:

NO	NAME OF THE INSTRUMENTS	MAKE	VALIDITY UP TO
1	Digital Tachometer	ROTOTESLA	JUNE-19
2	Tong tester/Clip on meter	AMTEK	DEC-19
3	Measuring tape of 100 meter	3M	-
4	Lux meter	AMTEK	DEC-19

Table-01: Instruments used during energy audit

1.10.   TARRIF PLAN:

Rate - LTMD Plan (2018-2019)

This tariff is applicable to the services for the premises those are not covered in any other tariff categories and having aggregate load above 40 KW and up to 100 KW.

LTMD tariff is addition of three charges i.e.

Fixed Charges + Energy Charges + Reactive Energy Charges, as shown below.

1. Fixed charges

1.	For billing demand up to the contract demand	Charges
	1. For first 40 KW of billing demand	Rs. 90/- per KW/ month
	2. Next 20 KW of billing demand	Rs. 130/- per KW/ month
	3. Above 60 KW of billing demand	Rs. 195/- per KW/ month
2.	For billing demand in excess of the contract demand	Rs. 265/- per KW

Plus

2. Energy charges

For the entire consumption during the month	460 Paise per Unit

Plus

3. Reactive energy charges

For all the reactive Units (KVARH) drawn during the month	10 Paise per KVARH

Billing demand:
The billing demand shall be highest of the following:
1. Eighty-five percent of the contract demand
2. Actual maximum demand registered during the month
3. 15 KW

MINIMUM BILL :
Payment of demand charges every month based on the billing demand.

2.0. R.R FABRICATORS

2.1. DESCRIPTION OF THE INDUSTRY:

The energy audit was conducted at R.R. Fabrication Industries, Plot No. 814 & 815, GIDC, Makarpura Vadodara, INDIA. This Industry is Steel & Aluminum-Fabrication Industry which manufactures the equipment and accessories as per approved design data in Chemical, Petrochemical & Dairy Industries .Main products of this industries are CVT Tanks (400 KV, 765 KV), 800 KV Conductors and couplings ,Corona Ring (135 KV, 400 KV, 800 KV), Core supports, Top and bottom chambers of HV Bushings.

The total area of industry is 220 square meter and total staff strength 24. It has many types of equipment and heavy machinery like Shearing machine, lathe machine, milling machines, Power press, Welding sets, Cutters, Air Conditioners, Drill machines, Sheet rounding machine, Hand Grinder (as shown in Table-05)

The Company's primary source of power supply is from Madhya Gujarat Vij Company Limited (MGVCL) with Tariff Plan LMTD.

This plan is applicable to the services of the premises having aggregate load of above 40 KW and upto 100 KW.

2.2. GENERAL PLANT DETAILS:

Connected load details– (lighting):

| No	Type of Lighting and Fans	Machine Shop	Welding Shop	Stores and Office
1	CFL Lights (85 W)	10	10	6
2	Air conditioner (1500 W)	0	0	2
3	Computers and accessories (150W)	0	0	3
4	Total Load	850 W	850 W	3960 W

Table-02: Connected lighting load

Total lighting Load including industrial Fans
= 850+850+3960
= 5660 W
=5.66 KW

Machinery and Equipment in the Industry:

| No	NAME OF THE MACHINARY / EQUIPMENT	QTY	CAPACITY OF THE INSTALLED EQUIPMENT IN KW / KVA
1	OVERHEAD CRANE	1	10KW
2	TIG RECTIFIER TRANSFORMER	7	160 KVA (5), 130 KVA (2),
3	MOTOR FOR LATHE MACHINE	4	7.5KW(3), 10 KW
4	MOTOR FOR SHEARING MACHINE	2	2KW, 5KW
5	KW MOTOR FOR PRESS MACHINE	3	10KW, 15KW (2)
6	MOTOR FOR DRILLING MACHINE	2	2 KW (2)
7	MOTOR FOR GRINDING MACHINE	2	2KW,3KW

