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ENERGY AUDIT IN CEMENT INDUSTRY

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ABSTRACT

The energy cost plays a major role in production cost of the cement, so both electrical and thermal energy conservation study is carried out in a cement industry (located in Tamilnadu, India). The conservation is concluded in three ways, effective use of electrical equipment, effective and change in operation of existing operational equipment without investment, change of the existing equipment with latest technical up gradation (state-of-the-art) system equipment with investment. Historical data regarding Specific Energy Consumption (SEC) for ten years were collected for sections such as crusher, raw mill, cement mill, kiln packing house etc. Except for crusher and packing house section the SEC values were above the norms. From the energy study 16 numbers of Energy Conservation Opportunities (ECO) amounting to a net saving in SEC 14 kWh / ton of clinker (11.67%) was identified. On successful implementation of the suggestions given for each ECO's, there will be net saving of 473958 kWh/month and the reduction in monthly bill by Rs. 20.14 lakhs(Indian). Out of the net saving (14 kWh / ton of clinker), 9.56 kWh/ton of clinker (7.97 %)can be realized without any major investment. The monthly energy savings will be 323645 kWh and reduction in monthly bill will be Rs 13.75 lakhs. Eco's, which are investment oriented, contribute to the remaining portion of saving i.e. 4.44 kWh/ton of clinker (3.7%) the monthly energy saving will be 150312 kWh and the reduction in monthly energy bill will be Rs 6.388 lakhs. The total investment required to implement the proposal will be Rs 103.96 lakhs, which gives an over all pay back period of 16.3 months.

Keywords: Energy Conservation Opportunities (ECO), Specific Energy Consumption (SEC)

1. INTRODUCTION

Energy is present in nature in various forms. The various forms of energy used by mankind for different purposes consist of lighting, heating, running machinery, transportation and for other applications. In short, energy has therefore applications in different spheres of activities such as domestic, Industrial, Agricultural, Commercial & transportation.

Energy should be efficiently utilized in order to ensure that for a given amount of energy maximum activities, productive work and profitability is achieved. It is thus slightly different from the word **'saving'** which may in strict sense, mean avoiding spending or consumption or suppression of demand. While the word conservation appropriately denotes efficient, economical and careful use of energy**.**

The availability of commercial sources of energy such as oil, coal and gas with in our country (India) are rapidly dwindling and the supply of them has to be supplemented by imports. The cost of importing them is very high and steeply increasing, which will drain the foreign exchange reserves of the country. It has been established that the gap between our future demand and supply of energy is bound to increase in industrialization of the country.

The estimated availability of domestic resources of commercial energy against present demands will create considerable gap in supply especially for oil and gas unless imports are resorted to supplement the domestic supply. Thus the known commercial energy resources will

- Last for limited time only, at present rates of consumption.
- Last for much lesser periods at the increased anticipated consumption rates, which is Necessary to sustain present economic growth.
- Entertains huge imports to fill in the supply demand of valuable foreign exchange to the nation.

Hence alternate sources of energy need to be explored.

There are only few alternatives left which would find public acceptance. Alternatives such as creating new thermal power plants, mining of more coal and tapping of more gas reserves will deplete the present availability very much faster, apart from their contribution to environmental effects and increased pollution. Production of more power through hydel stations will depend on vagaries of rain fall and will also cause detrimental effects to environment such as denudation of forests, dislocation of wild life, villages etc. The alternatives of increased use of wood only cause faster deforestation and consequent environmental degradation. The use of solar and wind energies are yet prove commercially viable except probably in isolated places or in large organization where such capital-intensive appliances are affordable. Energy for rural areas from bio-gas offers considerable scope but cannot be carefully produced in large quantities for distribution to a large segment of consumers. Production of Nuclear Energy is a subject of strong public dispute and will need public acceptance before setting up of large nuclear stations.

Conserving Energy in Comparison to the above alternatives has many advantages. It is the cheapest and yet most pragmatic of the alternatives. Some conservation methods do not cost any thing at all as we will see subsequently. It is environmentally a clean alternative which ensures that environment-degrading Smoke, gases, effluents and so on are minimized due to better use of raw material, Equipment and other sources of energy.

Many Western nations through early resource conservation schemes, drastically reduced their energy consumption per unit of production and many of them have achieved a reduction in Specific Energy Consumption (SEC) of 20 % to 30 % during the period 1975-85, While ensuring a steady industrial and economic growth, in India, it has been different scenario. During the same period our SEC has increased by similar amounts mainly due to the following.

