Energy Conservation through Motors in Pakistan's Industrial Sector- Need to Use of Energy Efficient Motors

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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 different sectors, this paper also describes the usage of energy efficient motors technologies for the industrial processes because 30% - 70 % of electricity is consumed by motors load. Different countries use their codes, standards and regulation as voluntarily, mandatorily to conserve electricity but Pakistan yet lacks behind.

Keywords
Energy Efficiency in motors, industrial motors, Energy audit

1. INTRODUCTION
Global warming, fossil fuel depletion, the growth of new large economies interlace the uncomfortable situation on world's energy outlook, this ultimately makes higher energy commodity prices and economic disruption to the society. The following Fig 1 shows the oil and gas production and demand level, the increasing line showing the demand is increasing

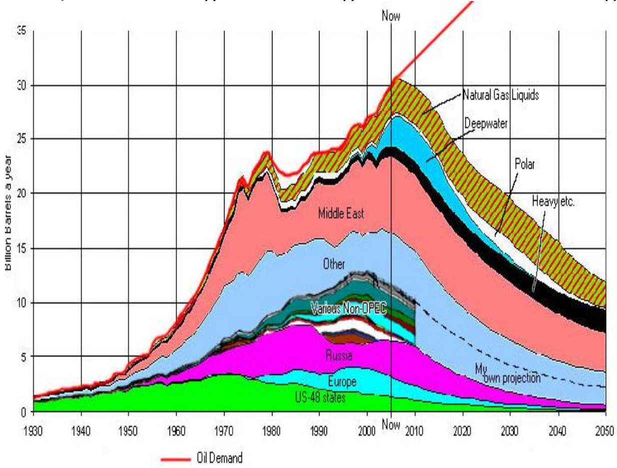

Fig 1: Global Oil and gas production and demand

Pakistan's economy activity is always remain debatable on the impact of higher oil prices, the crude oil prices goes up from 33 US dollar in January 2009 to 120 US dollar [3]. The impact of increased oil prices brings high inflation, high budget deficit and slow down the foreign exchange rates putting expensive import and ultimately affect the generation of electricity. As the industrial sector consumes large amount of energy in motors, the efficient use of energy will play an important role to reduce the energy use and emission that releases to atmosphere. Energy efficient motors are generally 4-5% more efficient than standard motor, so improving energy efficiency of motors in industrial sector will make sustainable development for any country.

2. ENERGY SITUATION IN PAKISTAN

Energy shortage in Pakistan as a whole started in FY 2007 worsened the situation during FY 2008-FY 2011. The energy supply deficit reached 5000 MW as it can be seen by the figure 02. 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 [4, 5].

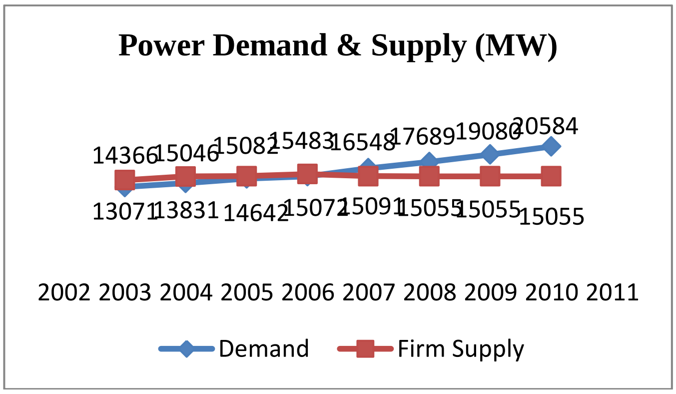

Fig 2: Power Demand and Firm Supply

In this year 2012, Pakistan government trying to take various measures to tackle the situation, while energy efficiency has also been identified as an effective tools for short and medium term for the economic growth.

2.1 Energy consumption in Pakistan by sector wise

Figure 03 shows the energy consumption in Pakistan; from the figure it can be seen that industrial sector is larger consumer of energy includes oil, gas, electricity etc [6].