Table-03: List of machinery & equipment

Energy consumption - department wise:
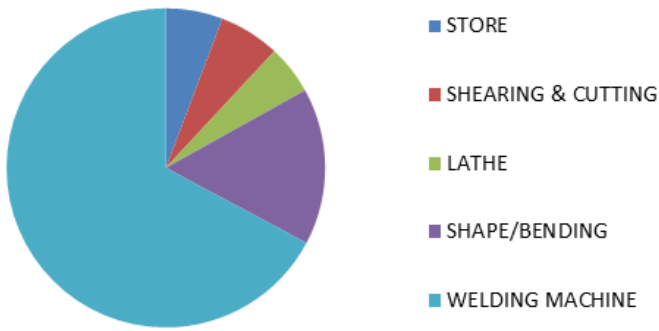
Graph-01: Department wise energy consumption

Equipment layout in the industry:
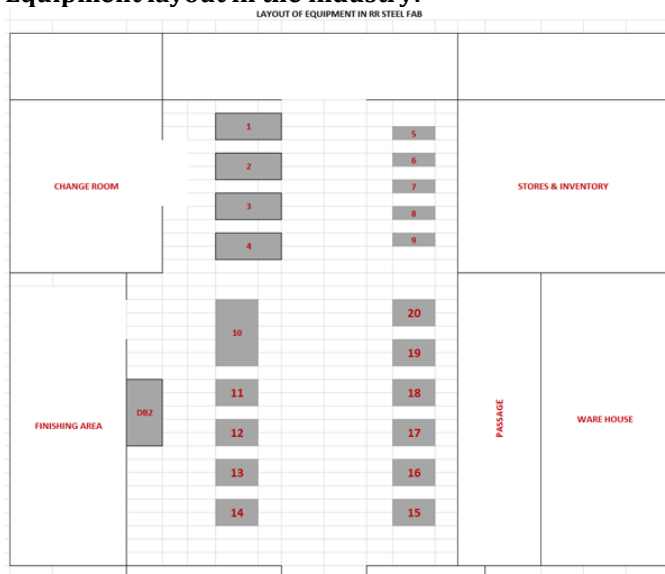
	EQUIPMENT LIST
1	TIG RECTIFIER TRANSFORMER- 1
2	MIG RECTIFIER TRANSFORMER- 2
3	MIG RECTIFIER TRANSFORMER-3
4	TIG RECTIFIER TRANSFORMER- 4
5	RECTIFIER TRANSFORMER FOR AL WELDING 5
6	MIG RECTIFIER TRANSFORMER-6
7	MIG RECTIFIER TRANSFORMER-7
8	7.5 KW MOTOR FOR LATHE MACHINE 1
9	10 KW KW MOTOR FOR LATHE MACHINE 2
10	7.5 KW MOTOR FOR LATHE MACHINE 3
11	7.5 KW MOTOR FOR LATHE MACHINE 4
12	5 KW MOTOR FOR SHEARING MACHINE 1
13	2 KW MOTOR FOR HEXO SHEARING MACHINE 1
14	10 KW KW MOTOR FOR PRESS MACHINE 1
15	15 KW KW MOTOR FOR PRESS MACHINE 2
16	15 KW KW MOTOR FOR PRESS MACHINE 3
17	2 KW MOTOR FOR DRILLING MACHINE 1
18	2 KW MOTOR FOR DRILLING MACHINE 2
19	2 KW MOTOR FOR GRINDING MACHINE 1
20	2 KW MOTOR FOR GRINDING MACHINE 2

