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MITIGATING GLOBAL WARMING THROUGH ENERGY OPTIMIZATION IN INDUSTRIAL DRIVES: THE SANJIVANI SUGAR FACTORY APPROACH

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Abstract: India's growing demand for electricity presents an acute problem for its power sector. Employing energy-efficient devices, including electric motors, could be a better alternative for meeting part of this demand. This paper examines the use of energy-efficient motors instead of standard induction motors in the agricultural and industrial sectors, which may result in substantial savings in electrical energy. The study analyzes the use of additional energy in different norms in a cycle plant and the utilization of energy-efficient motors over standard induction motors, considering factors such as motor input power, energy consumed, apparent power, power factor, and efficiency. The paper presents a comparison of motor running costs via life cycle analysis, demonstrating the importance of efficiency in achieving significant cost savings. The design of an energy-efficient motor and factors that impact its efficiency, such as harmonics, load variation, and environmental conditions, are discussed. Finally, the paper calculates the payback period for using energy-efficient motors at the Sanjivani sugar factory and concludes that replacing conventional motors with energy-efficient motors can lead to substantial energy savings and cost reductions.

Keywords: Motor losses, rewinding, payback period, energy-efficient motor, harmonics, energy crunch, induction motor, efficiency.

Introduction:

India's electricity demand is growing, and its power sector is struggling to meet this demand. Power generation and consumption are significantly influenced by industrial use, with electric motors being essential components of various industries. Electric motors consume a significant amount of power in the country, and the use of energy-efficient motors can lead to energy conservation and cost reduction. The need for energy-efficient motor technology has never been more critical, as it can help mitigate global warming and optimize energy consumption. This paper examines the energy optimization of industrial drives at the Sanjivani sugar factory, emphasizing the replacement of conventional electric motors with energy-efficient motors. The study analyzes the energy consumption of different types of electric motors and examines the impact of harmonics, load variation, and environmental conditions on motor efficiency. The paper calculates the payback period for using energy-efficient motors and compares the running costs of energy-efficient motors and conventional motors via life cycle analysis. The paper concludes that replacing conventional motors with energy-efficient motors can lead to substantial energy savings and cost reductions.

2. Energy Efficient Motor

The motivation behind energy effective motors is to have the option to supply a similar degree of energy administration just utilizing less energy. Effective energy use is accomplished principally through a more proficient innovation or interaction instead of by change in individual conduct. Energy preservation diminish the energy utilization. Additionally, the energy productive motors use worked on motor plan and great materials to decrease motor misfortunes, in this way working on motor efficiency. Performance of EEM is better than STM under full, partial and no-load conditions. Due to higher efficiency, EEM not only save energy in their own and contribute to reduced demand but also energy in the cables and transformer that supply the motor.

Energy efficient motor runs cooler. As thermal stresses are low, cooling requirements are low. EEM orientation runs about 10ºC cooler than STM bearing. This duplicates the protection life. EEM windings run 20ºc cooler which expands protection life by multiple times. As EEM have lower losses, their slip is smaller than the standard motor. This small slip causes them to have lower starting torque than the standard motor. Produces a similar shaft yield yet utilizes less input power than a standard efficiency motor is a tradeoff between efficiency perseverance, beginning force and starting expense with solid accentuation on introductory expense standard motor for the most part finishes on costs, not efficiency not cost. There are generally three stage acceptance motors are utilized in industry.

3. Type of Induction Motors

3.1 Squirrel cages induction motor: Squirrel cage induction motor is including various slim bars, typically aluminum mounted in a covered chamber in rotor the bars are organized evenly and generally corresponding to rotor shaft. Toward finish of rotor bars be situated associated along using shorting ring.

3.2 Phase wound or slip ring IM: Slip ring induction motor is kind of IM in which slips ring are associated with rotor twisting and, in the motor, there is additionally a copper wire winding is place instead of copper bars staring force of slip rung motor can be expanded by embedding outer opposition in rotor circuit.

Fig. 1. A picture of actual induction motor for which calculation done

It is worthwhile that a motor rating survey is carried out in Sanjivani Sugar Factory and Fig. 1 shows an image of authentic induction motor for which payback period calculation was done out of total 28 motors. The following methodology can be adopted.

