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Electrical Energy Conservation in Glass Industry

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Abstact : *Electrical energy is the most common and widely used type of energy in the world. The subject of energy conservation is a concern for most energy users particularly industry. Energy Conservation (ECON) becomes even more important for the third world, developing countries, where the rising energy costs and the use of efficient energy apparatus are of significant concern to both the industry and the utility. In this paper, the application of the ECON techniques by which electrical energy can be saved and made cost efficient from the industrial perspective are presented for a sheet-glass industry in a developing country (India-Asia). The selection, in particular, of a sheet-glass industry was done because electrical energy constitutes only a small amount of the overall energy used. A complete energy conservation guideline is recommended. The load profile and its overall improvement in light of these recommendations are also illustrated along with the proposed utilization of the techniques and their applications. Electrical energy management (EEM) approach for motors, pf, and tariff control is outlined and the emphasis on energy conservation technology has been elaborated. More findings of the application of energy conservation techniques of high significance are presented in the paper.*

Keywords: *Energy Conservation, Energy Management, Industry, Sheet-Glass, Load, Motors, Efficiency.*

1. INTRODUCTION

Electrical energy is the most expensive and the most important form of purchased energy. For this reason its use must be confined to a minimum for efficient operation. Because of its great flexibility, electricity offers advantages over the conventional fossil fuels and efforts to conserve electricity can result in significant cost savings [6]. Literature [5-10], is available on the notable research in the area of energy conservation and energy management. The importance of energy conservation in terms of energy and cost savings has been outlined in greater detail in [5], [8], [10]. 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. In the developing countries where electrical energy resources are scarce and production of electricity is very costly, energy conservation studies are of great importance. The following two objectives are considered when discussing electrical energy conservation:

(1) kWH (Energy) Savings.
(2) Energy Cost ($) Savings.

For both industry and the utilities, the above objectives are of great importance. It has been mentioned [8-10] that the use of efficient electric equipment in industry and the energy conservation technologies may have great cost savings specifically where electrical energy constitutes a smaller amount as compared to the other energy sources.

I. 2. ENERGY AUDIT & CONSERVATION

To test electrical systems and identify conservation opportunities, the steps found in [6] that must be carried out by an industry are.

(1) kWH (Energy) Savings.
(2) Energy Cost ($) Savings.
(3) Carry out Detailed Energy Survey

The energy survey is the first step in collecting all the relevant data for the industry for which the conservation techniques are to be applied Data must be obtained for each type of energy used and costs incurred by the industry for at least 2-3 previous years of the year of study. Also the actual measurements (on-site) of the various energy devices (motors, lighting etc.) Should be included as part of the energy survey. The energy survey team has the task to explore the potential areas of energy conservation based on the findings of the survey. This could involve energy management with motors and lighting, tariff control, power factor (pf) management, the use of energy efficient devices (motors and lighting), the possibility of cogeneration and the use of technical awareness and motivation programs for the industry personnel. More details on energy management and conservation techniques can be found in [2, 5, 6, and 10].

II. 3. ELECTRICAL ENERGY CONSERVATION FOR A GLASS INDUSTRY

Background: Glass is used as components in many industries. The types of glass, their use and properties are briefly given in Fig. 1 Since electrical energy conservation has two objectives, for the purpose of illustration, a sheet glass industry namely the Nowhere Sheet Glass industries (GBL) in India were chosen as a case study. GBL produces nearly 45 K Tones of Sheet Glass annually (2016) This data is the base for the analysis and calculations carried out in this paper, however, the prices are based on 2016 market price.