- Lack of awareness for conservation.
- Unbridled production increases, with scant regard to proper resource utilization and productivity ideals.
- Continued use of old and inefficient plants, machinery and process technologies.
- Recourse to short-term measures such as having captive generation of power etc.
- Lack of motivational aspects, incentives and legislative polices for promoting reduced energy consumption.

Table 1.1 shows the energy consumption norms in selected industries as compared to prevailing abroad norms in the corresponding energy intensive industries. The table 1.1 shows that our energy consumption is 50% to 100% more than that of other countries. (Except in the case of fertilizer industry) This shows the vast potential that exists in India for more economic and efficient use of energy.

Table 1.1 Energy consumption in selected industries (GCal/tone.)

Country	Steel	Cement	Aluminum	Pulp & Paper	Fertilizer	Textiles
INDIA	9.50	2.00	33.00	11.13	11.25	22.40
ITALY	4.63	0.89	-	-	9.82	-
JAPAN	4.18	0.89	16.90	-	-	-
SWEDEN	5.02	1.4	16.50	7.56	-	-
UK	6.07	1.3	21.10	7.62	11.23	-
USA	6.06	0.95	9.50	9.70	11.32	12.1
W GERMANY	5.21	0.82	4.90	-	-	-

2.CONSERVING ENERGY:

Conserving energy is a national need where in every individual at whatever level-can participate. Energy conservation can be practice by school children, house wives, farmers, factory workers in fact, any adult or child in their respective share of work or leisure life. One can save 10 - 30 % of energy and cost through simple action. Energy conservation can be attempted through three levels of implementation based mainly on the capital investment required and efforts needed as under.

2.1 No cost or low cost methods:

There are actions, which need the least effort, and many such actions are generally termed as ‘good house keeping’. Actions such as switching off lights and other appliances when not actually needed, Use of natural light, Good operations/maintenance practices to prevent losses of heat and energy through leakage etc. will come under this categories. These actions will not take long time to implement but could conserve energy from 5 to 10 % with practically no investment at all.

2.2 Medium cost methods:

These would normally cover simple modifications to existing equipment such as efficiency improving ballast replacement of inefficient lighting fixtures with more efficient fixtures, capacitors or other control mechanisms. Use of efficient burners, more effective insulation materials etc. Such actions would contribute a further consumption of 10 % to 15% in addition, but would involve nominal expenditure which may establishments be able to easily afford.

2.3 Capital intensive or high cost methods:

These methods would involve substantial investment of money in partially or wholly adapting new and efficient accessories to existing plant and machinery. These methods generally form part of long range planning and would additionally contribute to another 10 % to 15 % of energy conservation. In most of the cases, money spent would be recovered in what is called as pay back period (2 to 3 years) after which all savings would add into direct profits of the organization.

3 ENERGY CONSERVATION STUDY IN CEMENT INDUSTRY.

To conserve energy in cement industry a detailed study is conducted in TANCEN, Tamil nadu, India.

3.1 Energy conservation by effective use of electrical equipment's

In this cement factory nearly 30 electrical drives are running below 50% of the rated loading. In some places the usage of the electrical motors are above that of the required capacity. The electrical drives less than 50 % of loading can be used in star drive instead of delta drive. The details of the above observations are given below.

3.1.1 Electrical motors:

Electrical motor drives account for about 75 % of electricity used in industry 90 % of electrical motors used in industry are squirrel-cage induction motors, DC motors, slip ring motors account for the remaining 10 %.

Before 1973, Motors manufacturers concentrated on optimizing the use of materials, especially copper and iron. Improvements of performance parameters like efficiency and power factor were secondary imposture. Many time's performance was sacrificed to reduce material cost. After 1973 energy crisis, the emphasis is on improving performance. Energy saving opportunities can be summarized as follows.

- Selection of motors properly matched with load.
- Minimizing idle running, Maintenance & Rewinding.
- Efficiency of driven equipment's.
- High efficiency motors.

For selection of motor ascertain the total cost and cycle cost. Running cost of the motor in just one year is many times its purchase cost with electric motor life 10/ 15 years first cost is negligible portion of the total cost. The widely prevalent practice of purchasing motors by comparing the initial cost has little justification now.

Table 3.1:life cost of motors

MOTOR RATING	7.5 kW	15 kW	37 kW
Efficiency	86	89	91
Input kW	8.72	16.85	40.65
kWh Consumption	52325	101123	243956
per annum (6000 run			
hours)	156975	303369	731868
Running cost/annum			
@Rs. 4.25/kWh	156975	303369	3033690
Running cost for 10	0	0	
years			
Initial capital cost			92500
Capital cost at	18000	39000	1.264%
percentage	1.146%	1.295%	
Of running cost.			

