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# High Efficiency Motors and Variable speed drive a powerful combination for carbon footprint and costs reduction

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**Abstract:** Reducing global power consumption is a major theme in responding to global warming. Climate conferences, soaring oil prices, energy taxation – the incentives for saving energy are more present than ever. Motors represents nearly 50% of the world electrical consumption. This article contains a review on recent technologies toward electrical motors. Alternative Current (AC) and (DC) Direct Current are studied. Variable speed drive technology contributes greatly to motor efficiency. Therefore, it is included in this research. Maintenance and policy are also studied due to their significant impact. Energy savings can be up to 50% (all benefits combined).
**Keywords:** Motors carbon; Motors costs; Variable Speed Drives

## Introduction

Climate conferences, soaring oil prices, energy taxation – the incentives for saving energy are more present than ever. This approach is not only the result of an awareness of the energy problem but also of international political activities which are reflected, for example, in the classification of yields according to the European sector committee of Manufacturers of Electrical Machines and Power Electronics (CEMEP) and in the Energy Policy Act (EPACT) in the USA.

Each increase in tariffs increases operating costs and reduces profitability. Saving energy resources has become an ecological and economic necessity. To face the challenge of sustainable development, each organization must mobilize and commit to improve its competitiveness.

Electric power, as the main energy source in industry, keeps motors, machines, and production running. Therefore, it is not a surprise that industry accounts for 32% of total energy consumption. Even more astonishing is the share that goes to electric drives, namely two-thirds of the consumption.

Improving energy efficiency involves optimizing the consumption of motors systems such as production systems (grinders, extruders, etc.), compressed air production systems, ventilation systems, pumping and pumping systems **[1]**. Indeed, the optimal design of equipment, coupled with a targeted choice of components, would generate savings of several billion dollars and tons of CO2.

In industry, electric motors alone account for 70% of overall electricity consumption and 33% in the tertiary sector **[2]**. Located at the heart of drives, electric motors and electronic variable speed drives constitute a major source of energy savings and a strong opportunity to reduce cost. The high-efficiency motor, especially in continuous operation, induces substantial kilowatt-hour savings, and the variable speed drive introduces additional savings by adapting to the optimum operating point **[3]**.

The savings are substantial just by running a motor engine at the right speed. When a motor is driving with an electronic speed controller, this last one adapts the energy consumption exactly to the needs of the moment **[4]**. Varying the speed moves the motor characteristic to where it is optimal for the process, thereby optimizing the motor's power draw. Power factor and efficiency remain nearly constant. Energy savings can be up to 60% (all benefits combined).

Variable Speed Drives (VSD) control energy. They avoid current peaks, torque surges and unfavorable operating conditions, and by starting and stopping gently. Theyalso spare the entire drive train. Mechanical regulation is unnecessary. This results in better transmission, lower maintenance costs, and longer life. These are positive for installation.

For each application, the most suitable technology in fixed or variable speed motorization and reactive energy compensation must be identified and put in place to reduce carbon emissions and energy bills.

The aim of this paper is to bring to the literature arecent comprehensive review ininnovation on electrical motors and variable speed drive. Moreover, there is a focus on maintenance and policies related to motors.

Premium efficiency motors use less energy to do the same work as standard motors. It is important to replacestandard motors by premium efficiency electric motors (rather than rewinding the existing motors as its efficiency will be several percent inferior). This will lead to greater efficiencies and decreaseenergy costs.

  

In fact, depending on horsepower, high efficiency motors operate from 1% to 10% more efficiently than standard motors**[5]**. The savings are larger on smaller motors because the efficiency improvement is greater, and on motors that operate for extended periods.

When acquiring a new motor, do not consider only its purchase price but also the costs energy it generates. In fact, energy costs directly affect operating costs. A reduction in operating costs increases profitability – and alsocontributes to the preservation of the environment. High energy-saving motors are models of economy and efficiency: for the same power, they consume less energy.

More than 92% of a motor's life cycle costs come down to energy costs – and only 8% to purchase and installation.

## Recent Technology Development on Motors

Technological innovation has always been a major asset in development. The active and regular contribution of researchers in a field is essential to bring it on the path of development.