- Select important motors by size and long running hours. Initially, ignore small motors (below 3.7 kW) as well as those running for few hours (less than 3000 hours/annum).
- Measure normal running current and input power. Kindly note that even on no load, motors take

- 30% to 40% of the rated current. Hence percentage motor load is not given exactly by the ratio of motor input current to rated current.
- Identify motors with loads less than 40%, out of these again categories frequently rewound motors.
- Prepare a list of desired, properly sized motors for all important applications.
- Interchange by properly sized motors (available in the plant) whenever possible.
- After motor burnouts, instead of rewinding, replace with properly sized high efficiency motors The process of energy audit flowchart shown in the Fig. 2.

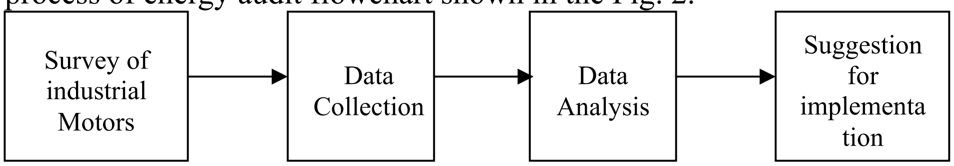

Fig.2. Energy Audit process flowchart

Table 1: Comparison of motor running cost life cycle costs

	Motor A	Motor B	Motor C	Motor D
Motor rating (kW)	7.5	7.5	37	37
Efficiency,p.u	0.86	0.88	0.92	0.93
Power input(kw)	8.72	8.52	40.22	39.78
Running hours/year	6000	6000	6000	6000
Energy input(kwh/year)	52320	51120	241320	238680
Running cost @Rs.5 per kwh	26,16,000	25,56,000	12,06,6000	11,93,400
Running cost for 10 years (Rs.)	26,16,000	25,56,000	12,066,000	11,93400
First cost (Rs.)	15000	18000	80000	96000
First cost as % of running cost for 10 years	0.6	0.7	0.8	0.9

Table 1 shows importance of motor running cost- life cycle costs by comparison of two motors, i.e. Motor A and Motor B having same rating. A small amount of difference in efficiency play a major role in running cost of motor for a particular period. Similarly, for Motor C and Motor D is having same rating but running cost affects due to slight change in efficiency of the motor. The law of diminishing returns suggests that even a good thing can be overdone, properly applied, life-cycle cost analysis (LCCA) is a decision support tools that will lead to appropriate energy project choices. In many applications it is worthwhile replacing motors even when considerable working life remains. Motors can run without problems for 20 years or more with good protection and routine maintenance. However, if they are running inefficiently, it is worthwhile replacing them as running costs are much more than first costs. Motors can be considered as consumable items and not capital items, considering the current energy prices.

4. Rewinding of A Standard Motor

When the motor winding burns due to overheating old winding is stripped out and replaced with a new one this rewinding is very common which often leads to poor performance and deterioration of efficiency in case of a standard motor for this there are number of reasons which are as follows.

- Every slight damage of core or insulation between the stamping may result into increased losses.
- Overheating prior to rewinding might change the characteristics of stator core which may result in increase in iron losses.
- In addition, if better insulation is not provided or if proper procedure is not followed degradation takes place which is often overloaded so as to minimum the cost but that result into high running charges.

- Fitting of all-inclusive cooling fans, which may possibly nor intend aimed at specific motor, prompts increment in windage misfortunes.

5. Efficiency of EEM

An Energy Efficient Motor (EEM) creates a similar shaft yield power, however utilizes a smaller amount input power than a standard efficiency motor. Energy proficient motors smear less power & preceding more than NEMA motors of a similar size.

$$\text{EFFICIENCY} = \frac{\text{MECHANICAL POWER OUTPUT}}{\text{ELECTRICAL POWER INPUT}}$$

Motor productivity is a factor of an assortment of mechanical and electrical defects inside the engine. Whatever input power supplied to the motor or is not converted to output due to the losses taking places in the motor as.