Figure–01: Industries equipment layout
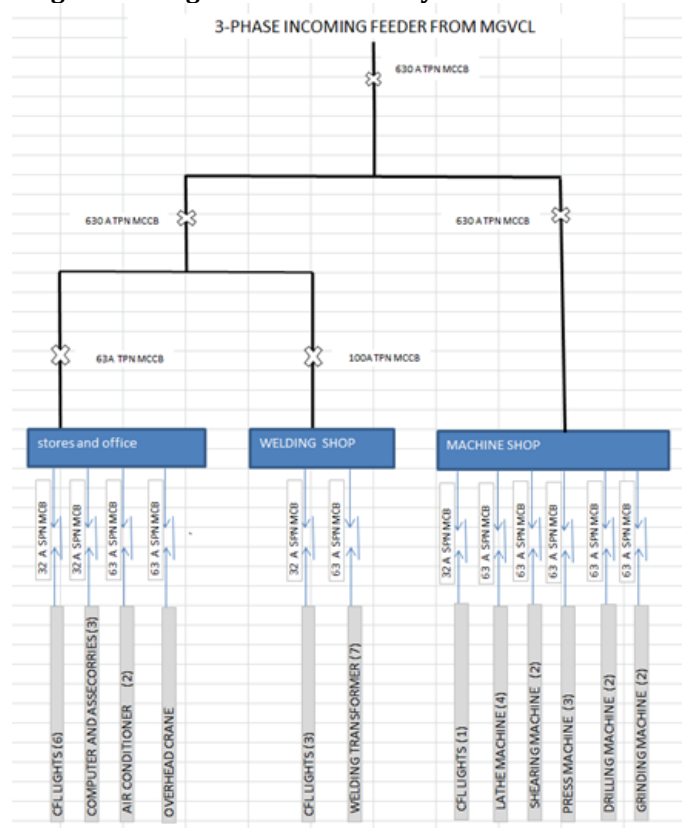
Single line diagram of electrical system:

Figure-02: Single line diagram of electrical system
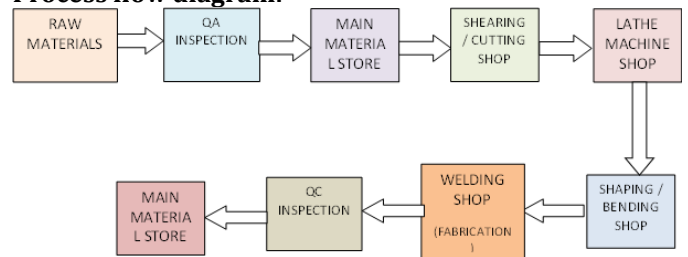
Process flow diagram:

Figure-03: Industries process flow diagram

2.3. MEASUREMENT OF ELECTRICAL PARAMETERS:

Rated values of electrical equipments:

No	NAME OF MACHINE / EQUIPMENT	RATED NAME PLATE VALUES			
		KW	VOLT	AMP	RATED SPEED
1	OVERHEAD CRANE	10	440	53	700
2	MOTOR FOR PROCESS	2	440	3	700

	COOLING WATER				
3	MOTOR FOR LATHE MACHINE 1	7.5	440	12	1450
4	MOTOR FOR LATHE MACHINE 2	10	440	16	1450
5	MOTOR FOR LATHE MACHINE 3	7.5	440	12	1450
6	MOTOR FOR LATHE MACHINE 4	7.5	440	12	950
7	MOTOR FOR SHEARING MACHINE 1	5	440	8	2850
8	MOTOR FOR HEXO SHEARING MACHINE 1	2	440	3	2850
9	MOTOR FOR PRESS MACHINE 1	10	440	16	700
10	MOTOR FOR PRESS MACHINE 2	15	440	19	700
11	MOTOR FOR PRESS MACHINE 3	15	440	19	950
12	MOTOR FOR DRILLING MACHINE 1	2	230	10	700
13	MOTOR FOR DRILLING MACHINE 2	2	230	10	950
14	MOTOR FOR GRINDING MACHINE 1	2	230	10	950
15	MOTOR FOR GRINDING MACHINE 2	3	230	13	950
	TOTAL POWER LOAD	418.5 KW			