The international community, led by the largest consumers of electricity, namely the United States, China, and Europe, has set up a standard (IEC 60034-30-1) to classify the energy efficiency of asynchronous motors (four efficiency classes):

- IE1: Standard Efficiency
- IE2: High Efficiency
- IE3: Premium Efficiency
- IE4: Super-premium Efficiency

The standarddefines efficiency classes IE1 to IE4 (Fig. 1), where IE1 is the least efficient, IE4 is the highest efficient motor efficiency class. The new class IE5 is not yet defined in detail but is envisaged for potential products in a future edition of the standard. It is the goal to reduce the losses of IE5 motors by about 20% in relation to the IE4 class.**[6]**

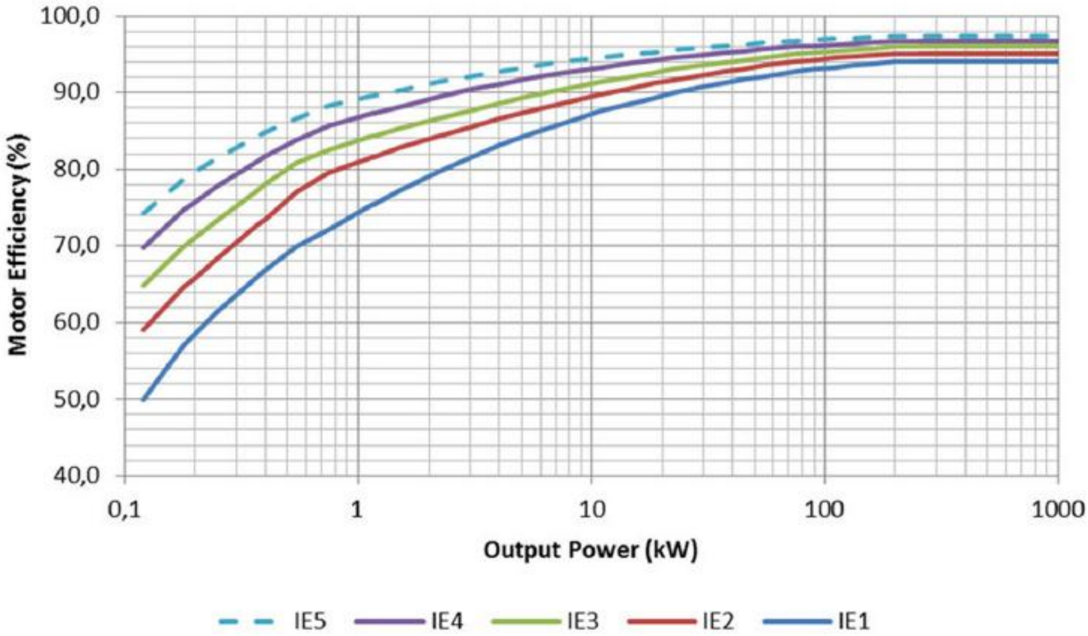


Fig. 1 Efficiency levels in the IEC 60034-30-1 (2014) classification standard, curves for 50 Hz, 4 poled motors [6]

The IE4 and IE5 classes are in the category of super premium motors (for recent technologies). **[7]**

Efficiency class IE4 applies to all types of alternating current electric motors. The efficiency class of permanent magnet synchronous motors falls into the IE5 motor class. A permanent magnet generates its own magnetic field autonomously and without the need for induced current. There is neither iron loss nor loss by Joule effect in the rotor.

  

Emerging countries consume more and more electricity and industrialize. Therefore, theirpower consumptions globally increase linearly.

Fig. 2 shows that motor system's electricity consumption is growing fast, and is projected to almost double by 2040, even with motors being targeted by energy efficiency promoting policies. **[6]**

Organizations and governments have understood that energy efficiency is one of the most effective levers for reducing carbon emissions. As seen in Fig. 2, the proportion of IE3 motors tends to increase and will exceed from 2030 the proportions of IE2 and IE3 motors.

Induction motors with IE4 efficiency are now widely available on the market. Using other technologies such as permanent magnet motors and synchronous reluctance motors allows motors to exceed the IE4 and IE5 efficiency limits.