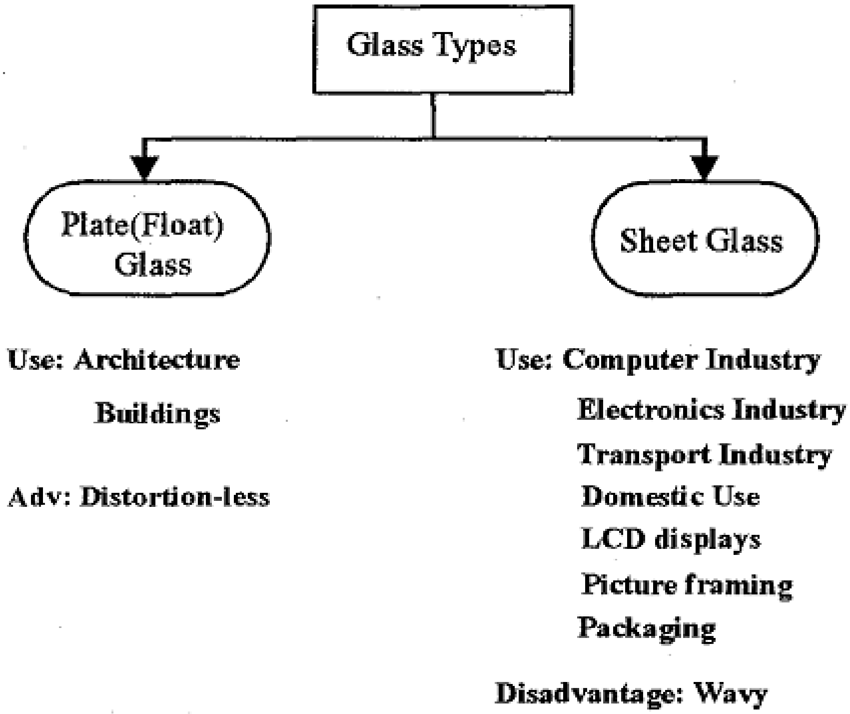

Fig. 1 types of glass, their use and properties

GBL was selected because it uses the least amount of electrical energy of the total energy used, whereas its cost in the energy bill is significant. It is also to show that even for such a small electrical energy user industry, energy conservation can play a vital role in reducing the overall energy costs.

Table 1
Energy Usage at GBL (2016)

Energy	**Annual energy consumption**	**Annual cost (US $)**	**% of total cost**
Electric	23725000 kWH	1977083.33	42.62
Natural gas	7921962.71 SCM	2661779.47	57.38
Total		4638886.8	100
Annual Avg. Elect. Energy cost: 0.083$ /kWh (2016) Annual Avg. Gas Energy cost: 0.36$/SCM (2016)			

Table 2
Connected Load details at GBL, (2016)

Types of load	**Connected load (KW)**	**% of total load**
Motoring load	4630.7	43.41
Lightning load	234.25	2.19
Furnace/Heaters	5683	52.28
Welding/rectifier	84	0.78
Others	224	1.34
Total	10665.95	100

Analysis and Methodology:

The objective here is to study and analyze the use of electrical energy in the glass industry so as to;
(1) Determine the energy inputs to the various stages in the process carried out in the industry, thereby arriving at the energy content of the major products, and in particular indenting the process stages for which the largest amount of energy are needed.
(2) Decide where the most significant energy savings are possible, quantifying such savings and the cost of achieving them.
(3) Assist the industry administration in making recommendations on energy savings and in its policy and plans for energy conservation.
The main components of the glass industry which may bring about very significant electrical energy conservation are:

A: Saving through peak savings:

As per the norms of the GUVNL, the maximum demand charges for any month at the point of supply shall be based on the highest KVA demand recorded during any consecutive thirty minutes in that month or 100% of the sanctioned demand, whichever is higher. In addition, for exceeding the sanctioned maximum demand, the charges per exceeded KVA shall be at double the normal rate (say penalty).

Finding: The Maximum Demand during the financial years 2014-14 And 2015-15 has increased in March and April, due to the early summer peak loads, and the production target initiative at the beginning of the financial year. During the EC project period (2015-16), the peak demand was found to be 3750 KVA. But in few days MD is increasing up to 4000 KVA it was noticed that the available Diesel generators were used only at the time of power-cut and at grid failure cases.

Recommendations: The recommendation for the use of one 1000 KVA Generator at the time of peak loads during 2015-16 and to transfer the excess loads to the generator supply so as to avoid the excess KVA penalty charges. If critical loads also contribute to facility peaks, consider shifting these loads to generator power during peak periods. In case, if emergency backup power is needed, the remaining two Diesel Generators shall be put in service even during peak periods

Benefits: Considering the peak demand during February-March of this year of the 3750 KVA exceeding the demand by 150 KVA for duration of 3 hours/day in one month. Diesel generator supply is worked out to be \$0.19/kWh. Maximum demand charges for per KVA are 6.16\$. Net saving by peak shaving per month is 839.5\$

B: Replace inefficient motors with EEM:

The industry has about 425 motors of various sizes, 75% of which are rewound Studies [6] have shown that electric Motors lose about 3-7% efficiency when rewound. It was also observed that there were a total of 325 motors rated $\leq$ 10 hp (7.5kw) and above with total rating of 927.35 kW. The details are given below.