Stator copper loss	40%
Rotor copper loss	20%
Iron loss	25%
Friction and windage loss	10%
Stray loss	5%

5.1 Factor Effecting Motor Efficiency:

A. Effect of harmonics on motor efficiency -

Harmonics are distortions in voltage and current waveform which impact greatly on the efficiency of a motor. With the development in power electronics, impact of harmonics in the industrial loads has been significant. These are harmonics are nonlinear in nature and as such, on-sinusoidal currents are drawn by motors.

B. Effect efficiency and the environment -

Currently, there is a growing concern of global warming which has driven passion towards designing machines with capacity to conserve the environment. With an improvement in energy efficiency conversion, dangerous gases such as CO2 would be reduced drastically as more energy would be produced, this will also lead to large amount of energy saving

C. Motor efficiency variation with load -

Design specification requires that electric motor among 50 percentages to 100 percentage of valued load. Typically, maximum efficiency remains achieved close to 75 percentage of rated load efficiency of motor decreases below 50 percentage of rated load. Nevertheless, efficiency varies with type of motor. Motor appears to be overloaded, efficiency decreases.

6. Design of EEM

Design of EEM to involves addition of more active magnetic and conducting material, optimum design of slots, air gaps winding so as to achieve maximum efficiency points are considered.

1. Core losses
2. Friction and windage losses
3. Copper losses
4. Stray losses
5. Other design aspects

Design aspect air gap between stator and rotor is improved to decrease the magnetizing current and related losses these results addicted to improved power factor.

6.1 Data Analysis: In this project, the data of 25 electric motor are operating in industry have been collected. the data include motor rating, speed, efficiency, current and power factor. following table shows the data of operating motors in industries.

6.2 Data Collection: In this project data of 25 induction motors functioning in a process factory have been considered. Standard induction motor operating in sanjivani sugar factory is ancient in addition to have deprived efficiency. The functioning time for motor is 24hr every day. because of low force factor and high misfortunes, a standard acceptance motor devours more energy. The absolute heap of 8 standard acceptance motor is 597kw, so to decrease industry load and for energy preservation we use energy productive motors. the functioning days are viewed as 300 days. The data were calculated for 25 motors and shown in the table 2.

Table 2: Data collection of 25 motors

Sr. No	RPM	KW	HP	Mounting	Efficiency	Current	Voltage	Frequency	Frame Size	Amb	Ins. class	Location	Company
1	1485	110	150	Foot mounted	94.50%	240	415±10	50 Hz	ND-315S	50ºC	F	Mill section crane carrier	NGEF
2	992	400	550	Foot mounted	93.50%	728	415±10	50 Hz	SCXF100X V-T	50ºC	F	Mill section crane carrier	Kirloskar
3	2955	30	40	Flange mounded	91%	50	415±10	50 Hz	SC200L	50ºC	F	Boiler section	Kirloskar
4	2955	200	270	Foot mounted	91%	323	415	50 Hz	315L	50ºC	F	Boiler section	Kirloskar
5	2825	15	20	Foot mounted	90.30%	27	415±10	50 Hz	ND160M	50ºC	F	Centrifugal section	Siemens
6	960	18	25	Foot mounted	85%	32	415±10	50 Hz	SR1808	50ºC	F	Centrifugal section	Apex
7	740	560	750	Foot mounted	86%	992	415	50 Hz	TPR500E	50ºC	F	Mill section	Kirloskar
8	1474	18.5	25	Foot mounted	91.50%	32	415±10	50 Hz	ND180M	50ºC	F	Rack carrier mill section	Crompton
9	1440	125	170	Foot mounted	94.80%	230	415	50 Hz	B160	50ºC	F	Raw juice pump mill section	Crompton
10	1200	525	700	Foot mounted		931	415	50 Hz	ILFC400L	50ºC	H	Sugar mill section	Kirloskar
11	1400	30	40	Foot mounted	83.58%	53	415	50 Hz	LD250S	50ºC	F	Boiling house	IEC
12	980	45	60	Foot mounted		73	415	50 Hz		50ºC	F	Boiling house	Kirloskar
13	1440	1.1	2	Foot mounted	86.50%	2.2	415	50 Hz	090LD	50ºC	F	Boiler section no.1	Kirloskar
14	1460	30	40	Foot mounted		53	415	50 Hz	LC180L	50ºC	F	Boiler section no.1	Kirloskar
15	1250	145	190	Flange mounted		353	415	50 Hz	ILFC280L	50ºC	F	Centrifugal section	Kirloskar
16	1440	3.7	5	Flange mounted	86%	7.5	415	50 Hz	ILFC280L	50ºC	F	Centrifugal section	IEC
17	1440	11	15	Flange mounted		21	415	50 Hz	ILFC280L	50ºC	F	Centrifugal section	Kirloskar
18	1445	3.7	5	Flange mounted	86%	7.5	415	50 Hz	112M	50ºC	F	Boiling house	Kirloskar
19	2980	160	215	Foot mounted		285	415	50 Hz	315L	50ºC	F	H.P boiler section	Kirloskar