Table–04A: Rated values for Rotating Machines

No	NAME OF THE MACHINE / EQUIPMENT	RATED NAME PLATE VALUES				CALCULATED INPUT KVA
		KVA	VOLT	AMP	EFFICIENCY %	
1	160 KVA TIG RECTIFIER TRANSFORMER - 1	160	440	210	64	250
2	160 KVA MIG RECTIFIER TRANSFORMER - 2	160	440	210	64	250
3	100 KVA MIG RECTIFIER TRANSFORMER -3	100	440	130	67	149
4	100 KVA TIG RECTIFIER TRANSFORMER - 4	100	440	130	67	149

5	120 KVA RECTIFIER TRANSFORMER FOR AL WELDING 5	120	440	155	65	184
6	100KVA MIG RECTIFIER TRANSFORMER -6	100	230	430	67	149
7	50 KVA MIG RECTIFIER TRANSFORMER -7	50	230	210	65	76.9
	TOTAL POWER LOAD	790 KVA				

Table – 05A: Rated values for stationary Machines

Measured values of electrical equipment:

No	NAME OF MACHINE / EQUIPMENT	MEASURED VALUES		
		ACTUAL CURRENT	ACTUAL SPEED	% LOADING
1	OVERHEAD CRANE	51.2	710	80
2	MOTOR FOR PROCESS COOLING WATER	9.8	712	76
3	MOTOR FOR LATHE MACHINE 1	10.9	1458	84
4	MOTOR FOR LATHE MACHINE 2	14.3	1461	78
5	MOTOR FOR LATHE MACHINE 3	11.1	1460	80
6	MOTOR FOR LATHE MACHINE 4	10.9	962	76
7	MOTOR FOR SHEARING MACHINE 1	7.5	2890	73
8	MOTOR FOR HEXO SHEARING MACHINE 1	2.2	2893	71
9	MOTOR FOR PRESS MACHINE 1	14.5	712	76
10	MOTOR FOR PRESS MACHINE 2	17.3	712	76
11	MOTOR FOR PRESS MACHINE 3	17.9	960	80
12	MOTOR FOR DRILLING MACHINE 1	8.7	715	70
13	MOTOR FOR DRILLING MACHINE 2	8.5	963	74
14	MOTOR FOR GRINDING MACHINE 1	8.8	964	72
15	MOTOR FOR GRINDING MACHINE 2	11.2	965	70
	AVERAGE % LOADING			75.7

Table – 04B: Measured values for Rotating Machines

| No | NAME OF THE MACHINE / EQUIPMENT | MEASURED VALUES | | |
		AMP	VOLT	% LOADING
1	160 KVA TIG RECTIFIER TRANSFORMER- 1	205	432	61.2
2	160 KVA MIG RECTIFIER TRANSFORMER- 2	207	430	61.6
3	100 KVA MIG RECTIFIER TRANSFORMER-3	123	430	61.0
4	100 KVA TIG RECTIFIER TRANSFORMER- 4	121	439	61.7
5	120 KVA RECTIFIER TRANSFORMER FOR AL WELDING 5	149	428	59.2
6	100KVA MIG RECTIFIER TRANSFORMER-6	418	228	63,8
7	50 KVA MIG RECTIFIER TRANSFORMER-7	199	232	60.5
	TOTAL % LOADING:			60.8

**Table–05B: Rated values for stationary Machines**

Utility bill with pf:

Contract kw – 21 KW

NO	Month & Year	PEAK LOAD (KW)	Reactive power (KVARh)	UNIT CONSUMED (KWh)	PF	Bill Amount
1	Dec-17	11.3	1196	1992	.85	15905
2	Jan-18	11	899	1714	.88	13944
3	Feb-18	10.5	1120	1594	.81	12841
4	Mar-18	11	1205	1870	.84	14872
5	Apr -18	11	1102	1972	.87	15334
6	May-18	11.9	1410	2150	.83	15538
7	Jun- 18	12	1427	1937	.8	15458
8	Jul- 18	10.4	1329	1910	.82	14951
9	Aug- 18	10	1175	2117	.87	16288
	AVERAGE VALUES	11.02	1207	1917.3	.84	15014