Table 3
Motoring load detail

Rating (kW)	7.5	5.5	3.7	3.0	2.25	1.5	1.12	0.75	0.55	0.22
No. of motors	32	31	40	9	75	56	48	24	30	12

The average operating efficiency of these motors was very low and thus replacing them with the energy efficient motors (EEM) could improve energy savings significantly
The energy cost savings by replacing an old motor with an EEM is given by the following formula [5]

$$S = PLCT\,(100B - 100/A) \_\_\_\_\_(1)$$

Where S = Annual savings (\$/year) =?
P = kW rating of motor B (old inefficient) = 927.35 kW
L = load factor (avg.) = 0.8
C = Average Electricity cost (\$/kWH) = 0.083
T = running time (hour/year) = 6000
A = Efficiency of motor A (New EEM) = 0.90
B = Efficiency of motor B (Old inefficient) = 0.73
Total Cost savings: Using eqn. (1) above, the total cost savings calculated were 13460 \$/year.
Total Investment cost: The total prices of new EEM motors of the ratings given above were found to be \$92737 (2016 market price). The payback period and return on investment (ROI) is given in Table 4.

Table 4
Energy conservation opportunity with motors

Existing System	Proposed System	Savings
- 75% of the total motors in industry have been rewound - All motors rated at ≤10hp have lower operating efficiencies - Operating time = 6000 hrs/year - operate at 80% rated load - efficiency = 73%	increase motor efficiency to 90% (by replacement) • Replace all ≤10hp motors by EEM • Investment Cost $113982.66	$92737/year Using conversions =11, 12,820 kWH/year (eqvt.)
Payback = Total investment / total cost saving × 12 = 113982.66 × 12 / 92737 = 14.75 Month ≈ 15 Month **Return of investment = 1 / payback** = 1 /15 = 6.67%/month		

C: Change lighting system.
The existing lighting scheme at the GBL was studied carefully and measurements were taken for each light levels and fixture ratings. A new scheme with consideration to maintain or enhance the existing lighting levels (Ft. Candles) and reduce the kW rating was presented. The existing system of incandescent and mercury lighting was found to be consuming extra energy at the expense of lighting level. It was suggested to increase the light level while at the same time reduce the overall energy consumption (see table 5). Total Cost savings: From Table 5, the overall kW savings (difference in the existing and the proposed system) is equal to 100.4 kW. Operational time of lighting are 1200 hrs/year, equal to 9977.85 $/year.

Table 5
Energy conservation opportunity lighting

Existing System	Proposed System	Savings
Incandescent: 328 Fixtures 100 Watt each 32.8 kW 35 Ft. Candles 1200 hours /year Cost = 0.083 x32.8 x 1200 = $3266.88/year -----(1)	328 Fixtures 20 Watt each Fluorescent 6.56 kW (Inc. ballast loss) 60 Ft. Candles Investment: $1749.33 ----(3) Operation per year: 1200 Hours Cost = 0.083 x 6.56 x 1200 = 653.37 $/year ---(4)	= (1) - (4) = 2591.51 $/year
Mercury: 206 Fixtures 400 Watt each 82.4 kW 2500 Ft. Candles 1200 hour/year Cost = 0.083 x 82.4 x 1200 = 8207.04 $/year ----(2)	206 Fixtures 40 Watt each Fluorescent 8.24 kW 2500 Ft. Candles Investment: $1030 ------(5) Operation per year: 1200 Hours Cost = 0.083 x 8.24 x 1200 = 820.70 $/year ---(6)	= (2) - (6) = 7386.34 $/year
Total Cost (Existing system): = (1) + (2) = 11473.92 $/year	Total Investment: (3) + (5) = $ Total Cost (Proposed system): = (4) + (6) =1474.07 $	Total : = 9977.85 $/year = 120215.06 kWH/year
Payback = Total Investment/total cost savings x 12 = 2779.33 / 9977.85 x 12 = 3.34 Months Return of investment (ROI) = 1/ payback =27.85% per month		

Total Investment cost: The average cost of fluorescent fixtures was 5 $/fixture (2016 market price). For 328, 20W fixtures, the total investment would be $1748.33. Similarly the investment for 204, 40W fluorescent fixtures was found to be $1030. Thus the total investment required is $1474.07. Using this data the payback period and ROI is computed and given in Table 5

D: Use Gas Heaters instead of Electric heaters:

The existing system at GBL consists of 30 heaters The total energy cost (assuming an operation of 8 hours/day for five winter months i.e. 1200 hours/year and avg. rate of 0.083 $/kWH) is computed as 5930 $. Since the industry uses a large amount of natural gas energy, it was proposed to replace the 30 electric heaters with 30 gas heaters each consuming 9 cft./hr. The energy consumption of gas heaters will then become 324 MCF per year. The corresponding yearly cost is given in Table 7.