Three-phase induction motors, because of their reliability, are still the preferred choice for fixed speed applications. Other technologies capable of starting direct-on-line (DOL) have also appeared, such as Line-Start Permanent Magnet Motors (LSPM) and DOL Synchronous Reluctance (SynRel) motors, but they still present some operational drawbacks which limit their widespread use. **[6]**

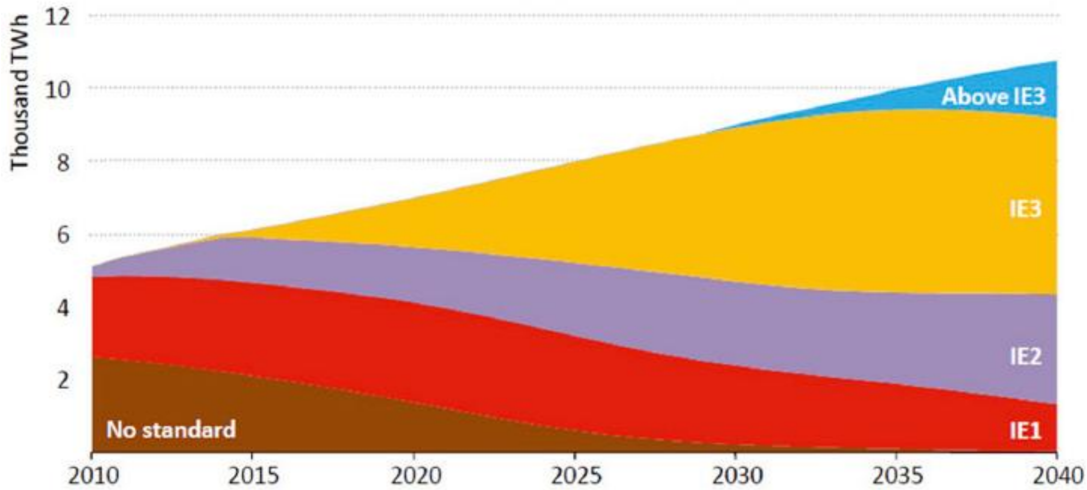


Fig. 2Global industrial electricity consumption by motor efficiency class in the New Policies Scenario [6]

The electronically commutated (EC) motor is also a novelty. This type of brushless direct current motor has the particularity of operating from an alternating current source. As represented in Fig. 3, the rotor is made up of permanent magnets (magnetic poles, rare earth) and the stator is made up of windings controlled by a microcontroller.

EC motors have superior performance to class IE4 (Super Premium Efficiency) motors. This technology has many advantages, high efficiency, flexible and economical operation thanks to easy management of the motor's rotation speed **[8]**.

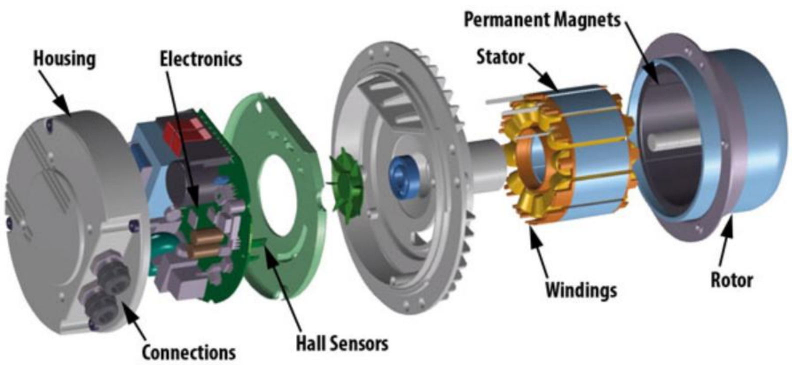


Fig. 3 EC Motor elements [9]

## Variable Speed Drive

A Variable Speed Driveis a device that can control the speed of an electric motor. Most conventional motors run at full speed only, but aVSD-equipped unit means it can run at a variable rate. This allows themotor to drive a pump or fan at a speed appropriate to the requirementsof the process.

Often, fans and pumps work harder than they need to. Fitting a Variable Speed Drive to a fan or pump powered by an electric motor can greatly reduce the amount of energy consumed **[10]**. Lowering the speed of a motor by just 18% can produce an energy saving of up to 44%.

