GLOBAL ENERGY EFFICIENCY POLICIES FOR ELECTRIC MOTOR DRIVE SYSTEM – A REVIEW

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Abstract

The paper emulates the electric motor-driven Systems and applications, global electricity consumption and CO_2 emissions of electric motor-driven systems, energy-savings technologies and savings potentials applicable to electric motor-driven systems, the economics of energy savings in electric motor-driven systems, barriers to optimization of efficient electric motor-driven systems, energy-efficiency policy experience for electric motor-driven systems. The above mentioned notions are well examined with the support from different papers published internationally and quoted in many research propositions. We finally accomplish that the appraisal made here is premeditated to any industry or individual were interested in exploring the opportunities of energy saving in electric motors.

Keywords: *MEPS- EMDS- IEA, VFDs, adjustable-speed drives, original equipment Manufacturers.*

I. INTRODUCTION

The paper explores the present complexity in the working of electric motor driven systems and come out with ideas to reduce the energy demand of such systems by cost effective means. Globally it is forecasted that electric motors is the first largest source of electricity use in industry, for commercial, residential, agriculture and transportation as whole. In each application mentioned above, the electric motor is only one part of the whole electromechanical system. The motor together with the controller is the only part that uses electricity, but the amount of electricity required to fulfil its function is determined by the amount of mechanical power required and the magnitude of the losses that occur in the delivery of that power. The U.S. Department of Energy (DOE) issued new efficiency regulations in May 2014 [1] for integral horsepower motors effective June 2016. This article will provide an update on these new regulations for 1-500-hp low-voltage (LV) ac induction motors. The scope of coverage has been expanded to cover more configurations than in previous regulations[1]. The U.S. Department of Energy (DOE) issued new efficiency regulations in May of 2014 for integral horsepower motors effective June 2016. This paper will provide an update on these new regulations for one (1) through 500 horsepower (HP) low voltage AC induction motors. The scope of coverage has been expanded to cover more configurations than in previous regulations[2]. Enhancing transportation efficiency is the preeminent place to start efforts to minimize emissions of carbon dioxide which is a crucial malefactor in global warming. Due to awe-inspiring advantages over vehicles with internal combustion engines, use of electric vehicles (EVs) finds application in a variety of areas[3]. Electric motors and the systems they drive are the single largest electrical end-use; it is estimated that they consume between 43% and 46% of all global electricity consumption. Recent studies show that efficiency values of induction motors can be successfully increased, with improvements up to 20%-30%[4].

This paper introduces a torque distribution strategy for a pure electric vehicle with multiple traction motors in an electric propulsion system. This electric propulsion system consists of three motors - an indirectly - driven traction motor for front wheels and two in-wheel motors installed inside both rear wheels[5]. In order to save resources and prevent global warming, there has been a pressing need in recent years to reduce the volume of CO2 emissions, and to improve the fuel consumption of automobiles. Due to environmental concerns, the recent regulation on automobile fuel economy has been strengthened[6]. Electric vehicles must extremely improve its electric drive system efficiency and effectively use its limited energy. In this paper, a structure diagram of the induction motor in synchronously rotating frame of reference including iron loss is given at first, the losses of induction motor in operation is discussed and an efficiency optimization[7].

The paper analyses the types of electric motor driven systems and analyses the different technologies in use and the potential to save energy through better design, configuration and operation. Electric motor efficiency is the ratio of mechanical output power to electrical input power.

Theweighted average efficiency of the running electric motor stock depends on:

a) Size distribution of the motor stock;
b) Relative shares of energy-efficiency classes;
c) Mandatory energy performance standards (MEPS) and other policy measures in place and their period of introduction/reinforcement.

The efficiency of motors depends both on their size and their efficiency quality, which can be characterized by efficiency classes. For small motors, size is the most important factor in determining efficiency; for large motors, efficiency classes are relatively more important. As per the figure1, in 2008, IEC 60034-30, the International Electro technical Commission introduced the precisely defined and open-ended international efficiency-classification scheme using IE1, IE2, IE3 and IE45 as the classification system