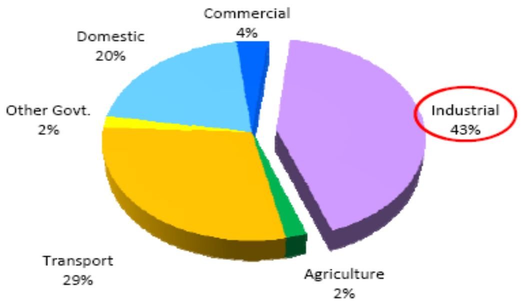

Fig 3: Sector wise break up of Energy consumption

2.2 Electricity consumption in Pakistan by sector

Fig. 04 shows the electricity consumption by the sector it can be observed from figure that industrial sector is second larger consumer of electricity in Pakistan which consumes about 27.5% of energy where as the agriculture consumes 12.5 % of the electricity. The main load to these sectors is electrical motor about 30% to 80%, in industry it used for different rotating different machines for process, in pumps, compressors and in fans etc whereas in agriculture it uses for motor-pump driven system [7].

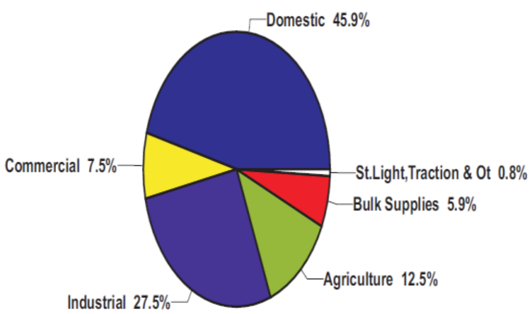

Fig 4: Sector- wise breakup of electricity consumption

The Industrial sector is the biggest consumer of energy, it consumes 43% of total energy and as for electricity concerned the industrial sector is second large consumer, it consumes 27.5% of electricity. Being a larger energy consumer it accumulated only 19% GDP in the FY 2008 (ADB) due to inefficient technology and decaying of infrastructure, lesser energy productivity affects the industrial competitiveness.

According to the report of Asian Development Board, Pakistan's electricity saving potential in the industrial sector is expected 11.2% for ten year forecasted period from 2009 to 2019 with the investment of 1850 million US dollar, and major energy efficiency improvement is observed in the textile, iron, steel and sugar industries as shown in Table 1 [6].

Worldwide industrial sector consumes a substantial proportion 30% to 70% of electricity in motors load; out of which Malaysia 48%, UK 50%, US 75%, India 70%, Turkey and EU 65%, Jordon 31% and Canada 80% [8].

According to Proposed work plan for energy efficiency policy opportunities for electric motor-driven system from International Energy Agency about 15 TWh/year is being consumed in Paksitan's all sectors inculding, industry, agriculture, resedential and transport that is about 38.3% of toal demand of electricity of the country[9]

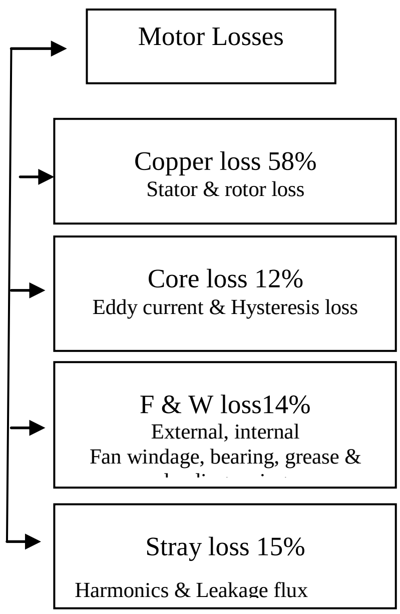

Fig 5: Technical motors losses

Table 1. Energy consumption, realizable saving and investment requirement for electricity in industry.

Electricity Forecast		Iron & Steel	Paper	Textile	Sugar	Other industries
Electricity consumed FY 2008 (GW)		2704	572	5318	150	11985
Electricity consumption Forecast, FY 2019 (GW)		5475	1157	10768	304	24267
Energy efficiency potential (%)	Technical	12	0	7	0	10
	Realizable	50	0	50	0	35
	Effective	6	0	4	0	3
Realizable savings FY 2019 (GW)		166	--	186	--	817
Investment required $ million		17	--	42	--	183
Simple Payback (yrs)		1.3	--	2.9	--	2.9