VSDs aren't as expensive as many thinks. Fittingone to an average motor can cost around $650 – including installation. Whenit can be considered that a single average (2.2 kW)motor can consume over400 worth of electricityper year, a VSD is well worth the investment.

Because energy and motor speed are exponentially related, evena relatively small reduction in speed can result in a significant energysaving. Fitting a VSD to a motor is an attractive cost-saving project formany businesses, as it can provide quick results and a relativelyshort payback period.

The optimization of motorization must be done with suitable drives.

SINAMICS® manufactured by Siemens are good examples because they are economical, robust, reliable, and easy to use. These innovative variable speed drives are effective means of exploiting energy saving potentials. In their version with robust encoder less vector control, SINAMICS® are dedicated to drive applications without energy recovery, in particular for turbomachinery (pumps, fans, compressors) and positioning, processing or machining. With a wide range of complementary components and options, these drives can be configured exactly as neededby the user. The price/performance ratio is positively affected.

The increased use of Variable Frequency Drives for applications with variable load, which can bring large energy savings, has also led to the awareness of its own energy losses and the further losses inflicted to the motor due to the non-sinusoidal power supply.Fig. 4 shows the European Union VSD market penetration forecast up to 2020, when motors equipped with VSD are expected to reach over 40% of all motors sold.**[6]**

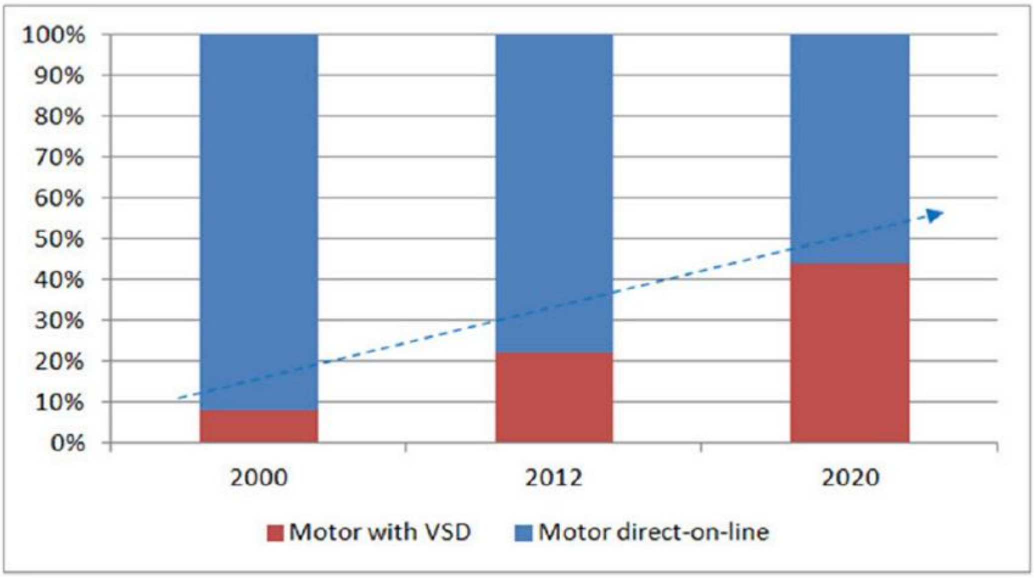


Fig. 4 European VSD market penetration [6]

**Below, four steps to keep energy consumptions and costs under control with a Variable Speed Drives:**

**1. Consider**

A variable speed system consists of two main components – the motor anda variable speed drive, sometimes integrated as a single unit. The VSD takesinformation from sensors and adjusts the speed of the drive accordingly.

A VSD installation is not just a motor – sensors and control elements arealso essential.

  

Not all processes will benefit from a VSD, first consider whether:

- There are fans or pumps in any systems that don't need to run at full capacity all the time.
- There are processes or systems which are driven by a pump or fan, but in which the flow is controlled by dampers and valves. With a VSD, the dampers/valves can be opened or removed, and the flow is controlled by adjusting the motor speed.
- There isother motor driven equipment in which speed could be varied without affecting the process, for example conveyors and some mixers, agitators, and compressors.

**2. Select**

Always use a reputable manufacturer to select your VSD. A good manufacturer willdiscuss with you in detail about your requirements and will select the mostappropriate equipment.