20	1440	2.2	3	Foot mounted		3.7	415	50 Hz	KH100L	50ºC	F	H.P boiler section	Kirloskar
21	2935	22	30	Flange mounted		38	415	50 Hz	LDIBOLM K11	50ºC	F	H.P boiler section	Rimmi
22	1440	0.55	1	Flange mounted	83.50%	1.5	415	50 Hz	BN-71-B-4	50ºC	E	H.P boiler section	Bonfingoli
23	1410	5.5	7.5	Flange mounted	73%	11	415	50 Hz		50ºC	E	H.P boiler section	CG
24	1450	5.5	7.5	Foot mounted	73%	11	415	50 Hz	PM112M	50ºC	F	Mill section	CG
25	975	10	15	Foot mounted	88.70%	22	415	50 Hz	ND160L	50ºC	F	Mill section	Crompton

7. Payback Period

Payback period calculation for EEM may be carried out for three different cases shown in the table 3. Annual energy saving due to EEM is given by

Simple Payback for new motor purchase or repair versus replace scenario, years

= Price premium – Utility rebate

Total annual cost savings

Simple payback period for replacing an operating motor, years

= Fresh motor cost + installation charge – utility rebate

Total annual cost savings

Annual energy saving in rs,

$$= KW * P * H[\frac{100}{E2} - \frac{100}{E1}]$$

saving in demand charges

$$kW * P * H \left[\frac{100}{E2 * P.F} - \frac{100}{E1 * P.F}\right] * RS/KVA$$

E1, E2 = Efficiency of EEM and STM

KW = Motor rating

P = rate of energy Rs/kwh

H = On. Of motor operating hours per year

$$\text{Payback period} = \frac{extracostofEEM}{totalsaving}$$

For replacement of STM by EEM payback period may vary from 2 to 4 years.

Sample Payback Period Calculations

1. kW consumption for existing motor=110*100/94.50 = 116.4021164
2. kW consumption for IE4 motor=110*100/96.30 = 114.22633759
3. Saving in Kw consumption=116.4021164-114.22633759 = 2.175405
4. Saving in kw-hr (considering 300 day &24 hr consumption)
5. Energy consumption of existing motor=110*24*300/0.9450 = 838095.2381
6. Energy consumption for IE4=110*24*300/0.9630 = 822429.90
7. Saving in kw-hr=838095.23-822429.90 =15665.33
8. Saving in INR considering INR 8 per kw-hr = 8*15665 = 12322Rs.
9. Invest for IE4 motors =Rs.523368
10. Payback period =523368/12322 = **4.2 years**

