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Energy Conservation and Emission Reduction through Electric Motors in Industrial Sector of Pakistan

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Abstract: Pakistan is an energy deficit country. The purpose of this research paper is to shed light on current Pakistan's electrical energy conservation efforts and on potential of electrical energy saving in motors, and to reduce Carbon foot prints, this paper also describes the usage of energy efficient motors technologies for the industrial processes, because 30% - 80 % of electricity is consumed by motors load. Different countries use their codes, standards and regulation as voluntarily, mandatorily to conserve electricity.

Keywords: Energy efficiency in motors, Induction motors, Industrial motors efficiency.

1. INTRODUCTION

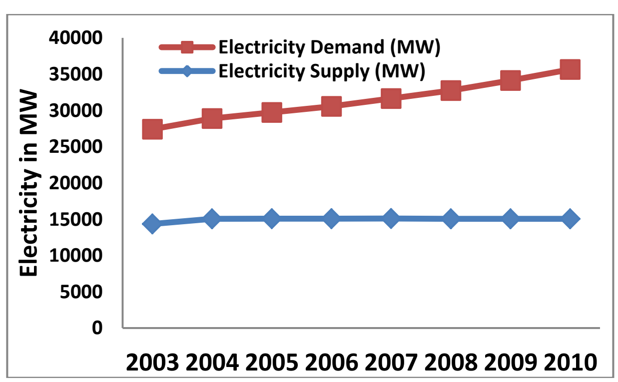
The industry all around the world consumes highest amount of energy. Pakistan's industrial as well other (commercial, domestic and agriculture) sector are highly suffered due to shortage of electricity. Modern energy efficient technologies should be focus on top priority basis for nation's socio-economic development. A major load in any industry is the electric motors which account 30% to 80 % of total energy consumption and considerable proportion of national power consumption (Thirugnanasambandam *et al.*, 2011). Motors are used for powering a variety of equipment i-e wind blower, pumps, compressors and machine rotating parts. Its applications are not only limited to industry but also agriculture is heavily dependent on motors for tube wells. Moreover induction motors are driven for heavy load in industry. Pakistan's industrial sector is the second largest consumer of electricity; the motors are used for cutting, grinding, mixing, and compacting and for pumps, compressors and refrigeration.

The another factor with power consumption leads to Green House Gas (GHG) emissions in environment which causes urban air pollution, global temperature increase, the loss of ecosystems and potentially severe effects on health of people. All over the world government and different organization are paying attention on the problems like acid deposition, nuclear accidents contamination, nuclear waste and concentration of CO_2 in atmosphere. GHG emissions can be reduced 10% to 30% by selected options (Saidur, 2010). Recently a number of studies have been adopting to reduce GHG emission and Energy saving options, out of which few are used as energy efficient motors and lighting, demand side management and fuel alternate in the industrial sectors (Al-Ghandoor *et al*, 2008).

Energy saving and GHG reduction can be achieved by reducing electrical energy use or by increasing production. By contrast improving energy efficiency and reducing GHG emissions will play an important role.

2. ENERGY SITUATION IN PAKISTAN

The peak electricity demand in Pakistan is 17861 MW while peak generation 14317 MW with short fall of 3544 MW (PEPCO, 2012). Pakistan's current supply demand gap reaches to 5000MW as shown in fig 1. (Ullah,I *et al.*, 2013). This extended power outage lasting more than 12 hours a day in rural areas and 6-8 hours in urban areas have put the negative effect and reduces the socio economic development, these indeed putting industries off or reduces their production level, impacts on unemployment and reduces the income of workers.