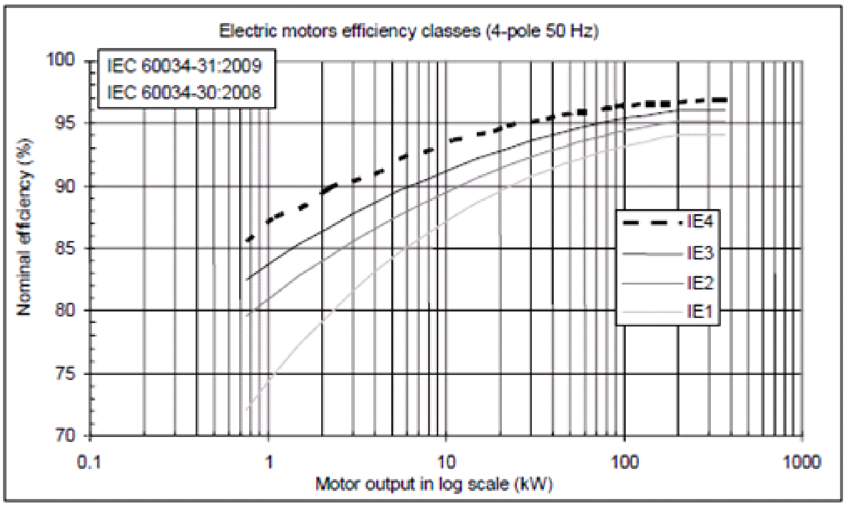

Figure1: Source from IEC 60034-30 and IEC 60034-31

When a new and higher motor-efficiency class is introduced, it diffuses slowly into the national market. The rate of diffusion depends on national motor producers, additional price, electricity cost, financial incentives, MEPS, etc. to our surprise some large motor-using economies, such as India, Japan and Russia, have not yet adopted MEPS. The diffusion of motors with higher efficiency starts earlier for larger motors than for smaller ones, since more engineering time and money is usually spent in the search for the best-matching motor when a large motor has to be renewed.

II. MARKET PENETRATION OF VFD TECHNOLOGY

Motors are sometimes sold together or later matched with a variable-frequency drive (VFD) to enable greater efficiency when operating at partial loads. The VFDs were mainly 0.75 kW to 4 kW in output size. Small pumps and fans are also increasingly sold in integrated packages that include a VFD. The energy efficiency of the Japanese new motor market is slightly lower than in the European Union, and significantly lower than in the United States and Canada.

However, Japan is the global leader in production and use of inverters (VSDs/VFDs), and thus may well be using electromotive power more efficiently on average than other OECD economies. In non-OECD economies, VSD/VFD (inverter) use is thought to be quite low due to the higher initial cost of inverter-based technologies.

III. GLOBAL ELECTRICITY CONSUMPTION AND CO_2 EMISSIONS OF ELECTRIC MOTOR-DRIVEN SYSTEMS

The global electricity consumption by electric motor-driven systems (EMDS) has not previously been measured or estimated in a consistent way, and few reliable data exist on which to base such estimates.

We projects alternate top-down and bottom-up methodological approaches to develop estimates of global electricity consumption and CO2 emissions from EMDS. These analyses draw on dispersed and inconsistent data on stock and sales of electric motors, electric motor power and electricity demand, and attempt to organize the available data within a consistent analytical framework.
Figure 2 shows that the scope of study is limited to the following considerations,

a) An electric motor may be manufactured integrally with its pump, fan or compressor wheel. In this case, it cannot be separated and counted as a single piece. This is typically the case for motors of up to 2 kW used in small packaged applications.
b) An electric motor may be manufactured in parallel with a piece of application equipment, either in the same manufacturing plant or in a different plant. An eventual match is preconceived by standardized hardware interconnection and software compatibility.
c) A standard electric motor (as based on IEC classifications for frame-type and size, output size and performance categories) may be manufactured by a company. In this case, the motor will no longer be separately visible from the machine as a whole and can no longer be treated or tested as such.