Table 3: Payback Period Calculations of Motors

Sr No	Rpm	Rating (kw)	Efficiency	Frame Size	ABB Frame	IE4 Efficiency	Kw consumption for Existing motor	Kw consumption for IE4 motor	Saving in kw consumption	Saving Kw hrs. (considering 300 day for 24hr.per day)	Saving in INR Considering INR 8 per Kw-hr per year	Invest for IE4 mot or	Payback period(Yrs.)
1	1485	110	94.50 %	ND-315S	M3BP315SMC4	96.30 %	116.402116	114.226376	2.17570449	15665	125323	523368	**4.2**
2	2955	30	91 %	SC200L	M2BAX200MLA2	94.50 %	32.967033	31.7460317	1.22100122	8791	70330	160720	**2.3**
3	2955	200	91 %	315L	M3BP315 MLB2	96.50 %	219.78022	207.253886	12.5263338	90190	721517	887490	**1.2**
4	1400	30	83.58 %	LD250S	M3BAX200MLA4	94.90%	35.8937545	31.6122234	4.28153109	30827	246616	147744	**0.6**
5	980	45	92.70 %		M3BP280SMB6	94.80%	48.5436893	47.4683544	1.07533489	7742	61939	381510	**6.2**
6	1460	30	92.30 %	LC180L	M2BAX200MLA4	94.90 %	32.5027086	31.6122234	0.89048517	6411	51292	147744	**2.9**
7	2980	160	94.80 %	315L	M3BP315 MLA2	96.30 %	168.776371	166.147456	2.62891544	18928	151426	779922	**5.2**
8	2935	22	91..30 %	LDIBOL MK11	M2BAX180MLA2	94.00%	24.0963855	23.4042553	0.69213022	4983	39867	106624	**2.7**

8. Results

In this project, the data of 27 electric motor are operating in industry have been collected, analysis and send for implementation. The one operating motor data is selected for analysis shown in table 4 which clearly shows improvement in efficiency 1.80 percentage increment for the same rating, speed and voltage.

Table 4: Data for one operating motors

Parameter	Standard Induction Motor	Energy Efficient Motor
RPM	1485	1485
Voltage	415	415
Efficiency	**94.50%**	**96.30%**
Kw(rating)	110	110
Frequency	50Hz	50Hz
Frame size/ ABB Frame	ND-3155	M3BP315SMC4

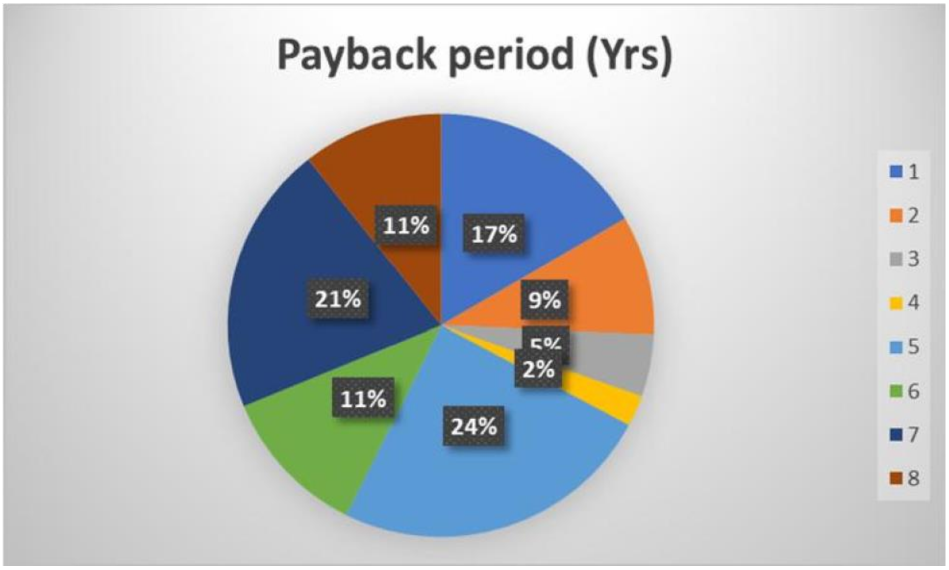

Fig.3. Payback period (Years) of motors

From the Fig. 3, it has been tracked down that the restitution period for utilizing energy effective motors is reasonable. (for example inside 1 to 3 years). Below Fig. 4 shows study which exposed that a significant measure of energy as more service bills can be saved assuming that high productivity motors are utilized for modern motors. Instruction and data dessimation through mass or broad communications may surely assume significant part in making mindfulness about the advantage of energy efficient products. In the field of sugar factory like this, which are established in era of 1970s and till running, doing production of sugar and byproducts, there is serious need to look in such aspects and increase utilization of energy efficients motors and other advanced energy efficient products to reduce consumption of energy from demand side. In the sugar factory, the old and rewound induction motors of different horsepower are to be studied for different types of losses so as to determine the overall efficiency of the induction motors. Then, these efficiencies are compared with the efficiencies of new induction motors. After that, it has been found that it is better to replace the old and rewound induction motors with the new ones as the payback period is found to be existing in the range of 1 to 4 yrs to as less as 6 months.