Calculate the running profile of your equipment, select the most suitable motor and VSD combination, and calculate the savingsand payback period of the VSD.

**3. Installation**

Onceyou select the right VSD, it will need tobe installed. This requires specialist knowledge, so use an authorized installer rather than attempting the procedure yourself.

Although the motor unit may seem simple to fit, it must be mountedcorrectly to avoid vibration and poor alignment – both will generate energy lost.

Set up and calibrate the control system so that the VSDmatches therequirements of your process or equipment. Correct set-up isvital for maximum payback.

**4. Monitoring performance**

Your installer should compare how the VSD is running compared to theprofile calculated by your supplier. They will also show you how you cancheck system performance and whether it is meeting the processrequirements.

Regularly check the system to ensure that it is functioningand calibrated correctly.

This monitoring performance step is part of the energy management **[11, 12]**.

## Policies

Given the place of motors in industry, it is imperative to define and deploy an energy policy for this type of equipment.

Major countries have formulated several energy efficiency standards to improve the motor energy efficiency. The standards are implemented and reviewed phase by phase. Furthermore, all of the imported or sold motors are required to comply with the high efficiency standards. The purpose is to improve the industrial energy use as efficiently as possible to increase national industrial competitiveness and enhance R&D capabilities and manufacturing technologies for high efficiency motors. Thus, the '3E' objectives of economic prosperousness, environmental protection, and energy conservation can be achieved simultaneously. **[13]**

The United States has implemented the Energy Policy Act in 1992 toward energy efficiency. This act is regularly reviewed by the US government.

In 2005, Congress passed the Energy Policy Act of 2005 (EPAct 2005), which required all federal motor purchases to attain NEMA Premium efficiency ratings (i.e., higher than EPAct 92). The NEMA Premium motor efficiency ratings are up to several percentage points higher than those of their EPAct predecessors. In 2007, Congress passed the Energy Independence and Security Act (EISA), which updated efficiency regulations for motors covered under EPAct 92, extended coverage to several new categories of motors and established efficiency regulations for them.**[14]**

The European Union has also implemented a specific policy toward energy efficiency for electrical motors.

In fact, the European Union adopted minimum efficiency regulations for electric motors in European Commission Regulation No. 640/2009 of 22 July 2009, which implemented Directive 2005/32/EC with regard to Eco-design requirements for electric motors. **[14]**

Any governmentshould implement an investment-friendly environment to persuade industrial companies to submit candidacyfor investments **[15]**.

Through policy incentives, the combination of various sources from academia and industry, integration of down-, middle-, and upstream-manufacturers, such as steel materials, permanent magnet, core stamping, motor winding machine manufacturers and motor assembly, etc., organization of joint R & D alliances and sharing research results will be doubly effective strategies. Referring to the current standards of developed or neighboring countries to establish rational and progressive motor efficiency standards, e.g., Japan, the European Union, and United States. The key component manufacturers can develop high-grade silicon steel, copper rotors, no/less rare earth permanent heat- resistant magnet motors, high power drives and electronic components for permanent magnet motors of low cost. **[15]**

Permanent magnet motors will become the mainstream marketwhile brushless DC motors will be the future.

## Maintenance

It is crucial to implement a robust maintenance strategy on motors **[16, 17].** Indeed, it is one of the most important levers to reduce electrical consumption on a motor during its life cycle.

The proposed maintenance strategy presented below helps in preventing the increase in motor running cost due to fault or unscheduled downtime due to motor failure. **[18]**

The proposed methodology is presented in the form of a flowchart in Fig. 5. When a fault occurs, $P_{i,m} > P_{i,0}$, therefore efficiency decreases from $\eta 0$ to $\eta$m i.e. $\Delta\eta = \eta o - \eta m$ between time zone t m-1 and t m and the time left for schedule maintenance be $\Delta t = T - tm$ . As discussed earlier, the efficiency drop depends upon the type of the fault and its severity level. Proposed flowchart terminates immediately, if there is no drop in estimated efficiency inspected at a given instant of time. Otherwise, it proceeds further to identify the reason for drop in efficiency. If any anomaly in supply voltage, frequency and voltage waveform is detected, the flowchart terminates by stating poor power quality as the reason for drop in efficiency. If power quality is good then the flowchart suggests, identifying the presence of fault in the motor using condition monitoring techniques. Once the type of fault has been detected, trend in efficiency drop has to be estimated by regular efficiency estimation followed by computation of running loss using. This will lead to an appropriate decision making based on the maintenance aspect of the motor. A maintenance decision can be made based on the cost - benefit analysis, which considers trend in the efficiency drop and the type of fault. **[18]**