Table–06: Utility bill with pf

Average power factor:
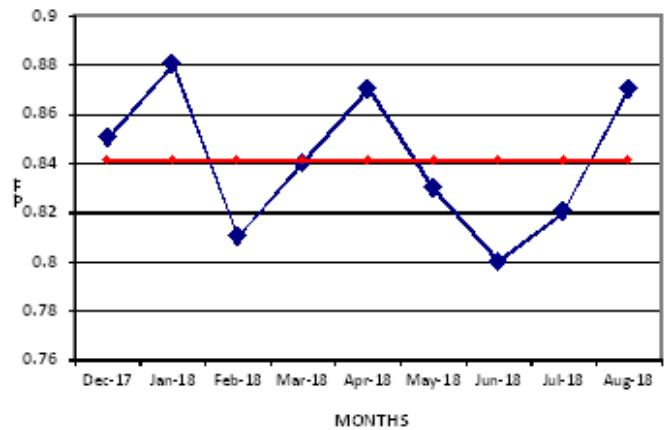
Graph-02: Average power factor

2.4. CALCULATIONS:

Reasons to Determine Motor Loading :

Most electric motors are designed to run at 50% to 100% of rated load. Maximum efficiency is usually near 75% of rated load. A motor's efficiency tends to decrease dramatically below about 50% load. A motor is considered to be under-loaded when it is in the range where efficiency drops significantly with decreasing load.

As per NEMA design criteria, for motors up to 500 HP in size, % efficiency for various loads requires to be measured and plotted (graph) by the manufacturer. It is also required to have a full-load efficiency value stamped on the nameplate. From the universal "efficiency-Load" (Graph-07) of motors it can be seen that motor efficiencies generally peak at around 3/4 or 75% of load, and is almost identical to the efficiency at full load.
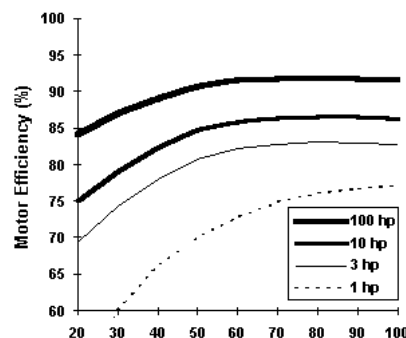
Graph–03: Efficiency and loading of motor

During this particular Energy Audit program, Percentage-Loading of rotating-machinery and static-machinery are calculated separately. For both type of above machines, a sample-calculation is separately provided for ease of understanding.

Percentage loading calculation for rotating machinery:

There are three methods to find % Loading of Electrical Motors
1. Input power measurement
2. Line Current measurement
3. Shaft Slip-Speed Method

For this particular energy audit, we have adopted **"Shaft Slip-Speed Method"** to calculate % Loading of the equipment i.e. Motors

** (Here, Overhead Crane, at serial No.1 of Table-04 A, is selected for below depicted sample calculation)

% Loading of the Motor   =   Slip x 100 / Ss – Sr

Where
Slip

=   Difference between synchronous speed and actual measured speed of motor

Ss   =   Synchronous speed of the Motor
Sr   =   Rated Speed of the Motor (Name plate rating)

=   Synchronous speed – Measured speed x 100 / Synchronous speed – Rated Speed

=   Operating slip / Full Load slip

=   (750-710) x 100) / (750-700)

=   40 / 50 x 100

=   **80 %**

Percentage loading of all rotating equipment is calculated based on the above sample calculation and is recorded as shown in Table – 04B.