Graph 01. Power Demand and Firm Supply

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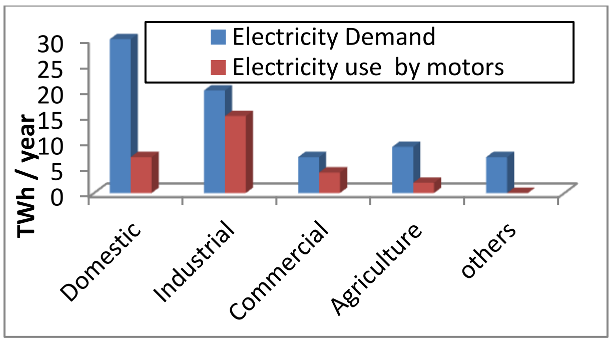
In the industrialized and developed countries the major portion of electrical power consumption is by motors load which generally accounts 30% to 70%, few countries statistics are illustrates for its total national power consumption in motors load, i-e US 75%, EU 65%, UK 50%, Malaysia 48%, Jordon 31%, Turkey 65%, Canada and India 80% and 70% respectively (Saidur, 2009). According to work proposed by Energy Efficiency policy opportunities for electric motors-driven system for IEA about 15TWh per year is being consumed by all sectors of Pakistan (Paul. Waide, 2012). **(Fig. 2)** represents the total demand and electricity used by different motors in Pakistan.



Graph 02: Power consumption by motors in sector wise

3. LOSSES IN MOTORS

These following losses notified from specialized literature presented the loss comparison determined as per IEEE 112 method B and result presented for standard and energy efficient motor of different rating of motors in **(Table 1)**. (Saidur, 2009). The most widely used techniques in manufacturing for high efficient motors are by use of high grade material other parameter to reduce the losses hence the motors are divided by different efficiency clauses like standard motor, high efficiency motor or energy efficient motor and premium motors(Van Wyk *et al.* 2009).

Table 01. A review on motors energy use and energy savings

Power loss to the Total loss ratio	Efficiency class	3kW	7.5kW	11kW	15kW
Core loss (%)	Sd Eff	17 11	17 14	20 15	17 12
F &W loss (%)	Sd Eff	3 14	4 12	4 14	5 10
Stator current loss (%)	Sd Eff	45 40	45 40	42 36	39 37
Rotor current loss (%)	Sd Eff	29 26	22 20	21 22	26 27
Stray load loss (%)	Sd Eff	9 6	12 14	13 13	13 14

4. MATERIALS AND METHODS

To compare the operating cost of on-going motors with new energy efficient motors, this paper chosen three phase induction motors, 50 Hertz, these motors run for different process in industry. First the Efficiency of existing motors has been found by measuring electrical parameters as discussed below then it is compared with energy efficient motors and amount of energy saved has been calculated. Later with proper mathematical model, the GHG emissions have been calculated. To find power used and efficiency of existing motors electrical parameters such as real measured current, power and power factor and no load current, nominal current can be chosen from manufacturers name plate is calculated and then subsequently putting in mathematical model suggested by (Antonio Vanderley *et al.*, 2011). The real load (γ) of on-going running motors can be calculated as:

$$\gamma = 1 + \left(\frac{1}{\alpha}\right) \times \ln\left(\frac{I_R}{I_N}\right) \qquad (1)$$

IR and IN shows the real current measured and nominal current from manufacturer (Antonio Vanderley *et al.*, 2011). The load current parameter(α) is given by

$$\alpha = -\ln\left(\frac{I_0}{I_N}\right) \qquad (2)$$

Where I_0 is no load current

The electrical efficiency of a motor is ratio of the output power (P_{out})to the input power (P_{in})and can be calculated as

$$\eta_L = \frac{P_{out}}{P_{in}} = \frac{(0.746 \times P_{HP} \times \gamma)}{P_R} \qquad (3)$$

PHP and PR show the power output and input of electrical motors in horse power. γis the rated load in percentage and $\eta_L$shows low efficiency.

The improved in energy efficiency is percentile energy saving by replacing low efficient motors with high efficient motors (Antonio Vanderley *et al.*, 2011). Low efficiency and high efficiency can be represented by $\eta_L$and η respectively. It can be calculated as:

$$IEE = \left(1 - \frac{\eta_L}{\eta}\right) \times 100\% \qquad (4)$$

4.1 Motor investment Value

MIV is the new price of motors and installation charges. The price for high efficiency motors are generally 20% higher than ordinary motors, its due to the material used and mechanical consideration.