Table 2. Different efficiency clauses of three phase induction motors

2 Pole			4 Pole		
kW	Efficiency (%)		kW	Efficiency (%)	
	Eff1 or above (High)	Eff 2 / Eff 3 (standard)		Eff1 or above (High)	Eff 2 / Eff 3 (standard)
1.1	82.8	76.2	1.1	83.8	76.2
1.5	84.1	78.5	1.5	85.0	78.5
2.2	85.6	81.0	2.2	86.4	81.0
3.0	86.7	82.6	3.0	87.4	82.6
4.0	87.6	84.2	4.0	88.3	84.2
5.5	88.6	85.7	5.5	89.2	85.7
7.5	89.5	87.0	7.5	90.1	87.0
11	90.5	88.4	11	91.0	88.4
15	91.3	89.4	15	91.8	89.4
18.5	91.8	90.0	18.5	92.2	90.0
22	92.2	90.5	22	92.6	90.5
30	92.9	91.4	30	93.2	91.4
37	93.3	92.0	37	93.6	92.0
45	93.7	92.5	45	93.9	92.5
55	94.0	93.0	55	94.2	93.0
75	94.6	93.6	75	94.7	93.6
90	95.0	93.9	90	95.0	93.9

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3. LOSSES IN MOTORS

Electric motor energy analysis and their associated losses are taken from specialized literature, and ways to reduce it is also explained [10, 11].The figure 05 shows the losses which occurs in the standard types of motors used previously. A few years back the manufacture's goal was to produce the motor that cost less in production thus using low grade material and offer reduced efficiency but now a days the goal is to use of high grade material so that reduce the electricity cost during motor's life.

The most widely used techniques in manufacturing 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. These following losses notified from specialized literature [10, 11, and 12].

4. ENERGY EFFICIENT MOTOR

An improved design, manufacturing and material techniques enables the energy efficient motors to perform more work onto per unit electricity consumption. Energy efficient motor has

- High magnetic properties
- Reduced rotor and stator gap
- High laminated stator winding
- Reduced heating and fan losses
- Better insulation.

4.1 Standard and energy efficient motors efficiency clauses

Motors Efficiency labeling scheme Brook Crompton shows the different efficiency clauses of three phase induction motors as shown in Table 2. [13].

5. MOTOR SYSTEM AND OPTION FOR ENERGY EFFICIENCY

The concept of energy efficiency forced by literature like (Mckane et al 2007, Oikonomon et al 2009, Sola & Xavier 2007, R. Saidur 2010) , through the process of energy efficiency one can say that a product or process is energy efficient if compared with reference, the efficiency of motor are actually to be compared with new technology introduced or new motor with high reliability and manufactured warranties, there is different ways to improve energy efficiency in motors among the ways replacement of standard motors to high energy efficient motors is recommended [14].

5.1 Energy efficiency policy

Pakistan lacks an energy efficiency management system though a few of organization like ADB,NPO, ENERCON,AEDB etc are working on energy efficiency and conservation program but Energy consumption in different process or industries is not practically observed, according to Pakistan quality control and regularity authority the standard for motor is PS IEC: 60034/2007 (Part 1 to 4) but practically there is no implementation of this standard, not even rules and regulation on mandatory or even voluntarily to be set yet to implement whereas other countries are very much engage to set rules and regulation on the mandatory and voluntary basis.

5.2 Cross country motors energy use and saving

The industrial sector around the world consumes 30%-40% of global electricity and 30% to 70% of the total power of the nations is being consumed by electrical motor as specified in specialized literature, number of developed and developing countries like Brazil, Malaysia, Canada, America, China, India etc are involved to implement the projects for conservation of energy; Table 3 shows the agreement done by different countries [15].

Garcia et al in 2006 has taken 9000 industrial motors in Brazilian for the estimation of capital cost and dollar saving by analyzing the energy efficiency in electrical motor by replacing it with energy efficient motor, he concludes that industrial motor consumes 121TWh/year, energy saving and dollar saving for Brazilian country can be approximate 1621GWh per year with annual cost of 37 million US dollar [16].

Saidur et al in 2010 has done the case study for Malaysian industries' motors, he suggests if standard motors are low efficient and if it replaced with high efficient motors can save energy about 1575GWh for all category of motors for the year 2010 with 105 million US dollar to reduce the utility bills for the same period of time [17].

De Almeida et al has worked on standardization of the new energy efficient motors to put on work for the nation, according to his study in Oct 2001 manufactured or imported three phase induction motors ranging from 0.37KW to < 185Kw must fulfill MEPS requirement in Australia. In 2005 Australia come up with 10% share of premium efficiency, 32%and 58% as high and standard efficiencies of motors [18].