Calculation for stationary machinery :

** (Here, value of Table-05A, is selected for below depicted sample calculation)

Sample Calculation:

Rated Input power in KVA	=	Rated output capacity of the equipment / Efficiency
	=	160 / 0.64
	=	250
Actual input KVA	=	Measured Voltage x Measured Current
	=	1.732 x 432 V x 205 A
	=	153 KVA
% Loading	=	Actual input KVA /

Rated input KVA

=   153 x 100 / 250

=   **61.2 % Loading**

Calculation of power factor:

The required details, for power factor calculation is collected from MGVCL's monthly utility bills as shown in Table - 06 The formula, for calculating Power factor, is as shown below:

Tan θ   =   KVARh / KWh

Where

Tan θ	=	Trigonometric Ratio of reactive power and Real power
KVARh	=	Reactive power hour
KWh	=	Real Power hour – Unit

Tan θ	=	1196 / 1992 = 0.6
Θ	=	30.98
Cos θ	=	0.857

Power factor = 0.857

Calculation for sizing of power capacitor :

KVAR   =   KW x (Tan θ₁ – Tan θ₂)

Where

KVAR	=	Required capacity of the Power Capacitor in Kvar
KW	=	Contracted Active power
KVA	=	Apparent Power
cosθ₁	=	Average Power factor of the system (Table - 09)
θ₁	=	Inv.Cosine of above average value of power factor
Tan θ₁	=	Trigonometric ratio for present power factor
Cos θ₂	=	Desired power factor
θ₂	=	Inv. Cosine of above desired value of power factor
Tan θ₂	=	Trigonometric ratio for the desired power factor
KVAR	=	21 X (1.55 – 0.044)
	=	21 X 0.57
KVAR	=	12.56 KVAR

Sizing of power capacitor in KVAR =12.56 KVAR

Calculation for energy saving:
Total Connected Load:

Lighting Loads + Rotating machine Load + Static Machine Load

= 5.66+ 418.5

= 424.16 KW

Ampere calculation:

Actual average current with existing Power Factor of 0.84	=	Actual Load in Watts / 1.732 x 440 x0.84
	=	42,416 / 640.9
	=	66.18 Amp
Average current with desired Power Factor of 0.999	=	**56.22 Amp**

KVA Calculation

Apparent power in KVA for existing power factor 0.84	=	Actual KW / Power factor 504.35 KVA
Apparent power in KVA with desired power factor 0.999	=	Actual KW / Power factor 424.58 KVA
Difference in KVA	=	504.35 – 424.58 79.76 KVA

KW Calculation:

Real power in KW for existing power factor 0.84	=	P.F X KVA = 424.15KW
Real power in KW for desired power factor 0.999	=	P.F X KVA = 420.33 KW
Difference in KW	=	424.15 - 420.33 = 3.8 KW

KVAR calculations:

Reactive power in KVAr for existing power factor	=	KVA X sin θ = 272.87 KVAr
Reactive power in KVAr for desired power factor	=	KVA X sin θ = 59.89 KVAr
Difference in KVAr	=	272.87 – 59.89 = 212.97 KVAr

Total Energy Saving:

KVA - SAVING PER MONTH	=	79.76 KVA X 9 HOURS/DAY X 26 DAYS/MONTH = **18663.84 KVA**
KW - SAVING PER MONTHING	=	3.8 KW X 9 HOURS/DAY X 26 DAYS/MONTH

		= **889.2 KWh**
KVAR - SAVING PER MONTH	=	141 KVAR X 9 HOURS/DAY X 26 DAYS/MONTH = **49,834.98 KVARh**

COST BENEFIT WITH INCLUSION POWER CAPCITOR

	BENEFIT IN ENERGY CHARGE		
1	889.2 KWh X 4.60 RS	Rs. 4090.32 MONTHLY SAVING.	Rs. 49083.84 ANNUAL SAVING
PLUS			
	BENEFIT IN REACTIVE ENERGY CHARGES		
2	49834.98 KVARh X 10 PAISE	Rs. 4983.49 MONTHLY SAVING	Rs. 59801.97 ANNUAL SAVING
3	**TOTAL SAVING**	Rs. 9073.81 MONTHLY SAVING	Rs. 108,885.81 ANNUAL SAVING