4.2 Energy Saving (KWh/year)

Energy saved is the electrical units saved. Therefore the quantity of energy saved (QES)per year is given by multiplying with electrical power measured, rated load, operating time and difference of efficiencies between motors with low and high efficient motors:

$$QES = 0.746 \times P_{HP} \times \gamma \times t \times \left(\frac{1}{\eta_L} - \frac{1}{\eta}\right) \quad (5)$$

Where t is operating time (h/year) .

4.3 Energy savings (in Rupees)

Energy saving (in rupees) is the amount of rupees saved by multiplying with energy unit saved with current per kWh tariff. In this study the cost for B3 industrial sector has been chosen form Hyderabad Electric Supply Corporation (HESCO) Pakistan. The energy save values per year is given by following equation:

$$ESV = QES \times C \text{ (Rupees/year)} \quad (6)$$

where C is cost per unit.

4.4 SimplePayback(SPB)

The payback is amount of time required to return the invested money that utilized for new efficient motors. The payback can be calculated as:

$$SPB = \frac{MIV}{ESV} (year) \quad (7)$$

5. EMISSION REDUCTION ASSOCIATED WITH ENERGY SAVING

It is known that generation of electricity is high dependent on burning of fossil fuel, and saving electrical energy will reduce the MW, and will reduce the emissions (CO_2, SO_2, NO_x, and CO) in turn save the environment. The amount of emission that can be reduced by energy saving can be estimated by using following equation and emission factor ratio for different fuel is given **(Table 2)** (Saidur *et al.* 2010) and **(Table 3)** presenting electrical energy mix.

$$AES = (PE^1 * Emp^1 + PE^2 * Emp^2 + PE^3 * Emp^3 + \ldots\ldots\ldots\ldots PE^n * Emp^n) \quad (8)$$

Table 02. Parentage share of fuel mix to generate electricity in Pakistan

Oil (%)	Hydro (%)	Gas (%)	Coal (%)	Other (%)
40	33	24	0.1	2.9

Table 03. Parentage share of fuel mix to generate electricity in Pakistan

Fuels	Emission factor kg/Kwh			
	CO_2	SO_2	NOx	CO
Coal	1.18	0.0139	0.0052	0.0002
Petroleum	0.85	0.0164	0.0025	0.0002
Gas	0.53	0.0005	0.0009	0.0005
Hydro	0.000	0.000	0.000	0.000
Renewable	0.000	0.000	0.000	0.000

6. TECHNICAL DATA FOR MOTORS

In this research paper 180 motors are chosen which are 7.5 KW,11KW, 15KW, 18KW and 22KW all are 3 phase induction motor, are ten years old and operating time for a whole year 8760 hrs. The nominal power, nominal current, no load current and actual power measured through power analyzer meter, the electricity per Kwh charges set as 10 rupees. Few motors for calculation are being shown in **(Table 4 , 5).**

Table 04. 3-Φ induction motors data from standard motors

Motors	Power rated (Kw)	Nominal current (amp)	No Load current (amp)	Current measured (amp)	Power measured (Kw)
M1	7.5	12.7	6.49	12	7.8
M2	7.5	12.7	7	11	6.72
M3	7.5	12.7	6.59	11.5	7.2
M4	7.5	12.7	6.49	11.3	7.1
M5	11	20.8	8.5	13.27	6.44
M6	11	19	8.5	17.2	11.21
M7	11	23	8.5	15.57	7.83
M8	11	19	8.5	11.8	6.36
M9	15	24.5	9	16.37	10.11
M10	15	24.5	9	16.17	9.9
M11	18.5	33.3	13	19.67	9.3
M12	18.5	33.3	13.1	21.17	10.8
M13	22	38	14	21.83	11.27
M14	22	38	13.5	22.6	12.45
M15	22	38	14.2	21.85	11.12