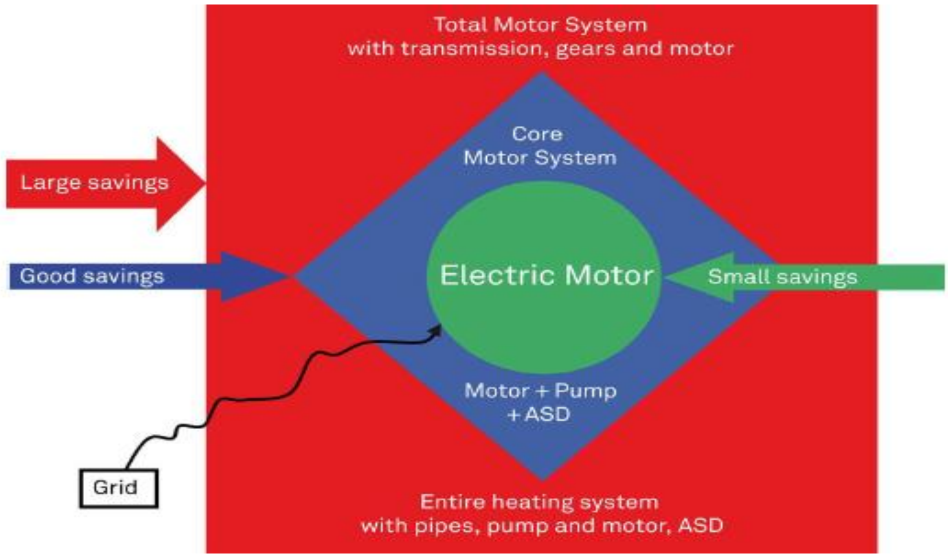

Figure 2. Motor manufacturing/ Savings

3.1 Manifestation of motor usage in field

Small motors with a power rating of up to 0.75 kW account for about 90% of all electric motors in the global stock, but for only about 9% of the total electricity used by electric motors. About 68% of the electricity consumed by electric motors is used by medium-size motors, those in the 0.75 kW to 375 kW input power range.

For the most part, these are asynchronous AC induction motors of 2, 4, 6 or 8 poles, but some are special motors. These motors account for about 10% of all motors and are used in pumps, fans, compressors, conveyors, and industrial handling and processing applications. Large motors with a rated power of 375 kW to 100 000 kW are polyphase, high voltage motors operating in the 1 kV to 20 kV range.

They are custom designed, synchronous and assembled on site. They account for only about 0.03% of the stock of all electric motors but about 23% of energy use. Most and are used in industrial and infrastructural applications. To the attention the analysis focuses only on electricity delivered directly from the grid to the motor, excluding special applications run from fossil-driven generators or batteries.

IV. METHODOLOGY

Currently there are only few reliable statistics or information about the global electricity use of electric motors. Neither data from individual countries nor data available on a global level are based on harmonized and consistent methods, or on published data. Therefore, some authors have developed and applied a methodology to make a best estimate of electric motor electricity use from the available data sets. It was roughly estimated that 46% of total energy consumption by electric motor in the annual year 2009.

Table 1: Energy consumption

Sector	All	Light	Electronics	Electrolysis	Heat	Standby	Motors
Industry	6500	500	200	500	800	100	4400
Transport	300	100	0	0	0	0	200
Residential	4300	900	700	0	1400	200	900
Commercial and public services	3700	1300	500	0	300	200	1500
Agriculture, forestry and fishing	400	0	100	0	200	0	100
Others	500	100	100	0	200	0	200
Total	15700	2900	1600	500	2900	500	7200
Share of Total %		18.6%	10.0%	3.2%	18.7%	3.3%	46.2%

A. Top-down approach

The methodology applied involves estimating all non-motor electricity uses and assuming the residual part of total electricity consumption is that used by electric motors. Explicitly, the approach looks at sector-level electricity use in some 55 large countries and assumes an average fraction of electric motor usage in each sector.

B. Bottom-up approach:

The national energy use of electric motors is calculated based on available data (annual sales, running stock) and estimates of the average size, efficiency, running hours and load factor of the motor stock, which is then used to calculate motor system power and electricity demand.

4.1 Energy Saving Technologies and savings potentials applicable to Electric motor driven systems

The energy efficiency of the AC motor is classified by IEC 60034-30 (October 2008) into three commercially available energy-efficiency classes:

a) IE3 Premium Efficiency (equivalent to 60 Hz operation with NEMA Premium)
b) IE2 High Efficiency (equivalent to 60 Hz operation with EP Act, similar to 50 Hz operation with Eff1)

c) IE1 Standard Efficiency (similar in 50 Hz operation with Eff2)

To initiate a competition for higher motor efficiency in future, the IEC standard indicated a Super Premium class with 15% lower losses than the IE3. General understanding is that this will be not a standard AC induction squirrel-cage motor, but either an electrically commutated or copper rotor motor. These efficiency classes cover motors from 0.75 kW to 375 kW, 2-pole, 4-pole and 6-pole, and in 60 Hz or 50 Hz operation with a supply voltage of 200 V to 700 V. This efficiency classification asks for IE2 and IE3 motors to be tested with a method of "low uncertainty" among the various testing methods provided by IEC 60034-2-1.

Only motors running continuously for more than 500 hours to 1000 hours per year use significant amounts of energy. It is only at this level of operation that the cost of more efficient technologies can be fully offset by reduced energy use and operational expenses.

Now copper rotor motors from 0.1 kW to 100 kW are available. The design effort and the advanced production technology add considerable cost to the product, but this allowed a gain of almost one efficiency class within the same frame size. Some manufacturers offer motor-stator combinations with either traditional aluminium rotors or special copper rotors. This is done especially for long-stack motors to avoid larger diameters.