Table-07: Cost benefits with inclusion of power capacitor

2.5. INVESTMENT:

NO DESCRIPTION OF ITEM	UNIT COST (IN RS)	QUANTITY	TOTAL PRICE
1. AUTOMATIC LIGHTING CIRCUIT	3,500	1	3,500
2 13 KVAR CAPACITOR	1,000	13	13,000
TOTAL INVESTMENT			16,500
GRAND TOTAL : TOTAL INVESTMENT PLUS 12 % INTEREST RATE			**18,480**

Table-08: Total Investment required.

2.6. ANNUAL ENERGY SAVING AND PAYBACK PERIOD:

NO	ENERGY SAVING RECOMMENDATION	ANNUAL ENERGY SAVING	ANNUAL COST SAVING IN Rs.	CAPITAL INVEST IN Rs,	SIMPLE PAYBACK PERIOD IN MONTHS
1	Reduce the existing Contract- Demand from	72 KW	8,100 (includin	00	00

	existing 21 KW to 15 KW		g 25% tax saving)		
2	Power Factor correction capacitor of 13 KVAR to increase the existing power factor of the system from 0.84 to 0.999.	10,670 KWh	49,000	13,000	1.2
		5,98,000 KVARh	59,800		
3.	Solar Panel of 6 KW Capacity	10,800 UNITS	49,680	2,10,000	50

Table–09: Annual cost saving and payback period

2.7. AUDIT OBSERVATIONS

Primary observations :

1. It has been observed that the operators fail to turn OFF the equipment when not in use.
2. Aluminum sheets and scraps are not properly discarded so there may be a danger of accident.
3. It is observed that there remains a certain amount of smoke build-up inside the welding shop.
4. A.C ventilation needs to be checked regularly to safe guard from certain on-going spraying / painting activity.

Observation - Energy consumption and Power Factor:

The monthly electricity bill for the year 2018, showing energy consumption (KWh) is tabulated in Table-09.
From this table it is observed that the energy consumed varies from a maximum value of 2150 KWh Units in the month of May 2018 to a minimum value of 1594 KWh Units in the month of February 2018.
The variation of power factor is also is tabulated in Table-09. It is observed that the power factor value varies between 0.8 to 0.87. These values of the power factor are found to be less than the desired value of 0.999.

Observation - Percentage Loading of Equipment

% Loading of of motors

Table 08A shows the Performance of different rotating machines in terms of its % loading.
From this table it can be seen that:
All motors, are working at average %loading of 75.7%. So we can say that all motors are loaded nearly or above the ¾ loads i.e. nearly 75 %. So we can say that they operate very near to maximum efficiency.

% Loading of Welding-Rectifiers

It is observed that most of the welding rectifier are working above 60% loading. This loading is sufficiently good for welding machine, since the output of the welding machine is nearly short-circuited.

2.8. RECOMMENDATION FOR ENCON

No cost measures:

1. We strongly recommend the management to change their existing contract demand of 21 KW to 15KW with immediate effect.
2. Cleaning of A.C ventilation should be included in PREVENTIVE MAINTENANCE schedule.
3. Aluminum scrap sheets should be collected time to time and store in a proper place. They may be re-used or sold to earn certain amount of money.
4. Replace Compact Fluorescent Lamps (CFL's) by LED lights.

NOTE:
It should be noted that In energy Conservation in lighting system, good lighting is required to improve the quality of work, to reduce human's / worker's fatigue, to reduce accidents, to protect his eyes and nervous system. It improves production, and quality of products / work.
Optimum use of natural light, whenever the orientation of a building permits, day lighting has to be used in combination with electric lighting.
The maxim use of sunlight can be utilized by means of transparent roof sheets.
For lighting system, the advantage of sunlight should be availed by leaving lights off during the day.
Additionally, It is strongly suggested to create awareness among the workers about the important of ENERGY SAVING AND CONSERVATION.