It is possible to select motors with highest available efficiency, power factor can be corrected by the external means but efficiency can not be corrected by external means. There are wide variation in efficiency for standard motors and it is worth while to collect performance data from different manufacturers and select a motor with good performance. Many times motors come as integral part of machinery like machine tools, compressors, ring frames, paper machines etc. In such cases motors selection must be discussed with machine manufacturer. If after installation and operation it is found that change in motor is economical, one should not hesitate to do so.

Motor power factor varies depending upon the load on the motor and is very low at no load and may increase to 0.8 or higher at full load and no load current may be 30 to 40 % of the full load current.

3.1.2 Motor and load matching:

Extensive study conducted Electrical Engineers show that a large motors (>50 %) work at loads less than 50 %. In most of the cases this is due to large factor of safety or lack of knowledge of actual operation loads. Over sized motors loads to following penalties**.**

- Low efficiency and higher power consumption.
- Poor PF higher maximum demand and distribution losses.
- Higher first cost for motor and control gear.
- Higher installation cost and larger space requirement.
- Higher rewinding cost.

Table 3.2: Load matching of motors

MOTOR LOAD	3.7 KW	3.7 KW	3.7 KW
MOTOR RATING	3.7 KW	7.5 KW	18.5 KW
% LOAD	100 %	50 %	20 %
EFFICIENCY	83 %	83 %	77 %
KW INPUT	4.45	4.45	4.8
KWh for 6000 hrs /annum	26746	26746	28832
POWER FACTOR	0.8	0.65	0.5
KVA INPUT	5.57	6.85	9.6

3.1.3 Use of over sized motors

For most industrial facilities, it is essential to carryout a motor load surveys and prepare a list with proper rating. A general replacement program can be taken up by inter changing of motors. Similarly when a motor burns out, replacement by properly sized motors should be considered. It will be cheaper for lightly loaded motors, Energy saving starters and star connection offer other opportunities.

It is worthwhile stopping motors when running idle. In most Industrial plants, there are many situation machine tools are not stopped in recess or other periods. When there is rework conveyor continues to run without load. Auxiliaries like exhaust fans, cooling tower fans, pumps continue to run when many process machines have stopped or running at lower loads. A careful study and training of operators can lead to significant savings. Safety and quality should not be sacrificed but there is not justification for wasteful running.

Regular maintenance of motors will keep the bearing in good condition and it will keep cooling passages clean, leading to good airflow and proper heat dissipation. Motors are cleaned in every shift in cement industries. In some factories, they are not cleaned at all. Poor ventilation can increase the winding temperature and lead to higher copper losses. Overhauling of machine rolls, ring frames etc., leads to as much as 5 to 10% reduction in consumption.

Rewinding of motors normally lead to deterioration in motor efficiency. Rewinding can lead to increase iron losses due to damage of stamping insulation that leads to heating of stator while running. Rewinding with small wire-size will also lead to loss of efficiency. When slot space is available putting more copper by increasing the wire gauge will improve the efficiency. When motor are oversized opportunity should be taken for replacement of new motors rather than rewinding older motors.

3.1.3 High efficiency motors

After 1973 energy crisis, considerable attention has been focused on improving motor efficiency. Most manufacturers now offer a line of high efficiency motor with price premium of 30% to 50%. In India also, these are available main features of high efficiency motors are

- More copper / Aluminum in stator and rotor to reduce core losses.
- Improved quality of stampings to reduce iron losses.
- Improved design of fans and ventilation circuits.
- Improved Electromagnetic design and manufacturing methods to reduce stray losses**.**

BIS (Bureau of Indian Standards) has brought out IS-12615 of 1990 on energy efficient motors.

3.1.4 Energy saving by star delta change over

For delta-connected motors running at light load, connection in the star reduces the motor voltage and saves energy. The scheme is explained with the help of performance curves of a 3.7 KW 4 pole motor. The principles developed are applicable to motors of any capacity. The performance curve of a 3.7 KW 4 pole motor with delta star change over is as shown in fig 3.1, where the abscissa shows per unit output i.e. ratio of given output to the rated 3.7 KW, ordinate represents efficiency per unit current.

The motor is a normally Delta connected one, the performance curve of delta and star connection is as shown in the fig 3.1. If a vertical line is drawn at point of intersection of these performance curves. The zone left of this line represents star zone and towards right represents the is the Delta zone. It is clear from the fig 3.1 that is star zone; the star connection has better performance than delta connection. Therefore for a given load the motor if per unit output is in star zone then the motor should connect to star. The following feature may be noted.