Total Cost savings: From Table 6, the total cost savings by replacing the electric heaters with gas heaters is equal to 5076 $/year.

Total Investment cost: Price of one gas heater (consuming 9 cft / hour) including installation charges was $60 (2016 market price). Thus the total investment cost was $1800. The Payback period and ROI is given in Table 6.

Table 6
Energy conservation opportunities with heaters

Existing System	Proposed System	Savings
30 Electric Heaters: 60 kW Assume 1200 hours operation per year Consume:72000 kWh/year @0.083 $/kWH Cost/year = 5930 $/year ---- (1)	30 Gas Heaters : Gas energy consumption : 9 Cft /year/heater Total Gas consumption: 9x30x1200 = 324 MCF/year @2.63 $/MCF Cost/year = 852 $/year ---- (2) Initial Investment: 60 x 30 = $ 1830	(1) - (2) 5078 $/year = 61656.14 kWH/year
Payback = Total investment/total Cost Saving x 12 = 1830 x 12 /5078 = 4.32 Months Return on Investment (ROI) = 1/payback = 23.15% per Month		

E:Running of Parallel Cable:

Findings: Two Aluminum Armored, 3 core, 1.1 KV,335 A, 400 square mm, 0.0915 resistance/core/km, PVC Underground cables are running from the sub-station; one cable of length 100 meter to Air conditioning control panel and another of 75 meter to the Departmental over-head bus bars. Considering the reliability of supply and the magnitude of cable power losses, it is not advisable to go for a single cable feeding system to essential floors.

Recommendations: The EC recommended, as one of the energy conservation measures, to run a similar cable in parallel with the existing one. Since the existing cables were found to be in sound working conditions, it was decided to retain the cable as it was. Instructions were given to mark the changes in the Blue print for future reference.

Benefits: Total length of both existing cables was 175 m. Total resistance of the cable, 3 × 0.0915× 175/1000 = 0.0480375 Ω For a load current of 300 A, the cable power losses for a total load current of 300 A was worked out as: $I^2R = 300^2 \times 0.0480375$ = 4.3234 KW. Assuming 8000 hours of operation/year, the energy loss in the cables was 8000 × 4.3234 = 34 587 kWh.

For parallel cables:

Assuming equal load sharing, the current in each cable is 300/2 = 150 A. The power loss in each cable is $150^2 \times 0.0480375$ = 1.0808 KW. Total power loss for both cables is 2 × 1.0808 = 2.1616 KW and total energy loss is 17 293 kWh.

Saving in energy loss/year is (34 587 -17 293) kWh = 17 294 kWh (50%saving as expected). Annual saving in energy cost due to parallel cables@$0.0875/kWh = $1513.23. Cost of 3×400 square mm cable per meter length =$20.

Expenditure on additional 175 m cable $20 ×175= $3500. Labor on running additional cable is $140, and hence total expenditure on running additional cable is $3640.
Payback period = (3640/1513.23) ×12 =28.87 say 29 months.
Return on investment 1/29 = 3.45% per month.

4. CONCLUSIONS

The analysis and calculation of electrical energy conservation of the glass sheet industry for a developing country were carried out, even though the amount of the electrical energy used was low (42.62%) compared to the gas energy (57.38%) provided to the said industry, remarkable energy cost savings were demonstrated . Adapting and following the electrical energy conservation guidelines are recommended for a developing country i.e glass industry. These recommendations if applied to any similar industry in other developing countries may also lead to very reasonable cost savings. Having listed all the different remedies which should be taken to have electrical energy conservation, the implementation and the application of these recommendations is very crucial in the glass industry of developing countries to reach the desired cost savings. Focus should be directed to the demand side management, and the use advanced electronic programmable switching for achieving the desired savings. Gas heat energy is a potential savings even though its cost is less than fossil oils. A developing country which does not possess these raw materials may face higher energy prices in this sector. Therefore, instead, a complete updating, maintenance and the use of energy efficient equipment may reduce energy costs. The limited capital and investment becomes an obstacle for applying a comprehensive conservation plan in developing countries. Therefore partial solutions if followed may give pronounce energy cost savings. Generally, in a developing country, capital, raw material and the lack of advanced technology equipment are of a direct relationship to energy cost savings.

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