Low cost measures:

1. The welding shop should be provided with adequate size of energy efficient exhaust fans (minimum 2 nos.) to remove smoke.
2. Install Timer-based automatic lighting circuit.

Medium cost measure:

1, Based on calculation, as shown in Para 5.4.6, we strongly recommend the Management of R.R. Fab Industries to install a Power Factor correction capacitor of 13 KVAR rating (rounding off to 15 KVAR) which would increase the existing power factor of 0.84 to 0.99.
Energy Conservation can also be achieved by using Automatic power factor controller (APFC).

2, The management is recommended here with, to offset the

lighting load of 5.78 KW (as shown in table-06) with installation of 5KW of solar energy(solar panel). Each 1KW panel would produce 5 units per day. Total annual saving by installing this 5KW panel would be @ Rs. 41,000. The payback period would be around 4 years.

3. CONCLUSIONS:

Through conducting this energy audit in the industry, we achieved every set objective and if, the following proposed recommendations are accepted and implemented by the management of the industry, then they would certainly get mentioned benefits within the specified pay-back period.

Recommendations:

1. **Reduction in the Contract Demand in KW :**

   This is basically a No-Cost measure. If this measure is implemented, then the monetary benefit would be of @ Rs 8100/- annually.

2. **Inclusion of 13 KVAR sized Power Capacitor**:

   Inclusion of above recommended power capacitor would help to achieve near Unit power Factor which has direct effect on Active and Reactive power of the system.
   The investment involved in implementing this recommendation is @ Rs 13,000/- only however if implemented, this would generate a benefit of @ Rs 108,800/- annually.
   The calculated minimal Pay-Back period would be 1 months 5 days.

3. **5-KW Renewable solar panel system Installation:**

   We strongly recommend for installation of 6 KW renewable Solar panel system, which would assist to supply energy to the overall Lighting system of 5.66 KW.
   This installation would certainly minimize the monthly energy bill.
   The total investment of 5 KW solar panel installation would be @ Rs 240,000/-.
   The Pay-Back period would be @ 4 years and 2 months (50 months).

ACKNOWLEDGEMENT :

REFERENCES

[1] Bureau of Energy Efficiency
[2] https://www.sgs.com/en/sustainability/environment/energy-services/energy-audits-and-management/energy-audit
[3] https://ieeexplore.ieee.org/document/4250239/
[4] https://www.google.com/url?sa=t&source=web&rct=j&url=https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-20956.pdf&ved=2ahUKEwihuIa8zrfcAhXWfisKHYyYB0sQFjAKegQIAhAB&usg=AOvVaw1iOzkgvh7z9tefTJigyrwA

BIOGRAPHIES :

Mr. Simon Shiney was born in Vadodara, Gujarat. Currently pursuing his Bachelor in Engineering in Electrical Engineering from ITM UNIVERSE, Vadodara.

Mr. Akash Chauhan was born in Vadodara, Gujarat. Currently pursuing his Bachelor in Engineering in Electrical Engineering from ITM UNIVERSE, Vadodara.

Mr. Abhishek Singh was born in Vadodara, Gujarat. Currently pursuing his Bachelor in Engineering in Electrical Engineering from ITM UNIVERSE, Vadodara.

Mr. Arun Nair was born in Vadodara, Gujarat. Currently pursuing his Bachelor in Engineering in Electrical Engineering from ITM UNIVERSE, Vadodara.

Mr. H.V.Rupareliya born in Wankaner, Gujarat (India).Graduated from Gujarat University in July 2009 and Post-Graduation in Electrical Power Systems from BVM Engineering College, Vallabh Vidyanagar, Gujarat. Currently working as Assistant Professor in Electrical Department in ITM UNIVERSE since 2015.