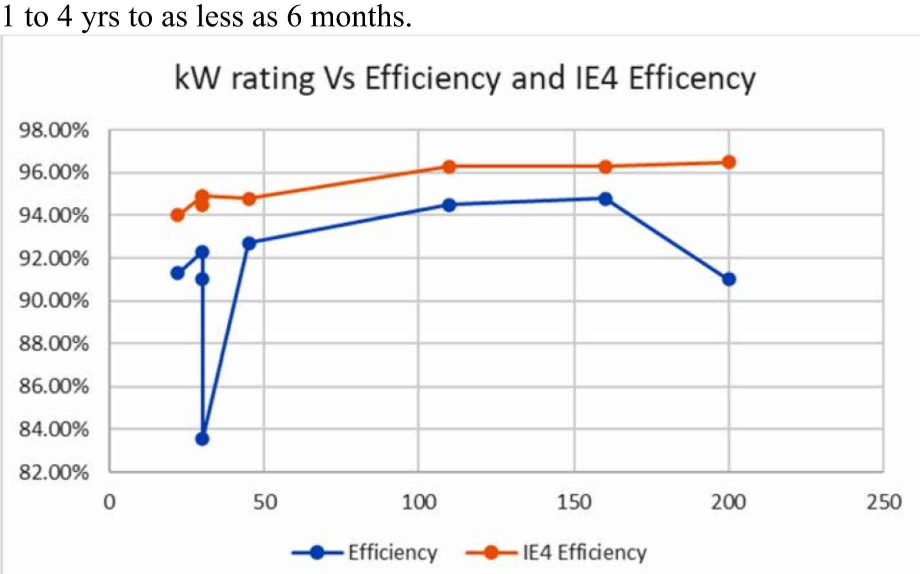

Fig.4. kW rating Vs Efficiency and IE4 Efficiency

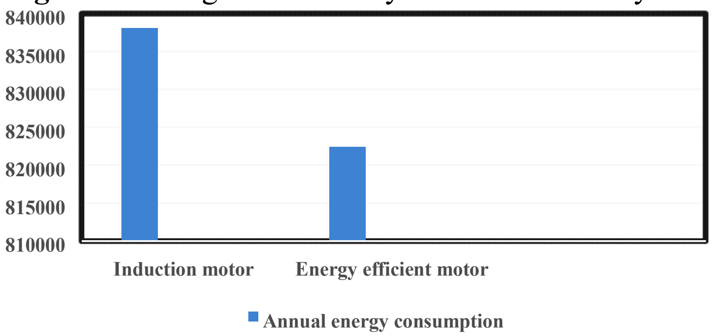

Fig.5. Comparative result of total annual energy consumption of EEM and regular induction motor

Fig. 5 is a figure that shows comparative result of EEM and induction motor and iinvestigation of residual energy productive motors supplanting over standard acceptance motors of same rating should be possible similarly. Also, it is tracked down that the all-out motor heap of energy proficient motors is 499 kW when contrasted with 511 kW of standard motor. The underlying expense of energy proficient motor is high when contrasted with standard motors yet prompts enormous energy saving in measure plant. The restitution time of any remaining rating motors fluctuates from 1.36 to 3.4 year is determined as above and it is affordable for plant. For different motors a lot of energy additionally saves.

9. Conclusion

It has been observed that, within the same frame size, the full load efficiency of the new motor is about 2.5% more than that of the standard motor and the input kVA is 3% less than that of standard motor. The active material cost of the energy efficient motor is up to 15% more than that of the standard motor, but the extra cost is paid back within a reasonable period, which is calculated to be even less than very short period for the prevailing cost structure. Though there are few limitations of EEM over STM, like 15 to20% increase in the cost, low starting torque etc. EEM should be preferably installed for the application where annual motor running is minimum 1500 hours. The results show that the conditional monitoring to the motor helps to reduce the energy losses as well as to reduce the overall economical parameters of motor

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