Table 05. Calculation for standard motor's efficiency

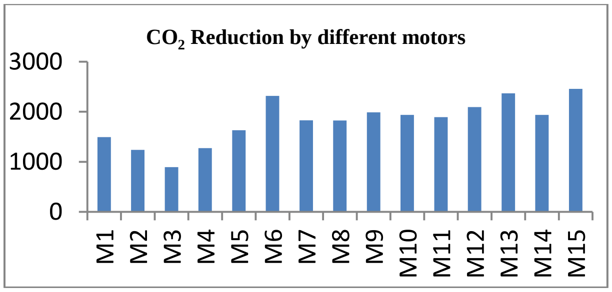
Motors	LF (%)	Pout (Kw)	Pin (Kw)	Measured Eff (%)	New Eff (%)
M1	0.9	6.75	7.8	0.865	0.905
M2	0.78	5.82	6.72	0.866	0.905
M3	0.84	6.33	7.2	0.879	0.905
M4	0.82	6.16	7.1	0.86	0.905
M5	0.49	5.56	6.44	0.86	0.918
M6	0.87	9.8	11.21	0.87	0.918
M7	0.6	6.8	7.83	0.86	0.918
M8	0.48	5.4	6.36	0.85	0.918
M9	0.59	8.9	10.1	0.88	0.923
M10	0.5	8.7	9.9	0.88	0.923
M11	0.4	8.21	9.3	0.88	0.926
M12	0.51	9.59	10.84	0.88	0.926
M13	0.44	9.95	11.27	0.883	0.928
M14	0.49	11.14	12.45	0.894	0.928

Table06. Energy saving, motor investment and CO_2reduction

Motors No.	Energy Consumed MWh/year	Energy Saved MWh/year	MIV (Million Rs)	Rupees Saving (Million Rs)	Pay Back (years)	Emission Reduction (Kg)			
						CO_2	SO_2	NOx	CO
180	3800	150	6.47	1.5	4.3	1862000	25965	4940	823

After calculation of efficiency of existing motors, it is compared with new efficiency motors available as Energy efficient motors. It is observed that huge amount of energy units can be saved. The amount of power saving reduce the different emission reduction as Carbon dioxides (CO_2), Sulfur dioxides (SO_2) , Nitrogen oxides (NOx) and Carbon monoxides (CO). The result is projected in the **(Table 6).**

It can be observed from Table 6, that there is lot of Quantity of Energy saved in Mw from different energy efficient motors and ultimate rupees saving and CO_2 emission reduction is also depicted in table.



Graph 03. CO_2 Reduction by different motors

Table 07. Total energy saving, cost associated and emissions reduction

Motors	QES (kW)	ESV (Rs)	MIV (Rs)	SPB (years)	Emission Reduction (Kg)			
					CO_2	SO_2	NOx	CO
M1	2991	29910	80000	2.6	1495	21	4	1
M2	2475	24751	80000	3.2	1237	17	4	1
M3	1787	17872	80000	4.4	893	13	3	<1
M4	2549	25494	80000	3.1	1274	18	4	1
M5	3263	32632	125000	3.8	1632	23	6	1
M6	4631	46317	125000	2.6	2316	32	5	1
M7	3661	36619	125000	3.4	1830	25	5	1
M8	3652	36526	125000	3.4	1825	25	5	1
M9	3975	39757	150000	3.7	1987	28	6	1
M10	3874	38743	150000	3.8	1937	27	5	1
M11	3786	37867	200000	5.2	1893	26	5	1
M12	4190	41904	200000	4.7	2095	29	6	1
M13	4739	47395	225000	4.7	2369	33	7	2
M14	3878	38789	225000	5.8	1939	27	6	1
M15	4918	49189	225000	4.5	2459	34	7	2

Table 7, gives overall result of energy saving in Mw, rupees saving (in rupees) and pay back (in years), It can be seen that average payback by energy efficient motors are 4 years to 5 years.

7. RESULT AND DISCUSSION

It can be concluded that a huge amount of energy can be saved by introducing energy efficient motors for industry, agriculture and domestic levels, which will benefit not only to reduce peak level and energy shortage but also greatly helps to reduce the GHG emissions. The result illustrates only 180 motors can save 1.5 million rupees per year with 1862000 Kg of CO_2 reduction. It is recommended that the government should focus on implementation of energy efficient motors and performs energy audit to promote industrial competitiveness to reduce the energy demands and carbon foot prints.

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