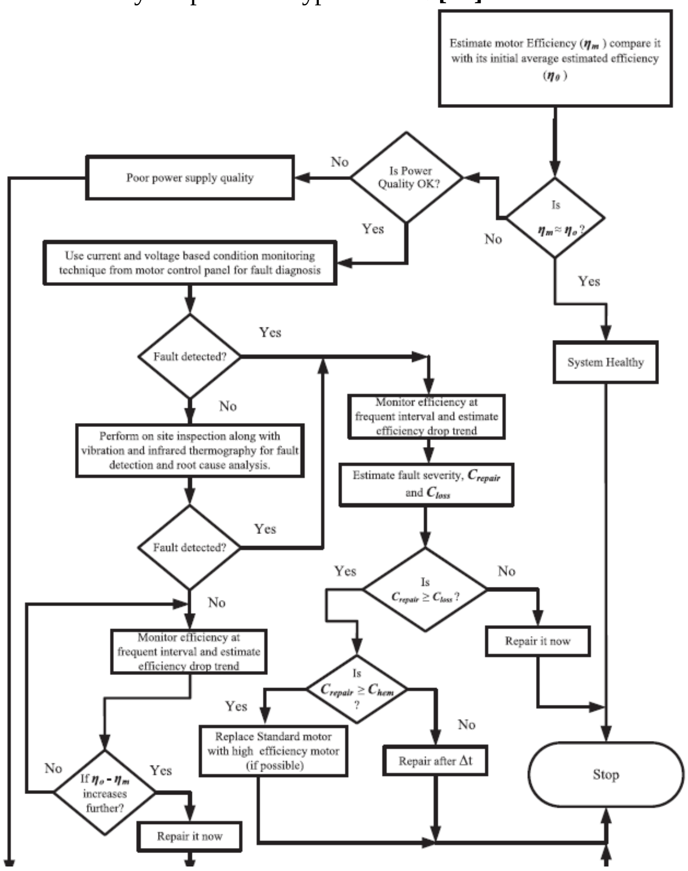


Fig.5. Flowchart for efficiency monitoring and decision-making using cost benefit analysis. [18]

## Conclusion

This article demonstrates that significant savings can be done on electrical motors consumption. Key topics must be studied, and action plan defines and implemented to reach targets (e.g., carbon emissions significant reduction and cost reduction). New technologies have been developed on motors and variable speed drive and continue to develop.

A strong policy combined to a relevant maintenance program contribute greatly.

It is obvious toward this paper that industrial and other organization should focus on motors for reducing their impact on climate.

## References

[1]. S. Sakunthala, R. Kiranmayi and P. N. Mandadi, "A study on industrial motor drives: Comparison and applications of PMSM and BLDC motor drives," 2017 International Conference on Energy, Communication, Data Analytics and Soft Computing (ICECDS), Chennai, India, 2017, pp. 537-540, doi: https://doi.org/10.1109/ICECDS.2017.8390224

[2]. A. Boglietti; A. Cavagnino; L. Ferraris; M. Lazzari. Energy-efficient motors / In: IEEE INDUSTRIAL ELECTRONICS MAGAZINE. - ISSN 1932-4529. - STAMPA. - 2:4(2008), pp. 32-37. https://doi.org/10.1109/MIE.2008.930360

[3]. Agenor Gomes Pinto Garcia, Alexandre S. Szklo, Roberto Schaeffer, Michael A. McNeil, Energy-efficiency standards for electric motors in Brazilian industry, Energy Policy, Volume 35, Issue 6, 2007, Pages 3424-3439, ISSN 0301-4215, https://doi.org/10.1016/j.enpol.2006.11.024