There are a number of advantages to using copper rather than aluminium in AC motors:

a) Lower coefficient of expansion: aluminium will creep and move approximately 33% more than copper.
b) Tensile strength: copper is 300% stronger than aluminium and thus able to withstand high centrifugal force and the repeated hammering from current-induced forces during each start.
c) Higher melting point: copper can better withstand thermal cycling over the life of the motor.

Independent tests show that a copper rotor can reach slightly higher than IE3 performance values, though at a considerable cost premium.

Gears and transmissions are two mechanical elements which offer significant potential for improved efficiency. In motor efficiency of around 100 kW output, just two percentage points separate one motor efficiency class from the next. This means it can be easier or more cost-effective to change transmissions and gears to achieve the same overall performance improvement. Many of the new motor technologies operate with variable speeds. This means that they electronically adapt the speed rather than being based on a fixed-speed design with 2, 4, 6 or 8 poles. Advanced adjustable-speed controllers offer two energy-efficiency advantages:

a) They can eliminate the major source of partial-load losses, such as mechanical resistance elements (throttles, dampers, bypasses).
b) Adjustable-speed and torque systems can be used for direct drive, eliminating unnecessary components such as gears, transmissions and clutches, and reducing cost and losses.

4.2 Related Energy Saving Opportunities

The largest benefit in energy-efficiency improvement comes from a systematic integration and optimization of all mechanical and electrical components in a total motor system. Motor-system efficiency can be improved from 42% to 63% or the total required grid peak load can be reduced from 240% to 160% of the net mechanical load. The improvement (red surface) results from several individual and consecutive improvement steps.

Typical inappropriately sized machines have efficiency disadvantages. Figure 3 shows that with regard to electric motors, peak efficiency of high-efficiency motors (depending on motor size) is at 75% to 100% load. Below 50%, the decrease in efficiency is severe. In older applications, the efficiency peak was closer to 100% and the decrease was already below 75% load. Past engineering practices were aware of critical temperature rises in full load and overload that could damage motor insulation.

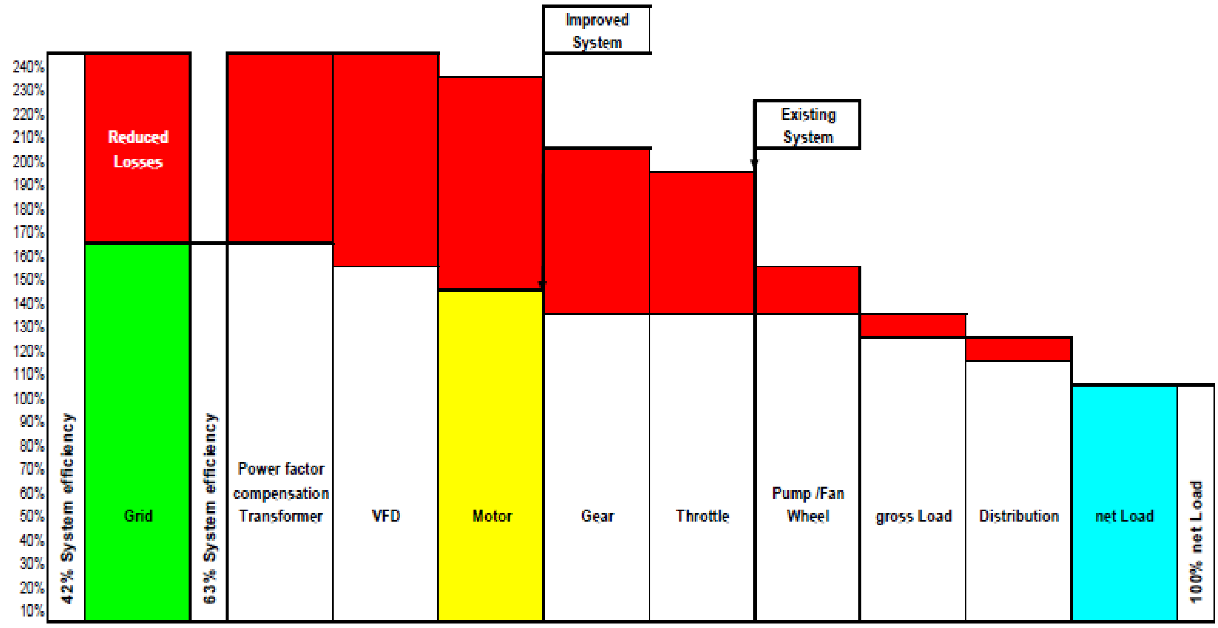

Figure 3: Efficiency of each stage

Proper sizing is, of course, an issue not only with electric motors but with other system components, (*e.g.* in applications such as pump and fan systems, in which correct size pipe or duct work minimizes flow velocities and friction losses). The proper sizing of a motor system requires knowledge on all typical use stages of an entire machine. This is relatively easy for a closed-loop water-pumping system, but it can be difficult for a complex material-handling process in which charges can vary within large boundaries. Proper sizing offers several advantages:

a) Motors usually run more smoothly and for longer with less wear
b) They have fewer losses
c) They cost less than oversized motors.