- Efficiency in star connection is higher than that in delta connection up to 48 % of full load. Difference in Efficiency is significant (10% to 20 %) up to 30% load.
- Current is significantly lower in star connection up to 50% of full load. At no load, current less than 50 % of value of delta connection, Distribution also thus would be less.
- Power Factor is also significantly higher in star connection compared to delta connections.
- RPM in star connection is marginally lower than RPM in delta connection. This mean that output of equipment like fans and pump Continued use of old and inefficient plants, machinery and process technologies pf will be lower.

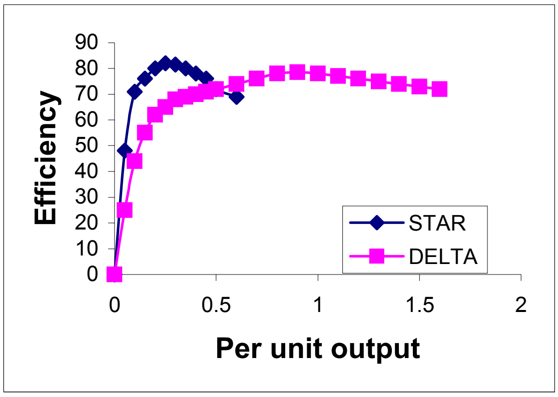

Fig 3.1 Performance curve for 3.7 kW, 4 pole motor with star delta change over.

3.1.5 energy saving by micro processor controllers

By reducing terminal voltage at a motor under part load, it is possible to reduce the magnetic core losses and copper winding losses there by increasing the over all efficiency.

- The controller is a microprocessor controlled thrister based system, which has Phase-Control to vary the motor terminal values in, responds to changes in loading on the motor. It is also ensures sudden heavy loads transients are handled without noticeable slowing of motor.
- Increasing motor efficiency Below 50 % of full load, when motor efficiency falls off, The controllers Improves efficiency, giving energy savings up to 40 %, at Very light load. Over all savings depends on the proportion of time spent at loads below 50 % loading will not show any savings.
- Soft starting By progressively ramping up the voltage, a motor may be started smoothly to reduce starting current to a value typically 2.5 times the direct on line value and to avoid mechanical shock to the drive mechanisms and load The ramp starting line is adjustable from 1/2 to 60 sec.
- Power Factor and Supply Current Improvements: The over all power factors at light loads is much improved without affecting the full load value. Supply current demand is reduced progressively towards zero load and is typically one third of the uncontrolled value at very light loads, Full load current is unaffected.

3.2. Efficiency of drive transmission:

Direct drive is the best option where belt drives are used. Modern flat-belt with synthetic material can give transmissions as high as 97-98%. This is to be compared with 90-92% of conventional V-belts.

3.2.1Gear drives:

Efficiency of spur gear and bevel gearing for high speed gearing can be 99% and for slow speed gear about 96% on an average of 97-98%. Efficiency is normal as in shown in table 3.3. In helical gear friction is much greater due to considerable transverse sliding motion.

Table 3.3: Efficiency of drive transmission

TYPE	METHOD OF Mfr.	%
Spur gear	Cast teeth Cut teeth	93 96
Bevel gear	Cast teeth Cut teeth	92 95
Worm gear	For thread angle 30o For thread angle 15o	85-95 75-90

3.2.2 Efficiency of various gear drives:

Efficiency of integral HIGH POWER motors are always in the range of 80 % and above, Efficiency of driven equipment's like pumps and fans can be appreciably lower. Also pumps are designed to operate maximum efficiency at certain head flow condition. Operation at other condition will lead to significant drops in efficiency. In view of this much more care needs to be taken in improving efficiency of driven equipment. Better design of fans has lead to drop power consumption by 30 %. Trimming of impellers, change in number of stages lead to significant reduction in power consumption. Similarly proper size of distribution lines, stoppage of air leakage etc. can lead to significant reduction in power consumption of compressor motors.

4. ENERGY CONSERVATION IN RAW MIX SILO FEED AIR LIFT BLOWERS:

4.1Existing system:

At present there are totally 4 nos. of airlift blowers for conveying finished product from the Raw mill to raw mix silo. Out of these one is used as standby and the remaining three used to lift raw mix. The capacity of each blowers is 74.33 m^3/min. (Pr. 0.6 Kg/sq,cm) with a motor rating of 110 kW . The power consumption in the silo feed airlift blower is around 75 kW. Thus the total power consumption in the silo feed airlift blower is 225 kW, which is works out to 2.25 kW/Ton of raw mix.

The conveying rate of raw mix is typically around 100 TPH. When three blowers are running, the total air flow rate will be 17 TPH and the material loading (weight of material to weight of air) works out only 5.87 Ton of materials per ton of air. This is very low material loading for pulverized limestone (lean phase) , For which material loading of up to 17 Tons/Ton of air can be employed. The lower the material loading, the higher the requirement of air quantity and power for pneumatic conveying.