[4]. R. Saidur, S. Mekhilef, M.B. Ali, A. Safari, H.A. Mohammed, Applications of variable speed drive (VSD) in electrical motors energy savings, Renewable and Sustainable Energy Reviews, Volume 16, Issue 1, 2012, Pages 543-550, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2011.08.020

[5]. I. Boldea, "Electric generators and motors: An overview," in CES Transactions on Electrical Machines and Systems, vol. 1, no. 1, pp. 3-14, March 2017, doi: https://doi.org/10.23919/TEMS.2017.7911104

[6]. A. De Almeida, J. Fong, C.U. Brunner, R. Werle, M. Van Werkhoven, New technology trends and policy needs in energy efficient motor systems - A major opportunity for energy and carbon savings, Renewable and Sustainable Energy Reviews, Volume 115, 2019, 109384, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2019.109384

[7]. Trianni Andrea, Cagno Enrico, Accordini Davide, Energy efficiency measures in electric motors systems: A novel classification highlighting specific implications in their adoption, Applied Energy, Volume 252, 2019, 113481, ISSN 0306-2619, https://doi.org/10.1016/j.apenergy.2019.113481

[8]. S. Schroth, D. Bortis and J. W. Kolar, "Impact of stator grounding in low power single-phase EC-motors," 2014 IEEE Applied Power Electronics Conference and Exposition - APEC 2014, Fort Worth, TX, USA, 2014, pp. 783-790, doi: https://doi.org/10.1109/APEC.2014.6803397.

[9]. https://www.axair-fans.co.uk/news/ec-motors-from-ecofit/

[10]. M.A. Hannan, Jamal A. Ali, Azah Mohamed, Aini Hussain, Optimization techniques to enhance the performance of induction motor drives: A review, Renewable and Sustainable Energy Reviews, Volume 81, Part 2, 2018, Pages 1611-1626, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2017.05.240

[11]. Dasheng Lee, Chin-Chi Cheng, Energy savings by energy management systems: A review, Renewable and Sustainable Energy Reviews, Volume 56, 2016, Pages 760-777, ISSN 1364-0321,-https://doi.org/10.1016/j.rser.2015.11.067

[12]. Andrea Costa, Marcus M. Keane, J. Ignacio Torrens, Edward Corry, Building operation and energy performance: Monitoring, analysis and optimisation toolkit, Applied Energy, Volume 101, 2013, Pages 310-316, ISSN 0306-2619, https://doi.org/10.1016/j.apenergy.2011.10.037

[13]. Shyi-Min Lu, A review of high-efficiency motors: Specification, policy, and technology, Renewable and Sustainable Energy Reviews, Volume 59, 2016, Pages 1-12, ISSN 1364-0321, https://doi.org/10.1016/j.rser.2015.12.360

[14]. Waide, P. et C. Brunner (2011), « Energy-Efficiency Policy Opportunities for Electric Motor-Driven Systems », IEA Energy Papers, n° 2011/07, Éditions OCDE, Paris, https://doi.org/10.1787/5kgg52gb9gjd-en

[15]. Kanako Tanaka, Review of policies and measures for energy efficiency in industry sector, Energy Policy, Volume 39, Issue 10, 2011, Pages 6532-6550, ISSN 0301-4215, https://doi.org/10.1016/j.enpol.2011.07.058

[16]. Choudhary, A., Goyal, D., Shimi, S.L. et al. Condition Monitoring and Fault Diagnosis of Induction Motors: A Review. Arch Computat Methods Eng 26, 1221–1238 (2019). https://doi.org/10.1007/s11831-018-9286-z

[17]. L. Magadán, F.J. Suárez, J.C. Granda, D.F. García, Low-cost real-time monitoring of electric motors for the Industry 4.0, Procedia Manufacturing, Volume 42, 2020, Pages 393-398, ISSN 2351-9789, https://doi.org/10.1016/j.promfg.2020.02.057

[18]. Gurmeet Singh, T.Ch. Anil Kumar, V.N.A. Naikan, Efficiency monitoring as a strategy for cost effective maintenance of induction motors for minimizing carbon emission and energy consumption, Reliability Engineering & System Safety, Volume 184, 2019, Pages 193-201, ISSN 0951-8320, https://doi.org/10.1016/j.ress.2018.02.015

  