6. MATHEMATICAL FORMULAS

To work on efficient motors first it is required to find the existing efficiency of motors for that a few electrical parameter like, I_R (real measured current), I_N (nominal current) from manufacturer, I_o (no load current from manufacturer or measured has to be find in order to find the real load of motors:

$$\gamma = 1 + (1/\alpha) * \text{Ln}\,(IR/IN) \quad \textbf{(1)}$$

Load current parameter is measured by

$$\alpha = -\text{Ln}\,(Io\,/IN) \quad \textbf{(2)}$$

Io = no load current

I_N = nominal current

The electrical efficiency of different components is calculated by power output to power input

$$\eta = Pout/Pin = (0.746 * PHP * \gamma)/PR \quad \textbf{(3)}$$

P_R = measured input power
P_{HP} = output power
γ = rated load (%)
η_L= exiting motor's efficiency

The IEE factor is the energy efficiency tells, percent of energy saved by replacement with new energy efficient motor, given by:

$$IEE = (1 - \eta L/\,\eta) * 100\% \quad \textbf{(4)}$$

6.1 Motors investment value (MIV)

Motor investment value is price plus installation charges, actually high efficient motors are more expensive about 20% than ordinary motors because it uses greater amount of copper and other mechanical parameters so as to increase the efficiency. Because of high price new high efficient motor are conflicting factor in industry.

6.2 Energy saving (kWh)

Energy saved values is the electrical unit saved. To find quantity of energy saved per year, compare standard motors efficiency with new one and motors operation hours with its real load values, QES is given by:

$$QES = 0.746 * PHP * \gamma * t * (1/\,\eta L - 1/\,\eta) \quad \textbf{(5)}$$

6.3 Energy saved values (in Rs.)

Energy saved values is given by multiplying the energy unit saved with tariff per kwh. The cost of electricity is different for peak demand and for off peak demands thus a particular motor for the same rating operating on same time will consumes same unit but giving the different values. In this study the cost for B3 industrial sector is taken form HESCO.
The energy save values per year is given by following equation:

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

Table 03. Motor efficiency voluntary agreement and regulation around the world [15].

Country / region	Mandatory agreement (year of implementation)	Voluntary agreements (year of implementation)
USA	EPAct-high efficiency (1997) NEMA Premium (2011)	NEMA Premium (2001)
Canada	EPAct level high efficiency (1997)	NEMA Premium (2001)
Mexico	EPAct level high efficiency (1998)	NEMA Premium (2001)
EU	-	Efficiency classification and market reduction of Eff3 (1998)
Australia	high efficiency (2006)	Premium efficiency (2006)
New Zealand	high efficiency (2006)	Premium efficiency (2006)
Brazil	Standard efficiency (2002) High efficiency (2009)	High efficiency
China	Standard efficiency (2002) High efficiency (20011)	Premium efficiency (2007)
Korea	Standard efficiency (2008)	Premium efficiency (1996)

6.4 Payback period

The payback period tells the invested money when to be returned back, installing the new energy efficient motor is costly so a huge amount of money is to be invested. The pay back or simple payback can be calculated by considering MIV and ESV, given by following equation.

$$SPB = MIV/ESV\ (yr) \qquad (7)$$

7. 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 Fluke power analyzer meter. The electricity per unit cost for B3 type connection is Rs 10/KWh according to Hyderabad Electric Supply Corporation (HESCO) in may 2011

Table 04. Three phase 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 5 showing the author's calculation and new efficiency taken from European Union standard for Energy-efficiency policy opportunities as shown

Table 5. 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
M15	0.43	9.79	11.12	0.87	0.928

As from above table the efficiency of existing motor is very low, whereas the new efficiency is determined from manufacturer's table for motor-driven system (paul-waide with international energy agency 2011).when the existing motor is replaced with energy efficient ones, it not only saves electricity units, rupees saving but also increased the efficiency of machines, result is presented in table 6. Figure 6 and Table 7 are showing the overall energy saving in motors and comparison with motor investment and energy saving.