4.3 Economics of Energy saving in Electric motor driven systems

In general, electric motor-driven systems cost far more to operate over their lifetime than the initial cost of purchase. Power is the largest part of the cost of operating an electric motor. The US Department of Energy estimates power cost over the 20-year life of an electric motor to be 90%. Some of the findings to be highlighted are as follows,

a) Motors with over 2 000 hours per year are cost effective with current industry electricity prices.
b) Life-cycle cost savings are higher in smaller motors (5% to 10%) than in larger motors (1% to 2%) because the relative efficiency improvements in the smaller range are much greater.
c) Typical operating hours in industry and infrastructure systems of between 4 000 hours per year and 8 000 hours per year produce bigger energy savings.
d) The life-cycle cost of systems using VFDs is less than those without VFDs for those operating above 1 000 hours per year.

Larger motors are repaired one, two or even three times during their lifetime. According to repair and winding assessments, the average motor comes out of a rewinding with a 1% to 5% lower efficiency, depending on the practice used (EASA, 2006). Nowadays, an old motor, with a 10-to-20-year running history, is typically an inefficient motor. This indicates that even with quality rewinding and repair, an inefficient motor often gets worse Countries with MEPS for new motors (e.g. New Zealand) have considered banning rewinding of motors below 50 kW to avoid a secondary market disrupting mandatory introduction of new higher-efficiency motors.

4.4 Barriers to international trade

Electric motors and motor systems are mass-produced. For producers of electric motors and motor systems, well-functioning international trade is important to realise economies of scale and reduce their production costs.

Barriers to international trade include regional differences in voltages and frequencies, different measuring systems, and differences in standardization and related testing standards.

The majority of countries operate their regular electric grid at 50 Hz frequency (62% of global electricity demand), while the minority are at 60 Hz (38% of global electricity demand, mainly in Brazil, Canada, part of Japan, Mexico, and the United States). Special grids for electric railway trains and tramways are run with DC (600 V to 3 000 V) or AC (15 000 V to 25 000 V) and also in different frequencies (50 Hz, 16.66 Hz, etc.).

Electric motor shafts with a supply frequency of 60 Hz rotate 20% faster (*e.g.* 1 800 rpm instead of 1 500 rpm), thus they potentially have a 20% higher torque. The sum of all mechanical and electrical loss components in a 60 Hz motor with the same torque is lower than in a 50 Hz motor. Nominal supply voltage for low-voltage three-phase motors varies between 380 V and 480 V depending on national voltage standards. Also, the supplied voltage can vary in a given location more than the standard ±10% of the rated voltage.

Motors are typically designed and optimized for a given frequency and a nominal voltage, and cannot normally be exchanged without loss of optimum performance and efficiency. There are also dual-frequency and multi-voltage designs available for special markets (Brazil, Japan, etc.) that generally have lower efficiency than single frequency and fixed-voltage systems. If the markets for electric motors and motor systems are no longer segmented by technical standards but harmonized by global standards, the potential for further cost decreases from the highly efficient solutions can be realized.

This would make investments in premium efficiency solutions profitable where they currently are not (*e.g.* also in lower annual operating hours). Overcoming the barriers identified along the product cycle requires simultaneous introduction of a portfolio of measures: if all barriers are not removed or alleviated at the same time, there is high risk that the impact of a single measure, such as efficiency standards or labelling, will not bring about the expected efficiency potential.

V CONCLUSION

Electric motors account for between 44% and 46% of total global electricity consumption; industry accounts for 64% of this, the commercial sector for 20% and the residential sector 13%. Four major motor applications dominate the electricity demand of motors: compressors (32%), mechanical movement (30%), pumps (19%) and fans (19%). We also state that premium Efficiency motors and motors systems is a complex issue requiring multiple approaches. Improving the efficiency of electric motors and the equipment they drive can save energy, reduce operating costs, and improve our nation's productivity. We conclude that energy efficiency should be a major consideration when you purchase or rewind a motor. The annual energy cost of running a motor is usually many times greater than its initial purchase price.

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