4.2 Suggestion for modification:

Since 2 nos. of blowers itself will satisfy the requirement, author suggest to run only 2 nos. of blowers for the above application. By this, the material loading will be increased to 8.81 ton of material per ton of air and 75 kW of power can be saved by stopping of one blower in service.

4.3 Energy conservation in sizing of rawmill TAS (Turbo Air Separator) drive:

Existing system**:** Previously the rawmill TAS was driven by 250 KW motor. It has been changed to 200 KW LT drive motor. Presently the power consumption is around 100 to 110 KW.

4. 4 Suggestion for modification:

As per the motor characteristics curves, any motor will be running at maximum efficiency near its maximum load. More over at lower loads the power factor also reduces. It is observed that loading is 50 to 55 % and the power factor is 0.85. It is suggested to replace the existing with lower rated high efficiency motor rating 110 KW.

Table 4.1 Investment, savings and payback prior.

Investment	1.98 Lakh Rupees.
Saving in energy SEC	0.415 kWh/Ton of clinker
Annul saving in energy	168593 kW h
Saving in energy cost per annum	7.17 Lakh Rupees
Payback period.	3.31 months.

5.Energy conservation in sizing of cement mill TAS drive:

5.1 Existing system:

The cement mill TAS is being driven by a constant speed slip ring motor (1 number) and variable speed DC motor (1 number). The 250 kW HT motor has been replaced by 200 KW LT slip ring motor. The power consumption is around 100 to 110 kW.

5.2 Suggestion for modification:

Motor operation at lower loads (below 50 % load) is uneconomical, and maximum efficiency can be obtained above 60 % of full load. By operating the motor at its optimum load, even the power factor increase slightly. Presently the motor is loaded 51 %. It is suggested to replace the existing motor with 110 kW energy efficient motor.

Table 5.1 Investment, savings and payback period.

Investment	1.98 Lakh Rupees.
Saving in energy SEC	0.3325 KWh/Ton of clinker
Annul saving in energy	135078 KWh
Saving in energy cost per annum	5.74 Lakh Rupees
Payback period.	4.138 months

6. Energy conservation by replacement of kiln feed air lift by bucket elevator:

6.1Existing system:

At present pneumatic conveying (airlift) is used to feeding the raw meal to KILN I & KILN II. Two numbers of air blowers are used for airlift of each of the Kilns.

6.2 Suggestion for modification:

It is suggested to install bucket elevators in the place of the airlift. It is well proven technology that material conveying is energy efficient as compared to pneumatic conveying. By this modification, 75 % of the present power consumption can be saved.

The existing system of airlift can be kept as stand by and can be used during maintenance / repairs of bucket elevator without affecting production.

The specific power consumption of air lift blower as 1.225 (Kiln I) and 1.233 (Kiln II) KW/Ton of clinker.

Table6.1 Investment, savings and payback period.

	KILN I	KILN II
Investment	25 Lakh Rs	25 Lakh Rs
Saving in energy SEC	0.919	0.925 KWh/ Ton of clinker
Annul saving in energy	186671	187890 KWh
Saving in energy cost per annum	7.933	7.985 Lakh Rupees
Payback period.	3 year &2 months,	3 year & 2 months

7. Energy conservation by replacement of silo feed air lift by bucket elevator:

7.1Existing system:

At present pneumatic conveying (airlift) is used to feeding the raw meal To Raw meal silo. Three numbers of air blowers are used for airlift for the Silo feed.

7.2 Suggestion for modification:

It is suggested to install bucket elevators in the place of the airlift. It is well proven technology that material conveying is energy efficient as compared to pneumatic conveying by this modification 75 % of the present power consumption can be saved.

The existing system of airlift can be kept as stand by and can be used during maintenance / repairs of bucket elevator without affecting production.

The specific power consumption of airlift blower is 3.963 (Kiln II) KW/Ton of clinker.

Table 7.1 Investment, savings and payback period.

Investment	50 Lakh Rs
Saving in specific energy consumption	2.772 KWh/Ton of clinker
Saving in energy per annum	1126125 KWh
Saving in energy cost per annum	47.86 lakh Rupees
Payback period.	1 year & 1 month.

8.Conclusions:

From the above energy study in cement industry the following points are concluded.

- Over sized motors can be replaced by new energy efficient motors.
- Motor running under 50 % of rated load is operated by star connection instead of delta connection
- Replace air lift system (pneumatic system) by bucket elevators.

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