Table 6. Energy saving and pay back

Motors	QES (kw)	ESV (Rs)	MIV (Rs)	SPB (years)
M1	2991	29910	80000	2.6
M2	2475	24751	80000	3.2
M3	1787	17872	80000	4.4
M4	2549	25494	80000	3.1
M5	3263	32632	125000	3.8
M6	4631	46317	125000	2.6
M7	3661	36619	125000	3.4
M8	3652	36526	125000	3.4
M9	3975	39757	150000	3.7
M10	3874	38743	150000	3.8
M11	3786	37867	200000	5.2
M12	4190	41904	200000	4.7
M13	4739	47395	225000	4.7
M14	3878	38789	225000	5.8
M15	4918	49189	225000	4.5

Table 7. Electricity consumed, saving and payback from high efficient motor

Electricity consumed (MWh/year)	Electricity Saved (MWh/year)	MIV (Million Rs.)	Payback (years)
3800	150	6.47	4.5

Figure 6 representing the motor investment value purchased from market versus rupees saving by replacing the standard motor with energy efficient one.

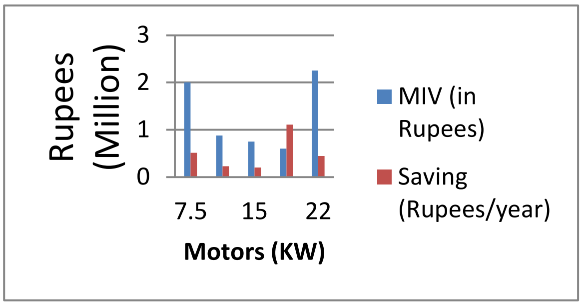

Figure 06. Motors investment versus saving in Rupees

8. MOTOR ENERGY SAVING

The following are different ways to improve the efficiency of overall industrial sector by reducing the electrical energy waste from motors by adopting energy saving strategies.

8.1 Using Regulation

8.1.1 Approaches (mandatory/regulatory and voluntary)

For public and private sector the mandatory and regulatory approaches increase their knowledge that certain level of MEPS (minimum energy performance standard) has been achieved nationally. By putting mandatory approaches one image of organization and of policy makers is been promoting and ultimately reduces the energy demands and CO2 emission factors. It is essential besides setting a minimum performance standard, there can be voluntary schemes for increased awareness and derive towards improvement. Furthermore mandatory/ regulatory measures can be classified (MEPs, Enforcement, Certification, Testing) where as voluntary approaches classified as (Labels, training and tools, public procurement programs).

USA Energy Policy Act (EPACT-1992)

In October 1997 it was enforced mandatory by USA that electrical motor either manufactured or imported should meet minimum energy efficiency performance standard levels. EPACT motors constitutes about 54% of motors share in market in 2009.

NEMA – Premium (2002)

National Electric Manufacturing Association (NEMA) introduces a scheme of premium higher efficiency motors because fewer utilities and industry association were promoting with higher efficiency than EPACT level. In 2005 NEMA premium motors constitutes the market share of 16 % in USA and US decides that by 2011 NEMA premium level should be increased to Minimum energy performance standard for electrical motors.

Mexico, Brazil and Canada

Mexico Brazil both working to enhance the standardization of motors and have their own MEPS system. Currently Mexico is following NOM-016-ENERB 2002 matching with efficiency of same EPAct index. Mexico's standard has somewhat greater application as of EPAct that covering motor only ranging from 0.746KW to 373 KW. Canadian Standard Association sets their standard as of same as EPAct with slight difference that EPAct uses 50/60Hz dual frequency electric motors.

EU (Europe and Pakistan)

The EU-CEMPS provides rating and identification of motors efficiency. Eff 1 is high index and Eff 2 motors with efficiency value between two levels of low and high and Eff 3 is classified as low efficient motors. This standard is been followed by 23 countries including Pakistan.

8.1.2 Incentives

The government should support the organization and manufacturer in the sense there should lesser taxes on materials purchased or imported. The government and R&D provide loans and free audits and rebate for investments.

8.1.3 Application of technology

The organization should be aware and having high technical personal for auditing and using of proper technology to reduce the demand of electricity by putting VSD's, PF improvement or new HEM motors.

8.1.4 By housekeeping

Proper maintenance, switching off and on for auditing the equipment.

9. CONCLUSION

In the country like Pakistan where, industrial and agriculture sectors used motor they are old, re-winded, if purchased than due to low initial cost they are inefficient, if these sectors are to be audited a huge potential of electricity can be saved. It is suggested that the government should support and implement energy audit, energy efficiency and conservation efforts so that on voluntarily or mandatory action can be taken place in order to increase the competitiveness of industrial sector and fulfill the supply demand gap.

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